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DECADE VI. VOL. VI.

OR

VOL. LVI OF WHOLE SERIES.

JANUARY—DECEMBER, 1919.

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OR

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WITH WHICH IS INCORPORATED

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EDITED BY

HENRY WOODWARD, LL.D., F.R.S., F.G.S., F.R.M.S.

LATE OF THE BRITISH MUSEUM OF NATURAL HISTORY; PRESIDENT OF THE PALÆONTOGRAPHICAL SOCIETY; ETC.

AND

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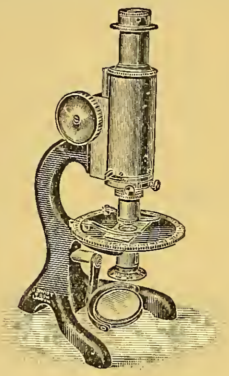

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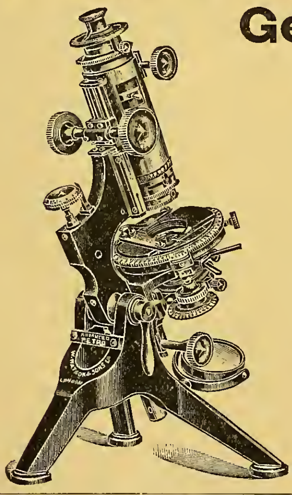

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Charles D. Walcott

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. VI.

No. I.—JANUARY, 1919.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Dr. Charles Doolittle Walcott, For. Memb. Geol. Soc. Lond., Secretary of the Smithsonian Institution, Washington (D.C.).

(WITH A PORTRAIT, PLATE I.)

DR. CHARLES DOOLITTLE WALCOTT acquired a taste for geology and natural history when very young. As a schoolboy he made large collections in the region of his home, and determined to follow a scientific career if possible.

Descended from New England settlers who emigrated from Shropshire, Dr. Walcott was born in New York Mills, Oneida County, New York (U.S.A.), March 31, 1850. His first American paternal ancestor was Captain Jonathan Walcott, of Salem, Massachusetts, who died in 1699. Of the grandfather of Dr. Walcott, Benjamin Stuart Walcott, a writer says[1] that he "moved from Rhode Island in 1822, and became one of the leading manufacturers of central New York; he had broad interests in educational matters, was the founder of a professorship at Hamilton College, and was well known as a philanthropist. His son, Charles Doolittle Walcott, was a man of unusual energy, was well established in business, and held an influential and leading place in the community. Dying at the early age of thirty-four, he left a wife and four children, the youngest, two years old, being the subject of this sketch".

Dr. Walcott's early education was in the public schools of Utica, which he entered in 1858, and in the Utica Academy, which he left in 1868. He then entered a hardware store as a clerk and, continuing in such occupation two years, acquired a practical business training, which has proved of great value to him.

His scientific tastes were developed at the age of 13, when he became interested in the systematic collecting of fossils and minerals. The following winter he met Colonel E. Jewett, geologist, palæontologist, and conchologist, from whom he borrowed books and received many suggestions. Geological reading and collecting were continued, and for two winters he devoted much time to optics and astronomy, and incidentally made large collections of insects and birds' eggs in the spring and summer months.

Of this period he says,[2] referring to fossils accidentally opened up by his wagon wheel when driving: "In a small drift block of

[1] Appleton's *Popular Science Monthly*, vol. lii, No. 4, February, 1898, p. 547.

[2] *Evidences of Primitive Life*, Smithsonian Report, 1915 (1916), p. 243.

sandstone which I found in 1867 on the road from Trenton to Trenton Falls, Oneida County, New York, there is an unusual apparent association of Upper Cambrian (Hoyt limestone) and Ordovician (Aylmer sandstone, Chazy) fossils. When as a boy I found the rounded block of sandstone referred to I broke out all the fossils possible, as at the time I was well acquainted with the Trenton limestone fauna, and the fossils in the block were strangers to me, with the exception of *Leperditia armata.* The following winter I endeavoured to locate the stratigraphic position of the associated trilobites, but could not, further than that they were evidently of pre-Trenton age. This study aroused an interest in the American early Paleozoic fossils that gradually led me to take up the Cambrian rocks and faunas as my special field of research.

"As a boy of seventeen I planned to study those older fossiliferous rocks of the North American Continent which the great English geologist Adam Sedgwick had called the Cambrian system on account of his finding them in the Cambrian district of Wales."

In 1871 business took Mr. Walcott to Indianapolis, Indiana, where his scientific tendencies were further stimulated by Professor E. T. Cox, who was then making a geological survey of the Indiana coal-fields. The time now arrived when it seemed necessary to choose between a business life and a life of research. A partnership was offered him on favourable terms, but if accepted little time would remain for study and investigation. Deciding in favour of scientific work, Mr. Walcott left Indiana and returned to New York State.

Establishing himself on the farm of William P. Rust, at Trenton Falls, he arranged to do a certain amount of farm-work for his board and lodging, reserving the remainder of his time for study and field-work. Here he remained five years, making a rich collection of unique Trenton limestone fossils, which was sold in 1873 to the Museum of Comparative Zoology of Harvard College. He made an arrangement to go to Cambridge (Massachusetts) and pursue a course of study, under the advice and direction of the great naturalist Louis Agassiz, but this was frustrated by the death of Agassiz.

Of this period Dr. Walcott writes: [1] "In September, 1873, I said to Professor Louis Agassiz that if opportunity offered I would undertake as one bit of future research work to determine the structure of the trilobite. This promise has kept me at the problem for the past forty-five years, and except for the demands of administrative duties the investigations would have advanced more rapidly. Since 1873 I have examined and studied all the trilobites that were available for evidence bearing on their structure and organization."

In November, 1876, he received his first official appointment, becoming assistant to Professor James Hall, State Geologist of New York. While holding that position researches were made in New York, Ohio, Indiana, and Canada. In July, 1879, Mr. Walcott was appointed field assistant in the United States Geological Survey, then under the direction of Clarence King, and was assigned to the

[1] "Appendages of Trilobites": Smithsonian Misc. Coll., vol. lxvii, No. 4, pls. xiv–xlii (in press).

study of the great geological section extending from the high plateaus of southern Utah to the bottom of the Grand Canyon of the Colorado. In 1882 he collaborated with Mr. Arnold Hagne in the survey of the Eureka mining district in Nevada and the working out of the great Palæozoic section of central Nevada. The charge of the Palæozoic palæontology of the Survey was now assigned to him, and though this entailed considerable routine work in the identification of fossils brought from many fields by the various geologists, he was enabled to pursue with vigour his cherished plans for the investigation of the older faunas. He examined the Cambrian formations of the Appalachian belt all the way from Alabama to Quebec, and carried his researches on a more easterly line through New England and New Brunswick to Newfoundland. He also began a series of Western studies which eventually included the most important known bodies of Cambrian and pre-Cambrian rocks in Texas, Arizona, California, Idaho, Nevada, Montana, Wyoming, and South Dakota. In 1888 he was advanced to be palæontologist in charge of invertebrate palæontology in the Geological Survey; in 1891, to be chief palæontologist; and in 1893, to be geologist in charge of geology and palæontology, in which capacity he had the general direction of that branch of the work of the Survey. In July, 1894, Major J W. Powell retired from the office of director of the Survey, and Mr. Walcott was selected by President Cleveland to succeed him. This position he held until his resignation in 1907 to become Secretary of the Smithsonian Institution, of which he had previously been assistant secretary in charge of the United States National Museum. During those years he reorganized and developed the Geological Survey on scientific and business principles. The confidence reposed in him by the Congress is attested by the fact that the initial appropriation of $484,640 was increased during his administration to several times that amount ($1,700,000).

Between 1902 and 1907 Dr. Walcott directed the organization and conduct of the United States Reclamation Service. He fostered interest in the forestry movement, and in 1898 he secured the passage as an amendment to an appropriation for the Geological Survey of the first comprehensive law organizing the forest reserves of the United States.

As the initiator and secretary of the Carnegie Institution of Washington, and its direct administrative officer from 1902 to 1905, and as a member of its Executive Committee from 1902 to the present time (now chairman), he has assisted largely in the successful organization and development of the administrative and research work of that Institution.

Since 1907, when he was chosen by the Board of Regents as Secretary of the Smithsonian Institution, Dr. Walcott has directed research investigations in various parts of the world, and has personally studied large areas in the Rocky Mountains of British Columbia and Alberta, Canada. The Smithsonian foundation was established by Act of Congress in 1846, under the terms of the will of James Smithson, an Englishman, who in 1826 bequeathed his fortune to the United States of America "to found, at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men". It was under the direction of the Smithsonian Institution that Colonel Theodore Roosevelt (1909–10) made his memorable African expedition, being accompanied by representatives of the Institution and its branches. The administration of the Smithsonian Institution includes the Unites States National Museum, International Exchanges, Bureau of American Ethnology, National Zoological Park, Astrophysical Observatory, and International Catalogue of Scientific Literature, besides the Aerodynamical Laboratory and the National Gallery of Art.

Dr. Walcott is especially known as a student of the Lower Palæozoic (Cambrian) and pre-Palæozoic (Algonkian) sedimentary formations and included organic remains. Of his work he says[1]: "My own investigations have been mainly in the Cambrian and pre-Cambrian strata, and have involved new and somewhat startling discoveries that helped to show how very much earlier life was developed on our planet than we had previously supposed. These researches have taken into consideration the records left on all the continents and many of the great islands. Field-work, with compass, hammer, and chisel, has been the rule, followed by laboratory and critical comparison of many thousands of specimens of fossil genera and species of ancient marine life, and often study of microscopic sections of rocks and fossils in the hope of finding evidence of the presence of minute and active bacterial and simple algal workers, such as exist in modern seas and lakes, which by their united efforts form great masses of the recent sea and lake deposits."

He has worked up and correlated the Cambrian formations and included faunas on the North American continent, has personally discovered large and unique additions to the previously known Cambrian faunas, and has published his researches on the Cambrian faunas of the world; studied and developed the history and sedimentation of 30,000 feet of Algonkian sediments in western North America, and discovered and published an account of the organic remains in the Algonkian. An important find by Dr. Walcott a few years ago of a rich fossil locality in the Burgess shale, near Field, British Columbia, Canada, has given the finest and largest series of Middle Cambrian fossils yet discovered, and the finest invertebrate fossils yet found in any formation, including—besides brachiopods and trilobites—merostomes, holothurians, medusæ, annelids, brachiopods, malacostracans, etc. Many of the forms are not yet described and illustrated.

His many published works include especially studies of the Cambrian Brachiopoda and Trilobita. A few titles, suggestive of the scope of this work, are: *Paleontology of the Eureka District*, *The Cambrian Faunas of North America*, *The Fauna of the Lower Cambrian or Olenellus Zone*, *Pre-Cambrian Fossiliferous Formations*, *Correlation Papers*, *Cambrian Brachiopoda*, *The Cambrian Faunas of China*, *Discovery of Algonkian Bacteria*, *Evidences of Primitive Life*, and an

[1] *Evidences of Primitive Life*, loc. cit., pp. 235–6.

extended series under Cambrian Geology and Paleontology in Smithsonian Miscellaneous Collections, including "Appendages of Trilobites" (now in press).

Dr. Walcott's activity in other directions besides his own scientific field is well known. He is a director and was one of the founders of the Research Corporation of New York City, which is affiliated with the Smithsonian Institution. He is a member of two military committees: chairman of the Executive Committee of the National Advisory Committee for Aeronautics, appointed by President Wilson in 1915, and chairman of the Military Section of the National Research Council. Since 1917 he has been President of the National Academy of Sciences.

Of his varied inquiries Dr. Walcott says,[1] "I have had generous assistance in obtaining collections and exchanging publications with students all over the world, including geologists, paleontologists, zoologists, and paleobotanists in America and Europe, and in far-away outposts of China, Siberia, India, Australia, and New Zealand."

In 1888 he visited Wales for the purpose of making a personal study of the type district of the Cambrian system—the district rendered classic by the original labours of Sedgwick and the subsequent researches of Hicks. It was on this visit to England that he presented his Cambrian researches before the International Geological Congress at London. The London Geological Society in 1895 awarded him the Bigsby Medal, and in 1918 the Wollaston Medal.

Dr. Walcott is an active member of many scientific and literary bodies, both at home and abroad. These include the National Academy of Sciences (President), American Association for the Advancement of Science (Fellow; Vice-President, 1893), American Academy of Arts and Sciences (associate fellow), American Society of Naturalists, Geological Society of America, American Philosophical Society, Washington Academy of Sciences (President, 1899–1910), Archæological Institute of America (President, Washington Society, 1915–17), Academy of Natural Sciences of Philadelphia (Hayden Medal), Geological Society of London (Bigsby Medal, Wollaston Medal), Société géologique de France (Gaudry Medal), Christiania Scientific Society, corresponding member of l'Academie des Sciences of Institut de France, Royal Geographical Society of London, honorary member Imperial Society of Naturalists of Moscow, foreign associate Royal Academy of Sciences of the Institute of Bologna, etc.

The occasion of Dr. Walcott's visit to Cambridge, England, in 1909, was a happy one, the degree of Sc.D. being conferred upon him. Other degrees which he has received include LL.D. from Hamilton (1897), Chicago University (1901), Johns Hopkins (1902), Pennsylvania (1903), Yale (1910), St. Andrews, Scotland (1911), and Pittsburg (1912); Ph.D., Royal Fredericks, Christiania (1911), and Sc.D., Harvard (1913).

Since the entrance of the United States into the great war, in

[1] *Evidences of Primitive Life*, loc. cit., p. 236.

1917, Dr. Walcott has divided his time between war work and the administrative duties of the Smithsonian, but his leisure for research has been curtailed. In spite of this, however, he has prepared a paper of unusual interest to palæontologists, on "Appendages of Trilobites" (now in press). This represents the fulfilment of the promise to Professor Louis Agassiz, in 1873, that he would undertake the investigation of the structure of the trilobite.

To the War Service his contribution has been especially in Aeronautics. He has given two sons to the Air Service, one of whom, Benjamin Stuart Walcott, fell in combat over the German lines December 12, 1917, and the second son, Sidney, is on active service. His daughter, Helen, served for nearly a year as nurse in a French military hospital, and is now in Italy. The present war activities have made heavy claims upon Dr. Walcott's time and strength, but in spite of this he has again this summer (1918) succeeded in going on an expedition to the Canadian Rockies to continue investigations in Alberta and British Columbia.

Dr. Walcott has been favoured by fortune in many ways. A short acquaintance with him suffices to reveal some of the causes which have contributed to his success. His commanding figure is an indication of exceptional energy and physical strength, and on seeing him one is not surprised that at a ripe age he is able to carry out his field-work under arduous conditions. His unwearied industry also strikes one at once, for no opportunity for work is lost. The powers of specialization and generalization are equally developed with him; while missing no feature in the minute anatomy of some organism, he is able "to think in continents" and has thus contributed largely to the elucidation of physiographical problems connected with Palæozoic times. He can turn at will from one task to another. The onerous duties of administrative work in no wise check the enthusiasm with which he enters into his field labours. Fascinating as is the revelation of the rich faunas of the Cambrian rocks of British Columbia, he also recognizes the importance of the search for organic remains in the barren Algonkian strata, and discovers *Beltina* and "a pre-Cambrian (Algonkian) Algal flora from the Cordilleran area of Western America".

He has been fortunate in his home life. His first wife helped him with ever-ready sympathy throughout the years when he was rising to fame, and the present Mrs. Walcott is already known to the geological world by her writings. His sons and daughter have laboured with him in the field, and especially in that wonderful and prolific district of British Columbia, where so much of his recent work has been done.

Dr. Walcott has been also happy in his environment, especially of later years, when he discovered the remarkable Cambrian faunas in a region which he himself terms "a geologist's paradise". Amongst the fairest scenes of nature he has toiled month by month and year by year, and unearthed that marvellous series of faunas, one of which is preserved in a rock recalling the Solenhofen Slate alone among geological formations, so faithfully are the most delicate parts of organisms preserved in it. Truly, the Burgess shale is a silent witness of the imperfection of the geological record, which the discovery of its treasures has lessened at a bound. We look forward eagerly to the publication of the full accounts of these Cambrian faunas, of which preliminary descriptions only have yet appeared. But Dr. Walcott has already admitted others to his paradise by the publication of the beautiful photographs and photographic panoramas of the British Columbian Alps, which bear testimony to his skill in yet another direction—as an expert photographer of mountain scenery.

Well might the ex-President of the Geological Society (Dr. Harker) state when handing the Wollaston Medal to the Attaché to the Embassy of the United States in London for transmission to Dr. Walcott, that "his personal researches have excited interest and admiration wherever geology is cultivated".

Dr. Walcott has many friends in this country who are proud of the friendship. He has been the recipient of honours here; he has encouraged British workers with much kindly help; some of his most brilliant discoveries have been made in the territories of the British Empire; and as we have seen, he has done his work and suffered loss in connexion with the great war for the sake of civilization. He has forged a prominent link in the chain that unites the English-speaking peoples on the two sides of the Atlantic.

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II.—Review of Progress of Mineralogy from 1864 to 1918.

By G. T. Prior, M.A., D.Sc., F.R.S., Keeper of the Mineral Department of the British Museum (Natural History).

A BRITISH MUSEUM official may perhaps be pardoned if, in a review of the progress of mineralogy since the first appearance of the Geological Magazine, he begins with a reference to scientific work done in the Museum with which the Editor was so long associated. At the time when the Magazine first saw the light the Keeper of the Mineral Department was the late Professor Nevil Story-Maskelyne. He was one of the first to grasp that efficient tool for deciphering mineral aggregates which had been provided by Nicol and Sorby in the thin-section. He was engaged in the particular work to which Keepers of that Department have since appeared to consider they must in duty bound devote much of their time and energy, viz. the investigation of meteorites, and, assisted by the microscopic examination of thin slices of these bodies, he was soon able to announce the discovery in them of several new species, one of which, the sulphide of calcium, oldhamite, must have been formed under conditions very different from those which prevail on the earth's surface.

Shortly before this time the sciences of both geology and mineralogy, having passed through times of stress, had been placed upon the sure foundations on which the present superstructures have been built.

In the case of geology, starting with the broad conception of the earth's crust as made up of rocks, the founders of the science, after a prolonged and bitter struggle between "neptunists" and "plutonists", had at length learned, by accepting truth from both sides, to distinguish clearly between two main types of rocks, the sedimentary, owing their origin to superficial agencies acting on the earth's surface, and the igneous, resulting from deep-seated agencies acting from the earth's interior. Guided by the principle that the present is the key to the past, which had been enunciated by Hutton and enforced by the teaching of Lyell, the geologist soon saw spread before him the ordered sequence of the sedimentary rocks, with their fossils giving a record, imperfect though it might be, of the gradual evolution of plant and animal life down the ages. Along these lines geology, on its stratigraphical and palæontological side, could develop, and has indeed continued to develop up to the present day, without feeling the necessity for paying a great amount of attention to the mineral composition of the rocks with which it dealt. The investigation of the igneous rocks, however, presented a different problem. After the main facts of the processes of vulcanism and igneous intrusion had been grasped, further progress might have been barred for a long time but for such work as that of Sorby in directing attention to the use of the microscope in determining the mineral composition of rocks. The branch of microscopical petrography thus initiated, and developed later by the exertions of Zirkel, Rosenbusch, and Teall, forms the connecting link between geology and mineralogy. As has been rightly said, mineralogy is the chief buttress on which the science of rocks, or petrology, rests; for to attempt to study rocks without minerals would be like trying to investigate and classify a group of animals by their external features with little reference to their internal anatomy.

Into an error of this kind mineralogy, indeed, had been in danger of falling in the earlier stages of its career. Under the influence of Mohs an attempt had been made to restrict the study of minerals to their natural history characters, such as crystalline form, hardness, and specific gravity, to the exclusion of the chemical properties. Mineralogy without elements would thus have been in a state comparable to that of geology without minerals. No branch of science, however, as pointed out by Sir Henry Miers in a recent lecture on this same subject before the Chemical Society, can afford to maintain a position of splendid isolation for long. Sooner or later in its development there comes a stage when for any further advance it becomes necessary to seek the aid of other sciences in order to elucidate the new problems presented. The importance of the accurate determination of the chemical composition of minerals, as insisted upon by Berzelius and Rammelsberg, was too obvious to be long neglected; and in 1850 J. D. Dana, in the third edition of his *System of Mineralogy*, the textbook which has since become the standard work of reference for English-speaking mineralogists, rejected the natural history classification, "with its classes, orders, genera, and Latin names," as set forth in the first edition, and replaced it by a chemical one. As Dana remarked, however, the natural history classification had some advantages in "displaying many of the natural groups which chemistry was slow to recognize", for example, the felspars. A reconciliation of the purely chemical and the natural history classification was effected by Gustav Rose, who in 1852 published his crystallo-chemical system under which crystalline form was given almost as much importance as chemical composition in the distribution of minerals into groups. This was the system which was adopted by Story-Maskelyne for the re-arrangement of the mineral collection of the British Museum. The general acceptance of such a system, in which minerals were classified, in the first place by chemical composition, and in the second place by crystallographic characters so as to bring together members of isomorphous groups, marked a distinct advance in the science of mineralogy.

It was in the very year in which the GEOLOGICAL MAGAZINE first appeared that Tschermak published his discovery of the nature of the felspar group. The fact that minerals with such apparently dissimilar chemical compositions as albite and anorthite should crystallize together in all proportions threw a new light upon the principle of isomorphism, and helped to pave the way towards the modern view that it is the arrangement in space of the atoms themselves that determines the crystal structure.

During the period under review, indeed, the great problem which has exercised the minds of mineralogists has been the determination of the connexion between the chemical composition, the crystalline form, and the physical (more especially optical) characters of minerals.

The close interrelation between optical and crystallographic characters had been to a large extent already recognized by the work of Brewster, who had shown how different types of crystals differed in their behaviour towards polarized light. The gradual accumulation of knowledge which led to the distribution of crystals into groups or systems, each distinguished from the others by the optical characters of its members, is well brought out in the *Introduction to the Study of Minerals*, one of the British Museum Guidebooks, first published in 1884, for which geologists desirous of gaining some knowledge of minerals owed a debt of gratitude to Sir Lazarus Fletcher, the successor to Story-Maskelyne in the Keepership of the Mineral Department. The exact determination of the optical characters of rock-forming minerals such as the felspars, pyroxenes, and amphiboles, which has been rendered possible, first by the researches of Des Cloizeaux and Tschermak, and later by the improvements in apparatus and methods effected by more modern workers, of whom mention may be made of Becke, Fedorov, and Wright, is of the utmost importance for the development of petrology. Such advances have been made in this direction that it will soon be possible from the determination of the optical characters of any one of these minerals, as seen in thin-sections under the microscope, to make fairly accurate deductions as to its other properties, including the chemical composition.

Steps towards the solution of the other branch of the problem with which mineralogists have been concerned, viz. the connexion between crystalline structure and chemical composition, had also been taken, before the period under review, in the study of isomorphous groups. More recently, series of brilliant researches, of which those made by Tutton on isomorphous groups of sulphates and selenates are the most remarkable, have shown that the individual members of such groups are not crystallographically absolutely similar, but that quite definite and concordant, though minute, changes in the crystal form and optical characters are produced by the replacement of one metal by another. Most notable also in this connexion are Penfield's classic demonstration of the isomorphous replacement of fluorine and hydroxyl, and his investigation of the morphotropic relations of the members of the humite group of minerals.

It was as far back as 1850, however, that perhaps the most striking advance was made towards the goal to which mineralogists were striving. In that year was published what might appear at first sight to have little bearing upon the matter, viz. the mathematical memoir of Bravais on the regular arrangement of points in space. Bravais' work was a more complete development of the geometrical investigations of Frankenheim on parallelepiped networks of points known as space-lattices. In a space-lattice points are arranged in space for the most part at the intersections of three sets of planes, the planes in each set being parallel and spaced at equal distances apart. In such an arrangement space is divided up by the points into parallelepiped cells, just as the space of a room may be regarded as divided up into so many cubic inches, the shape of the cell depending upon the inclinations to each other of the three sets of planes, and upon the distances apart of the parallel planes in the three sets. It was assumed that as crystals are homogeneous structures they must be built up of units occupying the position of points in space-lattices; and according to the particular kind of space-lattice, i.e. to the shape of its elementary parallelepiped cell, crystals could be divided into the same seven systems into which they had been grouped by the consideration of crystal-symmetry.

Since the publication of Bravais' memoir crystallographers have realized that crystals can be divided according to the degree of symmetry they exhibit, i.e. according to the number of planes and axes of symmetry they possess, into thirty-two distinct classes, and that these may be regarded as to some extent mutually independent, although capable of being distributed through the seven larger systems according as they have certain geometrical and physical relations in common. The fact that only thirty-two types of symmetry are possible in crystals had been discovered by Hessel as far back as 1830, and rediscovered by Gadolin in 1867, but the actual grouping of crystals into these classes is of comparatively recent date; for although prominence is given to it in Miers' *Mineralogy*, published in 1902, and in Lewis, *Crystallography*, published in 1899, it is not taken into account in Story-Maskelyne's *Morphology of Crystals*, published in 1895.

Now space-lattices only sufficed to represent the symmetry of the most symmetrical (holohedral) class in each system. It has been the work first of Sohnke and later of Schönflies, Fedorov, and Barlow to show how all the thirty-two types of symmetry recognized in crystals can be represented by point-systems, which are generally reducible to a certain number of interpenetrating space-lattices in each case of the same kind. The kind of space-lattice determines the system, but the mode of interpenetration of several lattices of the same kind determines the particular class in that system. In setting up a crystal, crystallographers have now in most cases to choose as axial planes three faces which they have reason to suppose are parallel to three sides meeting in a corner of the elementary cell of the space-lattice. Recently Fedorov, by choosing crystallographic axes somewhat on these lines, has prepared a general table of the characteristic angles of all measured crystals, which makes it possible to identify quickly from its crystals any substance that has been previously measured.

The question now arose as to the nature of the units involved in the crystal structure. The old notion that the crystal-molecule consisted of a polymerization of many chemical molecules was soon discarded, and, through such a work as that of Tutton, the idea was gaining ground that the units in the crystal structure might be single molecules or even the atoms themselves, when Barlow and Pope brought forward their well-known valency theory, according to which the crystal structure of any chemical compound can be explained by the "close-packing" of spheres representing the atoms of its molecules, the sizes of the spheres being approximately proportional to the valencies. This theory has been applied with a fair measure of success to many organic compounds as well as minerals, though the recent demonstration, by means of X-ray experiments, of the equality in volume of the elementary cells of the space-lattices of crystals of ammonium sulphate and rubidium sulphate, would appear to suggest that some modification of it may be necessary which shall take into account other properties of the atom besides the valency.

Quite recently, as all the world knows, actual experimental proof has been forthcoming of the space-lattice arrangement in crystals. To Laue first came the truly brilliant inspiration that, just as a closely ruled (1,000 lines to the inch) diffraction grating behaves towards light with its wave-lengths measured in thousandths of a millimetre, so it was conceivable would the parallel planes of atoms, as arranged in interpenetrating space-lattices in a crystal, behave as diffraction gratings to X-rays with their wave-lengths (of the order 10^{-9} cm.) so infinitely more minute than those of light. The experimental testing of this stupendous idea was marvellously successful. Photographic plates exposed to X-rays which had traversed plates of crystals showed spots of maximum effect which were distributed in accordance with the symmetry of the crystal. In the hands of W. H. Bragg and W. L. Bragg a modification of this method of experiment has given results, the most reasonable interpretation of which fixes the actual arrangement in space of the atoms in crystals of many minerals. In crystals of common salt, for example, the experimental data indicate that the atoms of sodium and chlorine are each distributed on a separate space-lattice of which the elementary cell is a centre-faced cube (i.e. a cube with points not only at the corners but also at the centres of faces), the two lattices interpenetrating in such a way that the sodium and chlorine atoms occur alternately at equal distances apart. In another cubic mineral, iron pyrites, the three atoms of its molecule are again distributed on centre-faced cube lattices, but the interpenetration of the three lattices is so much more complex as to account for the fact that whereas salt crystallizes in the most symmetrical holohedral class, iron pyrites belongs to the less symmetrical pyritohedral class.

With the account of this brilliant consummation this review may well come to a close. Limits of space allow of a reference only to the wonderful series of experiments by van't Hoff and his pupils on the Stassfurt salt deposits, which have shown how their minerals separated from solution; and to the investigations by Vogt, Doelter, and the band of energetic workers in the Geophysical Laboratory at Washington on the problem of the crystallization of silicates and sulphides from fused magmas. These researches which are still in progress are of great geological interest, as they may be expected to throw much light upon the origin of rocks and ore deposits. Other recent investigations, also having their appeal to geologists, are the determinations by Fenner of the temperatures of inversion of quartz, tridymite, and cristobalite, which enable these silica-minerals to be used as geological thermometers; and the use made by Joly, Strutt, and others of radioactive work on the rate of disintegration of unstable elements such as uranium and thorium in order to measure geological time, and thus to help towards the solution of the vexed question of the age of the earth. Many of these researches, however, as well as the attempts, both experimental and theoretical, made by Clarke, Tschermak, and others, to elucidate the chemical constitution of silicates, have been the subject of some controversy; and none have as yet reached such a climax as the demonstration of the atomic structure of crystals.

This last attainment, it may be noted, has been the result of a gradual extension of investigation from great things to the infinitely small. The science of geology began with the study of rocks, the large bodies which constitute the earth's crust. In order to determine the composition of rocks geology had to seek the aid of mineralogy. The latter science, in its turn, after concerning itself at first mainly with the natural history characters of minerals, had to apply for knowledge of their elemental composition to the science of chemistry which it had itself originally created. Finally physics and mathematics had to be invoked in order to explain how the atoms of the elements are arranged in space in order to produce those exquisite shapes, the crystals, in which minerals generally occur. It may be that the problem of crystal structure will eventually receive its complete solution by a continuation of the same process in making use of the knowledge now being acquired of the complexity of the atom and the immense forces stored up in it. Mineralogists, having done so much for crystals, may then perhaps direct more attention to the study of non-crystalline colloidal minerals, and thus possibly forge a connecting link with the biological sciences.

In conclusion, the dominant impression produced by a review of the progress of mineralogy during the past half-century is that it is only in their initial stages that natural history sciences can attempt to keep in rigid compartments mutually independent of each other. As they continue to advance the greater becomes the necessity, and this is true not only of those which concern themselves with the inorganic world but also of those which deal with the living things upon it, to stretch out for aid to the sciences which really stand at the base of all others—chemistry, physics, and mathematics. In the future it is probable that a much more thorough training in these fundamental sciences than is at present considered sufficient will be regarded as an essential preliminary to the proper study of any department of natural history.

III.—A Mines Department for the United Kingdom.

THE formation of a new Government organization to foster and promote the interests of the Mining Industry of the United Kingdom has been recently proposed in two distinct quarters. The Coal Conservation Committee of the Ministry of Reconstruction, which issued its report (Cd. 9084) early in the past year, recommended the establishment of a Ministry of Mines and Minerals, to be presided over by a Minister with a seat in Parliament; while in a report to the Minister of Munitions, issued as a white paper (Cd. 1984) on November 15, Sir Lionel Phillips, late Controller of the Department for the development of Mineral Resources in the United Kingdom, favours the setting up of a Mines Department, to be attached to one of the existing great Departments of State.

In a country like ours, which has probably greater mineral wealth than any area of equal size on the globe, and where the development of vast untapped resources of coal and iron-ore is to some extent hampered by ancient vested interests, the necessity for an organization of the kind indicated scarcely needs any advocacy. We can therefore confine ourselves to the discussion of the functions that such a Mining Department should be designed to fill.

Some of them are already performed by various existing Government departments. Thus the *Home Office* administers the legislation affecting mines and quarries and, in connexion therewith, carries out an inspection by qualified officers: it also collects and publishes in an annual report certain statistics regarding accidents, labour, and output; and it conducts examinations for colliery managers' certificates. The *Board of Trade* collects, under the Census of Production Act, 1906, particulars of the quantity and value of the output of coal, metalliferous minerals, and of works engaged in the smelting of metals; and during the War it has been largely concerned with the regulation of the supply and distribution of coal and coke. The *Board of Education*, in its capacity as administrative head of the Geological Survey (in succession to the old Science and Art Department), has to do with the Geological Survey of the United Kingdom, i.e. with the preparation of geological maps, explanatory memoirs, and of special Reports on Mineral Resources, as well as the maintenance of a Museum of geological collections and economic resources. The *Woods, Forests, and Land Revenues*, through its Commissioner, acts as Gaveller of the Forest of Dean and also exercises the rights of the Crown in respect of mines under the sea, below high-water mark, in all parts of the Kingdom. Similar Crown rights are exercised by the *Duchies of Lancashire and Cornwall.* During the War the *Ministry of Munitions* has, under the Defence of the Realms Act, exercised many of the functions of a Mines Department. Its activities with regard to minerals have separated naturally on the lines of ferrous and non-ferrous. Through its Iron and Steel Department under the administration of Sir John Hunter and Colonel Charles Wright, C.B., it has been able to develop rapidly home supplies of iron-ore so as to more than make up for any loss of foreign supplies due to the activities of the enemy submarines; in connexion with this, it became necessary, in order to properly gauge the industrial situation, to organize the collection of very complete statistics of production of raw and semi-finished materials, and it is understood that in the course of this work a most valuable series of records has been accumulated. The Department for the Development of Mineral Resources was established for the purpose of increasing in the United Kingdom the supply for War purposes of minerals other than coal and iron. Sir Lionel Phillips was made Controller; and his Report, which has just been issued, is the one referred to above.

The proposal made by the Coal Conservation Committee is that the duties hitherto performed by so many different Government bodies should, with certain specified exceptions, be transferred to and administered by a Ministry of Mines for the United Kingdom. The functions of such a Ministry would from the foregoing appear to be: to collect statistics of production, consumption, and metal requirements of the United Kingdom; to provide for the certification of the managers of all mines and quarries; to safeguard the health and safety of the employees by administering the legislation affecting mines and quarries; and finally, to set up machinery to deal with such local mining problems as the working of barriers, the drainage of waterlogged areas, wayleaves, royalties, etc.

In Sir Lionel Phillips' scheme it is suggested that there should be attached to the proposed Mines Department, (1) an Imperial Mineral Resources Bureau, forming a link with the self-governing Dominions, (2) a Mines and Minerals Commission to watch and foster the interests of the Empire in the output and trade in mineral and metallic products. Other notable points in his scheme are (1) the appointment of commissioners authorized to take action in cases of improper exploitation of properties, or unreasonable or prohibitive conditions imposed by landowners for royalties and wayleaves; (2) the provision and administration of a fund for the purpose of undertaking experimental work.

Since Sir Lionel Phillips wrote his report an Imperial Mineral Resources Bureau has been set up. It has been designed as an Imperial link between the respective Mines and Mineral Departments of the self-governing Dominions, India, and the United Kingdom, and its constitution would not appear to permit of its being attached to a Mines Department of the United Kingdom. The Bureau is, we understand, already at work on its internal organization. It is an Imperial body to be incorporated by Royal Charter under the Presidency of the Lord President of the Council, with a governing body containing representatives appointed by the self-governing Dominions, India, and the United Kingdom, as well as certain technical men appointed by the Minister of Reconstruction to represent the mineral, mining, and metal industries generally. In the collection of statistical information it will work through the Mines Departments of all parts of the Empire, including the United Kingdom, and as an Imperially constituted body its relations to a Home Mines Department should be of similar nature to those of the self-governing Dominions.

From what has been said, however, it must be clear that it would be a great advantage for the dispatch of important business relating to the mining industry of this country to bring under one official head the functions performed by so many different governing bodies. Whether an independent Ministry should be formed or to what existing Department of State a Mines Department should be attached are questions of comparatively minor importance. But if a Ministry to deal with Commerce and Industry were to be formed this would obviously be the proper home for a Department of Mines and Minerals, just as in France the *Conseil général des Mines* is a department of the *Ministre des travaux publics.*

IV.—The Interior of the Earth.

By R. D. Oldham, F.R.S., F.G.S.

Being the Introduction to a Geophysical Discussion organized by a Committee of the British Association for the Advancement of Science, and held in the rooms of the Royal Astronomical Society on November 19, 1918.

WHEN I received the invitation to open this discussion my first feeling was of diffidence, for, the interior of the earth being necessarily inaccessible to direct observation, the solution of the problems connected with it has principally been left to mathematical research, and this must remain the final court of appeal. In these circumstances it seemed verging on presumptuousness to address an audience consisting so largely of mathematicians in inauguration of a discussion on the interior of the earth. Second thoughts showed that there was much to be said against this view, for, though mathematics is the court of appeal, it can only decide on the facts placed before it by the sciences of observation, and so the discussion seems profitably prefaced by a statement of the leading facts which have been collected, and those conclusions which are so directly derived from them as to have almost the validity of observation.

The first, and still one of the most important, of these observations is that the temperature rises regularly to the greatest depth yet penetrated into the earth, the rate of increase being on the average about 1° C. for every 25 m. of depth; we also know that at depths from which volcanic eruptions take place the temperature reaches at least 1000° C. So long as the nebular hypothesis held undisputed sway, it was natural to suppose that the increase of temperature was continuous to the centre of the earth, and, as long ago as 1793,[1] we find Benjamin Franklin indicating the necessary corollary from this, that below a certain depth the material, of which the earth is composed, must necessarily be in a molten, and, at a still greater depth, be converted into a gaseous, condition, an hypothesis very similar to that associated in recent times with the name of Arrhenius.

The fundamental assumption on which this deduction is based has been sapped by the discovery that the radium content of the outer layers of the earth is amply sufficient to account for the whole of the temperature gradient observed in its superficial portion, and, other considerations being ignored, the hypothesis which has been seriously proposed, that the innermost parts of the earth may be intensely cold, approaching the absolute zero temperature of space, is a possible one. We have also the demonstration that the earth as a whole is something like twice as rigid as an equal-sized globe of solid granite, which precludes the assumption that the interior can be in a fluid or gaseous condition in any ordinary sense of the word, but here we must allow for the effect of pressure. When it is remembered that at a depth of but 4 km., or about 2½ miles, the pressure is already greater than the crushing strength of the strongest known rock, and that at the centre it is about three thousand times as great as this, it becomes evident that the properties of matter may be very greatly modified and that the terms used to describe the three states, as we know them under surface conditions, may need to be used in a very esoteric sense when transferred to the interior of the earth. For the present all that need be said is that material, which can be shown to be from twice to six times as rigid as strong granite, can only be described as fluid or gas in a very Pickwickian sense of the word, and it is possibly a mere accident that the threefold division of the interior, outlined by Benjamin Franklin, comes so near that which I propose to show is the deduction to be drawn from the present state of knowledge.

Taking the outer layers of the earth first, we find that the rocks which are exposed at the surface consist in part of material which has been disintegrated by the processes of surface denudation, transported, deposited, and resolidified, and partly of rock which has not

[1] Trans. Amer. Phil. Soc., iii, pp. 1–5, 1793.

yet undergone these processes, but is thoroughly cooled and solid in every sense of the word. To the greatest depth yet reached the rocks are of this type, and it evidently continues for some distance below the depths which can be reached by direct observation or by immediate deduction. This outermost portion of the earth, in which the physical condition is similar to that of the surface rocks, is commonly known in geology as the crust, a name which originated in the days when the earth was supposed to consist of a molten interior and an outer solid crust, and has survived that supposition for want of a better, and after all the word does not necessitate a fluid interior; a loaf of bread, for instance, has a crust, though the interior should be solid. At the present day the term means no more than the outer layers in which composition and constitution have not undergone any great change, as opposed to the more deeply seated material, which differs on one or both of these characteristics. The thickness of this outer crust has been estimated by various methods, the increase of temperature, the pressure under which certain minerals must have been formed, the strength of the crust as indicated by the anomalies of gravity, and some others, all of which agree in putting the lower limit at about 50 km., or some 30 miles, well under one-hundredth of the radius of the earth.

In the outer regions of the crust geological investigation has shown that movements of displacement have taken place on a large scale. Over widths of some hundreds of kilometres rocks have been compressed to the extent of one-third to one-half or less of their original extension, as is shown by the folds into which originally horizontal strata have been thrown. In other cases clean-cut, gently sloping, or horizontal fractures have been recognized, and, along these fractures, displacements have taken place to the extent, well established, of over 60 km. and in some cases possibly of over double this, or from $\frac{1}{2}^\circ$ to 1° of the circumference of the earth. In other places there is evidence of extension, much less capable of measurement than the compression, which, though probably smaller on the whole than the compression, may be comparable in amount. Displacements in a vertical direction have also been well determined, along defined surfaces of fracture the displacement of opposite sides of faults has been established up to about 5 km., and possibly to half as much again, and, as regards places less than a couple of degrees apart, such as the crests of the Himalayas or Andes compared with the plains at their foot, or the mountains of Japan with the bottom of the Tuscarora deep, the vertical displacements may be as much as 15 km.

The cause of these great earth movements is still an unsolved problem of geophysics. At one time they were generally attributed to compression of the earth's crust through contraction due to gradual cooling, and the notion is by no means extinct, but the curiously local distribution of the compression is against this interpretation, no less than the fact that the amount is largely in excess of any contraction permissible on this hypothesis, and besides we have the equally well-established facts that regions of very considerable extent show signs of tension and expansion of their dimensions.

Especially in the case of the great thrust-faults is explanation difficult; the appearances are such as suggest a simple fracture and displacement by compression due to approach to each other of the limits of the region affected, but it can easily be shown that the thrusts involved in this explanation are many times greater than those which could be transmitted by the material of which the blocks are composed. The final explanation must wait until it can be treated by one who is at the same time fully cognisant of the geological results and of the physical principles involved, probably also till a further advance is made in our knowledge of the physical properties of the material under conditions such as exist, even at the comparatively small depths involved.

Leaving this question aside, it is clear that extensive displacements have taken place in the outermost layers of the crust, and these are presumably taken up, possibly in a somewhat different form, by the lower layers, but in any case necessitate that, below the rigid and solid crust, must come material which possesses some of the properties attributed to a fluid, though not necessarily more than the power of changing its form when exposed to stresses of sufficient magnitude and of long enough duration. This has been recognized for some time, and we were content to accept the general conclusion without giving it a name, but this does not satisfy American thought, and Professor J. Barrell has not only introduced the name asthenosphere for the region of material comparatively weak as against permanent stress, but has given a numerical estimate of this weakness or strength. According to him the material at the weakest part of the asthenosphere reached by his investigation, placed at 400 km. from the surface, is about $\frac{1}{25}$ of that of massive surface rocks, and of the order of a capacity of sustaining stress differences of about 1,000 lb. per sq. in. with extreme permissible limits of 100 and 5,000 lb. per sq. in. At this depth the conclusions drawn from his method of deduction become distinctly doubtful, but, at the lesser depth of 50 km., the strength is only about six times that quoted and at 100 km. about four times this amount.[1]

The nature of the transition from the solid crust, or lithosphere, to the underlying asthenosphere is of interest, and on it two lines of reasoning can be brought to bear. First, we have Professor Barrell's calculations, according to which the permanent strength between the depths of 20 and 30 km. amounts to about four to five times that of granite, and at a depth of 50 km. to only one-quarter, showing a very rapid diminution of strength at depths below 30 km. and a tolerably abrupt transition from the crust to the underlying material. The other line of reasoning depends on the phenomenon of reflection of earthquake waves. It is now pretty well established that long distance records, when clear enough, show the arrival not only of waves which have travelled from the origin by a direct path, but of others which have been reflected at or near the surface. In the mathematical treatment of these waves it is necessary to assume

[1] *Journal of Geology*, xxiii, p. 44, 1915.

a spherical body with a definite outer surface, from which reflection takes place, and it was not unnatural to regard this as the outer surface of the earth, but there are some very real difficulties in the way of this interpretation. Just thirty years ago Dr. C. G. Knott showed[1] that, in the heterogeneous material of which the outer layers of the earth are composed, simple condensational and distortional waves could not be transmitted, as each would undergo a breaking up into two forms at every passage from rock of one kind to that of another; ten years later Professor M. P. Rudzki further showed[2] that only a very small proportion of known rocks possessed those characters of elasticity which would enable them to transmit unaltered the two simple forms of elastic waves, and the records of seismographs show that the movement of the wave particle at the surface is of a very complicated nature, having no relation to the simple movements required by the theory of reflection. For these reasons it seems probable that the reflection, of which we find evidence in long distance records, does not take place at, but a short distance below, the surface, and it is natural to place it at the limit where the more heterogeneous rocks of the outer layer pass into the more homogeneous material of the central core—in other words, at the lower limits of the crust or at about 30 km. below the outer surface. Professor Barrell's figures suggest that the limit is probably sufficiently defined to give rise to reflection, and the fact that the reflected waves are not always equally conspicuous is in consonance with the natural assumption that the lower limit of the crust may be more sharply defined in some places than in others, an assumption which is strengthened by fact that these reflected waves are especially conspicuous where the point of reflection lies under the great nexus of mountains forming the Pamir Plateau and the "Roof of the World". It is not unnatural to suppose that this region, unique as regards surface features, should be equally singular in the character of the under surface of the crust, and so give rise to the more than usual prominence of the reflected waves, where incidence takes place under this region.

For the rest of the interior of the earth we are principally dependent on the results obtained by the modern development of seismology. When it was recognized that the long distance records of great earthquakes represented the arrival of mass waves which had travelled through the earth it must have occurred to more than one worker that they would give information regarding the constitution of the material traversed by the wave paths, but I know of no published work previous to a paper by myself, read before the Geological Society in February, 1906, on the "Constitution of the Interior of the Earth as revealed by Earthquakes",[3] to which, doubtless, I owe the honour of having been invited to address you to-day, and in treating the subject the most convenient course

[1] Trans. Seismol. Soc. Japan, xii, pp. 115 ff., 1888.
[2] Beiträge z. Geophysik., iii, pp. 519–40, 1898.
[3] Quart. Journ. Geol. Soc., lxii, p. 456, 1906.

will be to outline the position as there presented, and the modifications which have been introduced by subsequent work. In 1905 there were twelve earthquakes of which direct and accurate knowledge was available of the place and time of origin, and two of which the place was known, but the time had to be inferred from distant records. Tabulating the records of these earthquakes, it was found that the intervals taken by the first and second phases to reach the place of record increased regularly up to a distance of about 120° from the origin. The rate of transit increased more rapidly at first, less rapidly later, and showed that the deeper the wave path penetrated the greater became the rate of transmission, which meant that the wave paths were curved with a convexity towards the centre of the earth. Up to 120° there was no breach in the regularity of the time curve, and the ratio between the rate of propagation of the condensational and distortional waves remained much the same; beyond 120° distance an irregularity appeared, the first phase, or commencement, was appreciably delayed, and the second phase completely disappeared, only at about 140° did something reappear which was recorded as second phase, but must either be distinct from the second phase at lesser distances, or be delayed by about ten minutes in its arrival. From these facts it was concluded that the earth, down to the depth reached by wave paths emerging at 120°, or to a little more than half the radius measured from the surface, was composed of material capable of transmitting the two primary forms of wave motion, and that down to this depth there was no indication of any change of condition, the increase in elasticity, indicated by the increasing rate of propagation, being no more than might be attributed to the increased pressure and compression of the material. Beyond this depth there is a rapid transition to a material which can only transmit the condensational waves at a somewhat reduced rate, and is either incapable of transmitting the distortional waves, or transmits them with a reduction to about half the velocity attained in the lower parts of the outer shell; at that time it was impossible to decide between the two alternatives which were both presented, with some leaning towards the former.

In dealing with subsequent developments it will be convenient to take the two parts of the time curve, and of the resulting parts of the earth's interior separately. Beginning with the outer shell the first work to be noticed is the often quoted paper by Professor Wiechert, which appeared in 1907,[1] where the subject is treated in a more elaborately mathematical form, and appended to it is a detailed discussion of the records by K. Zöppritz, the most important part of which, from the present point of view, is the discussion of the depth reached by the wave paths. For those emerging up to a distance of about 45° the depth reached by the two wave paths is about the same, and increases rapidly at first, then less rapidly; from 45° to about 70°, where the depth reached is about 1,400 to 1,500 km., there is very little increase, but a considerable difference

[1] "Ueber Erdbebenwellen": Göttingen Nachrichten, 1907.

in the depth reached by the two forms of waves; beyond that distance the depth reached increases again, and gradually becomes more equal for the two forms of wave motion till the limit of about 120° is reached. In detail these results have been modified by later work and more exact and numerous determinations of the time intervals, which Professor H. H. Turner has, within the last three years, found to require considerable corrections; it is also a fact that the mathematical methods were not altogether sound, and quite recently the problem has been tackled anew by Dr. C. G. Knott.[1] He informs me that he has succeeded in solving the integrals in an unequivocal manner, no longer needing the use of any assumptions, as had previously been used by himself and by Professor Wiechert. From this he has computed and plotted the wave paths for various distances, which show that those emerging at from 45° to about 75° are crowded together in their deepest-lying parts, in a zone lying just outside about one-quarter of the radius from the surface, or at a depth of 1,300 to 1,500 km. The flattening of the wave paths in this region shows that the increase in rate of propagation suffers a check, and in the case of waves emerging at 73° the lower part of the path is actually concave towards the centre, indicating a temporary decrease in the rate of travel.[2]

The coincidence of these results make it apparent that a change of some kind takes place in the neighbourhood of 1,400 km., or rather less than a quarter of the radius, from the surface, but it is equally clear that it is not a change of state, for both here and at greater depths the two forms of simple mass waves continue to be propagated at about the same relative rates as is demanded by theory. The change indicated is rather of chemical composition than of physical constitution, and in discussing this it is necessary to hark back.

There is a considerable body of evidence, principally astronomical, though partly also geological, which goes to show that the central portion of the earth is composed of metal, principally iron, surrounded by a sheath of stony material. In part this deduction is reached from spectroscopic analysis of the sun and stars, in part from the composition of meteorites, which, whether regarded as the fragments of older worlds, or as the material from which worlds are built up, may be regarded as fair samples of the composition of our earth, and in part from certain geological observations which indicate that deep down in the earth masses of metallic iron are associated with the

[1] Not yet published in full; for an abstract see *Nature*, November 21, 1918, p. 239.

[2] In this connexion it is noteworthy that just a year ago Dr. G. W. Walker announced his conclusion that many of the earthquakes which give rise to long distance records originate at about this depth (Brit. Assoc. Rep., 1917). The conclusion cannot be regarded as fully established, and there are some difficulties in the way of its acceptance, but it is an important and interesting suggestion, which must receive serious consideration, with the reservation that the origin is not of the earthquake proper but of the bathyseism, of which the surface quake, which is felt and does damage, is a secondary result (see Quart. Journ. Geol. Soc., lxv, p. 14, 1909).

stony matter of the outer layers. This hypothesis was mathematically investigated by Professor S. Wiechert in 1897,[1] who found that, within permissible variations, the earth might be regarded as composed of a central core of density about 8 and an outer sheath of density about 3, the dimension of the core being from about three-quarters to less than four-fifths of the radius of the earth, according to the actual densities adopted, and that such an earth would satisfy the known conditions of mean density, as well as of precession and nutation. On the latter I can offer no opinion or criticism; the former is easy of verification, the densities are about right for the stony casing and the mainly iron core, allowing for the effects of pressure and compression, so that the hypothesis may be accepted as at least a possible one, and it is noteworthy that the limit of the two parts of the earth lie just where the earthquake records indicate a change in composition, unaccompanied by change in state, of the material of which the earth is composed.

There remains the central part of the earth, penetrated by wave paths emerging beyond 120° from the epicentre. In 1906 it was still doubtful whether the so-called second phase at these distances represented the much delayed distortional waves, travelling by a direct path, or was of a different character. In Professor Wiechert's paper, already referred to, the slowing down of the rate of transmission, at depths below a little more than half the radius, was recognized, but the second phase was accepted without question as representing the same phenomenon as at distances of 100° and less, and this has remained the interpetation accepted by the Göttingen school, up to the latest publication which has reached us. In this country the trend of thought has been different; the first noteworthy landmark was the demonstration by Dr. G. W. Walker that what was recorded as the second phase at these great distances synchronized with the time at which waves reflected at, or near, the surface of the earth would reach the place of record,[2] and this seems still the most probable interpretation. Lately Professor H. H. Turner has attacked the same problem and, in the latest reports of the British Association and the Shide Bulletins, has shown, by statistical methods, that the so-called second phase at distances beyond the limit of 120° must be a different phenomenon from the second phase at lesser distances. Meanwhile, by an entirely different path, I had myself arrived at a similar conclusion; the examination of records of instruments of the type generally used in Italy, which give the second phase in an exceptionally clearly marked and conspicuous manner, showed that the so-called second phase at very long distances was of a different type altogether, and a few years ago I was able to examine some of the records of the Galitzin instrument at Eskdalemuir, which gave just the same result. The typical second phase, when well developed, shows a distinct commencement, a well-marked maximum and a less rapid dying out; it is, in fact, patently the record of a single group of waves of one character and

[1] *Göttingen Nachrichten*, 1897, pp. 221–43.
[2] *Modern Seismology*, 1913.

form. At long distances, on the contrary, the commencement is more gradual; there is no well-marked maximum, but two or more succeeding each other, and the record bears the impress of being due to the successive arrival of more than one group of waves, just the appearance, in fact, which would be anticipated from Dr. Walker's interpretation. Taking all this into consideration it is not possible to accept the supposed second phase at distances beyond 120° as being identical in character with the feature which is so well marked at lesser distances, and in these very long distance records nothing can be recognized which may be identified as the arrival of condensational waves travelling by a direct path from the origin; if present they are much reduced in intensity and delayed in arrival. Hence we may conclude that the wave paths which penetrate deeper than the outer limits of a central nucleus, extending to something less than half the radius of the earth from the centre, encounter a material which is devoid of rigidity even against stresses of only a few seconds' duration.

A similar conclusion seems to have been reached by Mr. Harold Jeffreys, if I understand him aright, as the result of a mathematical investigation of the viscosity of the earth,[1] based on tidal deformation and the periodic variation of latitude, so that we have two entirely independent lines of research leading to the same conclusion.

To sum up, we have found that the interior of the earth is divided into three distinct regions, characterized by differences in the physical condition of the material. They are:—

1. An outer crust, of matter which is solid in every sense usually attaching to the word. Its thickness is comparatively insignificant, being little more than half a hundredth of the radius. At its lower limit this passes rapidly into

2. A shell of about half to three-fifths of the radius in depth, consisting of matter to which neither the term solid nor fluid can be applied without introducing a connotation which is contradictory to some of its properties, for while highly rigid as against stresses of short duration, or even of duration measured by years, it is capable of indefinite yielding to stresses of small amount if of secular duration. At its lower limit this passes somewhat rapidly, but more gradually than at the outer limit, into

3. A central nucleus consisting of matter having little or no rigidity, even against stresses of very short duration. Here the material may be described as fluid, whether liquid or gas, without introducing any contradictory connotation.

In composition, as distinct from constitution, the earth appears to consist of two parts; a central portion mainly metallic and principally iron, extending to somewhere between three-quarters and four-fifths of the radius, and an outer envelope composed of stony material.

Geologically, we have a twofold division, into the outer crust composed of material more or less similar, in composition and

[1] Monthly Notices of R.A.S., May, 1917, p. 454.

constitution, to the surface rocks with which we are acquainted, and an inner core which differs in one or both of these characters. Etymologically the word "geology" should apply equally to the study of both these regions, but, for convenience and from the limitation of the individual human mind, it is usually confined to the problems presented by the rocks composing the crust, while those of the deeper regions lie outside its scope.

Such, briefly, are the conclusions which may be drawn from the sciences of terrestrial observation. The statement, I know, is incomplete and imperfect; some at least of the conclusions will doubtless be traversed and regarded as incompatible with the results obtained from other lines of research, but in their main features of the threefold division of physical condition and the twofold division of chemical composition they seem to me so well founded that the burden of proof lies with those who would traverse, rather than with those who are prepared to accept, them.

V.—Notes on Ammonites.

By L. F. Spath, B.Sc., F.G.S.

I.

THE following notes were compiled, for the most part, some years ago, but their publication in the present form suggested itself to the writer on the perusal (during a short "leave" from active service) of a number of recent papers on Ammonites, principally Professor Swinnerton and A. E. Trueman's study of the "Morphology and Development of the Ammonite Septum".[1] The main part of that inquiry is devoted to the development of the septum, illustrated by successive "septal sections", and it is claimed that where sutural development cannot be worked out, "septal sections" will to some extent serve as a substitute. The writer has no intention of discussing the usefulness of "septal sections"; but some of the suggestions put forward, and conclusions arrived at, by the authors, as well as certain opinions, which they adopt from other workers on Ammonites, invite critical examination. Since, in the present paper, other recent work on the morphology and physiology of the Ammonite septum and suture-line, not yet embodied in text-books, is also included, and since the writer ventures to put forward opinions that differ in many essentials from the views of both textbooks and other authors, it is hoped that the paper may prove of general interest.

The Forward Bulge of the Septum.

Swinnerton and Trueman give interesting contoured plans of the second and of the adult septum of *Dactylioceras commune*, Sowerby sp., and graphs illustrating the average profile of these two septa, and restate that "on the whole the second septum tends to be concave rather than convex forwards" (p. 37), and that "it appears that the [adult] septum as a whole is convex forwards" (p. 32). Professor

[1] Quart. Journ. Geol. Soc., vol. lxxiii, pt. i, pp. 26–58, pls. ii–iv, 1917.

Blake's suggestion is adopted, that this forward convexity of the later septa (so conspicuous only because the average section of an Ammonite happens to pass through the ventral and dorsal lobes) is evidence of pressure from behind the animal; and it is assumed that "in Ammonites the vigour of secretion may have been so great that the gas exerted sufficient pressure upon the soft mantle to make it bulge forward while the septum was being deposited" (p. 33).

The influence of this pressure is referred to in connexion with the modification of the adult suture-line in Dactyloidæ, where among other "ageing" characters of the later suture-lines the authors mention the "more intricate wrinkling of the minor details". They state (p. 39), "This complexity is strongly suggestive of the wrinkling of a collapsing or flaccid bladder, as opposed to the simpler and more turgid outlines of the folioles in earlier septa, and suggests a diminution in the vigour of gas-secretion in the declining period of life." The association of complexity with decline may seem contradictory; for the authors, speaking phylogenetically, say (p. 51) "during retrogression this fringe [of complicated frilling] is gradually lost". This complexity is not so apparent, however, as the other "ageing" characters mentioned, namely the "decrease in the antero-posterior range of the lobes and saddles" or "crumbling down of the apices of the saddles to approximately the same plane", and the "swinging forward of the umbilical portion of the suture-line" (p. 39). Following S. S. Buckman, the authors consider the Dactyliocerates to be "evidently a decadent offshoot of *Cœloceras*", though to the writer neither the decadence of this most flourishing family nor the derivation from the Carixian *pettos*-group, to which the genus *Cœloceras* must be restricted, is evident. They see in them "the phenomena which characterize the first stages in the simplification of the suture-line, a simplification that is carried to such extremes in Cretaceous Ammonites" (p. 40).

Correlation of Suture-line and Whorl-shape.

Attention must be drawn in this connexion to the close relationship that exists between the suture-line and the shape of the whorl. In the Dactyloidæ the tendency is towards loosely coiled, more or less cylindrical whorls, and in the evolution from a cadicone ancestor, through depressed whorls, to the slightly involute shell of the *Dactylioceras* figured by Swinnerton & Trueman, the suture-line would adapt itself to the altered whorl-shape. Zittel[1] stated: "When the whorls are circular one observes ordinarily only a few lobes, and in that case they are of nearly equal dimensions (*Lytoceras*); upon a wide ventral area the external lobe and external saddle acquire considerable dimensions; the flatter the sides are and the thinner the ventral part, the larger the size of the lateral lobes and lateral saddles, and the more numerous the auxiliary lobes." Pfaff[2] mentions that "compressed forms would show the greatest differentiation of their suture-lines in the lateral region and in the

[1] *Handbuch d. Pal.*, vol. i, 2, pp. 332, etc., 1881–5.

[2] "Form u. Bau d. Ammon.-Sept., etc.": Jahresb. Niedersächs. Geol. Ver., vol. iv, pp. 221–2, 1911.

principal lobe; depressed forms on the other hand externally and internally. Again, as during growth the septal surface increases at the relatively quickest rate on the external side, differentiation must begin here".

On examination of the three types of Ammonites chosen by Swinnerton & Trueman, it is found that in *Tragophylloceras Loscombi*[1] with wide lateral areas, the first lateral lobe and first lateral saddle show the greatest differentiation; and in the depressed *Sphæroceras Brongniarti* it is the external saddle. In the Dactyliocerate suture-lines figured by the authors on p. 39 the widest-ventered form (fig. 4) has the external saddle strongly developed, and it has already been remarked that there is a tendency to equalize the size of the saddles on the adoption of a more cylindrical whorl.

It should be pointed out, however, that there are what may be called family peculiarities that modify the suture-elements in certain cases. They are of value in tracing the affinities of homœomorphs, such as the perfectly similar oxycones that appear at so many horizons. The Triassic *Entomoceras denudatum*, Mojsisovics, and the Cretaceous *Garnieria* e.g. had been put into the strictly Lower Liassic genus *Oxynoticeras* by different authors. Although, in the mechanical adjustment to a wider side, either by the spreading-out of the lateral lobes and saddles or by the addition of auxiliary or adventitious elements,[2] similar suture-lines may result in different stocks, yet the modified shells can generally be referred to their ancestral stock by means of some retained family characteristic.

Again, the genera *Macrocephalites*, *Cadoceras*, *Pachyceras*, *Tornquistes*, and *Erymnoceras*, with wide ventral areas, all have a very large external saddle. In *Chamoussetia*, a smooth and keeled descendant of the *Cadoceras* stock, what may be considered the natural adjustment of the suture-line to this type of shell is shown; yet in the later keeled *Quenstedticeras* and *Cardioceras* the suture-line at first still is more or less similar to that of the fat ancestral forms. This may partly be retention of the family character or hastening of the development of the keel; but it may be assumed that ornament and other mechanical expedients for the increase of the solidity of the shell also influence the septal edge. This may account for the changing width of the external saddle in *Macrocephalites* and *Tornquistes* to which R. Douvillé[3] has drawn attention. *Tragophylloceras ibex*, with strong ornament, has a simplified suture-line as compared with the smooth Phyllocerates[4] of

[1] The specimen used by Swinnerton and Trueman for their series of septal sections (fig. 13 on p. 46) shows the small terminal leaflets of the *ibex* group.

[2] Pictet (*Traité de Paléont.*, p. 669) pointed out already in 1854 that the inflated "varieties" of a species often differed from the compressed ones in the number of the accessory lobes, and that modification of the umbilicus produced the same result.

[3] "Etude sur les Cardioceratidés de Dives, etc.": Mém. No. 45, Soc. Géol. France, Pal., i, 19, fasc. 2, p. 14.

[4] Additional work on the various features of the suture-line has demonstrated to the writer the impossibility of basing the separation of genera which other

the ancestral stock. In *Baculites* again, where, theoretically, the suture-elements should be equal, there is a fair amount of variation, caused probably by the differences in cross-section, ornament, and thickness.

It may be added here that certain Lower Aptian developments of the Upper Barremian *Leptoceras* (*trispinosum*-group) show how with the gradual straightening out of the shell the suture-elements become more nearly equal. One such form is e.g. "*Hamites*" *nodosus*, v. Koenen,[1] which, of course, has nothing to do with the Albian genus *Hamites*, just as "*Bochianites*" *undulatus*, v. Koenen,[2] cannot be attached to *Bochianites*, a homœomorphous development of an earlier perisphinctoid Hoplitid. The suture-line of these hoplitid Crioceratids then assumes the aspect of that of the lytoceratid Macroscaphitidæ, and the distinction between these two important families becomes very difficult.

Correlation of Suture-line, Attachment to Shell and Mode of Life.

Another factor has to be considered here. It appears probable that in Ammonites, as in the recent *Nautilus*, the shell-muscle could easily be detached from the shell when the animal moved forward a certain space to form a fresh chamber, and that, as there would have been considerable risk of the shell falling away from its inhabitant, the folded posterior portion of the Ammonite animal with its lobes and saddles afforded the means of holding on, a function performed in *Nautilus* by the strong central siphuncle.[3] When a stock like *Baculites*, in addition to its tendency to equalize the suture-elements of its straight shell, also shows simplification of the suture-line, it may be assumed that it represents an adaptation to a benthonic mode of life which its form alone would indicate. For *Lytoceras* itself, "often as thin as paper and clear as glass, with feeble ornament, i.e. characters that clearly remind one of adaptive forms of nectonic Gastropods of the high seas, *Atlanta*,"[4] and the delicate and smooth shells of Phylloceratidæ and Arcestidæ do not generally show simplification of the suture-line. In the latter, and also in most oxynote shells, so admirably adapted for an actively swimming mode of existence, the need for secure attachment of the animal to its shell was probably greater than in benthonic crawlers.

In those one-sided Ammonites of the Lias, called *Turrilites* by d'Orbigny, which, unlike Buckman[5] I would consider to be such

characters and especially geological occurrence would appear to connect (in this case *Tragophylloceras* and *Rhacophyllites*) on the comparatively insignificant difference in the endings of the external saddle.

[1] "Ammonitiden des Norddeutschen Neocom.": Abh. Preuss. Geol. Landesanstalt, N.F., Heft xxiv, p. 393, pl. xxxv, fig. 13.

[2] Ibid., p. 398, pl. liii, figs. 11, 13, 14.

[3] See E. A. Smith, "Note on the Pearly Nautilus," Journ. Conch., Oct., 1887; and Foord, *Cat. Foss. Ceph. Brit. Mus.* (*Nat. Hist.*), pt. i, pp. xi, xii, 1888.

[4] Diener, "Lebensweise u. Verbreitung d. Ammoniten": N. Jahrb. Miner., etc., ii, pp. 67–89, 1912.

[5] "Vererbungsgesetze und ihre Anwendung auf den Menschen": Darwinist. Schriften, I, vol. xviii, p. 22 (214), 1893.

adaptations to a benthonic existence, the suture-line is not affected. But in such aberrant types as *Cochloceras*, *Rhabdoceras*, and *Choristoceras*, where the reduction of the septal edges to great simplicity is accompanied by modifications of the coiling, the adaptation to a different mode of life can scarcely be doubted. Professor J. P. Smith[1] calls these "reversionary" types; but if the reduction of the suture-line and uncoiling were reversions to a primitive type, they should be preservative. The writer would also look upon *Œcoptychius Christoli*, Beaudouin, sp., *Popanites patturatensis*, Greppin, sp., and similar forms as aberrant, benthonic types.

"Phylogerontic" Suture-lines. Correlation of Suture-line and Ornament.

With regard to the "reduction" of the suture-line, distinction has to be made between such simplification as is shown in many individual Ammonites, where the last few septa may be simpler and be associated with an (equally sporadical) approximation. This is a growth-phenomenon of the individual. The formation of septa probably ceased when maturity was reached and the character does not become "phylogerontic"; for the stock may continue to elaborate its suture-line. Or, again, in the broad stream of development of a whole family, one branch, under local influences or owing to a tendency to diversity, may modify or simplify its suture-line. It is clear that if whorl-shape and suture-line (and of course also the other characters of the shell) are as closely interconnected as the writer believes, a form like *Hudlestonia* must adapt the suture-line of its probable ancestor *Phlyseogrammoceras* to an oxynote shell, with wide lateral area, according to the general rules mentioned above.

Similar modification is shown in *Staufenia* and *Clydoniceras*.[2] The latter, a local development[3] of the Bathonian *Oppeliæ*, does not so much "reduce" its suture-line as, rather, take on a specialized type that resembles certain "Pseudoceratites", with an increased number of elements, but less frilling. It is to be noted that the families themselves (Ludwiginæ and Oppelidæ) are not affected. In *Proplanulites* and *Pictonia*[4] the reduction is shown in the shortening of the saddles and lobes and the decreased complication

[1] In Zittel-Eastman, *Text-book of Pal.*, 2nd ed., vol. i, p. 673, 1913.

[2] Menzel, *Zeitschr. Deutsch. Geol. Ges.*, vol. liv, p. 90, 1902.

[3] Blake (in *Great Oolite Mollusca*, Mon. Pal. Soc. vol.), from the occurrence of this genus in the southern part only of the Cornbrash outcrop in England, concluded that it was dependent on the presence of the Great Oolite Series below, of whose fauna it was a relic. Compared with the almost universal distribution of the genus *Macrocephalites*, this restriction of *Clydoniceras* is interesting and shows that, like many modern marine organisms, certain Ammonite genera were undoubtedly strictly limited in their horizontal distribution. In aberrant or benthonic types, of course, like the *Oxynoticeras* derivative "*Ægoceras*" *Slatteri*, Wright, or *Nipponites*, the local restriction might be expected, more than in active swimmers.

[4] Tornquist, "Proplanuliten a. d. Westeuropäischen Jura": Zeit. Deutsch. Geol. Ges., vol. xlvi, 1894; also "Die degenerierten Perisphinctiden d. Kimmeridge v. Le Havre": Abh. Schweiz. Pal. Ges., vol. xxiii, 1896.

of their margins. With regard to *Pictoniæ*, Tornquist[1] stated: "We get the impression that they are Ammonites that have resulted from different groups of normal Ammonites, through general degeneration affecting them under local influences during Kimmeridgian times." It must be repeated here that development or loss of strengthening ornament on the shell would affect the suture-line as much as change of whorl-shape. For e.g. in *Pictonia cymadoce* the ornament may be more "reduced" than the suture-line in one specimen, and in another the suture-line more than the ornament.[2]

Adaptation to a Nautiloid, or less exclusively swimming mode of life,[3] might have taken place in *Frechiella*, which is also often one-sided and which shows the modification of its ancestral *Hildoceras* suture-line in its ontogeny. And the oxycones of *Hudlestonia* and *Stanfenia* were better adapted to an actively swimming existence than their Grammoceratan and Ludwigian ancestors. With Renz and J. von Pia[4] the writer would be inclined to favour the theory of adaptation, therefore, even if the special mode of adaptation be not quite clear in some cases, rather than speak of decline of vitality or phylogenetic degeneration.

Wholesale Phyletic "Catagenesis".

This applies, of course, also to the modification of the suture-line in the Cretaceous Pseudoceratites, which, however, is on a different scale, and which has been explained as a phenomenon coincident with the approaching end of the whole race of Ammonites. Walther[5] had stated: "Ammonites, after dominating the seas through three long periods and nearing their end, show in all groups such clear symptoms of abnormal growth, such evident signs of senile degeneration, that their extinction through a kind of senile decay seems to us inevitable." As far as it affected the suture-line, this "degeneration" produced "forms which remind one of Triassic Ceratites and even of certain Palæozoic Goniatites".[6] Indeed, *Neolobites Vibrayanus* (d'Orbigny) and *Metatissotia Ewaldi* (v. Buch) e.g. had been put into the genus *Ceratites* by d'Orbigny and even into *Goniatites* by Pictet. Just as in the modification of the shell, only certain lineages were affected, however, and these differently and at different horizons. But this going back, as it were, along the line followed in the evolution of the group from Goniatites through Ceratites to Ammonites, however incomplete, fitted into the representation of Ammonite phylogeny as a series of cycles "which

[1] Op. cit., p. 42.

[2] Ibid., p. 39.

[3] Diener ("Lebensweise u. Verbreitung d. Ammoniten": N. Jahrb. Miner., etc., ii, p. 69, 1912) says that *Nautilus* lives chiefly crawling, but can swim well and quickly, and has also been found attached to the bottom, which "shows that its present mode of life is little stable yet". Diener, therefore, does not agree with Dollo ("Les Cephalop. adaptés à la vie nect. second. et à la vie benthique tertiaire": Zool. Jb. Spengel. Festschr., Suppl., xv, 1, p. 111, 1912), who ascribes a primarily benthonic mode of life to *Nautilus*, the "type of the ancient Cephalopod with functional, external shell".

[4] N. Jahrb. Miner., etc., ii, p. 169, 1913 (in review of Renz).

[5] *Geschichte der Erde und des Lebens*, 1908, p. 451.

[6] Haug, *Traité de Géologie*, vol. ii, fasc. ii, p. 1166, 1908–11.

is in direct contradiction to a causal explanation of their development"[1], as it conveys the impression of an inborn racial necessity of a predestined character.

The ceratitic suture is one type of line that may recur in the Ammonoid history, just as the same types of ornament appear repeatedly between the Devonian and the Cretaceous, owing to the limited possibilities of variation in each character. Hyatt[2] had considered "the multiplication of the principal inflections in Pseudoceratites of the Cretaceous" to be necessitated "in compensation for the suppression of marginals". The pseudoceratitic suture-line also is not by any means always "reduced", so that its function as a means of attachment of the animal to its shell is not impaired. A form like *Indoceras baluchistanense*, Noetling, with 37 lobes and 38 saddles or 75 elements in its suture-line, recalls the acme of specialization among Triassic Ammonites. According to its author, this youngest of all Ammonite genera, the well-formed specimens of which occur abundantly in beds that pass without break or unconformity into the Eocene, shows no geratologous characters.

Periodic Evolution and Unstable Environment.

It might be suggested that in the evolution of the suture-line "periodicity of elaboration" occurs such as is claimed for other features and as is observed in the Cretaceous Asteroidea by Spencer,[3] and that after a period of "catagenesis" affecting the Pseudoceratites in general, there was renewed elaboration in *Lybicoceras* or *Indoceras*. There can be no doubt, however, that Pseudoceratites represent a number of independent developments of different normal Ammonites, just as the tendency to attain dissimilarity in form, in response to differences of environment, is shown in many different stocks. This ranges from the Hauterivian *Crioceras* to the Maestrichtian *Bostrychoceras* and culminates (morphologically) in the incredible tangle of *Nipponites*; but their relationship is confined to a similar benthonic mode of life. Strong adaptive radiation, such as is generally shown in the young stages of a stock, occurs repeatedly during Cretaceous, as in previous, times. "Changes of structure and diversity of life" are probably "directly related to the physical conditions of habitat", and the "stability of organic forms is in direct ratio to the stability of the conditions of existence".[4] As mutation was so continuous during Cretaceous times, the conditions of existence in so far as they concerned the Ammonites cannot have been stable.

Extinction and Environment. Lime Secretion.

The writer favours the view that the disappearance of Ammonites was not due to inherent phylogenetic relations and inability to

[1] J. v. Pia, N. Jahrb. Miner., etc., i, p. 169, 1914, in review of Mr. Buckman's *Yorkshire Type Ammonites*.

[2] In Zittel-Eastman, *Text-book of Pal.*, vol. i, p. 544, 1900.

[3] "The Evolution of the Cretaceous Asteroidea": Phil. Trans. Roy. Soc. Lond., ser. B, vol. 204, pp. 156–7, 1913.

[4] Joel A. Allen, "The Influence of Physical Conditions in the Genesis of Species": Smithson. Inst. Ann. Rep., 1905, p. 401.

modify, but to physical causes. To quote Diener,[1] "A flourishing family like Lytoceratidæ, which during the whole of the Cretaceous period produced a number of irregular forms and which, itself, persisted later than these irregular forms, cannot by any means be considered degenerate."

One of the most reduced types, with "goniatitic" suture, is *Flickia simplex*, Pervinquière,[2] which is a morphic equivalent of the Triassic *Lecanites*. Whether this is regarded as a local modification of *Neolobites* or an independent benthonic dwarf development, its Cenomanian age is of no significance; for the writer has seen a specimen in the British Museum (Natural History) with a similar entire suture-line (at a diameter of 12 mm.) from the *Caloceras* bed of the Hettangian that looked like a Palæozoic *Pronorites*. The diminutive size of *Flickia*, of course, suggests unfavourable surroundings; but it appears that in the dwarf faunæ of Morade Ebro[3] and other localities the suture-line is little affected.

It is conceivable that thickening of the shell may take place in a series under local influences, i.e. increased lime-secretion, shallowing of the sea, or alteration of the incoming sediment in a more or less confined region. The simplification of the suture-line of *Metoicoceras*[4] (Turonian *Inoceramus* facies) as compared with that of the Cenomanian Acanthocerates may be due to such environmental changes, affecting metabolism generally, and thus the secretion of lime; and this might also apply to the Kimmeridgian *Pictoniæ* already mentioned, where the suture-line may be more reduced than the ornament in one specimen, and the ornament more than the suture in another.

With regard to the simplification in individual Ammonites referred to above, this follows on a continuous elaboration to often great complexity, and is associated occasionally with approximation of the last few septa, which association alone would account for the simplification of the edge. Or, again, they may be thickened, like the last septum of the recent *Nautilus pompilius* or certain Liassic *Nautili*, and thus make up in the enlarging of the adhering surface for what strength was lost in the simplification. No observations seem to have been made on this point, however.

It will be noted that in *Psiloceras* and other Ammonites the last few suture-lines show what Swinnerton and Trueman in *Dactylioceras* call "simpler and more turgid outlines of the folioles", as

[1] Op. cit., 1912, p. 79. Frech, "Neue Cephalopoden a. d. Buchensteiner, Wengener, and Raibler Schichten d. südl. Bakony": Res. Wiss. Erf. Balatonsees. Pal. Anh. z. Teil i d. Bd. i, p. 72 (quoted by Diener), expresses similar views.

[2] The local restriction and numerical insignificance of this "goniatitic" form compared with its normal contemporaries and the flourishing *Scaphites* and *Turrilites* shows the incompleteness of the "cycle".

[3] A. Wurm, "Beitr. Kenntn. Iberisch-Balearischen Triasprovinz": Verh. Naturhist.-mediz. Ver. Heidelberg, vol. xii, 4, 1913. This fauna is even more reduced than that of St. Cassian, which it resembles.

[4] M. Leriche, "Sur la présence du genre *Metoicoceras*, Hyatt, dans la Craie du Nord de la France, etc.": Ann. Soc. Géol. Nord, vol. xxxiv, pp. 120–4, 1905.

opposed to their "ageing" character of more intricate wrinkling, assumed to be due to diminished gas-pressure. *Psiloceras* shows not only complex suture-lines with dependent inner portions at first and simpler ones with ascending auxiliaries at the end, but also often asymmetry of the suture-line, and approximation of the last few septa, and these features will be considered in the following parts of this paper.

(*To be continued.*)

REVIEWS.

I.—On the Brachiopod Shales of Scania.

Om Skånes Brachiopodskiffer. By Gustav T. Troedsson. Meddelande från Lunds Geologiska Faltklubb, ser. B, Nr. 10, 1918.

THE memoir by Dr. Troedsson on the Brachiopodskiffer of Scania is of importance to students of the Ordovician strata, and must be consulted by anyone who proposes to work at the Ashgillian faunas. These Scanian beds have long been recognized as the general equivalents of the Ashgill Shales of the North of England, which they resemble in respect of lithological characters, fauna, and stratigraphical position.

The memoir is divided into two parts, the first stratigraphical, the second palæontological. In the first part the author gives a historical sketch, which is followed by details of the succession in various localities, and by a comparison of the beds with those of other areas. The second part is concerned with a description of the species.

The fauna consists largely of species which ascend from the *Staurocephalus* beds, but is much poorer in species than are those beds. The author, however, has made a noteworthy addition to the fauna; only five species were known before, whereas he gives a list of forty-six forms.

Although the beds as a whole are equivalent to the Ashgill Shales, it is possible that they contain earlier strata than the lowest part of those shales, for Dr. Troedsson divides them into two sub-zones, the lower (that of *Dalmanites eucentrus*) being distinguished also by the abundance of Ostracods. This is a characteristic feature of a calcareous band with abundant *D. eucentrus* below the Ashgill Shales, which has been bracketed with the underlying *Staurocephalus* beds, and this calcareous band may represent the lowest Brachiopodskiffer, though differing in lithological character. The summit of the Brachiopodskiffer is probably older than the uppermost Ashgill Shales, for the author separates from the former a zone of *Climacograptus scalaris*, which, like the highest Ashgill Shales, is succeeded by the beds of the zone of *Diplograptus acuminatus*. The zone of *C. scalaris* is probably only of local value. *C. normalis* is recorded in England in beds below the Ashgill Shales, and is abundant in the succeeding Valentian rocks, and although it has not yet been found in the shales themselves it must have lived at the time of their formation.

In the palæontological part of the memoir the author gives the distinguishing characters between *Dalmanites eucentrus* and *D. mucronatus*, concerning which there has been so much confusion. The former was described by Angelin from the Brachiopodskiffer of Röstånga, in Scania, and the same author described the latter from the Brachiopodskiffer of Ostrogothia, where it occurs in beds of a higher horizon than the highest beds of that name in Scania, in rocks which contain a Valentian fauna. These two species have been stated to be identical, and it is satisfactory to have a description of their differences. It must be noted, however, that in Scania the two forms occur in the Ordovician Brachiopodskiffer, though it is doubtful whether *D. eucentrus* has ever been discovered in strata of Valentian age.

A new *Dalmanites* (*D. Kiæri*) is described from the Norwegian Brachiopodskiffer, and stated "to be allied to *D. obtusicaudatus*, Salt., from the Upper Caradoc of England". The latter species is really of Lower Ludlow age, and the Norwegian form more closely resembles *D. Robertsi*, described by Dr. Cowper Reed, from the Ashgillian strata of Haverfordwest (Geol. Mag., Dec. V, Vol. I, p. 106, 1904).

An English summary of the two parts is given in the concluding portion of the memoir, which is illustrated by many plans and sections, and by two plates of fossils and illustrations of others in the text.

J. E. M.

II.—Santo Domingo Fossils.

Santo Domingo Type Sections and Fossils. By Carlotta Joaquina Maury. Bulletins of American Paleontology, 1917, vol. v, No. 29, pt. i, Mollusca, pp. 165–415 (1–251), pls. xxix–lxv (iii–xxxix); No. 30, pt. ii, Stratigraphy, pp. 416–59 (1–43), with sketch-map of expedition, views of country, geological sections, correlation table, and 36 plates of molluscan figures.

THE authoress is already well known to geologists for her memoirs on "Some New Oligocene Shells from Florida" and "The Paleontology of Trinidad". She was fortunate in being selected as a member of a small expedition to the Island of Santo Domingo, in 1916, for the furtherance of geological research, which was carried out under the auspices of the "Sarah Berliner Foundation". In the volume before us comprehensive details are given of the many sections visited on that occasion, from which numerous fossils were obtained, all having been zonally collected and properly localized. These fossils comprised a considerable fauna belonging to several groups of the animal kingdom, although the Mollusca form the larger series and contained over 300 species, many of them being described as new to science. The descriptions of the Mollusca, accompanied by more than 500 illustrations, form the first and largest part of this work, while the second part relates entirely to stratigraphy. The writer refers gratefully to the pioneer work of Colonel Heneken, who nearly seventy years ago surveyed the same country and made valuable collections of fossils, which he sent to the Geological Society of London, but which have been since transferred to the British Museum. Heneken described the geological features of the region, whilst the molluscan remains were studied by G. B. Sowerby and J. Carrick Moore, and the corals by W. Lonsdale, the combined results forming notable memoirs in the Quarterly Journal of the Geological Society for 1850 and 1853. Both Moore and Sowerby recognized that some of the shells exhibited Pacific affinities, although more often a Miocene facies was apparent with resemblances to those found in the deposits of Bordeaux, Touraine, and Malta, as well as to those of similarly aged beds in the more eastern parts of the United States. At a later date R. J. L. Guppy and W. H. Gabb contributed largely to our knowledge of this subject, and supported the Miocene age for the fossiliferous rocks as first ennunciated by Heneken and his colleagues. Like Heneken's collections most of the writer's fossils were obtained from the northern part of the island, in the Yaqui Valley. Among the Tertiary clays and limestones of that district, three well-defined formations, differing in their molluscan faunas, have been determined as the *Sconsia lævigata*, the *Aphera islacolonis*, and the *Orthaulax inornatus*, the last being the oldest. The first named is recognized as belonging to the Burdigalian stage of the Middle Miocene of Europe, the second is included in the Upper Aquitanian or Lower Miocene, and the third is regarded as Rupelian or Upper Oligocene. The Gatun beds of Panama, together with the Alum Bluff and Oak Grove deposits of Florida, are said to be synchronous with the *Sconsia lævigata* formation, whilst the Bowden beds of Jamaica, with a mixed fauna, are scheduled as belonging to both the *Sconsia lævigata* and the *Aphera islacolonis* formations, the latter also including the Chipola River marls of Florida. The *Orthaulax inornatus* formation includes the Tampa silex beds of Florida. Further, it is urged that this fossil fauna of the Yaqui Valley is not only most closely allied to that of the Bowden beds of Jamaica, but exhibits affinities with that characterizing deposits in Cumana, Trinidad, and Martinique.

It will be readily seen from this brief survey of Dr. Maury's book that all the best methods of investigation have been utilized in its preparation. Instead of being satisfied as to the Miocene age of the fossils under which they had hitherto been generally recognized, her employment of the zonal system of collecting, and a careful classification of the numerous molluscan remains obtained, have facilitated the recognition of some important faunal distinctions, and so enabled the writer to divide these Miocene and Oligocene rocks into certain stages which are in agreement with the European standard of stratigraphy.

This is a valuable and an authoritative memoir, and will be greatly welcomed by geologists and palæoconchologists alike, as a history of the Tertiary sequence in this and neighbouring parts of the Western Hemisphere, founded upon molluscan evidence.

R. B. N.

III.—Concretions in the Recent Sediments of the Auckland Harbour, New Zealand. By J. A. Bartrum. Trans. New Zealand Inst., vol. xlix, pp. 425–8, with 1 plate, 1916.

During the dredging operations of Auckland Harbour a number of calcareous concretions were brought up by the pumps. These consisted of nodular masses of hard, compact limestone, varying in size from ½ in. up to 6 inches or more in diameter. They enclose recent shells of all kinds, some of which seem to have served as nuclei for the precipitation of the calcium carbonate, and also diatoms and quartz grains. They give no indication of having been derived from any previously consolidated rock, and seem to have been formed contemporaneously with the harbour silt, by precipitation of calcium carbonate from the sea-water. This precipitation was probably occasioned by the decay of organic matter in the epidermis of molluscs, or the hard parts of crabs which form the nuclei of the concretions.

W. H. W.

IV.—The Jurassic Ironstones of the United Kingdom, Economically considered. By F. H. Hatch. Journ. Iron and Steel Inst., vol. xcvii, pp. 71—120.

Average Analyses of British Iron-ores and Ironstones produced in 1917–18. By F. H. Hatch. Published by the Ministry of Munitions. 12 pp. 1918.

An important part of the work of facilitating the supply of munitions of war lies in the proper development and economical utilization of raw materials. In the case of iron-ores the Ministry was fortunate in securing the services of Dr. Hatch to assist in supervising these matters. Besides the actual mining of the ores it was found that other subjects were also in need of attention, such for example as "blending" of ores of varying composition to produce a standard product, methods of calcining, and economies in transport. All of these are briefly touched on in the first of these memoirs, but the greater part of it is taken up with a description of the actual occurrences and mining of the Jurassic ironstones of the British Isles, with analyses and statistics of production.

The Jurassic iron-ores occur at three principal horizons, namely, in the Lower Lias in Lincolnshire, in the Middle Lias in Cleveland, Leicestershire, and Oxfordshire, and in the Inferior Oolite in Northamptonshire. Expressed in percentages of the Jurassic output the Lower Lias was responsible in 1917 for 22·3 per cent, the Middle Lias for 51 per cent, and the Inferior Oolite for 26·2 per cent. The Upper Lias ore of Raasay amounted only to 65,985 tons or 0·5 per cent of the total. The Corallian ores of Westbury are not now worked.

The most striking recent development is in connexion with the Middle Lias ores of Oxfordshire, which are now being exploited on a very large scale, largely for the supply of furnaces in South Wales. The total output of this county in 1917 was 434,435 tons, with an average iron content of 24 per cent.

The second publication above quoted contains some new and interesting material. It is mainly taken up by a tabulation of analyses of British iron-ores mined in 1917, but the brief introduction of two pages gives in a very condensed form a summary of the statistics of production for 1917. Of 15,028,000 tons mined in that year 89·5 per cent was phosphoric and of low iron-content, the remainder being high-grade hæmatite ore with low phosphorus, obtained almost entirely from Cumberland and Lancashire. The phosphoric ores derived from the Jurassic formation make up 80·6 per cent of the total productione the rest coming from the Coal-measures, with an almost negligib l amount (under 1 per cent) from other sources.

These facts may be summarized as follows:—

	per cent.	tons.
Lias	59·5	8,947,520
Inferior Oolite	21·1	3,169,110
Coal-measures	8·1	1,194,882
Miscellaneous	0·8	129,961
Hæmatite ores	10·5	1,586,429
	100·0	15,027,902

Thus it appears that at the present time the Jurassic System is the dominant factor in the iron-ore industry of this country, while the one-time importance of the Carboniferous is rapidly waning. It is, perhaps worth bearing in mind that it was the introduction of the basic Bessemer process that rendered possible the utilization of these low-grade ores, both in Britain and in Lorraine. Without this the course of recent industrial development must have been very different. Fortunately the mining of the Jurassic ores of the Midlands is a very simple matter, being quarrying rather than mining, and the introduction of suitable machinery has done much to stimulate large and economical production in a time of labour shortage.

R. H. R.

V.—An Ancient Buried Forest near Riccarton: its Bearing on the Mode of Formation of the Canterbury Plains. By R. Speight, M.Sc., F.G.S. Trans. New Zealand Inst., vol. xlix, pp. 361–4, with 1 plate, 1916.

The Canterbury Plains which form the eastern part of the South Island have been built up almost entirely by the alluvial cones brought down by the rivers from the western mountain chains. This deposition of alluvial gravel has been accompanied by a downward movement of the land, and timber is often found in boreholes as much as 450 feet below the surface. The stumps of the trees which formed the forest described in this paper were found in place on a bed of clay, under 12 feet of gravel, at a height of about 50 feet above the sea, in a pit near Riccarton. Some of the trunks were standing, but most of them had been snapped off very low down. This fact, and the general relations of the clay and gravel in which they were found, suggest that the forest was destroyed by the flooding of the surface with gravel from the migrating cones of rejection, a process which may be seen still in operation in other parts of South Island. The roots were held firmly by the gravel so that the trunks could be snapped off leaving the stumps in place and undisturbed. This occurrence, therefore, is additional evidence in favour of the idea that the Canterbury Plains were formed almost entirely above water, from the gravel of the alluvial fans of rivers, and that the material was not deposited under the sea.

W. H. W.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

November 20, 1918.—G. W. Lamplugh, F.R.S., President, in the Chair.

The President referred with regret to the loss that the Society has sustained by the death of Miss Maude Seymour, on November 6 last, after a very short illness. He alluded to the high value of her services as an Assistant in the Library, and to her energetic assistance in the preparation of the "List of Geological Literature".

The following communication was read:—

"The Geology of the Meldon Valleys, near Okehampton, on the Northern Verge of Dartmoor." By Richard Hansford Worth, M.Inst.C.E., F.G.S.

The area dealt with lies between the London and South-Western main railway line, from a point a litte east of Meldon Viaduct to near Sourton, and the ridge of Dartmoor occupied by Black Tor, High Wilhays, Yes Tor, and West Mill Tor, being the greater part of the valley of the Redaven and a portion of the valley of the West Okement.

The southern extreme of this area is occupied by the Dartmoor Granite, north of which are shales, in which occurs a patch of limestone, and these are intersected by numerous bands of igneous rock.

The shales as a whole, with but slight local deviations, strike north-east and south-west and dip north-westwards, the mean angle of dip being about 50°.

The sedimentary rocks are divisible into:—

1. An alumino-arenaceous series, extending from the granite northwards for a breadth of somewhat over half a mile.
2. A calcareous series, abruptly but conformably succeeding the last.
3. A limestone, which occurs a short distance south of the railway.
4. Radiolarian cherts a little above and a little below the horizon of the limestone.
5. An aluminous bed north of the railway.

Of these, (1) consists of impure grits, which, being well within the aureole surrounding the granite, have developed secondary mica, a little tourmaline, and small well-formed rutiles. In some places, at contacts with granitoid veins, andalusite is also found. (2) Consists mainly of porcellanites with beds of black chert-like rock. The characteristic mineral of the porcellanites is wollastonite, but at contacts with the Meldon Aplite garnet, idocrase, scapolite, axinite, and lepidolite are also developed. (3) Shows little sign of metamorphic action. (4) Are cherts of the character already well known as occurring in the Lower Culm-measures, and described by the late Dr. G. J. Hinde & Mr. Howard Fox. (5) Is a dark-grey rock, almost black, the characteristic mineral of which is chiastolite. All these rocks succeed each other conformably, and there is no evidence of folding or repetition.

In the sedimentary series planes of weakness have developed, the surface traces of which are broadly coincident with the strike, but which frequently lie counter to the dip. These planes have been more or less successfully invaded by at least three series of igneous rocks, the order of which, commencing with the earliest, is as follows:—

1. A felsite with phenocrysts of micropegmatite, and quartz which shows good rhombohedral cleavage.
2. A series, hereafter called the "dark igneous rocks".
3. Granitoid veins, subdivided into—
    (1) The Meldon Aplite and its associates;
    (2) Fine-grained granite of the ordinary Dartmoor type.

The evidence on which this chronology has been based seems fairly clear. The felsite with micropegmatite occurs as inclusions in the "dark igneous rocks". The "dark igneous rocks" occur as inclusions in the Meldon Aplite. The Meldon Aplite occurs as veins in the "dark igneous rocks". No evidence is available as to the relative age of the Meldon Aplite and the granite veins.

A marked feature of the "dark igneous" rocks is that they are locally agglomeratic; as such they have been identified as metamorphosed tuffs. But, on the other hand, every exposure is also in part homogeneous and compact, with clear flow-structure. The inclusions, where present, are always in part fragments of the contact-rocks of the walls of the sills or dykes. Some of the agglomeratic rocks are certainly dykes and not sills, and as such cannot be interbedded tuffs. Every exposure at some place irregularly invades the contact-shales. For these and other reasons their identification as tuffs is dismissed, and it is sought to explain the occurrence of the included fragments by successive injections of the same fissures and the break-up of previously consolidated injected material.

The geography of the Meldon Aplite is described; it occurs in several dykes, the principal of which extends from east of the western wall of Okehampton Park to the old Ice House on Sourton Tor, a distance of nearly 2 miles. There are other minor dykes north and south of this.

The texture of the aplite is micrograniitic. The principal minerals are albite, orthoclase, microperthite, quartz, lepidolite, green tourmaline, and topaz. Blue apatite is almost entitled to be classed with these. Fluorspar, montmorillonite, and axinite are accessories. Although, in conformity with other observers, the author has described this rock as an aplite, he uses the term with reservations. The rock is neither more acid than the normal granite, nor does it approach freedom from mica, and he submits that the true description, even if cumbrous, would be lepidolite-soda-granite. The whole of the mica is apparently lepidolite, and of 8·70 per cent, the total of the alkalies, roughly five-eighths are soda and three-eighths potash.

Some veins of true granite occur, always of fine grain: in these andalusite is locally developed. It is noted that topaz and andalusite have never yet been found side by side in any Dartmoor granite or granite vein, but topaz may occur in granite which is in contact with slate in which andalusite is present. In one and the same rock the minerals appear to be mutually exclusive, or, in other words, when the conditions are such that topaz may form andalusite is not to be expected.

II.—Edinburgh Geological Society.

October 16,[1] 1918.—Professor Jehu, President, in the Chair.

"Peat and its Utilisation." An Address by H. M. Cadell, B.Sc., F.R.S.E., Vice-President.

At times such as these, when the Great War had emphasised the need of conserving all natural and scientific resources, the peat question deserved its full share of attention. The high price and scarcity of coal made the prospect of success in the working of peat greater than it had ever been. During recent years peat had been found valuable for producing many other things besides ordinary fuel. By wet or dry distillation, peat products included alcohol suitable for internal combustion engines, ammonia for agricultural fertilisers, acetic acid and acetone for explosives, paraffin for making wax, creosote for preserving timber, tar for coating roads, oil and spirit for burning and power production, as well as gas and coke for heating and smelting. Besides these more or less complex products, the fibrous red peat of the surface of bogs was of great value for moss litter for bedding horses and cattle, and peat dust was useful for packing fragile objects such as eggs and fruit. Cardboard and brown paper, suitable for packing, had been successfully made in America from peat as a substitute for wood pulp, and as timber was now becoming scarce much saving might be made by this use of peat, which was one of the most abundant, but least developed, of our natural resources.

Immense areas of undeveloped peat moss occurred both in Europe and America, the utilisation of which would not only provide good fuel and other valuable things, but would afford useful employment to a large population in many otherwise poor rural districts. In Europe the peat mosses covered over 200,000 square miles, and in

[1] Received November 16, 1918.

Canada half a million, while two-thirds of Newfoundland were under peat. Some of the Scottish peat mosses were as much as 50 feet deep and of great age. Others had, like the Flanders Moss in the Vale of Menteith, been formed since the pre-existing forest had been felled by the Romans. The mosses varied greatly in quality as well as in thickness, and all of them in their natural state contained between 80 and 90 per cent of water, the elimination of which was generally the rock on which industrial peat-producing enterprises had been wrecked. Vast sums had been lost in trying to dry peat artificially either by pressure or by heat, and an evil spirit like the will-o'-the-wisp seemed to haunt the bogs and lure on the adventurer till he was finally swallowed up.

But the light of modern science could show the right path to follow, and as oil shale had only been recognised as one of the precious stones after much loss and hard-bought experience, so would peat moss be made to minister to the needs of man after the wrong roads had been abandoned and the right trail found out. Many new processes have been discovered lately, including Ekenberg's wet carbonising process of heating the wet peat so that it could be afterwards dried by pressure. The briquettes of dried peat were capable of distillation, and as two-thirds of the mass was volatile and about a quarter fixed carbon, it was clear that once the water was successfully eliminated the peat substance was far more valuable than oil shale. The nitrogen in peat was a very important item, and some mosses contained over 2·5 per cent, and the sulphate of ammonia derived from the nitrogen alone might in good mosses be worth twenty-five shillings per ton of dry peat, which was about five times as much as was yielded by oil shale. Alcohol had been made by the fermentation of peat and its wet distillation, and it was claimed that this product could be manufactured for 3*d.* or 4*d.* per gallon. Peat alcohol would be of great value for motors as a substitute for petrol, and if the Government wished to assist the development of this wealth-producing discovery after the War the excise duty might well be greatly reduced, so that the producer would be encouraged to go on and the consumer might obtain the large supply of liquid fuel that was becoming more necessary every day for vehicular traffic and agricultural motor machinery. The development of the peat industry was largely a matter of scientific investigation and technology, and there was in this country an open field and every prospect of final economic success, notwithstanding the failures to achieve it in the past.

III.—Geological Section of the Wellington Philosophical Society, N.Z.

The annual general meeting was held on August 21, 1918.

The annual report, which was read and adopted, stated that since the preceding annual meeting, September, 1917, five ordinary meetings had been held, at which there had been a number of interesting exhibits and eight papers had been read. The titles and authors of the papers were as follows: (September 19, 1917) "The

Geology of the Papakaio District," by G. H. Uttley; "A Comparison of the New Zealand and Western North American Cretaceous and Tertiary Formations," by P. G. Morgan. (October 17, 1917) "Natural Regions in New Zealand," by E. K. Lomas. (May 15, 1918) "The Geomorphology of the Coastal District of South-Western Wellington," by C. A. Cotton. (June 19, 1918) "Notes on the Post-Tertiary History of New Zealand," by J. Henderson. (July 17, 1918) "The Origin of the Amuri Limestone and Flint Beds," by J. Allan Thomson; "Notes on the Geology of Stephen Island," by J. Allan Thomson; "Permo-Carboniferous or Maitai Rocks of the East Coast of the South Island," by P. G. Morgan.

At the meeting a resolution was adopted expressing appreciation of the palæontological work of the late Mr. Henry Suter; and also a resolution expressing appreciation of the palæontological work of the late Dr. E. A. Newell Arber, in particular of his work on the Mesozoic floras of New Zealand.

CORRESPONDENCE.

THE GENESIS OF TUNGSTEN ORES.

Sir,—It is to be regretted that Mr. R. H. Rastall, when compiling his very useful summary of our present knowledge of the genesis, mode of occurrence, and mineral associations of the ores of tungsten, the first part of which appeared in the Geological Magazine for May, 1918, had not before him the results of later researches than those of Dr. Bleeck regarding the ore-deposits of the Tavoy district of Lower Burma, as his results have not been accepted entirely by later workers.

For the past three years a party of the Geological Survey of India has been working in Tavoy, and the district has also had the advantage of the presence of several enthusiastic private geologists. The Geological Survey party has examined most of the lodes which occur, investigated their contents as carefully as possible, and mapped the boundaries of the granite and the sedimentary series into which it is intruded. Our results may be summarized briefly :—

1. Up to the present time not a single specimen of columbite has been found.

2. Tourmaline does not occur in the ore mineral association, and is not a normal constituent of the granite. The occurrence of tourmaline pegmatites is known, but they are not associated with the ore-bearing zones and do not contain either wolfram or cassiterite.

3. Fluor spar is a widely distributed lode mineral, but it is only found in insignificant quantities.

4. Topaz is known to occur in one alluvial cassiterite deposit, and to-day, after three years of detailed field investigation together with petrological and chemical determinations in the laboratory, has only been found in situ once, in conjunction with fluor spar bordering a lode which contains relatively large quantities of pyrite, molybdenite, cassiterite, and very little wolfram. There are over one hundred producing mines in Tavoy district alone, and the lodes examined must amount to many hundreds.

Wolfram and cassiterite are nearly always associated together, though lodes containing one of these minerals, especially wolfram, to the entire exclusion of the other, are known. The mineral association in order of deposition is as follows: molybdenite, wolfram, cassiterite, native bismuth, bismuthinite, chalcopyrite, arsenopyrite, pyrrhotite, galena, and blende. Scheelite also occurs in small quantities. In Mr. Rastall's classification of tungsten occurrences into paragenetic sub-types Burma should be associated with Queensland rather than with Etta Knob and Ivigtut.

In a paper read before the fourth Indian Science Congress at Madras in January, 1916, of which only an incomplete summary has been published (see Journ. As. Soc. Bengal, N.S., vol. xiii, No. 2, pp. ccii–iii, 1917), I have suggested that the place of fluorine and boron may have been taken by sulphur and arsenic in the pneumatolytic stages of ore formation here. I am driven to this conclusion by the universal presence of sulphides, generally in the form of pyrite, in the Tavoyan lodes and the relative absence of minerals containing fluorine and boron.

Some of our lodes are pegmatites. They contain felspar as well as quartz. They have the composition, structure, texture, and other characteristic features of normal pegmatites, but they carry wolfram and cassiterite as well. I have suggested that others in which the pegmatitic origin is not so clear may represent a hydrothermal phase of pegmatite development resulting in the production of quartz with the ore minerals. There are cases here where true wolfram and cassiterite-bearing pegmatites pass in short distances along their strike directions into pure quartz veins with wolfram and tinstone.

I do not deny the part played by pneumatolytic reactions as they are generally understood. I cannot account for the greisens which sometimes border the walls of lodes in granite and also carry valuable quantities of ore minerals by any other theory, but I doubt whether fluorine and boron played much part in the reactions.

It is pleasing to note that Mr. Rastall concludes that there is no real distinction between magmatic segregations and veins in this type of ore-deposit, for if it is correct to regard the pegmatite-aplite group of rocks as differentiation products of granites, it is reasonable to regard their metallic ores as segregations from acid magmas to the same extent.

The wolfram occurrences in other parts of Burma are not identical with those of Tavoy, though this district produces by far the greater proportion of Burma's output. Tourmaline is present in the Mergui lodes and also in those of the Thaton district. Beryl is a common mineral in the lodes of the Yamethin district.

Mr. Rastall has alluded to the widely scattered literature on the subject, and to his bibliography on this district the following published papers may be added: "Economic Geology of Tavoy," by J. Coggin Brown; "The Origin of Wolfram and a Preliminary Investigation as to its persistence at depth in the Tavoy District," by Dr. W. R. Jones. Both these papers are published in a work entitled *Lectures delivered at Tavoy under the auspices of the Mining Advisory Board*, Superintendent Government Printing, Rangoon,

1918. "The Disintegration of Wolfram," a letter published in the *Mining and Scientific Press*, San Francisco, September, 1917, by myself; *The Ore Minerals of the Tavoy District*, by J. Morrow Campbell, published privately, but available from Messrs. Rowe & Co., Rangoon.

As far as I understand their published views, Dr. W. R. Jones supports the pneumatolytic theory of the origin of the deposits, while Mr. J. Morrow Campbell believes that highly siliceous water was the agent which leached tin and tungsten from the magma and at quite moderate temperatures deposited cassiterite, wolfram, and associated minerals in veins.

J. Coggin Brown,
Assistant Superintendent, Geological Survey of India.

Tavoy, Burma.
October 1, 1918.

THE FAUNA AND FLORA OF THE GREAT ICE AGE.

Sir,—The remains of the past fauna and flora have frequently been utilized in supporting the theory of an Ice Age. But little justice has been done to this subject, although it has been maintained by some authorities that the geological history of both animals and plants furnish strong evidence in favour of an Ice Age. In Sir Henry Howorth's series of instructive articles in the Geological Magazine of August, September, and October last he emphasizes some features in the past and present marine fauna of the Baltic which deserve very careful consideration. His remarks about *Yoldia* and its distribution apply with equal force to dozens of other species of marine organisms. The argument that because a species now lives at a certain depth in the Arctic Ocean it must have lived at the same depth during the Ice Age much further south is a fallacy, as Sir Henry Howorth points out. Although some forms of animal and plant life readily adapt themselves to changes of temperature in the course of their migrations most of them require for their existence and welfare a uniform temperature. The conclusions arrived at by Sir Henry Howorth are based on the conditions which obtain almost everywhere near the coasts of Europe at the present day. We may observe Arctic species thriving at considerable depths, while Southern species inhabit the shallow water of the same area. In elucidating the geological history of the Baltic these conclusions, with which I entirely agree, are of the highest importance.

R. F. Scharff.

National Museum, Dublin.
November 23, 1918.

OBITUARY.

JOHN DUER IRVING.

Born August 18, 1874. Died July 20, 1918.

John Duer Irving, the son of Professor R. D. Irving, of the University of Wisconsin, was educated at Columbia University, and after taking his degree he joined the United States Geological Survey, carrying out work in Dakota and Colorado in conjunction with Whitman Cross and S. F. Emmons. His most important Survey work was a memoir on the Leadville district of Colorado. In 1903 he was appointed professor of geology at the University of Wisconsin and afterwards at Lehigh University. In 1907 he became professor of economic geology at the Sheffield Scientific School at Yale. He was also editor of *Economic Geology* from its commencement in 1905 until his death. When the United States declared war he entered the Army, and soon left for France with the rank of captain. At first engaged in railroad work, he subsequently became instructor in a school of mining and engineering as applied to warfare. Hard work and unremitting attention to duty wore him out, and he succumbed to pneumonia following influenza, to the deep and lasting regret of all who knew him, both in the Army and in the scientific world.

MISCELLANEOUS.

On the Discovery of a Method of arresting the Decomposition of Meteoric Irons, applied successfully to Meteorites in the British Museum (Natural History).

Henry Gadsdon (1861–1918), who died on December 2, aged 57 years, had been for over ten years employed at the Natural History Museum as french-polisher. He was an excellent workman of the best type, one who took pride in maintaining the high quality of his work. It is thanks to his aid that the problem of safeguarding the Meteoric Irons in the National Collections has—so it is hoped—been successfully solved. Every curator who has had such specimens under his care knows well the difficulty of preventing them from rusting. The chief agent in causing the mischief appears to be the unstable protochloride of iron—lawrencite—which immediately breaks down in the presence of damp. This substance is disseminated through certain specimens in extremely thin veins, and, since the change that takes place causes it to swell, such specimens are often found to be split across; further, as a result of the alteration of the lawrencite the nickel-iron alloy which is the principal constituent of the meteorite is attacked, and finally nothing is left of the specimen but a lump of rusty fragments and powder. By keeping the air in the case as dry as possible, the rate of attack may be slackened, but only slackened; the ultimate end is just as sure and inevitable. Varnishing the specimen is more effective, but this process completely spoils the specimen for exhibition purposes. Six years ago, in 1912, as the result of experiments made on pieces of steel exposed to the weather, it was thought that coating the meteorites with a thin, transparent film of shellac by the process of french-polishing might overcome the difficulty without sensibly interfering with the appearance of the specimens, and the Keeper of Minerals decided to have first those specimens which showed considerable signs of rusting treated in this manner. The work was entrusted to Gadsdon. At first he experienced some difficulty in getting the polish to work properly on the metal, but soon discovered the proper temperature to give satisfactory results, and proved very successful and skilful in treating the specimens. It calls for a careful inspection at a glancing angle to realize that there is anything on a specimen which has been polished, and the harmful rusting has been all but stayed. It is true that some specimens have of necessity been treated more than once, but the cause is no doubt the action that has still gone on in the depths of the cracks within the specimen, and there is evidence that the action is steadily becoming feebler.

In one of his books Wells suggests that in the course of a century or two Meteoric Irons will be represented in museums by lumps of rust; at the Natural History Museum at least, thanks to the method first applied by Gadsdon, it may be that the Meteoric Irons will retain their original form and constitution much longer than that eminent writer foreboded.

G. F. H. S.

Honorary M.A. conferred by Cambridge University on Mr. F. W. Harmer, F.G.S.

At a Congregation in the Senate House at Cambridge on Dec. 7 the Public Orator, Sir J. E. Sandys, delivered the following speech in presenting Mr. Frederic William Harmer, F.G.S., for the titular Degree of Master of Arts *honoris causa*:—

"Abhinc annos quattuor et octoginta natus, adest vir in geologiae scientia penitus exploranda per vitae partem longe maiorem feliciter occupatus, qui patriae toti devotissimus, Angliae Orientalis regionem nobis propinquam ante omnia praetulisse confitetur. Vitae in parte prima, aevi tertii geologici reliquiis diligenter investigandis operam dedit; in secunda, comitatus Norfolcensis in urbe maxima honore municipali summo praeclare functus est; in tertia, ad aevi tertii geologiam, ad amorem suum primum, animi ardore prope iuvenili reversus est. Idem (ne plura commemorem) glacialis aevi et causas primas et eventus ultimos perscrutatus est; ventorum vim in caeli temperie mutanda antiquitus non minus quam recenter multum valuisse luculenter ostendit: ipsas denique causas sollerter investigavit, quae loca illa nobis propinqua, paludosa illa quidem et uliginosa, sed pulchritudine sibi propria exornata, aut olim crearunt aut in amplitudinem maiorem auxerunt.

"Habetis, Academici, exemplar viri, non modo et suo et uxoris suae solo natali, sed etiam patriae toti in unum coniunctae, et rerum naturae studiis devotissimi. Nostis Tulliana illa de loco suo natali verba: 'Omnibus municipibus duas esse censeo patrias, unam naturae, alteram civitatis . . . Hanc meam esse patriam prorsus numquam negabo, dum sit illa maior, haec in ea contineatur.'[1]

"Ut magister in artibus honoris causa nominetur, adduco vobis virum et suo et filiorum suorum nomine, et studiorum suorum propinquitate, nobis coniunctissimum, Fredericum Willelmum Harmer."

[1] *De Legibus*, ii, 2, 5.

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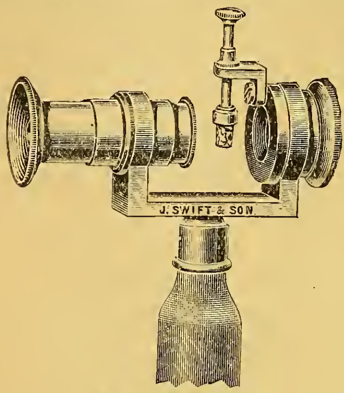

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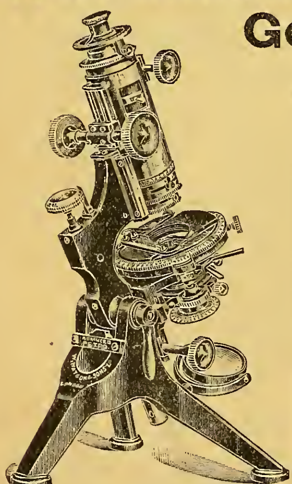

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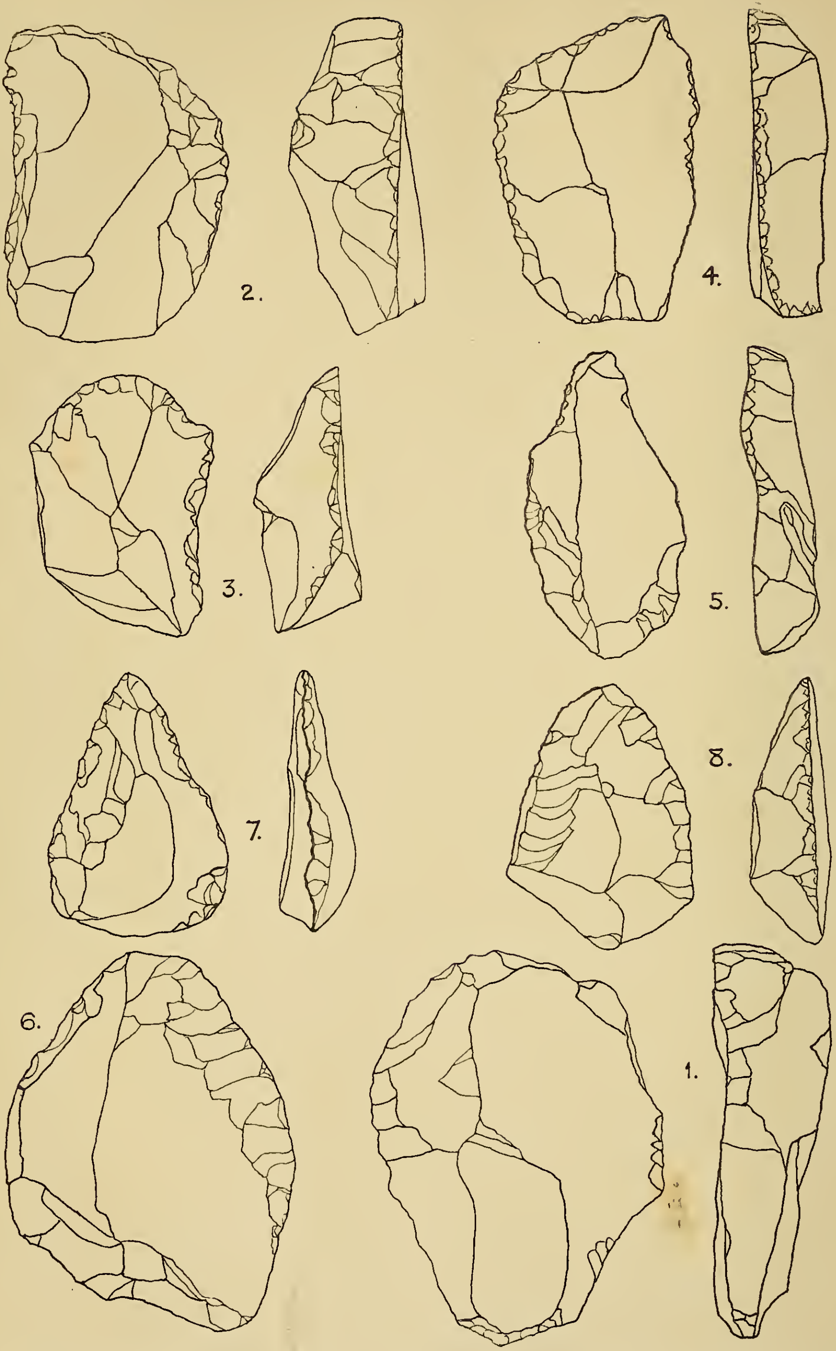

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PALÆOLITHIC FLAKE IMPLEMENTS, HIGH-LEVEL TERRACES OF THE THAMES VALLEY.

THE
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ORIGINAL ARTICLES.

I.—On some Palæolithic Flake-implements from the High Level Terraces of the Thames Valley.

By Henry Dewey, F.G.S., of H.M. Geological Survey.

(PLATE II.)

OVER most of North-Western Europe the occurrence of river-terrace deposits containing Palæolithic implements has been long known, and the establishment of a sequence of forms among these implements has resulted from the researches of Continental, and especially of French archæologists. With the pioneer work the name of M. Boucher de Perthes,[1] of Amiens, will always be associated. His was the task of convincing unwilling minds of the human workmanship of the ancient flint-weapons found in the gravel-pits of the Somme Valley. For the next great advance we owe a debt of gratitude to another French savant, the late Professor Victor Commont,[2] for his life-work was the taking up of the researches of his predecessor and establishing the sequence of cultural types and their relative chronology.[3]

Flint implements of the same forms had long been known to occur in the gravels of the Thames Valley; but as their precise stratigraphical position had never been ascertained, it was held generally that the several forms occurred on one and the same horizon. This assumption, based on careless collecting, became a strong prejudice in the minds of some archæologists, but no efforts were made to test by proper investigations the truth of the hypothesis they held. In view of the conclusions arrived at by the Continental authorities, however, it was certainly desirable to examine at home the validity of the stages of palæolithic culture they had found to hold good abroad.[4] Some investigations were therefore undertaken in the years 1912, 1913, and 1914, by the Geological Survey and the British Museum, in co-operation, at

[1] *De l'industrie antiquitées Celtiques et Antédiluviennes*, Paris, 1847.

[2] *L'Anthropologie*, xix, pp. 527–72, 1908; *Compte rendu de l'Association Française*, 1908, pp. 634–45; *Assoc. Préhist. Congrès de Lille*, 1909, p. 437; *Revue préhistorique*, 1909, No. 10; *Bull. Arch.*, 1911, p. 27; *Congrès international d'Anthropologie*, xiv, p. 240, 1912.

[3] The names of Prestwich and Lyell, and later those of Messrs. Spurrell, W. Smith, Kennard, Leach, and Chandler, should, however, be mentioned in connexion with the advance in scientific classification of the Palæolithic periods.

[4] These stages are in descending order: Azilian, Magdalenian, Solutrean, Aurignacian, Moustierian, Acheulian, Chellean, Strépyan.

various sites in North Kent and near Rickmansworth. The results are published in *Archæologia*,[1] but a brief account of these results is necessary for the discussion of the present paper. All the flake-implements illustrated[2] in Plate II, and described on pp. 53–5, were collected by the author, or in his presence, at these sites during visits made to the pits after the publication of the official work.

The chief interest attaching to these flake-implements is the light they throw upon the ancestry of the types that became dominant in the cave periods and in the Neolithic age. During the early palæolithic periods core-implements were characteristic and predominant; in the early cave period (Le Moustier) flake-implements suddenly, and almost completely, replaced them; but that the pattern was not unfamiliar to the earlier peoples is proved by the occurrence of similar types, and it may therefore be concluded, either that the earlier men were not in such urgent need of these forms, or that they preferred the use of others.

The age of these flake-implements is indicated by the position in which they were found.

Deposits of the 100 ft. Terrace of the Thames.

The first site selected for investigation was the large gravel-pit, at Milton Street, near Swanscombe, known to the owners (The Associated Portland Cement Manufacturers) as the Barnfield Pit. The Company, through one of their Managers, Mr. George Butchard, courteously invited the British Museum and the Geological Survey to undertake an examination of the sand and gravel for flint implements before this overburden was removed, preparatory to the quarrying of the underlying chalk for making cement.

A preliminary visit showed that over the whole area around the pit there was a persistent series of Pleistocene deposits composing a 35 ft. section. As the deposits had already been removed to various depths at different parts of the pit it was possible to examine nearly every bed without shifting those above, and the danger of mixing the beds was thereby avoided.

The following sequence was found to occur:—

	Feet.
Soil.	
Gravel, irregular pockets and pipes in stiff clay (the Upper Gravel) } Loam (the Upper Loam) }	4½
Gravel and current-bedded sand (the Middle Gravel) . . .	8–18
Loam and Marl (the Lower Loam)	2–4
Gravel (the Lower Gravel)	5–6

On the northern side of the pit the gravel overlaps the Thanet Sand and lies directly on the Chalk. The overlap is due to the general southerly dip.

About two weeks' digging resulted in the collection, and accurate location, of many palæolithic implements and rough flakes, and

[1] Vol. lxiv, pp. 177–204, 1913; vol. lxv, pp. 187–212, 1914; vol. lxvi, pp. 195–224, 1915.

[2] For these drawings and descriptions I am indebted to my friend Mr. Reginald A. Smith, of the British Museum.

sufficed to prove that there was a sequence of palæolithic types corresponding to a succession of Pleistocene deposits.

The beds of the lower gravel contained many large flakes without secondary working, and a few cylindrical nodules either chipped into a chisel edge or roughly pointed at one end. These resemble some of the implements discovered by Dr. A. Rutot from a locality known as Strépy, in Belgium. No true palæolithic implements, however, were found in this gravel.

The Middle Gravel contained a large number of true implements, those found near the base being of rougher workmanship than the smaller number lying at the higher levels. From the lower part nearly all were of "pear" shape, many carefully worked and devoid of cortex, while others were rougher, with much cortex remaining at the butt end. There was also a large number of chips and flakes without signs of trimming or usage, many closely resembling, except in size, the flakes from the Lower Gravel. Only four worked scrapers were afterwards found at this horizon, two round scrapers and two pointed forms (see Pl. II, Figs. 1, 3, 5, 6). None of the implements shows the slightest mark of abrasion, a fact which seems to indicate that they had not travelled far, but had rather been dropped into the river somewhere in the neighbourhood during the time the gravel was collecting. They are strictly contemporaneous, therefore, with the gravel and not derived from an older source. Moreover, as no forms characteristic of higher levels occurred with them the gravel in question may be assigned to one period.

In the Upper Gravel no implements were found, but the workmen stated that implements of ovate form and white patination had been found in the clay of this gravel-bed. On the eastern side of a road (Craylands Lane) bounding the Barnfield Pit, a small gravel-working had been opened. This deposit, which lies at a slightly higher level than most of the Middle Gravel, is current-bedded and overlain by even-bedded gravel with clots of clay and pebbles filling channels in its surface.

At the top of the current-bedded gravel some sixteen implements have been found. They are all ovates, most with the edge curved like a reversed S and patinated white. In other words, they are typical St. Acheul forms, and being practically unrolled must be contemporaneous with the gravel in which they were discovered.

All these deposits lie on a widespread terrace-platform cut by the Thames in the Chalk and Thanet Sand. The base of the Pleistocene beds is about 90 feet above the Ordnance Survey datum, and the deposits are described as those of the 100 ft. terrace of the Thames.

To summarize the evidence derived from these stone implements for a complete "Drift" sequence in the deposits of this terrace it has been seen that the lowest gravel contains no true palæolithic form. In the Middle Gravel all the forms may be assigned to the Chelles type of the Somme Valley, and especially to those of the lower series at St. Acheul.

The small collection of ovate forms from the pit east of Craylands Lane can be assigned provisionally to the St. Acheul type, as they are all of ovate form; several have a characteristic pronounced twist in the usual direction, and many have the white or cream patination so frequently found at St. Acheul.

In another pit (Globe Pit) near Greenhithe a flake-implement having a china-white patination was found in loam from which forms assigned to the Le Moustier period have frequently been collected. A racloir flake belonging to the St. Acheul period was dug out of the clay of the Middle Gravel.

Subsequently to the deposition of the 100 ft. gravels a tributary of the Thames, the Ebbsfleet, cut out a valley some 50 feet deep. This valley was afterwards partially filled up with an unstratified mass of chalky rubble, sand, pebbles, and clay containing a number of bones, teeth, and tusks of various extinct mammals. At the base of this rubble, and lying on a fairly even floor, many thousands of flakes, cores, and implements have been found. The cores resemble the carapace of a tortoise, and the worked flints are characterized by a peculiar faceting of the platform or striking-plane. The core was carefully flaked and a complete implement struck off at a single blow on one of the facets, but the underside carried an enormous bulb of percussion.

Precisely similar forms were discovered by Professor Commont, who succeeded in dating the finds as belonging to the early part of the Le Moustier period. In the Ebbsfleet Valley the flake industry had very nearly replaced the core implement, as has already been described by Mr. Reginald A. Smith.[1]

The investigations at Mill End, near Rickmansworth, were less decisive in their results. They were undertaken in the large gravel-pit where some 16 feet of red gravel with seams of sand are exposed. A peculiar feature of the gravel is the occurrence of large cave-like spaces, which may have been formed by the thawing of frozen masses of sand. These deposits rest upon a wide terrace flanking the River Colne. Palæoliths of Chelles type have been found in abundance in the past; in fact, nearly every implement that has come from this pit is of the early Chelles coup-de-poing form, with heavy base and acute point. The Croxley Green pit, higher up the river, on the other hand, has yielded numbers of the early St. Acheul, ovate, type of implement.[2] As a result of the joint examinations by the Geological Survey and the British Museum, but very few implements were found, although such as were discovered supplied confirmatory evidence of Sir Hugh Beevor's conclusions.

One good flake-implement resembling a coup-de-poing, but probably a racloir, was secured by the author: it is figured in Pl. II, Fig. 7, and may be compared with one found by the late Lieut. C. H. Cunnington at Knowle Pit, Savernake. The two implements are very nearly identical as regards workmanship, shape, size, and use.

These British deposits and their contained implements may now be compared with those examined by Professor Commont in France. He worked out in detail the palæolithic sequence in the Pleistocene deposits of the terraces in the valley of the Somme. There are there four terraces representing the succession of levels at

[1] *Archæologia*, lxii, 532.
[2] Sir Hugh Beevor, Proc. Geol. Assoc., xxi, 245.

which the river has undercut its banks since the Pliocene period. The deposits of the highest terrace are Pliocene, and no flint implements have been found in them. The second terrace deposits are early Pleistocene and contain Strépyan forms; the third, or 30 metres, terrace gravels have Strépyan forms at their base, and in the sands near the top implements assignable to early Chelles. Upper Chelles types are plentiful in the gravels of the lowest terrace. Sweeping downward from the plateau over these terraces are two mantles of loam, an earlier and a later, called respectively the older and the younger Loess. Each of these Loess deposits is separable into upper, middle, and lower beds—those of the younger Loess being called locally the Ergeron; each seam is underlain by a bed of pebbles, while the surface of each is an ancient soil.

Calcareous concretions, known as Poupeés or Loess-püppchen, occur at the base of both Upper and Lower Loess, those of the latter being larger than the püppchen of the Upper Loess.

The ancient Loess consists in upward succession of (*a*) the *limon rouge sableux*, (*b*) the *limon à points noirs*, and (*c*) the *limon rouge*. In gravels at the base of the *limon rouge sableux* the whole series of forms assigned to the St. Acheul stages are found, but no implements of any kind have so far been found in beds *b* and *c*.

In the younger Loess, and especially in the pebble-beds at the base, the Le Moustier types have been recorded; some occurrences of implements of the later cave periods also occur in this younger Loess.

Most of the Chelles implements are coups-de-poing. This fact is so striking that it led M. de Mortillet[1] to conclude that no other type of implement was made during that period, but more recent finds show that in the Somme Valley as in that of the Thames flake-implements also occur, though rarely, with the other forms. One of these[2] is practically identical in every detail with that figured on Pl. II, Fig. 2, and further corroborates the inference drawn from the English evidence. These curved scrapers possess the characteristics of the racloirs of Aurignacian age found at Châtelperron and to some extent the broad points from the Abri Audi. They are of clumsier technique, and are larger, but evidently designed to meet a similar need.

In the following notes a brief description is given of the implements figured upon Plate II.[3]

FIG. 1.—Large flake of yellow-mottled flint, unrolled, with broad rounded end flaked to form a scraper, the under (flat) face trimmed at end; bulb of percussion and flat striking platform or butt. A median ridge runs half-way from the rounded end, and the side edges are irregularly worked. Length 4·1 in., breadth 3·1 in., thickness 1·1 in. From the lower part of the Middle Gravel at Barnfield Pit, Swanscombe, Kent, for which see *Archæologia*, lxiv, 185. A specimen pairing with this is in the British Museum. It came from the Somme Valley drift at St. Acheul, and has the following dimensions:

[1] Bull. Soc. d'Anthr., Paris, 1887, ser. III, pt. x, p. 173.
[2] V. Commont, *L'Anthropologie*, xix, p. 551, fig. 40, 1908.
[3] [The Editor regrets that the name of the author has, by an accident, been inserted at the foot of Plate II instead of that of his friend, Mr. R. A. Smith, who kindly made the drawings for him.—ED.]

length 3·7 in., breadth 3·1 in., thickness 1·1 in. An inadequate drawing is included in Lartet & Christy's *Reliquiæ Aquitanicæ*, p. 14, fig. 7. Though rather darker in colour, the character and workmanship are identical, and the form must therefore be recognized, not as an accident, but as a type, though round scrapers or planes are seldom met with in the river gravels. Obermaier reproduces one 3·7 in. long from St. Acheul (Rue de Boves) and classifies it as a *grattoir* (*Die Steingeräte des französischen Altpaläolithikums*, fig. 84) dating not from the earliest but the best Chelles period, when hand-axes were the dominant form.

FIG. 2.—Massive yellowish-grey flake, lustrous and unrolled, with a straight edge on left used as a side-scraper, and on the right towards the top a thick curved edge, worked as a finger rest; bulb of percussion and flat platform at base. Length 3·3 in., breadth 2·3 in. From the pit east of Craylands Lane, Swanscombe. This is a rare form, and might be mistaken for a knife, but the plain underface on the left shows it was used as a *racloir*. The mode of holding such an implement (called a knife) was illustrated by the late Professor Commont in *L'Anthropologie*, xix, p. 551, fig. 40, 1908, reproduced by Obermaier, op. cit., fig. 67*a* ; a side-scraper with similar accommodation for the finger is represented in his fig. 99. A few bold striations on the bulbar face of this specimen should not be overlooked.

FIG. 3.—Round scraper on a broad gabled flake, with a spur at one end of the planing edge; of typical "mahogany" flint as common at Swanscombe, with bulb of percussion, large flat platform, and plain flat bulbar face. The side edges are parallel, as in the later blade-scrapers, but the specimen is rather broad for that category. Length 2·7 in., breadth 1·9 in., thickness 0·9 in. A rare form from the Drift, but two specimens somewhat larger were found in the same Barnfield Pit, Swanscombe (now in British Museum), one having a spur in the same position; and a more slender example, from the lower part of the Middle Gravel there, is recorded in *Archæologia*, lxiv, 187 (cf. Obermaier, op. cit., fig. 85, from Rue de Boves, St. Acheul).

FIG. 4.—Yellow-brown ridged flake, with bulb and flat platform at one end and at the other a sloping worked edge ending in a point at the top and extending round a shoulder down the left side. The longer edge on the right also has signs of use, and the plain bulbar face has a number of scratches nearly all parallel with the longitudinal axis. The principal features are the top angle and the steeper shoulder on the left; no doubt used for scraping. Length 3·2 in., breadth 2·1 in. Found in gravel at Milton Street, Swanscombe, Kent.

FIG. 5.—Black and yellow mottled flake, ridged and slightly notched on either side of the thinner end to form a nose ; the broader end rounded and underface quite plain, the bulb missing. The working end of an implement is often emphasized by one or two side notches, but the present specimen cannot be classed as a borer. Length 3·2 in., breadth 1·7 in. From gravel at Milton Street, Swanscombe, Kent. Similar specimens from St. Acheul are figured by Obermaier (op. cit., figs. 56, 78) and assigned to the Chelles period.

FIG. 6.—Broad olive-brown flake, with careful shallow working along the right edge, where secondary work indicates use as a side-scraper (*racloir*). The edge near the point on the left is zigzag and bruised, and the lower edge is thick and rough, the bulb remaining in the lower angle on the right. The bulbar face is not flat, and the edge is chipped in places. Length 4 in., breadth 3 in. From gravel at Milton Street, Swanscombe, Kent. The flaking of this specimen, apart from the result of use, seems to be rather in the style of St. Acheul than of Le Moustier, though in form the resemblance to the latter type is very striking. Compare specimens from St. Acheul figured by Commont, *Les Hommes contemporains du Renne*, figs. 45, 51.

FIG. 7.—Triangular hand-axe, lustrous brown, made from a flake, with bulb at angle of base ; the side edges nearly straight and the lower edge thick and crusted; worked on both faces along the edges, and the point carefully formed. Length 2·8 in., breadth 1·9 in. From Mill End Pit, near Rickmansworth. (See *Archæologia*, lxvi, p. 196.)

Fig. 8.—Small subtriangular implement, made of an olive-green flake, with crust at the butt and traces of an older ochreous surface on the front. The bulb is at one angle of the base, and the other is the lower limit of the work on the right-hand edge, which must be classified as a side-scraper, as the bulbar face is untouched. Length 2·8 in., breadth 2 in. From Knowle Farm Quarry, Savernake Forest, Wilts. The horizon is unknown, but the specimen has all the appearance of a *racloir* or side-scraper of Le Moustier date. (See *Archæologia*, lxvii, p. 30, fig. 2.)

Examination of any representative collection of flint implements shows that there are assemblages of forms each fashioned after an accepted pattern. Of the palæolithic implements, those belonging to the Drift period are chiefly of a general pear-shape in outline among the earlier deposits, but ovate in the later, but both are flat although made from trimmed *cores*; that is, they are chipped on two faces, and not simply spindle-shaped pieces with sharp points, but flattened cones and discs with cutting edges. With the advent of the Cave periods the core was given up and the flake adopted. Nearly all "cave" implements are made from flakes; some are carefully worked on a disc-face, a facetted platform prepared, and by a single blow on this platform a complete implement detached from the core. By this means half the work expended on their manufacture was saved and the implements were as effective as the earlier core-forms.

Many flakes were used as "scrapers"; some being trimmed along one side to make a comfortable hold which would not cut the hand. As a result of use the scraping edge gradually got chipped off so as to meet the holding-edge, and a triangular form resulted resembling in outline the coups-de-poing. Such are figured on Plate II.

The original implement was a racloir; by use it became a coup-de-poing, but it is doubtful if they were ever used as points.

In the later Cave periods the principal tools were the racloir or side-scraper, the grattoir or plane, and the burin or graver. Among the implements described on pp. 53–5 examples of the racloir and grattoir are noted. The age of the implements is determined by their stratigraphical position; they are either Chelles or St. Acheul. They were therefore evidently used by early palæolithic man, and that they were in use over widespread areas is proved by their occurrence alike in England, France, and Belgium.

What is perhaps of even more interest is the variety of form of the tools, pointing to the differentiation of function and of specialization among the workers. Thus the coups-de-poing, the grattoirs and the racloirs, three kinds of tools, of which each attains its maximum development both as to numbers and style of workmanship at a different period, are all known in the Chelles stage. The early palæolithic forms may therefore be regarded as the ancestral types of the later periods. During the palæolithic periods some tools and weapons decreased in numbers, while others greatly increased. Attending this alteration of dominant form was the gradual evolution from one type to another, and there is no more interesting instance of descent with modification than that of the Neolithic celt from the palæolithic coup-de-poing. This subject has already been dealt with by Mr. Reginald Smith,[1] and it suffices here to say that in any

[1] *Archæologia*, vol. lxvii, pp. 27–48, 1916.

representative collection similar instances could be found. It is to be hoped that the histories of the modification of other characteristic forms may be traced. They are suggested by such forms as are figured on Plate II, and especially the racloirs and grattoirs, and there can be but little doubt that intermediate forms exist.

These modifications of the implements imply changes in the needs of the men who used them; changes brought about presumably by different climatic conditions, the incoming of other animals and plants, and the substitution of co-operation for hostile competition. The decrease in the relative proportion of weapons to tools accompanies the increase of civilization and marks the advent of the artistic races. Co-operation among men was soon followed by that larger co-operation between man and the animals, when the hunter became the herdsman and shepherd; the resulting domestication was perhaps reciprocal.

But it must always be remembered that the histories of the several types of implement could never have been traced without the aid of geology. For certainty as to relative chronology was unattainable until the precise location of the finds was ascertained. Before the necessity of such precision was realized no better classification could be made than that of the late Lord Avebury,[1] who divided all flint implements into palæolithic and neolithic.[2] All that were not of the one age belonged to the other, and all members of each group were considered to be more or less contemporaneous. Geological observations, however, proved the error of such generalizations, and supplied the means of fixing the relative ages of the finds. Flint implements then promised to become of value to geologists as "zone" fossils, and although uncertainty still exists obscurities are being cleared up.

Conclusions.

The early palæolithic implements of France and Belgium have been classified according to their form into two groups, namely, the coup-de-poing or pear-shaped; and the limande, or ovate, forms.

Where these implements occur in river-deposits, e.g. in the Somme Valley, the beds containing the "coups-de-poing" always underlie those with the "limandes".

The "coups-de-poing" are therefore assigned to an earlier or Chelles period and the "limandes" to a later or St. Acheul period.

Later than these implementiferous deposits there are others of a different character in which lie flake-implements known as Le Vallois flakes; or, from their resemblance to the implements found in caves at Le Moustier, as Mousterian.

So far as scientific research has been carried in England a similar sequence has been found.

The dominant types of implements in the Chelles and the St. Acheul periods were made from cores, whereas the Mousterian ushered in a great abundance of flake-implements, among which coups-de-poing and limandes are rare.

[1] But see Lyell, *Antiquity of Man*, 4th ed., 1873, ch. viii–x.
[2] Lubbock, *Prehistoric Times*, 1869.

During the later Cave periods the flake-implements show more skilled workmanship and a greater variety of forms, and this improvement is maintained in the Neolithic age.

The occurrence, however, in the Chelles and St. Acheul periods of most of the types of flake-implements, such as the grattoir, the racloir, and the knife, points to the fact that early palæolithic man was already acquainted with the patterns and methods of making the flake-implements, but for unknown reasons he preferred, or was compelled to use, the core-implement.

Evolution or descent with modification can be traced from some palæolithic to neolithic types, corresponding with changes of conditions and a gradual advance in civilization.

Without the aid of geology no precise chronology among cultural stages could be traced; with its aid, time-relationships can be determined and the several types of flint-implements, instead of of being mere *objets de vertu*, acquire a new value as "zone-fossils".

II.—Climate and Time.

By R. M. Deeley, V.P.G.S.

Sir Charles Lyell in his *Principles of Geology*, published in 1834, remarks upon the accumulating proofs that the climate of the earth had undergone great changes in the past, and he endeavoured to show that these changes might have been produced by the varying distribution of sea and land. He says, "But if, instead of vague conjectures as to what might have been the state of the planet at the era of its creation, we fix our thoughts steadily on the connexion at present between climate and the distribution of land and sea; and if we then consider what influence former fluctuations in the physical geography of the earth must have had on superficial temperature, we may perhaps approximate to a true theory."

The attitude adopted by Lyell may be well illustrated by a few quotations from chapter vii of the above-mentioned work:—

"The ocean has a tendency to preserve everywhere a mean temperature, which it communicates to the contiguous land, so that it tempers the climate, moderating alike an excess of heat or cold. The elevated land, on the other hand, rising to the colder regions of the atmosphere, becomes a great reservoir of ice and snow, attracts, condenses, and congeals vapour, and communicates its cold to the adjoining country." "Among other influential causes, both of remarkable diversity in the mean annual heat, and of unequal division of heat in the different seasons, are the direction of currents and the accumulation of drifting ice in high latitudes." "If we now proceed to consider the circumstances required for a *general* change of temperature, it will appear, from the facts and principles already laid down, that whenever a greater extent of high land is collected in the polar regions, the cold will augment; and the same result will be produced when there shall be more sea between or near the tropics; while on the contrary, so often as the above conditions are reversed, the heat will be greater. If this be admitted, it will follow as a corollary, that unless the superficial inequalities of the earth be fixed and permanent, there must be never-ending fluctuations in the mean temperature of every zone; and the climate of one area can no more be a type of every other, than is one of our four seasons of all the rest."

Lyell goes on to describe the "position of land and sea which might produce the most extreme of cold of which the earth's surface is susceptible", and concludes that if the continents were grouped about the equator the extreme of heat would be experienced, whereas if they were grouped about the poles the extreme of cold would be attained.

There is nothing in Lyell's writings to lead us to suppose that he thought that the continents were ever grouped in this way. He assumes such an arrangement as an extreme case to show that his theory will hold even then; and he clearly recognizes the fact that even comparatively small changes in the distribution of the land would considerably affect the climate.

James Geikie,[1] discussing Lyell's theory, says, "But we are assured that no such distribution of land and water as Lyell thought necessary for the production of our Glacial Period ever obtained in Pleistocene times. We have no reason to doubt that the positions of land and sea were practically the same as they are now." But the view is now gaining ground that the changes in the distribution of land and sea which are known to have occurred in Pleistocene times were sufficient to affect the temperature appreciably.

Croll[2] also dissented from Lyell's theory. He says, "The only other theory on the subject worthy of notice is that of Sir Charles Lyell. These extraordinary changes of climate are, according to his theory, attributed to differences in the distribution of land and water . . . It will be shown in subsequent chapters that this theory does not duly take into account the prodigious influence exerted on climate by means of the heat conveyed from equatorial to temperate and polar regions by means of ocean currents." Lyell did not go to the lengths Croll did on this subject; but that he was quite well aware of it and considered it the following remarks of Lyell show: "The general climate of Europe is materially affected by the volume of warmer water thus borne northwards; for it maintains an open sea free from ice in the meridian of East Greenland and Spitzbergen."

Mr. C. E. P. Brooks[3] has recently devised an empirical method of calculating the probable alteration in the temperature that might be expected from known geographical changes in the outline of the continent of Europe during late geological times, and he considers that they were sufficiently great to cause the Glacial Period. However, he recognizes that such changes could not account for the four great cold periods of the Pleistocene we are now coming to recognize. He suggests that the weight of the ice slowly weighed down the land until the new geographical conditions thus introduced caused the ice to disappear and the climate to ameliorate. On the

[1] *The Great Ice Age*, 3rd ed., p. 792.
[2] *Climate and Time*, p. 8.
[3] Quart. Journ. Roy. Met. Soc., vol. xliii, pp. 159–73, and vol. xliv, pp. 253–70.

disappearance of the ice the land again slowly rose, reintroducing glacial conditions. This is supposed to have taken place four times in succession, each succeeding cold period being less severe than the last.

In Europe there may appear to be some evidence in favour of the view that the periods became less cold as they succeeded each other; but in America there is little evidence of this kind. In Europe during the first cold period the Straits of Dover probably did not exist and the ice advanced over the area now occupied by the North Sea. The opening of the straits at a later period much restricted the advance of subsequent ice-sheets.

I have suggested that the Glacial Period was the result of two agencies acting together. Separately they could not produce the required conditions; but jointly they could. It is well known that the great polar cyclones of the earth are acting in direct opposition to the gradient of temperature on the earth's surface, and produce the poleward flow of the air in temperate regions.[1] The energy which keeps these cyclones in action is very probably cosmical and may undergo periodic fluctuations. In pre-Tertiary times the distribution of land was seldom such as to lower the temperature sufficiently to enable a temporary decrease in the strength of the polar cyclones to produce a glacial period. In Pleistocene times, however, the polar areas became so continental or landlocked that the periodic waning and strengthening of the polar cyclones led to alternating cold and warm periods.

Winds from the Poles towards the Equator do blow, of course, but they are not anticyclonic. They are merely surface winds, or winds resulting from travelling cyclones. The great cyclonic low-pressure areas of the Poles persist throughout the year.

III.—On the Discovery of a Quartzose Conglomerate at Caldon Low, Staffs.

By J. Wilfrid Jackson, F.G.S., and W. E. Alkins, B.Sc.

DURING a visit to the limestone quarries at Caldon Low last September we had the good fortune to discover an interesting exposure of a quartzose conglomerate containing numerous fossils. The bed was exposed in a strong joint-face running approximately N.N.W. to S.S.E., at the northern extension of the quarry on the north-west flank of the Low, just beyond the mineral line of the North Staffordshire Railway. The altitude is about 900 feet O.D. The conglomerate apparently extended some little distance to the south-west before the opening of the quarry, as we ascertained that some 20 or 30 yards had been removed in gaining access to the limestone behind. It appears to extend for some distance round the flank of the Low towards the north-east.

In the section exposed the conglomerate did not appear to possess definite bedding in its lower portion; but higher up the slope of the hill, on the S.S.E. side of the section, it was seen to pass upwards

[1] *Phil. Mag.*, vol. xxx, pp. 13–33, July, 1915; vol. xxxi, p. 399, April, 1916; vol. xxxv, pp. 221–36, March, 1918.

into thinly-bedded impure limestones with arenaceous layers and lenticular beds of quartz-pebbles, dipping N.N.W. at an angle of 30°. Strong joints, at right-angles to these inclined beds, extended downwards into the more massive conglomerate.

The condition of the section rendered the relation of the conglomerate and upper inclined beds to the massive light-grey limestones (*Productus humerosus*-beds) of Caldon Low somewhat doubtful. On the S.S.E side the conglomerate and inclined beds appeared to overstep the truncated ends of the *Humerosus*-beds (which exhibited little or no dip), thus suggesting an unconformity or a fault. At the opposite end of the section some inclined grey limestones, in part crinoidal, had been left as a low ridge running approximately W.S.W. to E.N.E., i.e at right-angles to the conglomerate section. These beds formed a small anticline near the conglomerate, and may dip under it to the E.N.E.; but this is not certain. The relationship of these beds to the *Humerosus*-beds could not be ascertained owing to the intervention of the quarry-platform.

Judging from the specimens obtained the conglomerate appears to consist mainly of water-worn pebbles of vein-quartz and quartzite, about the size of hazel-nuts: many of these are green-coated. Mixed with them are small pebbles of red jasper, black limestone, chert, light-buff micaceous sandstone, purple volcanic ashes and tuffs, etc., together with water-worn fragments of grey compact limestone, sometimes of large size, the whole being cemented together by a calcareous matrix.

Numerous fossils, chiefly Brachiopods, were obtained from the blocks of conglomerate lying in the quarry. The matrix in and around these has a structure resembling oatmeal. Pebbles of limestone, vein-quartz, fine grey oolite, and other rocks, are also present. The peculiar "oatmeal" type of matrix is particularly striking, and in section the structure is not unlike that of the penecontemporaneously brecciated limestones figured by Professor S. H. Reynolds and Dr. A. Vaughan from the Upper *Seminula*-zone (S_2) of Burrington Coombe.[1]

The original source of the various pebbles is not easy to determine. The fragments of grey compact limestones are undoubtedly of Lower Carboniferous age, and the fact that they consist mostly of fairly large pieces suggests that they had not travelled very far. The black limestone, grey oolite, and chert, are also of Lower Carboniferous age; these, however, are smaller and more worn, and may have come from a greater distance. With regard to the vein-quartz, quartzite, volcanic tuffs, ashes, etc., nothing very definite can be said until further study and comparisons are made. The pebbles of this series are well-rounded by wave-action, the majority being no bigger than hazel-nuts. The included fossils comprise an interesting series. They are mostly in the form of casts, but several still retain the greater part of the shell. In most cases only single valves are present. The imperfect state of preservation of some specimens renders precise identification rather difficult, but careful comparison with examples in our own collections and with figures

[1] Q.J.G.S., vol. lxvii, pl. xxviii, figs. 3 and 4, 1911.

in Davidson's monograph,[1] and in the various papers on the sequence of the Carboniferous Limestone in the British Isles, has enabled us to identify most of the forms. The full list of species, with references, is as follows:—

BRACHIOPODA.

Orbiculoidea sp.
Dielasma hastatum (Sow.). Large form.
Seminula ambigua (Sow.)? Dav., pl. xv, fig. 16.
Athyris cf. *expansa* (Phil.). Cf. Dav., pl. xvii, figs. 3, 3*a*.
Martinia cf. *glabra* (Mart.). Dav., pl. xiii, fig. 8.
M. ovalis (Phil.). Dav., pl. ix, fig. 21.
Spirifer bisulcatus (Sow.). Dav., pl. vi, figs. 6–9.
S. semicircularis (Phil.). Dav., pl. vi, figs. 1–5.
S. aff. *grandicostatus*, M'Coy. Dav., pl. viii, fig. 8.
"*Rhynchonella*" cf. *carringtoniana*, Dav. Dav., pl. xxiii, figs. 22–2*b*; pl. liii, figs. 1, 2.
Orthotetes cf. *crenistria* (Phil.).
Rhipidomella michelini (L'Eveillé). Dav., pl. xxx, fig. 7.
Schizophoria resupinata (Mart.). Large forms.
Productus corrugato-hemisphericus. Including forms like *P. cora*, D'Orb., Dav., mut. D_1 of Vaughan, in Q.J.G.S., 1905, pl. xxv, figs. 4*a*, *b*.
P. cf. *giganteus*, Dav. (*non* Mart.). Dav., pl. xl, fig. 3.
P. longispinus, Sow.
P. concinnus, Sow. Cf. mut. D_2 of Sibly, Q.J.G.S., 1906, pl. xxxiii, figs. 3*a*, *b*.
P. martini, Sow. Dav., pl. xliii, figs. 7, 7*a*.
P. cf. *pyxidiformis*, De Kon. Dav., pl. xlii, fig. 4.
P. cf. *fimbriatus*, Sow. Narrow convex forms like Dav., pl. xxxiii, fig. 14*c*.
P. fimbriato-pustulosus.
P. punctatus (Mart.). Dav., pl. xliv, fig. 14.
P. cf. *aculeatus* (Mart.). Dav., pl. xxxiii, fig. 19.
P. cf. *margaritaceus* (Phil.). Strongly convex forms near Dav., pl. xliv, figs. 5, 5*a*.

OTHER GROUPS.

Phillipsia sp. Pygidium.
Leiopteria sp.
Bellerophon sp.
Phanerotinus cf. *nudus* (Sow.).
Fish-tooth. Cf. *Psephodus magnus.*

Near the top of the section a small, much-weathered, coral of Zaphrentoid type was noticed, but it was impossible to extract it without considerable damage.

The general faunal assemblage would seem to suggest that the forms represented belong to some of the higher beds of the Carboniferous Limestone sequence. As in the case of the pebbles these may all be derived. Comparing the above list with the faunal lists given by Dr. T. F. Sibly for the Carboniferous Limestone of the Midland area,[2] it will be seen that a number of species are identical, more especially perhaps with those listed for the subzone of *Lonsdalia floriformis* = D_2.

Highly fossiliferous white limestones without a trace of any pebbles or extraneous material occur in the churchyard at the

[1] Brit. Foss. Brachiopoda, Part V: The Carboniferous Brachiopoda. Pal. Soc., Lond., 1858–63.
[2] Q.J.G.S., vol. lxiv, pp. 42 et seq., 1908.

adjacent village of Cauldon, some 300 yards to the north of the conglomerate section. These beds resemble the "Brachiopod-beds" of Treak Cliff and Peakshill, west of Castleton, Park Hill, north of Longnor, and other places in the Midland area, and contain much the same fauna. Unfortunately there are no good exposures of these beds, the material collected by one of us (W. E. A.) over a period of two or three years having been obtained mainly from grave-shafts in the churchyard and from a small exposure in a field on the south side.

According to the 1 inch Geological Survey Map (72 N.E.) the limestone here is cut off from the Pendleside Series by faults on the north-west and north-east sides, but no faults are shown on the south, or Caldon Low, side.

Another somewhat similar exposure of highly fossiliferous limestones occurs off the main road, opposite the Red Lion Inn, about half a mile south of the conglomerate section.

The close proximity of a conglomerate to highly fossiliferous pure limestones recalls similar features elsewhere in the Midland area, especially in the neighbourhood of Castleton. A rolled-shell and limestone-pebble conglomerate has long been known in the latter area, and seems to lie at, or near, the top of the *Lonsdalia*-subzone $= D_2$. It is well seen on the eastern side of Cave Dale, Castleton, immediately above the limestone bluffs, beyond the second mineral vein (Faucet Rake?). The dip of the beds here is 30° N.N.W., and in addition to worn and fragmentary valves of *Productus* "*giganteus*" the conglomerate contains rounded pebbles of limestone, nodules of oolitic chert, and fragmentary corals. An imperfect tooth of *Petalodus* was also obtained here by one of the writers (J. W. J.). A further exposure of the conglomerate is seen at the foot of Cow Low, west of Castleton village. Here the beds dip at 15° N.W., and consist principally of abundant water-worn and rolled shells of *Productus* "*giganteus*". It extends westwards to the entrance to the Winnatts, near the Speedwell Mine, and is again seen in a quarry at the foot of Treak Cliff, where the beds dip at an angle of about 20° N.N.E. The conglomerate here contains much crinoid debris, large Productids, *Spirifer bisulcatus*, etc., and in the succeeding flaggy limestones (also in part conglomeratic) numerous fish-teeth, especially *Petalodus*, and the spines and plates of *Archæocidaris*, are to be found. The conglomerate is apparently cut off from the famous "Brachiopod-beds" of Treak Cliff by a fault running N.N.W. to S.S.E. from the Odin Mine to the Winnatts. It reappears, however, near Windy Knoll, where limestone pebbles and oolitic grains form a prominent feature; chert is also associated with it, as at Cave Dale.

Similar conglomerates are to be seen at Barmoor Quarry, near Sparrowpit, and at Glutton Dale, north of Longnor. Along with the shell-debris (*Spirifer bisulcatus*, etc.) and fish-teeth (*Psammodus*, *Psephodus*, *Petalodus*, etc.) at the Sparrowpit locality, a fairly large amount of quartz of a well-rounded character is said to occur.[1]

[1] Trans. Manchester Geol. Soc., vol. xxv, p. 125, 1896.

The only record of a rolled-shell conglomerate on the eastern side of the limestone massif appears to be that of Cracknowl quarry, near Hassop Station.[1]

It is interesting to note that Dr. Sibly[2] and Mr. C. B. Wedd[3] have described sections in the eastern part of the Midland area which afford evidence of local earth-movement and erosion in Upper Carboniferous Limestone times. One section is near Youlgreave, the other at Darley Bridge. The limestones in these sections are regarded as representing a high level in the *Lonsdalia*-subzone, and in both cases black shales, presumably of Pendleside age, clearly overstep their denuded edges, thus causing local unconformity. It is not improbable that the formation of the shell and limestone-pebble conglomerate of Castleton and other places was contemporaneous with the earth-movement and erosion which produced these unconformities.

In addition to the main unconformity near Youlgreave, Dr. Sibly also points out the probability of further contemporaneous elevation and erosion during the formation of the Upper *Lonsdalia*-beds, as in the lower part of the section the truncated edges of a series of limestone-beds form a surface upon which rests another series of beds, less steeply inclined.

In the North Wales sequence Dr. Wheelton Hind and Mr. J. T. Stobbs have described a similar phenomenon to that of Youlgreave in the upper beds of the Carboniferous Limestone seen in Waenbrodlas Quarry, Halkyn Mountain (Flintshire).[4] At or about the same horizon (D_2) in other localities in North Wales the same authors record the occurrence of a conglomerate with quartz-pebbles succeeding a *Productus giganteus*-bed.

The absence of sections at Cauldon renders it difficult to ascertain the relationship of the quartzose conglomerate to the limestones containing a fauna typical of the Brachiopod-beds of Castleton. Consequently, at the moment, it is not possible to correlate with absolute certainty this conglomerate with that of Castleton and other places. The contained fauna seems to suggest that it may be contemporaneous, and if so there appears to be a considerable gap between it and the *Humerosus*-beds of Caldon Low. The age of the latter beds is a subject upon which some difference of opinion prevails. Dr. Sibly, in 1908,[5] regarded them as probably belonging to the upper part of D_1, while others, including Dr. Wheelton Hind, are inclined to place them much lower in the sequence, viz. $C–S_1$.[6] In this connexion it will be of some interest to record the discovery by one of the writers (J. W. J.) of an interesting coral recently in

[1] Elizabeth Dale, *The Scenery and Geology of the Peak of Derbyshire*, 1900, p. 17.

[2] Op. cit., 1908, p. 63, and fig. 5 (p. 62).

[3] Discussion of Dr. Sibly's paper, op. cit., p. 81, and Mem. Geol. Surv., *The Geology of the Northern Part of the Derbyshire Coalfield and Bordering Tracts*, London, 1913, p. 35.

[4] Geol. Mag., n.s., Dec. V, Vol. III, p. 396, Pl. XXII, 1906.

[5] Q.J.G.S., vol. lxiv, p. 44, 1908.

[6] Geol. Mag., Dec. VI, Vol. V, p. 480, October, 1918.

these beds. This may prove of some assistance in arriving at the precise age of the limestones in question. The specimen, which is unfortunately rather imperfect, was obtained from a large block of limestone in a quarry worked for road-metal on the western side of the Low, midway between the Red Lion Inn and Cauldon village. Other blocks in this quarry contained numbers of *Chonetes* cf. *comoides*, *Bellerophon*, and *Productus humerosus* (*P. sublævis*) of two forms—one strongly convex and narrow with a broad shallow depression down the centre of the back;[1] the other broader and flatter with a similar depression down the back, from which later on a low central ridge bearing spine-bases arises: these spine-bases are also visible on the umbonal portion of the depression, and on the ears.[2]

The coral, which consists almost entirely of the calix, is distinctly Caninoid in character, and measures about 32 mm. in diameter. It is apparently closely related to *Caninia cylindrica*, mut. S_1, as figured by Dr. Vaughan in 1905.[3]

Regarding *Productus humerosus* (= *sublævis*) Dr. Vaughan states[4] that in the Franco-Belgian area an early smooth form occurs at the top of C_2. In the South-Western Province this form is very rare, but is recorded from the C_2-oolite of Burrington. In the Clitheroe region this early form enters at the top of C_1 and forms a persistent band at the top of C_2 (as in Belgium). *Productus* cf. *sublævis* is also recorded from the Lane Limestone (co. Dublin) = C_1. This limestone underlies the Lane Conglomerate = C_2, and both were formerly regarded as D.[5] Most of the Caldon examples we have seen agree closely with Vaughan's figure of the early form from the Franco-Belgian area,[6] and with a specimen from Twiston, Lancs, in the collection of one of the writers (J. W. J.); but there is the broader spinous form to be considered.

It is unfortunate that more definite conclusions cannot be given as to the age of the quartzose conglomerate and its relation to the *Humerosus*-beds of Caldon; but we are hoping that, in the near future, quarrying operations will expose further sections which will provide us with more conclusive evidence.

The material dealt with in this paper will be deposited for future reference in the Manchester Museum.

[1] Cf. Q.J.G.S., vol. lxxi, pl. vii, fig. 8, September, 1915.

[2] Cf. Davidson, Monograph, pl. li, figs. 1, 2. The original of fig. 2 is stated by Davidson, p. 234, to have been found at Caldon Low.

[3] Q.J.G.S., vol. lxi, pl. xxiii, fig. 1*a*, 1905.

[4] Q.J.G.S., vol. lxxi, p. 47, 1915.

[5] L. B. Smyth, Scient. Proc. Roy. Dublin Soc., N.S., vol. xiv, No. 41, August, 1915.

[6] Q.J.G.S., vol. lxxi, pl. vii, fig. 8, 1915.

IV.—Notes on Ammonites.

By L. F. Spath, B.Sc., F.G.S.

(*Continued from p. 35.*)

II.

Obliquity of the Suture-line.

A CHARACTER of the suture-line that has received considerable attention lately is the obliquity with regard to the radius. Of course, it had long been noticed that suture-lines may vary in the form and foliation of their elements (brachyphyllic, dolichophyllic, and leptophyllic suture-lines of Mojsisovics,[1] and euryphyllian and stenophyllian suture-lines of Haug[2]) as in their general course. There may be (externally) a strong convexity forward (*Cyclolobus*), a straight (*Sphenodiscus*) or wavy line (*Pseudosageceras*), or a convexity backward (*Protengonoceras*). Again, the suture-line may be inclined strongly forward towards the umbilicus (*Cheltonia*) or have a retracted or dependent inner portion (*Psiloceras*). It is this latter obliquity that has been used as a generic and even family distinction, e.g. by Mr. Buckman,[3] to determine the affinity of *Bredya* with Hammatoceratidæ, and not Hildoceratidæ.

On a previous occasion[4] when dealing with the "suspensive lobe" (dependent auxiliaries) of *Psiloceras* and its ancestors, the writer expressed the opinion that its significance was doubtful. Since then the dissection of a number of Ammonites showing this obliquity of the suture-line towards the umbilicus, e.g. Derocerates, and the developing of the whole of their external and internal suture-lines has confirmed his belief in the impossibility of using this variable character—like the above-mentioned divisions proposed by Mojsisovics and Haug—even for generic distinctions.

Mr. Buckman, in his Monograph of the Inferior Oolite Ammonites,[5] figures on pl. A, fig. 29, the suture-line of a *Hildoceras* that has a strongly ascending inner portion as compared with the type given in fig. 28. Waehner[6] has shown that dependent auxiliaries are neither always present in *Psiloceras*, nor always absent in *Arietites*. Tornquist[7] figures suture-lines of *Pictoniæ* that show the typical descent towards the umbilicus and others that are straight. And it may be recalled here what R. Douvillé[8] says concerning the genus *Macrocephalites*: "As regards the more or less great obliquity of the

[1] "Die Cephal. d. Hallstätter Kalke": Abh. k.k. Reichsanst., vol. vi, p. 2, 1873–93.

[2] "Les Amm. du Permien et du Trias": Bull. Soc. Géol. France, ser. III, vol. xxii, p. 409, 1894.

[3] "Certain Jurassic (Lias-Oolite) Strata of South Dorset; and their Correlation": Q.J.G.S., vol. lxvi, pp. 97–8, 1910.

[4] "Development of *Tragophylloceras Loscombi*": Q.J.G.S., p. 352, 1914.

[5] Pal. Soc., vol. i, 1887–1907.

[6] "Beitr. Kenntn. Tief. Zonen Unt. Lias Nordöstl. Alpen": Beitr. Geol. Pal. Österr.-Ung., vol. iv, pts. iii, iv, pp. 190–202.

[7] "Die Degenerierten Perisphinctiden des Kimmeridge von Le Havre": Abh. Schweiz. Pal. Ges., vol. xxiii, p. 41.

[8] "Etude sur les Cardioceratidés de Dives, etc.": Mem. No. 45 Soc. Géol. France, Pal. i, 19, fasc. ii, p. 14.

suture-line in relation to the radius, it seems to vary with time in the whole group, as has recently been shown by Lemoine (1910). The same thing is noticed in *Pachyceras* and *Tornquistes*, where the most recent forms have the most inverse suture-lines. We have to do here, therefore, rather with a general phenomenon, appearing in a parallel manner in the different branches of a given family, or even in fairly distant groups, than with a special character peculiar to a single branch, and permitting us, consequently, to follow it through time. In this connexion it may be called to mind that in quite another group of Ammonites, in *Simbirskites* of the Lower Cretaceous, identical and exactly contemporaneous forms may have either a normal or a freely inverse suture-line (*S. inversus* and *subinversus*). It does not seem, therefore, that this character of an oblique suture-line has very great importance."

It might be thought that the character of the umbilical edge or slope, and its ornament, could affect the position of the auxiliaries, but the evidence in favour of this is not satisfactory. One should not find in identical smooth oxycones, with an exactly similar, rounded, umbilical edge, suture-lines that may be either concave forwards or convex, either rising or descending towards the umbilicus. But in, e.g., *Cheltonia*, the extremely oblique and almost tangential suture-line of the sides is compensated for by a very deep internal lobe, and the variation in the course of the suture-line does not appear to affect the convexity of the septum as a whole. It may be recalled here that the deposition of calcium-carbonate, as in the recent *Nautilus*, probably began at the sides of the shell, i.e. in the region farthest removed from the siphuncle, so that dependent auxiliaries near the umbilicus suggest less penetration posteriorly of the attaching fibres of the lobes. Swinnerton & Trueman (p. 36) give two interesting illustrations of incomplete septa in *Dactylioceras* and *Polymorphites*. They show that the septa were indicated in all sutural details, and though only formed in part were situated at the normal distance from the preceding septa.

The functions of the septal edge are not impaired by the variation of its course or curvature, therefore, and the comparative insignificance of the obliquity is realized when the external and internal[1] suture-line is considered as one whole. That in a *Lioceras*[2] direction and curvature may vary within the same species, and that in *Psiloceras*[3] even in the same individual, first a complex suture-line with dependent inner lobes, and at the end a simple one with ascending

[1] The presence of a high internal saddle in certain Japanese *Scaphites* induced Yabe ("Die Scaphiten a. d. Oberkreide von Hokkaido": Beitr. Pal. Österr.-Ung., etc., vol. xxiii, p. 167, 1910) to create a new genus, *Yezoites*; but the writer would agree with Nowak (in "Untersuchungen ü. Cephal. Ob. Kreide in Polen", ii, Die Skaphiten: Extr. Bull. Acad. Sci. Cracovie, July, 1911, p. 549), who cannot admit that the internal portion of the suture-line of Ammonites is the most important as regards the determination of their relations, though "it must not be underestimated or, still less, neglected, as is still done very often at the present day".

[2] Horn, "Die Harpoceraten der Murchisonæ-Schichten des Donau-Rhein-Zuges": Mitt. Grossh. Bad. Geol. Land. Anst., vol. vi, pt. i, p. 264.

[3] Neumayr, "Kenntn. Fauna Unterst. Lias i. Nordalpen": Abh. k.k. Reichsanst., vol. vii, pt. v, p. 25, pl. iv, figs. 6*a*, *b*, 1879.

auxiliaries may be found, shows the unimportance of this character for classificatory purposes, even if, occasionally, it be constant in a group of forms.

Workers on Ammonites recognize that the details of the suture-line may vary greatly in a given species. Noetling,[1] e.g., in his research on the suture-line of *Pseudosageceras multilobatum*, examined many specimens, but found no two suture-lines alike. On pl. xxvii, e.g., he figures forty-eight suture-lines, arranged in six groups, and showing a great variability both in the ventral and in the first lateral lobes. Pompeckj[2] thinks that *Oxynoticeras oxynotum* presents as many varieties. On the other hand, the writer[3] found that the suture-line of young specimens of *Tragophylloceras Loscombi* was very constant, and that the only variability noticed was in relation to the degree of complication at a given size; whereas in larger examples, again, no two suture-lines were exactly alike. This only confirms that the development of the suture-line should be studied, from its first, angustisellate beginning, and when this, in conjunction with the development of all the other features of the shell, is used as a basis for classification, variability within a species will prove no obstacle.

That in Phylloceratidæ and Lytoceratidæ neither this variability and obliquity, nor the features of instability already referred to, are apparent, seems to the writer of some significance.

Spacing of the Septa.

Hyatt stated[4] that the septa "vary exceedingly in number among different species and also at different ages of the same individual, but they are tolerably constant, as a rule, within the limits of one and the same species, if specimens of the same age are compared. They follow one another in regular succession, but, as observed by Hyatt, the intervals are relatively greater in the young, more constant in the adult, and then markedly decrease in the oldest stage of development". Bather, before Hyatt, had been more definite, and stated that the "radio of the normal septal intervals was constant in any given shell, while the approximation of the last septa was a geratologous character".[5] Blake[6] remarked with regard to the latter statement that "if any law could be founded on this and applied to phylogeny, we should not find the ratio of the second chamber to the first so variable as Barrande has shown it to be, nor should we find approximate septa in the early *Orthocerata*, nor crowded sutures in Ammonites at their acme".

Both in *Nautili* and in Ammonoids there are many irregularities in the spacing of the septa. Mr. Crick[7] mentioned "two *Nautili*

[1] *Palæontographica*, vol. li, pts. v, vi, p. 259, 1905.

[2] "Notes sur les *Oxynoticeras* du Sinémur. Supér. du Portugal, etc.": Comm. Serv. Geol. Portug., vol. vi, pt. ii, p. 219, 1906.

[3] Op. cit., 1914, p. 346.

[4] Op. cit., i, p. 510, 1900.

[5] "The Growth of the Cephalopod Shells": Geol. Mag., Dec. III, Vol. IV, pp. 446–9, October, 1887; and "Shell-growth in Cephalopoda (Siphonopoda)": Ann. Mag. Nat. Hist., ser. vi, vol. i, pp. 298–310, April, 1888.

[6] "The Evolution and Classification of the Cephalopoda, an Account of Recent Advances": Proc. Geol. Assoc., vol. xii, p. 291, 1892.

[7] Proc. Geol. Soc., No. 979, p. 3, November 11, 1915.

from the Upper Cretaceous Rocks of Zululand. Each showed approximation of the last three septa . . . One specimen showed also irregularities of depth in the other chambers of the camerated part of the shell". Foord[1] figures two Inferior Oolite *Nautili* (*N. pseudolineatus* and *N. polygonalis*), one of which has the last septum closer than the usual interval, the other has it more distant. A fair amount of variability as regards the spacing of the septa (especially the last) is also found in Palæozoic genera, e.g. the Middle Devonian forms referred to "*Gomphoceras*" by Cleland.[2] In Wisconsin this genus is found not only in great abundance as regards the number of individuals, but is also represented by a variety of more or less closely related species, which rather suggests favourable conditions. In Bohemia also, where the Silurian period produced an exceedingly rich Cephalapod fauna, this variability prevails, as is shown in Barrande's classical work.[3]

As regards Ammonites, the irregularity is even more striking. A. E. Trueman[4] has recently figured some *Polymorphites* that show approximation of the last septa. This seems to be an unstable genus of generally small and very variable forms of limited horizontal distribution. But in *Hildoceras bifrons*, which species-group, with horizontal variants and vertical mutations, is found in North-Western Europe, in the Alpine-Mediterranean-Pontian province, and as far as Japan, the phenomenon is observed, as well as in its probably benthonic and often one-sided derivative *Frechiella*. Among fifty-six specimens of *Amioceras niger* (Blake), i.e. of another universal genus, that the writer examined, six specimens had their suture-lines fairly distant, and in five more the distance was somewhat less. Twenty-seven specimens had the septa a medium distance apart; in five they were fairly close, and in thirteen very close together. Besides, there were irregularities in almost every specimen, many of them showing closer septation after a fairly distant beginning.

On thirty-one specimens the last sutures were well displayed, and here even greater irregularity was noticed. In one specimen there was no approximation at all, and in two more it was only just noticeable. Nine specimens had the last two suture-lines fairly close, in three more they were very close. In eight specimens there was approximation of the last three septa; in one the last four suture-lines were fairly close, and in another they were very close together. One specimen had the last five septa closer than the previous ones, but they were equidistant from one another, whereas in another specimen the last five septa were gradually approximating. Two more specimens had the last six suture-lines gradually getting closer, and finally, in another two there was first

[1] Op. cit., vol. ii, p. 214.

[2] "The Fossils and Stratigraphy of the Middle Devonic of Wisconsin": Wisc. Geol. and Nat. Hist. Surv., Bulletin No. xxi, 6, 1911.

[3] *Système Silurien de la Bohême*, vol. iii (Cephal.), 1867–77.

[4] "Observations on the genus *Polymorphites*": Geol. Mag., n.s., Dec. VI, Vol. IV, pp. 443–4, figs. 1, 11, October, 1917. The writer cannot accept the derivation of this genus from the much earlier arietid *Agassiceras* development, *Cymbites*, and will refer later to the resemblance in the sutural development.

approximation, then wide intervals, and approximation again of the last two septa.

Amioceras nodulosum (J. Buckman) presents a similar variability, to judge by nineteen specimens examined. Among twenty-one specimens of *Peltoceras* aff. *Eugenii* (Raspail) there were seven that showed no approximation at all, and the majority of the remainder had only the last septum slightly closer. In only two specimens they were very close, and only one had the last three septa gradually approximating. In three specimens the distance between the third and second septum from the end was greater than that between either the fourth and third or between the second and the last. It was also noticed that in two specimens the last suture-lines (in both cases only slightly approximating) were much fainter than the others, indicating a thinner septum instead of a thickening as in the case of the *Nautili* mentioned, or else the beginning of deposition of calcium-salts on a conchiolin-membrane as noticed by Swinnerton & Trueman.

Again, R. Douvillé [1] found a great variability in the spacing of the septa in *Quenstedticeras lamberti*, and he figures two specimens which are very different in this respect. Douvillé adds: "As I have observed that in many dwarfed and œcotraustic forms, (which are in all probability the males, *Chapuisi*, etc.) the septa are always extremely close, it seems to me that one could see a certain connexion between small size and close septa. The *Quenstedticeras* with close septa would never have obtained great dimensions, and would be the males, and vice versa. Unfortunately there are too many transitions among the various distances of the septa to enable one to think of demonstrating this hypothesis. But it also does not disprove the theory, for if the spacing of the septa be a secondary sexual character in *Quenstedticeras*, it is possible that it may be very unequally developed in the individuals of the two sexes."

It seems to the writer that with regard to sexual dimorphism in Ammonites, the evidence to-day is as unsatisfactory as it was when Buckman and Bather inquired into this problem, and came to the conclusion that "sexual dimorphism had yet to be proved".[2] The two Ammonites figured by Douvillé differ, however, e.g., in the width of the umbilicus, and in the writer's specimens of *Arnioceras* the suture-lines were by no means all alike, so that it might be suggested that they represent several types, perhaps due to hybridization of the extreme members. As all my specimens of *Arnioceras niger* came out of one block it cannot be a question of different surroundings. Slight differences in the character and thickness of the shell or of the septa, and the simplification of the edges of the latter, might account for the variability in individuals of the same species; but rate and arrest of growth would differ especially if either the stock itself or the environment were unstable. What Edwards [3] said with regard to the London Clay *Nautili* may be

[1] Op. cit. (Cardioceratidés), p. 61, fig. 60.

[2] "Can the Sexes in Ammonites be distinguished?": Nat. Sci., vol. iv, p. 430, June, 1894.

[3] *The Eocene Mollusca*, pt. i: Cephalopoda (Pal. Soc. Mon.), 1849, p. 44.

quoted in this connexion: "The ratio of increase [of the chambers] is apparently uncertain and is influenced probably by the growth of the animal, which would, of course, depend on the supply of food and other circumstances."

Mode of Life.

In this connexion, again, it may be noticed that among Jurassic and Cretaceous Ammonites the long-lived Phylloceratids and Lytoceratids show the greatest constancy of the septal ratio; and their stability is further shown by the infrequency of another feature of the suture-line, namely its asymmetry, which will be considered presently. But since reference to the probably nectonic character of these Phyllocerates and Lytocerates and certain oxynote shells has been made, it is necessary to insert a few remarks on Hyatt's hypothesis, that the "progressive complication of Ammonite sutures took place because of their utility in helping to carry and balance the shell above the extruded parts when the animal was crawling".[1] That author believed that the complication was directly correlated with the outgrowth of rostra, and stated: "The presence of a rostrum indicates the disuse and disappearance of the swimming organ (hyponome), which in *Nautilus* causes the formation of the hyponomic sinus in the aperture and flexed growth-lines on the venter."

This connexion between the disappearance of the hyponomic sinus (not of the swimming organ) and the complication of the lobe-line seems very doubtful. A form like *Beloceras*, with hyponomic sinus, was probably as much an adaptation to an actively swimming mode of life as later shells of a similar flat and acute-ventered shape, whether they were Nautiloids like *Phacoceras oxystomus* (Phillips) and *Stenopoceras Rouilleri* (de Koninck), or typical Ammonites like *Pinacoceras* or *Aspidoides*. Kerr[2] suggested that "the structure of the infolding edges of the hyponome and the muscular character of this organ would enable the animal to unroll and flatten it out so as to be available for crawling". Thus it would be homologous with the foot of Gasteropods. And as Ammonoids gradually adopted a freely swimming mode of life, the hyponomic sinus disappeared. In *Beloceras* already, it must have lost its original use. Thus there would have been no disappearance of the swimming organ, but the absence of a hyponomic sinus in the later Ammonoids would show that the hyponome was not used for crawling as in typical Nautiloids.

Hyatt also thought that "the shells of Ammonoids, being less bulky in proportion than those of Nautiloids, were correspondingly less buoyant". But it has already been mentioned that *Nautilus* has been found attached to the bottom, whereas some of the least "bulky" of Nautiloids, like the above-mentioned *Phacoceras* and *Stenopoceras*, were adapted to an actively swimming existence. It is probable that neither the typical Ammonoids and Nautiloids, nor such a radially symmetrical, benthonic structure, as the Devonian "*Gomphoceras*", already referred to, or e.g. a delicate *Carthaginites*,

[1] Loc. cit. (in Zittel-Eastman, 1900), p. 544.

[2] "Anatomy of *Nautilus pompilius*": Proc. Zool. Soc., 1895, pp. 664–86 (quoted in Zittel-Eastman, 1900, p. 506).

were cumbered with a very buoyant shell. Solger[1] concluded from the fact that an injury to the chambers and destruction of several septa made no apparent difference to the animal, which continued its growth without noticeable irregularity, that the Ammonite was benthonic before the accident and could not have been a swimmer. But this may only show that the buoyancy did not depend on the air-chambers only; and "bulk" in the case of a sharp-ventered, thin shell, was not necessary to enable its occupant to swim well and quickly. The damage to the earlier whorls of large and evolute shells at a late stage (large Arietids often have no centre like certain perforated *Nautili* of the Palæozoic or Triassic) probably would not have affected the buoyancy of the shell and mode of life of the animal more than the loss of its apex would have affected an *Orthoceras*.

The problem of disposing of superfluous calcium salts was probably never a pressing one in Ammonoids, for as in other tubular organisms growth could generally continue indefinitely whether the cone was coiled or straight, and when a large amount of mineral matter went to elaboration of one feature, the equilibrium was generally maintained. The periodical thickenings of ridges and flares, e.g., which are also found in the long-lived genera *Phylloceras* and *Lytoceras*, cannot in the writer's opinion be looked upon as such deposits of superfluous calcium-carbonate, after the manner of tabulæ, diaphragms, etc., in other tubular organisms,[2] and it must be remembered that very elaborate apertural structures seem to have been resorbed occasionally. A more fundamental problem than the necessity of getting rid of an excess of calcium-salts is presented by *Pinacoceras*, which represents the extreme in sutural elaboration among Ammonoids, and where the septal edge seems to be complicated beyond utility and mechanical requirements, and by the crowding of septa, which also occurs during the Triassic acme of the group. This is probably comparable with the specialization and running to extremes in other directions, e.g., size, ornamentation, or uncoiling, a phenomenon not confined to Ammonoid phylogeny, and generally followed by the extinction of the specialized lineage at or near the height of its career.

V.—Notes on Yunnan Cystidea. III. *Sinocystis* compared with similar genera.

By F. A. Bather, D.Sc., F.R.S.

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A.—Comparison with *Aristocystis*, *Hippocystis* n.g., *Calix*, and *Archegocystis*.

The Diploporita, to which Order *Sinocystis* clearly belongs, have been divided into Families according to the greater or less extension of the subvective system over the theca and the modifications thus induced in the arrangement of the thecal plates.

[1] "Fossilien d. Mungo-Kreide": Geol. v. Kamerun, ii, p. 216, 1904.

[2] W. D. Lang, "Calcium Carbonate and Evolution in Polyzoa": Geol. Mag., Dec. VI, Vol. III, No. 620, pp. 74–5, February, 1916.

All those in which the epithecal food-grooves do not extend beyond the adoral circlet of plates are referred to the Sphæronidæ. The line between the Sphæronidæ and the more advanced Glyptosphæridæ cannot be drawn rigidly, and such a genus as *Proteocystis* constitutes a natural transition. *Sinocystis*, however, comes well within this boundary.

On the other side it is not easy to define the limit between the Sphæronidæ and the Aristocystidæ, from which, apparently, they were evolved. In 1899 and 1900, accepting the statement (which I was unable to disprove) that the genera referred to the latter Family had no exothecal skeletal processes (e.g. brachioles), and observing the irregular and apparently unspecialized arrangement of their pore-canals when present, I placed the Aristocystidæ in the Amphoridea. Jaekel (1899) removed from the Aristocystidæ all the genera that I was including in that Family, with the exception of *Aristocystis*, but added to it his new genus, *Trematocystis*, which will be discussed in Section B. In 1906 (Palæont. Indica, N.S., II, No. 3) I showed that the pores in *Aristocystis dagon* from Burma were haplopores, that is to say not yoked in couples but isolated and irregularly distributed, and that they might be connected by surface channels which had a radial arrangement and crossed the sutures. Consequently I was not induced to place *Aristocystis* with the Diploporita as Jaekel had done.

Taking *Aristocystis* as represented by its genotype, *A. bohemica*, with which *A. dagon* is in general agreement, one notices a considerable resemblance to *Sinocystis*: the extended peristome and the three other thecal openings occupy the same relative positions and have much the same shape in the two genera. The genera are distinguished by their pores, and by the less development of the brachiole-facets in *Aristocystis*. One would take *Sinocystis* to be derived from *Aristocystis*, but there is the possibility that Jaekel may be right in reversing the relation. Unfortunately there is at present no means of settling this question by reference to stratigraphical position.

It should be remembered that the pore-structures figured by Barrande for various specimens of *Aristocystis* fall into two categories. The pores found in the typical *A. bohemica* seem to be haplopores, united by surface-channels into series ranging from 2 to 6; in this species the channels do not cross the sutures. The channels are of approximately equal width throughout their length, but are sinuous and irregular. In the other category the pores are far more obviously in pairs, and those of each pair are connected by a rather narrow channel of horse-shoe shape, at the ends of which they lie (Barrande, 1887, pl. 13, figs. 4, 12, 13, 15, 18; pl. 17, fig. iii, 5; pl. 14, figs. 10, 11). On quite unimportant grounds of external shape, Barrande included these and other specimens in *A. bohemica* as varieties, but he did also suggest that none of those with horse-shoe channels really belonged to *Aristocystis*. The adoral region of the theca in the latter specimens is unknown, but the pore-character warrants their separation as a genus for which I propose the name *Hippocystis* in allusion to the horse-shoe. It may be left, pending further information, in the Aristocystidæ.

The genotype is *H. subcylindrica* (Barrande sub *Aristocystites ?*), and for this the original of Barrande's pl. 13, figs. 1–4, is selected as Holotype. The holotype of *A.? grandiscutum* (Barrande, pl. 17, fig. iii) should be referred to *H. subcylindrica*, and the two other specimens of *A.? grandiscutum* (pl. 14, fig. 20, pl. 38, fig. 30) revert to *A. bohemica*. These specimens were associated by Barrande on account of a similarity in the basal attachment—a character of individual adaptation, insufficient to distinguish them from the species to which they are now referred.

Calix sedgwicki Rouault, which was placed by me in the Aristocystidæ (1900), was, after examination of specimens, referred by Jaekel (1899) to the Sphæronidæ. The adoral region remains unknown, but the structure of the thecal plates shows some resemblance to *Sinocystis yunnanensis*, viz., in the umbonal pustule, and in the frequent radial arrangement of the diplopores on the surrounding area of each plate. Jaekel, as previously mentioned (vol. V, p. 513), believes that the diplopores of *Calix* had a covering of epistereom. Some specimens referred by various authors to *Calix* may belong to *Aristocystis*; *Calix sedgwicki* itself may not be generically separable from *Codiacystis* Jaekel (= *Craterina* Barr. non Bory).

Archegocystis Jaekel, with genotype *A. desiderata* (Barr.), may be mentioned here because Jaekel is uncertain whether the pores are diplopores or haplopores. Though found in the Lower Ordovician (D, 1, γ), it has five facet-bosses, each bearing five or six grooves, each of which presumably was provided with a brachiole as in *Codiacystis*. A hydropore-slit and gonopore are placed as in *Aristocystis*.

B.—Comparison with *Megacystis* (synn. *Holocystites*, *Trematocystis*).

The fossils to which, at first sight, *Sinocystis* bears the strongest resemblance, are undoubtedly those from the Silurian of N. America which for many years passed under the name *Holocystis* (*-ites*). Justifiably, therefore, Dr. Reed alludes to these in his account of *Ovocystis mansuyi*, but to make the resemblances and the differences clear it will be well to go into greater detail.

1. *History of the Genus.*

The fossils referred to were first made known by James Hall, in the form of internal casts from the Niagara Limestone of Racine in Wisconsin (1861, Ann. Rep. Geol. Surv. Wisconsin, p. 23; 1862, Rep. Geol. Wisconsin, I, pp. 69 and 431, text-fig. 16/1 & 2). He published figures but no description, and distinguished two species under the names *Caryocystites cylindricum* (fig. 16/1) and *C. alternatum* (fig. 16/2). In the 20th Report of the New York State Museum, of which the earlier pages seem first to have been issued in 1864, Hall established the new genus *Holocystites* (p. 311) for the reception of these two species as well as the new species *H. abnormis*, from Racine, and *H. winchelli*, *H. scutellatus*, and *H. ovatus* from Waukesha, Wis. The complete Report was issued (presumably in a limited edition) in January, 1865, and (more freely) in 1867; a revised edition was published in 1870. By 1865

Hall had recognized that the name *Holocystis* had been used by Lonsdale in 1849 for a Cretaceous coral; he therefore proposed (1865, p. 380; 1870, p. 429) to replace his own *Holocystites* by *Megacystites*. To clear this matter of nomenclature out of the way at once, it may be mentioned that, though Hall's proposal was entirely overlooked by S. A. Miller, it was adopted by Sven Lovén in editing Angelin's "Iconographia Crinoideorum" (1878), by P. H. Carpenter (1891, J. Linn. Soc., Zool. XXIV, p. 47) and by myself (1900, Treatise on Zoology, p. 47). We have all used the form *Megacystis*, recognizing no difference but that of length and cumbrousness between the ending in *-ites* and those in *-us*, *-a*, or *-is*.

Beyond the general shape and the number of plates, very little could be ascertained by Hall from the material at his disposal. In December, 1865, A. Winchell and O. Marcy (Mem. Boston Soc. Nat. Hist. I, p. 9) described a new species, *C. sphæricus*, from the Niagara [Racine] Limestone of Chicago, and mentioned a fine specimen of *Caryocystites cylindricus*, showing the anus.

The *Megacystis ovalis* of Angelin (1878, p. 30) belongs to the Rhombifera, and his "*M. alternata*, Hall, var." (loc. cit.) is a fragment, supposed from Kinnekulle, which may have belonged to any large elongate Sphæronid of Ordovician age.

It was not till October, 1879, when S. A. Miller (Journ. Cincinnati Soc. Nat. Hist., I, p. 129) began the description of species from the lower part of the Niagara Group in Indiana, that it was possible to form an adequate idea of the genus. Miller continued his descriptions through many years,[1] and raised the number of names for North American species from seven to forty-eight. In 1889 (op. cit.) Miller fixed the genotype as *H. cylindricus* Hall. The original of Hall's figure 16/1 of "*Caryocystites cylindricum*" is the holotype of the species (= pl. xii, fig. 4, and pl. xii*a*, fig. 7, of Hall, 1865–67).

Unfortunately Miller's conceptions of Echinoderm morphology were old-fashioned when he began and underwent no change. In reading his descriptions his use of the following terms must be kept in mind:—

"Ambulacral orifice"	Miller	= mouth or peristome.
"mouth"	,,	= anus or periproct.
"anal aperture"	,,	= hydropore, but may sometimes = gonopore.
"ventral" or "anterior"	,,	= posterior.
"dorsal" or "posterior"	,,	= anterior.
"right" and "left"	,,	= left and right.

A list of the American species, with references, will be found in R. S. Bassler's "Bibliographic Index of American Ordovician and

[1] Dec. 1879. Journn. Cincinnati Soc. Nat. Hist., ii, pp. 104–8.
Jan. 1880. Tom. cit., p. 259.
Dec. 1882. Op. cit., v, p. 223.
1889. *N. Amer. Geol. and Pal.*, pp. 253–5.
1891. Adv. Sheets 17 Rep. Geol. Surv. Indiana, Palæontology, pp. 13–18.
Sept. 1892. Ditto, 18 Rep., pp. 8, 9.
July, 1892. With Faber. Journ. Cincinnati Soc. Nat. Hist., xv, p. 87.
Dec. 1894. With W. F. E. Gurley. Bull. Illinois State Mus., v, pp. 5–8.
Dec. 1895. With W. F. E. Gurley. Op. cit., vii, pp. 84–6.

Silurian Fossils" (1915, Bull. 92 U.S. National Mus.), under *Holocystites*. From the Racine Limestone of Wisconsin and Illinois there are the seven species already mentioned as described in 1864–5, as well as *H. jolietensis* Miller (1882), from Joliet, Ill. From the underlying Laurel Limestone near Waldron, Ind., is *H. pustulosus* Miller (1878). The Osgood Limestone of Indiana, which is slightly older, has yielded specimens in Jefferson county, mostly from Big Creek, near Dupont, but some from the neighbourhood of Madison, and in Ripley county, mostly from near Osgood. On these Miller based forty species.

In time, then, these species are confined to a period extending from the top of the Clinton to the middle of the Lockport, approximately equivalent to the age of the Woolhope Limestone and the lower half of the Wenlock beds. In space they are confined to the south-eastern quarter of Indiana and a strip bordering Lake Michigan on the south-west. That is to say, they inhabited the Indiana Basin of the Mississippian Sea, which derived its fauna, according to Schuchert (1910), from the Atlantic by way of the Gulf of Mexico. The bare record of *H. globosus*, from the Rochester Shale of Hamilton, Ont.,[1] is for the present unsupported by published evidence, but it was just on the border of the same Basin.

2. *Specific Characters in Megacystis.*

Everyone who has alluded to the forty-one species proposed by S. A. Miller (especially P. H. Carpenter, 1891; Jaekel, 1899; R. R. Rowley, 1903) has considered that they might be reduced to a far smaller number. Even Miller himself wrote in 1892: "The Holocystites are so variable in all respects that it is hard to tell exactly what should be considered specific characters and what should be regarded as variations among fossils belonging to the same species."

Here we obtain some guidance from the specimens of *Sinocystis*, which no one could regard as representing more than three species. The size and form of the theca are seen to vary within wide limits, in part no doubt with age, and the absolute number of plates is correlated with the growth of the theca. The positions of the thecal openings are also subject to slight individual variation, possibly connected with the position assumed by the theca. The size and shape of the base depend, as usual, on the surface to which the theca chanced to become attached, and on similar external conditions. There is no doubt a difference of general form between the pear-shaped *S. loczyi*, the more globose *S. yunnanensis*, and the egg-shaped *S. mansuyi*, but this of itself would not enable one to determine the species of such a specimen as I, 10. Slight differences seem to persist in the form of the facets and cover-plates, and some definite character might be deduced from a large series. But the most easily recognized and quite constant differentia lies in the individual thecal plates; these differ in tumidity, but above all in the size, form, and distribution of the diplopores.

Returning to the Holocystites, we find that the pores are just the

[1] W. A. Parks, 1913, Canada Geol. Surv. Guide-book No. 4, p. 132.

characters about which Miller and the other American authors give least information. There is one exception. Under *H. subglobosus*, 1889, Miller says that the pores are in pairs forming figures somewhat like an omega, ω. This striking character was seized on by Jaekel (1899, p. 413) to warrant the separation of this (as genotype) and any similarly constituted species from *Holocystis* (= *Megacystis*) Hall, as a new genus *Trematocystis* with the following diagnosis: [An Aristocystid with] "Theca irregular, oval or pyriform, attached by a rather small surface. Plates fairly large and not very numerous. Apparently as a rule four brachioles at the corners of the peristome. Diplopores with long multifariously irregular pore-passages joined to one another in groups." To this genus Jaekel by implication referred all Miller's species from the Osgood and Laurel Limestones, but possibly he did not mean to include *H. jolietensis* from the Racine Limestone.

The first question to decide is whether this character really distinguished *H. subglobosus* Miller from *M. cylindrica* Hall. Jaekel does not discuss this particular question, but takes the more drastic action of removing all the species referred to the genus by Hall, together with *Saccocystis* [whatever that unknown name may denote], to his Cladocrinoidea [essentially Crinoidea Camerata], of which he regards them as an aberrant type. He gives no reasons for this step, and I have been unable to discover any. The specimens from the Racine Limestone are not preserved so as to show either the smaller thecal openings or the structure of the pores, since they are for the most part internal casts or incomplete external moulds. The surface, however, is said to be strongly granulose, and this agrees with many of the species described by Miller. The specimen from the Racine Limestone of Joliet, described by Miller, is also known from internal casts, but on these Miller detected the marks of pores penetrating the pustules, as in *H. papulosus*. In Hall's figures the pustules are clearly indicated, especially in *H. abnormis*. The later figures of *H. cylindricus* and *H. alternatus* represent the pores as having a radiating arrangement (cf. *S. yunnanensis*). This is also noticeable in Miller's figure of *H. tumidus* from the Osgood Limestone. Therefore there seems no reason to doubt that the American authors are right in associating all these species.[1]

This, however, does not fully answer the question whether all the species have the ω-channels. Owing to the peculiar preservation of the Racine fossils, it is not likely that direct evidence as to the structure of their pores will ever be available. It is legitimate to interpret them in the light of such forms as *H. papulosus*, *H. pustulosus*, and *H. ornatus*, which have plates ornamented with well-marked pustules, usually quite separate from one another. Setting minor differences aside for the present, I may express my conviction that these species, as well as all others from the Osgood Limestone, did possess ω-channels. This conviction is based on the following facts. Miller's silence on the subject, except in the case of *H. subglobosus* (1889), proves only that he attached far less importance to these structures than to the number of plates and the

[1] I do not include Hall's pl. xii, fig. 6, which if correct is almost certainly of a different genus.

shape of the theca; for ω-channels are clearly represented in the drawing of *H. sphæroidalis* Miller & Gurley (1895); the drawings of *H. canneus* Miller (1889), and *H. hammelli* Miller (1889), seem intended to show them; irregular peripores are represented in *H. adipatus* Miller (1891), *H. amplus* Miller (1892), and *H. gyrinus* Miller & Gurley (1894), and seem to have been observed in *H. dyeri* Miller (1879), and possibly *H. ventricosus* Miller (1879). Examination of twenty-seven specimens from the Osgood Limestone of Big Creek, now in the British Museum, show that, whatever the differences of form or surface ornament, all possess or possessed ω-channels. Among these specimens are some determined (rightly or wrongly) by Miller himself as *H. scitulus* (E 16167–8–9) and *H. globosus* (E 16170–1). If Miller did not observe the ω-channels in these and other species, that may be due to the facts that on well-preserved surfaces they are not clearly exposed (E 7673, E 16167), and that on much-weathered surfaces they have often been worn away (E 16171). The reason for this will appear later; for the present I confine myself to the preceding justification of the belief that all Miller's species did have ω-channels, whether he said so or not. This, then, leads to the further conclusion that the species from the Racine Limestone also had ω-channels; at any rate their general resemblance is such that the burden of proof lies on those who would deny this conclusion. Finally it follows that all the American species belong to a single genus, for which Hall's name *Megacystis* (*-ites*) should be adopted.

It may here be suggested that *Allocystites* Miller, 1889, with genotype *A. hammelli*, from the Niagara group of Jefferson co., Ind., is a *Megacystis*. Jaekel (1899, p. 398) placed it in the Sphæronidæ, believing that the pores were diplopores. I would go further, and point out that the drawing of these pores (Miller's fig. 242) indicates the presence of ω-channels. The unique holotype is drawn and described as having a raised margin to the periproct, and the peristome "covered by minute plates forming a pentagonal star". Possibly! but one cannot help doubting whether Miller correctly interpreted these peculiar appearances. There is already a *M. hammelli* (Miller, 1889), probably a synonym of *M. rotunda* (Miller, 1879).

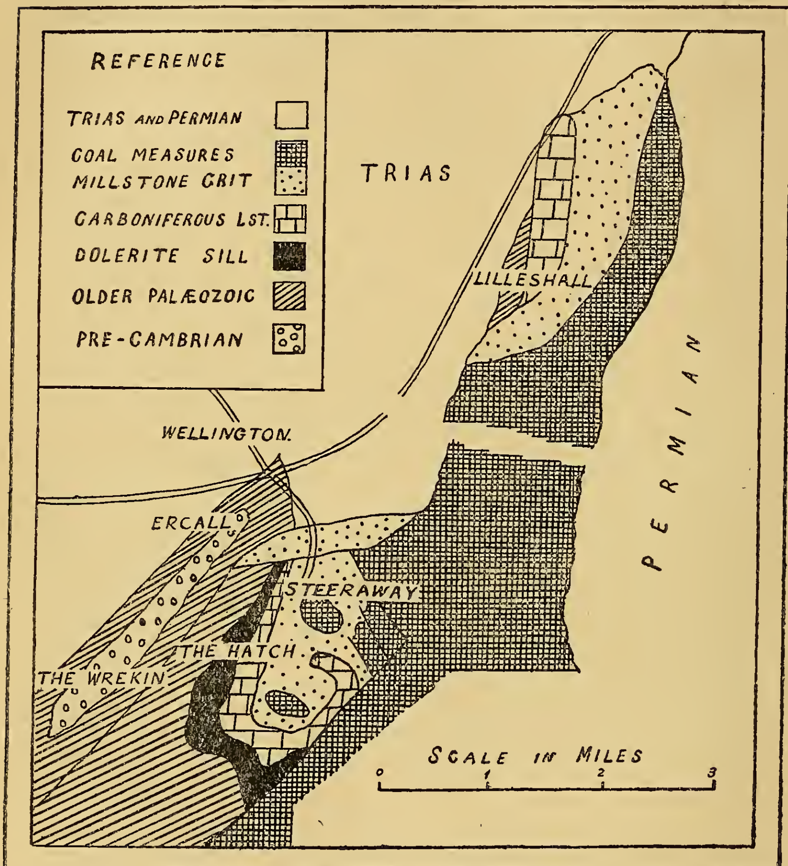
VI.—The Carboniferous Limestone of the Wrekin District.

By L. M. Parsons, M.Sc., D.I.C., F.G.S.

The Carboniferous Limestone cropping out near Wellington and near Newport in the Wrekin district has hitherto received little attention. One or two references to the Lower Carboniferous rocks of the area are made in *Geology in the Field*, in which the limestone is referred to the *Dibunophyllum* zone,[1] and the intrusive material underlying the limestone is described as an olivine-dolerite, probably of Tertiary age.[2] Apart from these references there does

[1] *Geology in the Field*, p. 762.
[2] Idem, p. 766.

not appear to be any published description of the limestone of the district. Although the Lower Carboniferous outcrops in the area are small, the faunal contents, stratigraphical horizon, and petrology of these rocks are subjects of interest in connection with recent work on the Carboniferous Limestone of various Midland districts.



Sketch-map of the Carboniferous Limestone outcrops near Wellington, Salop. (For the sake of economy of space in map, the Lilleshall outcrop has been brought *nearer* to Wellington; a break in the road and in the mapping of the Trias, Permian, and Coal-measures shows where the intervening space has been omitted.)

Some time ago Professor W. W. Watts suggested that I should examine the limestone near the Wrekin, and I propose to give, in this article, a brief summary of the more important results obtained.

The Lower Carboniferous outcrops of the area occur in two small linear patches, one fringing the hills extending southwards from the Ercall, near Wellington, the other at Lilleshall, near Newport, a few miles further to the north-east.

For the sake of convenience these may be termed the Ercall and the Lilleshall outcrops respectively. Before considering the Carboniferous Limestone in particular, we must note one or two important facts concerning the district in general.

The exact relation of the dolerite sill to the limestone above is now somewhat obscured. The Carboniferous Limestone seen in the area exhibits only a very thin development compared with that of other districts in the Midland Province, and there are no strata corresponding to "Pendleside" beds. The thin local development of "Millstone Grit" is unconformable on the limestone; it rests also upon older formations such as altered Ordovician material near the Ercall. In the neighbourhood of The Hatch, south of Wellington, the Millstone Grit passes up into Coal-measures, though the junction of these formations is often faulted as in the vicinity of Lilleshall.

With regard to the Carboniferous Limestone in particular, it will be as well to consider the two outcrops separately, as there are differences in petrology indicating somewhat different conditions of deposit.

The Ercall Outcrop.

The limestone comes to the surface in a narrow curved belt commencing at Steeraway, a short distance south of Wellington, and extending southwards some distance beyond a place known as "The Hatch". In the immediate vicinity of Steeraway the ground is very much overgrown and only talus heaps mark the sites of former workings. At this locality beds of Millstone Grit are seen, but their relation to the limestone below is obscured. A mineral railway passes from Steeraway southwards through dense woods to The Hatch, where is situated the only good exposure of this outcrop. Here the material is still being worked, and about 20 feet of thinly bedded argillaceous limestones with shaly partings are seen dipping at a small angle to the south-east. The relation of the limestone to either the dolerite below or the Millstone Grit above is again obscured. Petrologically the limestone is interesting on account of the high proportion of argillaceous impurities and the presence of a small amount of magnesium carbonate, which is not sufficient for the formation of dolomite crystals. As far as faunal contents are concerned these beds yield a fair number of specimens, which, however, belong to relatively few genera and species, as the following list shows:—

Faunal List of the Ercall Limestone.

Corals.

Syringopora cf. *geniculata*, Phillips.
S. cf. *reticulata*, Goldfuss.
Alveolites septosa (Fleming).
Lithostrotion junceum (Fleming).
L. irregulare (Phillips).
Diphyphyllum aff. *concinnum*, Lonsdale.
Lonsdalia floriformis (Martin).
Dibunophyllum sp.

Brachiopods.

Athyris planosulcata (Phillips).
Martinia glabra (Martin).
Spirifer planicosta (M'Coy).
S. striatus (Martin).
Productus giganteus (Martin).
P. scabriculus (Martin).
P. longispinus, Sowerby.
P. latissimus, Sowerby.
Chonetes cf. *hardrensis*, Phillips.

This faunal assemblage indicates definitely a D_2 horizon and a fair similarity to the D_2 fauna of the eastern typical facies of the Derbyshire area worked out in detail by Professor T. F. Sibly.[1]

Among the more important points of this similarity is the presence of *Alveolites septosa*, *Lithostrotion junceum*, and *Lonsdalia floriformis* in the coral fauna of both districts. Species of Brachiopods common to the two areas are, *Martinia glabra*, *Spirifer planicosta*, and scabriculate *Producti*.

On the other hand, the rarity of *Dibunophyllum* and the apparent absence from the Wrekin district of other important Derbyshire genera and species must be noted. I have not succeeded in finding either at the Ercall or at Lilleshall the following important corals: *Cyathophyllum regium*, *Campophyllum derbiense*, *Lonsdalia duplicata*, and Zaphrentids. The absence of the last two named has a special significance since they are found in Derbyshire towards the top of the *Lonsdalia* (D_2) sub-zone. It seems reasonable to infer that "Millstone Grit" conditions succeeded those of the Carboniferous Limestone in the Wrekin area during upper D_2 times.

With regard to the Brachiopod fauna, many of the Derbyshire forms, particularly various *Producti*, are absent from the Wrekin development, and another dissimilarity lies in the fact that in Shropshire the corals predominate, whereas in the typical eastern facies of Derbyshire both corals and Brachiopods are well represented.

The Lilleshall Outcrop.

The exposures of limestone seen at Lilleshall are situated at the northern end of the village, where there are one or two disused quarries, mostly overgrown. Examination is largely impeded by water, but in a field near the post office there is a dry exposure. All of these workings show about 25 to 30 feet of red mottled limestone arranged in almost horizontal beds. Unlike the Ercall limestones the Lilleshall material is not very argillaceous and contains little interbedded shale. The most striking feature of the limestone is its highly ferruginous nature. Analyses of this rock give the following average composition:—[2]

	Per cent.
Calcium carbonate	66·8
Iron compounds	28·9
Insoluble residue (silica)	3·8
Traces of magnesium.	
	99·5

Thin sections of this material show that the iron compounds consist mostly of interstitial hæmatite, the introduction of which occurred at a later date, and was probably connected with the Trias which covers the limestone at the northern end of the Lilleshall outcrop. Other points of petrological interest are the absence of dolomite and the presence of glauconite grains.

Palæontologically, the Lilleshall beds are much poorer than those seen at The Hatch. For this reason I give a separate faunal list as follows:—

[1] Q.J.G.S., 1908.

[2] For this and other analyses I am indebted to Mr. H. A. Doy.

FAUNAL LIST OF THE LILLESHALL LIMESTONE.

CORALS.

Syringopora cf. *geniculata*, Phillips.
Lithostrotion junceum (Fleming).
Alveolites septosa (Fleming).
Lonsdalia floriformis (Martin).

BRACHIOPODS.

Spirifer planicosta (M'Coy).
Productus giganteus, Martin.
S. bisulcatus, Sowerby.

This assemblage is sufficient to fix the horizon as being D_2. The remarks given above concerning the absence of *Campophyllum*, *Lonsdalia duplicata*, Zaphrentids, and other Midland genera, are apparently also applicable to the Lilleshall exposures.

SUMMARY OF CONCLUSIONS.

The Carboniferous Limestone of the Wrekin area represents part of the *Lonsdalia* sub-zone of other Midland districts. It has been deposited in shallow water, but without contemporaneous dolomitization, which frequently accompanies shallow-water conditions.

The Millstone Grit came on during upper D_2 times, and there are in the area no deposits similar to either D_3 or Pendleside developments in some other districts.

The fauna of the limestone is in many respects similar to, but in other respects different from, that of the D_2 eastern facies developed in Derbyshire. The limestones of The Hatch, near the Ercall, are of a more normal type than the deposits of Lilleshall, and are, therefore, more reliable as a means of comparison with the Carboniferous Limestone of other areas.

REVIEWS.

I.—THE GEOLOGY OF MANCHESTER AS REVEALED BY BORINGS. By G. HICKLING, D.Sc., F.G.S. Trans. Inst. Min. Eng., vol. liv, pp. 367–417, 1918.

THIS paper gives the results of an investigation carried out during the last two years in the Geological Department of the University of Manchester. It refers mainly to the Permo-Triassic belt, which separates the coalfields of Ashton and Pendleton, containing the Manchester coalfield as an island in the centre. A detailed and careful consideration of all available records of borings has led to the following among other conclusions. There is no evidence of unconformity between the Permian and Bunter. The Bradford fault is certainly, and the Irwell fault probably, to a large extent pre-Permian. There is some evidence that the Upper Coal-measures extend close to the surface from Collyhurst, under Cheetham, to Agecroft, and a considerable area of productive measures is probably within easy reach north of this line. An important N.W.–S.E. fault bounds the area just mentioned on the N.E., and the productive measures are probably too deep for some distance north of this line. The total thickness of the Permian strata is about 1,000 feet, while the Bunter Sandstones measure at least 760 feet. Part of the "Permian" Sandstones probably belong to the Upper Coal-measures.

R. H. R.

II.—The Association of Facetted Pebbles with Glacial Deposits. By J. W. Jackson. Mem. and Proc. Manchester Lit. and Phil. Soc., vol. lxii, No. 9.

FACETTED and wind-worn pebbles are described from Lancashire and Cheshire, and it is shown that they are of post-Glacial and pre-Neolithic age. The author considers, in accordance with the conclusion previously reached by Dr. Bather, that such pebbles do not in themselves provide evidence of arid or steppe conditions. At the close of glaciation in any country the land must have been bare, strewn with pebbles associated with an abundance of sand, and exposed to winds. Remembering that many of the pebbles had been already fractured by frost, the conditions were thus favourable for the development of facetted pebbles by the action of a natural sand-blast. It is suggested that an intimate connexion exists between the period of wind-erosion and the deposition of the æolian sand of Shirdley Hill.

III.—Yorkshire Type Ammonites. Edited by S. S. Buckman. Photographs mainly by J. W. Tutcher. Part xvii, pp. xiii, xiv, 8 plates and descriptions Nos. 117–119. London: Wesley. 1918.

THIS part is remarkable for the number of new names, not always of classic elegance. *Fimbrilytoceras* is for "the series to which *Am. fimbriatus*, Sowerby, belongs", since *A. fimbriatus* d'Orb., is the genotype of *Lytoceras*. The two genera are contrasted. "Owing to the regulations of the Oxford University Museum, photographs of" the holotype of *A. fimbriatus* Sow. "could not be obtained"—a statement that needs explanation. *Pseudocadoceras* is based on one syntype of *A. longævus* Bean, while the other syntype, now the lectotype, becomes the genotype of *Longæviceras*. *Eboraciceras* (an uneasy name) is founded for *A. dissimilis* Brown, here refigured; *Prorsiceras* for *A. gregarius* Bean-Leckenby, also refigured; and *Vertumniceras* for *A. vertumnus* Leckenby, as mentioned in the preceding Part. These last four are Cadoceratidæ. *A. crassus* Young & Bird, is refigured and referred to *Cœloceras*. Plates are also given of *Bifericeras parvum* (S. Buckman, 1904, sub *Microceras*), *B. nudicosta* (Quenst.), and *Beaniceras rotundum* nov. (based on *Ammonites centaurus* J. Buckman); but these are not from Yorkshire. The descriptions convey a large amount of information to those who will trouble to interpret them; the clear photographs speak for themselves.

IV.—The Water Supply of Essex. By W. Whitaker and J. C. Thresh. Mem. Geol. Survey. pp. 510 and 4 maps. 1916. Price 15*s*.

THE memoir contains, in addition to well-records, chapters dealing with the water-bearing beds, rainfall, chemistry of Essex waters with analyses, contamination and risk thereof, supplies from springs, wells, and borings.

It is accompanied by an extensive bibliography and by maps showing (1) the underground water-level in the Chalk around the head-waters of the Stort and Cam, (2) the amount of chlorine in deep-well waters, (3) wells giving alkaline waters, (4) the rainfall.

V.—Geological Structure of the Union of South Africa. By A. W. Rogers, Sc.D. pp. 13, with a coloured map. Reprinted from the Official Year Book, 1917.

In the space of thirteen pages Dr. Rogers manages to give a very complete account of the physiography and geology of the Union territories, which cover an area of no less than 476,000 square miles. The account is necessarily much compressed, but still a brief description is given of the characters and distribution of the long succession of rock-formations represented. The latest results of South African stratigraphy are condensed into a tabular form, giving the correlation and thicknesses, so far as known, of all the scattered and puzzling rock-groups which, in the absence of fossils, have given so much trouble to South African geologists. It is interesting to note that the Malmesbury series of the Cape Province is now definitely regarded as equivalent in a general way to the Transvaal or Potchefstroom system, and that the Matsap series of Griqualand West is now placed on the same horizon as the Waterberg, and below the Table Mountain Sandstone. The ages of the different series of igneous intrusions are also indicated, and their close connexion with periods of earth-movement come out clearly in the table. The intrusion of the Bushveld complex is considered to belong to the age of the Waterberg system. The enormous total thickness of the South African sedimentary rocks is very striking, especially when considered in connexion with the peculiar conditions under which many of them were deposited, as, for example, the Karroo system. Altogether South African geology presents many problems of interest towards the solution of which Dr. Rogers and his colleagues of the Geological Survey have made very notable contributions.

R. H. R.

VI.—The Cassiterite Deposits of Tavoy. By J. Coggin Brown. Rec. Geol. Surv. India, vol. xlix, pt. i, pp. 23–33, 1918.

At the present time Tavoy is one of the most important wolfram-mining centres of the world, but the occurrence of tin in notable quantities has been somewhat overlooked. Cassiterite occurs as an accessory mineral with wolfram and molybdenite in the granite, and in pegmatite veins and quartz lodes with ores of tungsten, bismuth, iron, copper, arsenic, antimony, lead, and zinc.

In the lodes cassiterite is almost always in close association with wolfram; in the Paungdaw-Wagon area the mixed concentrates may contain as much as 25 per cent of tin ore; cassiterite tends to be more common than wolfram in the greisens. The methods of lode-working still in use are somewhat primitive, being chiefly "cobbing and panning": the installation of a magnetic separator at Tavoy has improved the quality of the concentrates shipped.

The greater part of the output, however, comes from detrital deposits, which are exploited by hydraulic methods, especially by monitors. The richest tin-placers appear to be of sub-recent or late Tertiary age, forming raised river terraces and lake deposits and raised marine clay banks along the Tavoy estuary. The tin-bearing beds of the Kanbauk area must have been laid down in a rapidly sinking valley, but recent movements of the land were in an upward direction. The author gives a list of localities in which he suggests that prospecting is likely to give good results.

R. H. R.

VII.—Timiskaming County, Quebec. By M. E. Wilson. Memoir 103, Canada Department of Mines, No. 86, Geological Series. pp. 197, with 16 plates, 6 text-figures, and a map. Ottawa, 1918.

THIS well-produced memoir is a general statement of the results of geological work carried on for several years in the north-western part of the province of Quebec. Besides the special and detailed descriptions of the local geology of Timiskaming County, it contains a good general account of the geology of the Ottawa basin, which comprises rocks of early and late Pre-Cambrian and Lower Palæozoic age. The former are included by the author in the Basal Complex, Huronian, and Keweenawan groups, while the Palæozoic sediments contain representatives of the Ordovician and Silurian systems.

Timiskaming County lies wholly within the Laurentian plateau and possesses in part the rocky-lake topography characteristic of that region, but part of it is occupied by plains of Post-Glacial lacustrine clay, forming what is generally known as the "clay belt". There are also numerous linear gorge-like valleys, which are believed to be of tectonic origin.

The lowest rocks seen in the area are the gneisses and limestones of the Grenville series. These are succeeded by the sediments and igneous rocks, extrusive and intrusive, of the Abitibi series, into which are intruded the Pre-Huronian batholiths. Upon these lie unconformably the Cobalt series, consisting of conglomerate, arkose, greywacke, and argillite. The Keweenawan rocks are mainly of a basic character, ranging from olivine-gabbro to syenite-porphyry.

The Ordovician Black River Limestone is probably separated by an unconformity from the calcareous sandstones and limestones of the Niagara series, the youngest formation represented in the district, with the exception of the Glacial and Post-Glacial deposits. Hence it is seen that the geological sequence in this area is remarkably incomplete.

The Cobalt series shows some features of considerable interest, since many of its members are believed to be of glacial origin: they show a remarkable similarity, allowing for natural processes of alteration, to the deposits of the Pleistocene continental ice-sheets, laid down under lacustrine conditions in the outer zone of an area of glaciation.

The deposits composing the clay belt consist chiefly of finely laminated beds of clay and silt with occasional thin layers of calcium carbonate, sometimes passing into sandy beds. These were probably laid down in a great glacial lake, which is provisionally called Lake

Barlow. It does not seem to have formed part of Lake Algonquin, as suggested by Coleman.

The economic products of the county are not very important so far as is known: they include gold, silver, and molybdenite, but the only mine actually working produces galena. It is possible, however, that the veins of molybdenite may prove to be of value owing to the present high price of this ore.

VIII.—Rainy River District, Ontario, Surficial Geology and Soils. By W. A. Johnston. Canada Department of Mines, Geological Survey Memoir 82. pp. 123, with 8 plates, 1 text-figure, and a coloured map. Ottawa, 1915.

The Rainy River District lies about half-way between the head of Lake Superior and the Red River of Manitoba, near the International Boundary, and has a total area of 1,051 square miles, mostly covered by superficial deposits of Quaternary and Recent date, underlain by pre-Cambrian rocks. The superficial deposits consist for the most part of boulder-clays and other glacial material, together with lacustrine sediments laid down in lakes formed during the retreat of the ice-sheets, and a considerable area of recent alluvium, wind-blown sand, and peat.

A variety of drifts are found in the district formed by the Keewatin and Labradorean glaciers, as well as lacustrine deposits of a marginal lake described as "pro-glacial Early Lake Agassiz", a predecessor of Lake Agassiz proper: the genesis of this lake is discussed in some detail.

The main object of this memoir is the study of the soils and their economic possibilities. Much of the country is forest-clad, and the soils have for the most part the light colour characteristic of well-timbered regions, apparently belonging to the "grey forest soils" of the Russian classification: there are, however, large areas of peaty, and what American writers pleasingly call, "muck" soils. Detailed descriptions are given, with mechanical analyses of the soils lying on the different types of surface accumulations: most of them are somewhat heavy in character, the only light soils of importance being the sandy and gravelly loams of the old beach ridges, and the lacustrine sands. The heavier soils, which are for the most part still virgin, appear to be very fertile when properly drained.

IX.—Canada Department of Mines, Summary Report, 1917. Part D. pp. 46. Ottawa, 1918.

This short report contains descriptions of certain areas in Manitoba which have recently been examined, largely with a view to their economic possibilities in the direction of mining and agriculture. The districts described include the Schist Lake, the Wekusko Lake, and the Star Lake areas, the gold-bearing region of S.E. Manitoba, the Falcon Lake molybdenite region, and the refractory occurrences of the Swan River Valley. A reconnaissance soil-survey was also carried out along the line of the Hudson Bay Railway.

X.—South Australia, Department of Mines, Mining Review for the Half-year ended June 30, 1918. No. 28. Adelaide, 1918.

After the usual summary of outputs and values of minerals, this issue goes on to describe several interesting mineral occurrences.

Bores put down by the Government diamond drill on the Yelta Mine, adjoining the Moonta Mines property, traversed a copper-bearing lode which in one bore swelled to a rich ore body 21 feet thick, with an average copper content of 27 per cent, rising in places to 34·5 per cent; the lode is enclosed by the same country rock as that of the Moonta Mines.

An account is given of a graphite field on Eyre's Peninsula. The soil over part of the field is covered with a crust of travertine, but where this is absent flake graphite and graphite-bearing stones are found in a structureless subsoil stained with limonite. Magnesite is present and quartzite fragments are frequent. The nature of the decomposition products shows that the graphite has been developed in a series of sediments which have been greatly altered and invaded by pegmatites, and are now represented by a mixture of lime-silicate rocks and gneisses, such as are formed by the alteration of impure dolomitic limestones. The workings have not yet been carried below the zone of weathering, but the indications of workable graphite are promising.

In the county of Fergusson, on Yorke Peninsula, alunite has been discovered in the sea cliffs in a bed of clay resting on polyzoal limestone. The rocks are Tertiary in age and are overlaid by 50 feet of clay and 20 feet of travertine or superficial limestone. The alunite occurs as irregular layers, from 1 inch to 9 inches in thickness, and as nodular masses arranged in layers along a total width of about 12 chains.

The mode of origin of the alunite is rather obscure, but there are two possible explanations: the first supposes that the mineral was derived from sulphates generated from pyrites and from potash in the clay, and this idea is supported by the fact that samples of the same clay from a point a few miles away contain from 1·7 to 5 per cent of potash and from 2·38 to 0·23 per cent of SO_3 respectively. Alunite is soluble in sulphuric acid and, on coming within the influence of the limestone, the excess acid would be destroyed with the precipitation of the alunite immediately above the limestone. On the other hand, alunite is also known to have been derived from solutions rising from depth, and this may be the case here. It is likely that the fault fissures in the limestone along which the solutions could ascend did not extend into the clay, and that the alunite was therefore deposited just above the limestone.

The mineral is worked along adits from the shore; the samples taken contained from 60 to 87 per cent of alunite, corresponding to 6·3 to 9·3 per cent of K_2O.

W. H. W.

XI.—Permian Insect Remains from Sydney, N.S.W.

A Fossil Insect-wing from the Roof of the Coal-seam in the Sydney Harbour Colliery. By R. J. Tillyard. Proc. Linn. Soc. N.S.Wales, xliii, pp. 260–4, 1918.

THIS specimen is the portion of the fore-wing of an Orthopterous insect referred to the family Elcanidæ, and described as *Elcanopsis sydneiensis*, n.g. et sp. The horizon is Upper Permian. Members of the family are already known from the Lias and Upper Jurassic, and show an increasing tendency in their venational plan to the Acridiidæ of the present day. This new genus shows a still greater reduction in the number of branches of the radial sector and the number of cross veins, and suggests that the Acridioid plan may have been formed by the addition of new elements to what was originally a simpler and more open type of venation.

XII.—Diastrophic and other Considerations in Classification and Correlation and the Existence of Minor Diastrophic Districts in the Notocene. By J. Allan Thomson. Trans. New Zealand Inst., vol. xlix, pp. 397–413, 1916.

THE principles of diastrophism have been employed by Marshall, Speight, and Cotton in the correlation of the younger rocks of New Zealand. The succession of these rocks affords an example of a cycle of sedimentation between two periods of earth-movement, the middle of the cycle being marked by the occurrence of deep-water limestones. These authors assumed that the limestones were everywhere of the same age, although the palæontological evidence was incomplete. All the rocks formed between the early Cretaceous (post-Hokonui) and Kaikoura (late Tertiary) disturbances were named by Marshall the Oamaru system. Dr. Allan Thomson brings forward evidence to show that sedimentation began at very different times in different parts of the country, and that the Ototara, Otaio, Amuri, and Whangarei limestones are not contemporaneous. These limestones each represent a local maximum of depression due to provincial warpings of different diastrophic districts. For all strata deposited between the post-Hokonui and Kaikoura deformations the name Notocene is proposed, in order to avoid the necessity for exact correlation with the European Cretaceous and Tertiary divisions. In the same way it is suggested that the most recent superficial deposits, younger than the Kaikoura deformation, should be classed as Notopleistocene, since in the absence of mammals it is impossible to establish their equivalence with the subdivisions of the European and American Pleistocene. Some of these recent formations have undergone a good deal of tilting; in one place river gravels were observed dipping at 12° to the south-east; this suggests that the Kaikoura deformation lasted longer in some districts than in others and may even yet be in operation locally.

A description is given in an appendix of a new fossil, *Pachymagas abnormis*, n.sp., from sand interbedded with the Mount Brown limestone, Weka Pass, Canterbury.

R. H. R.

REPORTS AND PROCEEDINGS.

I.—The Royal Society. *December* 12, 1918.

"The Four Visible Ingredients in Banded Bituminous Coal." By M. C. Stopes, D.Sc. Communicated by Sir George Beilby, F.R.S.

The coal discussed is the ordinary streaky bituminous coal of the British Coal-measures widely used in home and factory.

Disregarding for the time being the ultimate morphological nature of the plant organs contributing to them, four differing substances or constituents are described as composing such coal. These can be recognized by differences in their general character.

1. Differences in their macroscopic appearance and texture (i.e. with the naked eye in hand specimens).

2. By their different behaviour when treated with various chemicals.

3. By the differences in the débris of each which result from their treatment with various chemicals.

4. By the differences in microscopic sections of untreated samples of each.

These differences are further followed up by analyses and distillations to be considered in a later paper.

Diagrams are given to show the characteristic distribution of these constituents in section, and to indicate, if not a parallel to, at least a possibly useful comparison with, petrological work on rocks.

The four ingredients thus determined are fusain (the already widely discussed "mineral charcoal"), and durain, clarain, and vitrain, the three latter names being given now for the first time.

II.—Geological Society of London.

1. *December* 4, 1918.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communication was read:—

"The Carboniferous Succession of the Clitheroe Province." By Lieut.-Colonel Wheelton Hind, M.D., B.S., F.R.C.S., F.G.S., and Albert Wilmore, D.Sc., F.G.S.

The tectonic structure of the province consists of three dissected parallel anticlinal folds in beds of Carboniferous Limestone, Pendleside, and Millstone Grit age. The general direction of the axes of these folds is east-north-east and west-north west. Dissection has exposed the lower beds of Z, C, and S age, as the tectonic axes and beds of D, P, and Millstone Grit age occur on the flanks.

The Limestone sequence shows all the zones from Z to D. *Modiola* and *Cleistopora* phases have not been exposed, the base of the Carboniferous not being seen. The Z beds are much thickened, and not so fossiliferous as in the Bristol Province. C and S beds are, as a rule, well-bedded, with shales intercalated between beds of limestone. There are crinoidal beds of considerable thickness in places, and shell-breccias are common in S. *Zaphrentis omaliusi* indicates an important horizon in Lower C, and these beds are characterized by numerous large Gasteropods. *Productus humerosus* (*sublævis*) marks an equally important horizon in Upper C, as it does in the Belgian Province.

D beds are peculiar in the western part of the Clitheroe Province, and are largely represented by shales, mudstone, and thin earthy limestone; but in the north and north-east in the Settle and Burnsall districts, thick, fossiliferous, obscurely bedded limestone with a rich brachiopod and molluscan fauna occur.

The Pendleside Series is well developed, and practically the whole sequence is exposed on the north-western flank of Pendle Hill. This series can be subdivided into life-zones by the Goniatites.

The lower 300 feet consists of well-bedded earthy limestones with much chert, characterized by the presence of *Prolecanites compressus*. As a rule, there is a well-marked limestone horizon, which the authors name the Ravensholme Limestone (from a farm of that name at the north-eastern end of Pendle); this limestone contains *Zaphrentis amplexoides*, *Cyathaxonia rushiana*, *Michelinia tenuisepta*, and *M. parasitica*, and the fauna is a very important and constant feature throughout the whole province. The Ravensholme Limestone is an important part of the "Pendleside Limestone" of the late Mr. R. H. Tiddeman.

The Pendleside Limestone is succeeded by hard, black, calcareous shales with *Glyphioceras striatum*, *Nomismoceras rotiforme*, and *Posidonomya becheri*; and these in turn by the Bowland Shales of Phillips, which contain the zones of *Glyphioceras spirale* and *Glyphioceras bilingue*.

The Upper Pendle Grit succeeds the zone of *Glyphioceras bilingue*, and is the homotaxial equivalent of Farey's Grit of the Peak Country.

An important horizon occurs between the Kinderscout and the Millstone Grit—Sabden Shales—characterized by a rich fauna with *Glyphioceras beyrichianum* and *Glyphioceras reticulatum*. It is considered probable that the well-known fossiliferous Hebden Bridge Beds may be on this horizon rather than in the Pendleside Series.

TABLE OF GONIATITE ZONES.

	"Middle" Coal-measures.	*Gastrioceras carbonarium*, von Buch.
	Lower Coal-measures.	*G. carbonarium*, von Buch.
	Upper Millstone Grit.	*G. listeri*, Martin.
	Sabden Shales.	*Glyphioceras diadema*, Beyrich.
Zones of the Pendleside Series.	Shales below Millstone Grit.	*G. bilingue*, Salter.
	Bowland Shales.	*G. reticulatum*, Phillips.
		G. spirale, Phillips.
		G. striatum, Phillips.
	Posidonomya becheri Shales.	*Nomismoceras rotiforme*, Phillips.
		Prolecanites compressus, Sowerby.
	Carboniferous Limestone D_2.	*Glyphioceras crenistria*, Phillips.

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2. *December* 18, 1918.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communication was read:—

"On a Bed of Interglacial Lœss and some Pre-Glacial Freshwater Clays on the Durham Coast." By Charles Taylor Trechmann, D.Sc., F.G.S.

A few years ago the author described a bed of Scandinavian drift that was found filling up a small pre-Glacial valley-like depression at Warren House Gill on the Durham coast. This section and others north and south of it have been kept under observation at different times, and several new features have been noticed as the high tides and other agencies exposed parts of the coast.

Towards the southern end of the old pre-Glacial valley at Warren House Gill a bed of material, varying from 4 to 12 feet in thickness, was found overlying the Magnesian Limestone and also the Scandinavian drift. This material has been carefully examined chemically and microscopically, and proves to be identical in chemical and physical characters with a sample of the true Continental lœss. It is light-brown or fawn in colour, very porous, and extremely finely divided, and is devoid of plasticity. Towards the base, where it has not been disturbed since it was laid down, it contains a number of rounded and elongated, often very hard, calcareous concretions. In the cliff section it shows little or no trace of bedding, but tends to break down along vertical clefts and cracks. It passes upwards into a few feet of material that consists of lœss which has been partly redeposited by water, and is mixed with sand, gravel, and other material derived from Scandinavian drift.

The bed of lœss and redeposited lœss-like drift has suffered much decalcification and weathering; near its surface there was a large boulder of Norwegian titaniferous syenite which was superficially rotted and decomposed to a considerable depth. Smaller granitic erratics in the redeposited lœss are generally very much rotted. The limestone rubble and stones beneath the lœss are strongly calcreted, apparently by material leached out of the lœss. In a fissure beneath the lœss some mammalian bones were collected, including astragali of two species of *Cervus*. It is argued that the formation and subsequent decalcification of the lœss deposit lying upon the Scandinavian drift indicates an interglacial lapse of considerable duration, as great as that which Continental geologists call an Interglacial Period, before the overlying English and Scottish drift was deposited.

About 2 miles south of the Scandinavian drift-bed several fissures occur in the Magnesian Limestone cliffs and on the foreshore, filled with various materials that were transported in front of the earliest ice-sheet that advanced upon this part of the coast. The author has already recorded the occurrence in these fissures of Upper Permian red and grey marls and dolomites with clay and peaty trees. Continued examination of two of the fissures where they are exposed between tide-marks on the shore resulted in the finding of a quantity of freshwater mollusca, Ostracoda, and fish-remains. Some mammalian remains also occurred, including those of an elephant (probably *Elephas meridionalis*) and of a vole (*Mimomys*).

Vegetable matter has been washed from various parts of the clay. A large number of seeds came from a single patch of clay, and prove to be of Teglian age; they seem to represent a pre-Glacial flora, half of the species of which are either exotic or extinct. Seeds from other parts of the deposit appear to indicate a later horizon and contain mainly living forms.

The deposit is a mixed one, and seems to have belonged to a series of late Pliocene and early Pleistocene beds that occupied part of the present area of the North Sea and were torn up by the advancing ice-sheet, like a great glacial erratic, and thrust into the fissures.

The fact that the Scandinavian drift in Durham contains only stones of Scandinavian origin has been confirmed, and the marine Arctic shells that occur in it were further collected, and a few additions to the faunal list were made. The most interesting of these is *Cyrtodaria siliqua*, Spengler, an American shell which has been recorded hitherto in Great Britain only from the Caithness Boulder-clays.

All the deposits described above are overlain and overridden by the main mass of local Cheviot and Northern drift that caps the cliffs of the Durham coast.

A suggested correlation of the Durham sequence with the European drifts is attempted, and it is concluded that the fringe of the Scandinavian ice-cap that reached the Durham coast probably corresponds with that of the second and greatest glaciation of Scandinavia, which some Continental geologists correlate with the Riss Stage of the Alps.

In that case the main local drift of the north-eastern coast falls into the third and last Glacial Period of Northern Europe. The evidence for Interglacial lapses in the local drifts is very inconclusive.

All the observed features seem to point to the fact that the Scandinavian ice-sheet advanced on the east coast of England in the same way as it invaded Northern Europe round the southern shores of the Baltic, and gave rise to analogous climatic conditions leading to the formation of lœss, a fragment of which is found protected from the erosive action of the later local glaciation in a small hollow on the Durham coast.

III.—Edinburgh Geological Society.

November 20, 1918 (received December 13, 1918).—Professor Jehu, President, in the Chair.

"The Iron-ore Deposits of Noblehouse and Garron Point and their Genesis." By Dr. J. S. Flett, F.R.S.

In the Upper Cambrian rocks, which form a narrow band along the southern border of the Highlands, thin beds of iron ore occur among cherts and pillow-lavas. They are best exposed at Garron Point and Craigeven Bay, about a mile north of Stonehaven. Owing to their limited extent and irregular character, no attempt has been made to work them. At Noblehouse, in Peeblesshire, the Arenig pillow-lavas and cherts contain at least one bed of iron ore which was mined, though not with much success, at two periods during the nineteenth century. In both these cases the iron ore occurs as beds interstratified with cherts and shales, which were deposited on the sea bottom shortly after eruptions of pillow-lava had taken place.

Although in Great Britain pillow-lavas and cherts are widely distributed, there are few records of iron-ore deposits in connection with them. In other parts of the world, however, some of the most important beds of iron ore belong to this association. In Germany the Lahn and Dill districts and the Upper Harz contain beds of iron ore in Middle and Upper Devonian strata; these rest on pillow-lavas and tuffs (schaalsteins), and are not uncommonly interbedded with cherts. For several years it has been clearly realized by German geologists that these deposits are products of the pillow-lava eruptions; and it is considered that they may have originated from emanations of ferric chlorides and other salts arising from the lava-flows during cooling.

The greatest iron-ore field of the present day is the Lake Superior district of the United States. Iron formations consisting of cherts and beds of hæmatite (sometimes siderite, magnetite, or limonite) are there found in pre-Cambrian rocks, principally the Keewatin and the Huronian. According to Van Hise and Leith, they are in all cases attended by eruptions of pillow-lava, and the source of the iron is to be traced to discharges of soluble iron salts proceeding from these lavas during their outflow, or shortly after they had come to rest.

In Northern Sweden and Lapland great masses of iron ore have long been known, and are mined on a very extensive scale. They are principally magnetite, with varying amounts of apatite, and are usually associated with syenitic eruptives, frequently rich in albite. Recently it has been shown that in the Kiruna district these eruptives belong to a suite in which pillow-lavas are strongly represented, and that all the rocks are very commonly albitized. The "syenites" (also described as "keratophyres") are the acid or leucocratic members of a "spilitic" suite. The iron-ore deposits are variously interpreted as stratified beds, magmatic segregations, and contact deposits.

Submarine deposits of iron ore in beds, such as the Noblehouse and Garron Point deposits, resting on or associated with pillow-lavas, are accordingly of worldwide distribution and sometimes of the highest economic importance. Their formation is due to the abundant discharges of vapours and salts from the cooling lava-flows, and, like the albitization and siliceous formations that characterize this group of rocks, they mark the special propensity to pneumatolytic discharges which is one of their distinctive peculiarities.

CORRESPONDENCE.

THE YUNNAN CYSTIDEA.

Sir,—Dr. Bather's articles (Geol. Mag. November and December, 1918) on the Yunnan Cystidea described by me in the *Palæontologia Indica*, n.s., vol. vi, Mem. No. 3, 1917, appear to require some notice, if only to correct some unfortunate mistakes into which he has fallen. But in the first place he may be congratulated on having at last published a clear terminology and definition of the morphological planes of the Cystidea which will avoid subsequent misinterpretation of his descriptions.

With regard to the genera *Sinocystis* and *Ovocystis* which Dr. Bather would unite, it is regrettable that when he had the actual figured specimens to examine his customary accuracy of observation seems to have been wanting, so that he has been led to doubt the presence of certain characters which I described. Indeed, he candidly admits (Geol. Mag. for November, p. 513) that he did not notice one of the structures in question till he had read my memoir and sent back the specimens. It must be accordingly concluded that his remarks are partly based on the casts and figures with their unavoidable defects and limitations. Two points may be specially mentioned. (1) *Sinocystis loczyi*. Of the many specimens of this species which were submitted to me for study, of which only a few were figured, it was observed that only in a very few instances was the summit of the tubercles missing and the diplopores exposed, and that this was due to abrasion, as clearly shown by the condition of the rest of the theca. In both large and small specimens the uninjured surface of both species of this genus possessed a thick layer of epistereom covering the tubercles and concealing the openings of the diplopores. In *Ovocystis mansuyi*, on the other hand, the diplopores were always seen to open freely on the surface, whether the specimens were large or small, worn or undamaged. The good preservation of much of the material which passed through my hands seems to render these facts beyond doubt. (2) The runnels on the surface of *Ovocystis mansuyi*, to which I applied the term "food-grooves" with perhaps too easy an assumption of their function, are more or less distinctly seen in a large number of the specimens which I examined, and are frequently quite conspicuous features impossible to confuse with the normal depressions between the plates of *Sinocystis* or *Ovocystis* itself, though Dr. Bather believes that they are of this nature and devoid of significance. It is true that they have not come out well in the collotype reproductions and much less in the casts on which he relies, but there can be no question as to the existence of these strange and often irregular grooves on the surface, whatever view we hold as to their character. If Dr. Bather had had the advantage of studying the large series of specimens which I had, and of observing the different degrees of development of these runnels, he would not have questioned their existence. Whether the differences between *Sinocystis* and *Ovocystis* are sufficient to separate them generically after taking into account these and other points which I mentioned may be a matter of opinion, but the presence and constancy of such characters have to be admitted.

F. R. C. Reed.

Cambridge.
December 18, 1918.

THE GENESIS OF TUNGSTEN ORES.

Sir,—In reply to Mr. J. Coggin Brown's letter in the January number of the Geological Magazine on the Genesis of Tungsten Ores I should like to state that my paper on that subject was written in the first two months of 1918. The valuable lecture by Dr. Jones was reprinted in the *Mining Journal* in March, 1918, but

I was unable to see the collected edition of the Tavoy lectures, published at Rangoon, until October, when Mr. J. F. L. Vogel, of High Speed Steel Alloys, Ltd., of Widnes, was kind enough to lend me the copy belonging to his company. I need hardly say that I should have been only too pleased to quote the results of more recent work had such been available at the time. Much of the difficulty of obtaining information no doubt arose from the prevalence of war conditions and the slowness of communications, but it is much to be regretted that geologists who have worked in Tavoy have almost always elected to publish their results in more or less obscure and inaccessible forms; copies of such publications are not always to be found in the principal scientific libraries. May I venture to suggest that the pages of the Geological Magazine are readily open to receive either original contributions or abstracts of other publications on matters of such high scientific interest and practical importance?

R. H. Rastall.

OBITUARY.

GROVE KARL GILBERT.

Born 1843. Died 1918.

Grove Karl Gilbert was born at Rochester, N.Y., on May 6, 1843. He received his early education in the same city and graduated in the classical course at the University there. After a year spent in teaching at Jackson, Michigan, he returned to Rochester, where he was employed for five years as assistant to a well-known dealer in scientific materials. In 1868 he became a voluntary assistant on the Ohio Geological Survey, but his real career may be said to have commenced in 1871, when he joined the Survey of Utah, Nevada, and Arizona; here Gilbert began the field-studies which led to the great work of his life, the investigation of the dependence of physiographic form on geological structure. The earlier publications of this Survey contained his exposition of the fault-block structure of the Basin Ranges and his masterly monograph on Lake Bonneville. In 1876 he explored the Henry Mountains and put forth the now accepted explanation of the peculiar forms of igneous intrusions, introducing the well-known term "laccolith". The report on the Henry Mountains also contains a chapter on land-sculpture, which is a classic of geological literature and the foundation of modern theories of denudation and the development of river-systems.

From 1884 to 1888 Gilbert was employed in the Appalachian region and occupied high administrative posts on the United States Geological Survey. Later he studied many other parts of the United States, including the Great Lakes and Alaska. He published a volume on the history of the Niagara River and a report on Earth-movements in the Great Lakes Region. His observations in Alaska in 1899 led to his introduction of the now universally used term "hanging valleys" with an explanation of their origin.

The physiographic work of G. K. Gilbert must always remain one of the outstanding features of physical geology in the nineteenth century; while it cannot be denied that he enjoyed exceptional advantages in working in regions built on a large scale and of notable simplicity of structure, nevertheless it needed a broad grasp of principles and great powers of generalization to formulate the laws of geological processes and their results which will ever be associated with his name. Not only in America, but throughout the world, his influence has made itself felt, and his death removes one of the outstanding figures of the geology of our time.

J. P. JOHNSON.

BORN 1880. DIED OCTOBER 18, 1918.

J. P. JOHNSON was born in London, 1880, and died in Johannesburg, October 18, 1918. He was educated at Dulwich College and the Royal School of Mines. He made many important discoveries in the Pleistocene geology of the South of England, the results being published in the *Essex Naturalist*, the Proceedings of the Geologists' Association, and in the columns of this Magazine.

Considerations of health compelled him in 1902 to leave England for South Africa, and in this virgin field his early training stood him in good stead, and numerous works and papers testify to the good work he accomplished; the most important being: *The Mineral Industry of Rhodesia*, *The Ore Deposits of South Africa*, *Geological and Archæological Notes on Orangia*, *The Stone Implements of South Africa*, and *The Prehistoric Period in South Africa*; two editions have been published of the last two. He was a member of the Council of the Geological Society of South Africa, and was appointed by the South African Government a member of the Commision to report on the petroglyphs and rock-paintings of South Africa.

MISCELLANEOUS.

POST-WAR HONOURS.

His Majesty the King has been pleased to confer upon Dr. Aubrey Strahan, F.R.S., Director of H.M. Geological Survey, the title of "Knight Commander of the Most Excellent Order of the British Empire, established in 1917, for services rendered to the kingdom whether at home or abroad". Every geologist will congratulate Sir Aubrey Strahan on this well-merited recognition of his own personal labours and that of his admirable staff of co-workers, who have contributed so largely to our increased scientific knowledge of geology, both stratigraphically and economically, not only within the British Isles, but beyond; many members of the Survey having joined our Forces abroad.

DIAMONDS, SOUTH AFRICA.

A telegram from South Africa announces the discovery of a large diamond at the Jagersfontein Mine, in the southern portion of the Orange Free State. The new diamond weighs 388¼ carats, and is therefore small in comparison with such great gems as the Cullinan and Koh-i-noor, but it is chiefly remarkable for its colour, which is described as soft blue and white. This is the second large diamond found in the last two years in the Union, for it will be remembered that a stone weighing 442½ carats was found in the Dutoitspan Mine, near Kimberley, in October, 1917.

Dr. F. H. Hatch described and figured "The Great Cullinan Diamond" in the Geological Magazine for 1905, Vol. XLII, pp. 170–2, with two plates (VII and VIII) and a diagram of the external form in the text.

Award of Medals by the Geological Society.

The Council of the Geological Society has this year awarded the Medals and Funds as follows:—The Wollaston Medal to Sir Aubrey Strahan, Director of H.M. Geological Survey; the Murchison Medal to Miss G. L. Elles, of Newnham College, Cambridge; the Lyell Medal to Dr. W. F. Hume, Director of the Egyptian Geological Survey; the Bigsby Medal to Sir Douglas Mawson; the Wollaston Fund to Dr. A. L. Du Toit, of the Geological Survey of South Africa; and the Murchison Fund to Mrs. Reid, widow of the late Mr. Clement Reid; while the Lyell Fund is divided between Mr. John Pringle, of the Geological Survey of England and Wales, and Dr. Stanley Smith, of University College, Aberystwyth.

Pulcrus of Rome, the first to make a Restoration of an Extinct Mammal.

"The grammarian Apollonius relates that there was an earthquake during the reign of Tiberius Nero, through which many celebrated cities of Asia were entirely destroyed . . . In those parts in which the earth was rent asunder very large dead bodies were found; the magnitude of which, indeed, so astonished the inhabitants, that they were unwilling to move them. That the affair, however, might be generally known, they sent to Rome one of the teeth of these bodies; and this was more than a foot long. The ambassadors, at the time they showed this to Tiberius, asked him whether he wished that the hero to whom this tooth belonged should be brought to him. Upon this Tiberius very prudently thought of a means by which he might neither be deprived of knowing the dimensions of this body nor yet be guilty of the impiety of robbing the dead. He ordered a celebrated geometrician, whose name was Pulcrus, and whom he honoured for his art, to be called, and desired him to make a face in proportion to the size of that tooth. The geometrician, therefore, having calculated from the size of the tooth the dimensions of the face and of the whole body, accomplished the task imposed on him with great celerity, and brought the face to the Emperor, who, after he had satisfied himself with beholding it, ordered the tooth to be restored to the place from whence it was taken"—Phlegon Trallianus, "On Admirable Things," *ex notæ* Taylor, ed. Pausanias, i, 97, in iii (1824), 240.

C. Davies Sherborn.

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Smithsonian Institution
MAR 24 1919
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AND

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MARCH, 1919.

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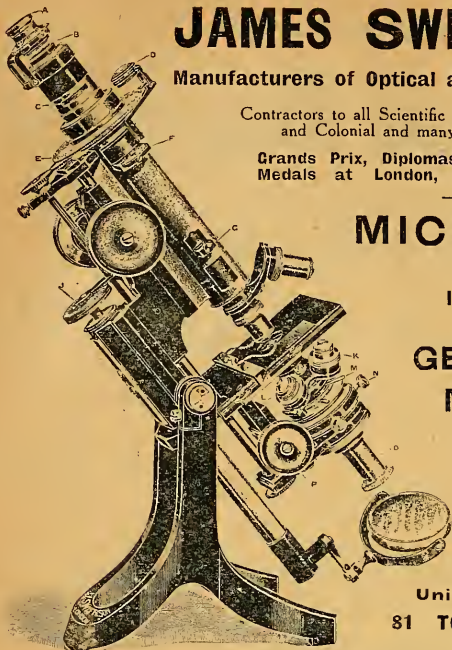

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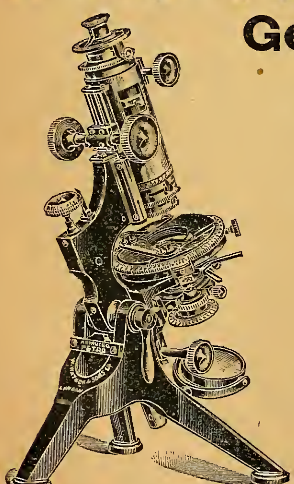

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GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. VI.

No. III.—MARCH, 1919.

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EDITORIAL NOTES.

WITH the present number a new feature is introduced into the GEOLOGICAL MAGAZINE, namely, an Editorial page. Hitherto announcements of events of current interest have been relegated to a section with the somewhat unsatisfactory title of "Miscellaneous" and have been confined within rather narrow limits. The intention is to extend this feature into the form of Editorial notes and comments on topical matters, personal, academic, administrative, scientific, and economic; in fact, any subjects bearing on the development and progress of geology at home and abroad. It is hoped by this means to extend the usefulness of the Magazine and to interest a still wider circle of readers by affording an opportunity for a free and informal discussion of the problems of the day. This is a period of altogether exceptional conditions and also, it is believed, the dawn of a new era in the history of science in general and of geology in particular. In order that geology may play its part in the great work of reconstruction that lies before us a wide dissemination of ideas is essential, and, without being unduly egotistical, it is the hope of the Editors that the GEOLOGICAL MAGAZINE may take a humble share in this great task.

* * * * *

MR. ALFRED HARKER, M.A., LL.D., F.R.S., has been appointed Reader in Petrology in the University of Cambridge. There is at present no permanent Readership connected with Geology in the University, but "having regard to the long service and scientific achievements of Mr. Harker" it was decided that a special Readership should be established for him, the appointment to date from January 1, 1919.

* * * * *

AT the annual meeting of the Geological Society, held on February 21, the officers for the ensuing year were elected as follows: President (for the second year), Mr. G. W. Lamplugh; Vice-Presidents, Professor J. E. Marr, Sir Jethro Teall, Mr. R. D. Oldham, and Sir John Cadman; Secretaries, Dr. H. H. Thomas and Dr. H. Lapworth; Treasurer, Dr. J. V. Elsden; Foreign Secretary, Sir A. Geikie. The following were also elected to replace the five retiring members of Council: Dr. G. T. Prior, Professor P. F. Kendall, Dr. G. Hickling, Mr. A. Howe, and Mr. R. S. Herries.

* * * * *

In view of the change in the political status of women brought about by the new Franchise Act it was inevitable that the question of their admission to the Geological Society should again be brought forward. In this connexion the award of the Murchison Medal to Miss G. L. Elles, as recorded last month, is significant. At the meeting of the Society on January 22 the President announced that a special general meeting will be held on March 26 to consider the following motion: "That it is desirable to admit women as Fellows of the Society." There can hardly be any doubt as to the outcome of the discussion, and we may hope that a long-delayed measure of justice will be carried out without serious opposition.

* * * * *

Messrs. George Allen & Unwin, Ltd., have done a useful service by publishing, under the title of *German Designs on French Lorraine*, a translation, with introduction, of the secret memorandum presented by the German iron and steel manufacturers to the Imperial Chancellor and to Field-Marshal von Hindenburg at the close of 1917. This is a document of remarkable interest in many ways, partly as an exposition of German unscrupulousness and cynical disregard for truth and partly as an example of how completely a case may be given away by excess of zeal. Since the main points brought forward are essentially matters of geological fact, distorted to suit German arguments, it may be briefly summarized here. The gist of the argument is as follows: Germany will require, after a peace victorious for the Central Powers, a greatly increased supply of iron and steel: her home supplies are approaching exhaustion, therefore it will be necessary for the continued existence of the Empire, and especially for the successful prosecution of the next war, to annex that part of Lorraine which still remains French. In order to diminish the atrocity of this annexation, the reserves still remaining in Germany are much under-estimated, while the amount of the supplies available in the rest of France are multiplied enormously. The figures given are stated to be on the authority of the well-known geologists Beyschlag and Krusch. These authorities value the average life of the German mines at 40 to 50 years. According to the best pre-War figures the German resources were in 1910 about 3,900,000,000 tons of ore: if this is to be exhausted in 50 years it would correspond to an average yearly production of 35,000,000 tons of pig iron from home ores alone, without counting imports, an apparently impossible figure, and more than double the pre-War production. The figures given for France are still more startling. In 1916 a German engineer estimated the resources of Normandy at 500,000,000 tons of ore, but the authors of this memoir adopt the figure of 5,000,000,000 tons for this area, or ten times as much. As a subsidiary argument the urgent need for phosphatic manures, i.e. basic slag, for German agriculture is insisted on, and this can best be obtained from the Lorraine ores.

This memorandum in point of fact proves in the clearest possible manner that without the Lorraine iron-fields the German Empire can never again conduct a great European war, and the general impression left on the mind of the non-political reader is that the one thing that really matters at the present Peace Conference is the restoration of Lorraine to France; without this iron-field Germany, on her own showing, is helpless for good or evil for evermore. This is of course an exaggerated view of the case, nevertheless it is clear that the matter is of paramount importance, and it is much to be hoped that the geological aspect of it has been duly placed before the responsible authorities.

* * * * *

The issue of *Nature* for January 16, 1919, contains a valuable article by Mr. V. C. Illing on Borings for Oil in the United Kingdom. The whole subject is reviewed from an eminently practical and common-sense point of view; while due weight is given to the admitted occurrence of petroleum in small quantities in many British localities, especially in the Carboniferous, these are reduced to their true proportions, which are shown to be insignificant, and the author evidently entertains no hope of a commercially successful result from the investigations now proceeding. The article should be read in conjunction with the memoir on this and cognate subjects recently issued by the Geological Survey, which likewise pours floods of cold geological common-sense on the rosy optimism which has lately been prevalent in the columns of the daily press. Such a treatment of the subject was much needed, since the indulgence of such hopes can, in the opinion of competent geologists, only lead to disappointment. Although the scheme now in operation in Derbyshire is on a somewhat higher plane than the famous leaky tank at Ramsey, nevertheless it is to be gravely doubted whether the results will be of much more practical value. It is of course possible, however, that these extensive borings may yield other results of unlooked-for scientific or economic importance, apart from the problematical supply of liquid fuel.

ORIGINAL ARTICLES.

I.—Fossil Fishes in the Devonian Rocks of North Devon.

By Inkermann Rogers.

THE Devonian rocks in Devon, like those of the Old Red Sandstone of which they are the equivalents, have been divided into three groups. Mr. T. M. Hall,[1] writing in 1879, quoted no less than five separate classifications suggested for the beds of North Devon, nor has uncertainty been removed by the conclusions arrived at by geologists since that date.[2] But we may for present purposes take the following as the nearest approach to a generally accepted succession:—

Upper Devonian	Pilton Beds. Baggy Beds. Pickwell Down Sandstones. Morte Slates in part.
Middle Devonian	Morte Slates in part. Ilfracombe Beds.
Lower Devonian	Hangman Grits. Lynton grits and shales. Foreland grits and shales.

While examining the rocks of the Middle and Upper series for fossil plants during the past eleven years (1907–18), the results of which have already in part been published,[3] other discoveries were made incidental to the work of collection of plant remains. Among these the discovery of fossil fish remains seems worthy of special notice.

The object of this brief note is to describe the discovery of fossil fishes made by the writer in the Pickwell Down Sandstone within a few hundred yards of the junction beds of the Morte Slates. As far as he has been able to ascertain, it is with one exception the only find of such remains made in any of the North Devon rocks classified above as Upper Devonian. The exception is a scale of *Holoptychius*

[1] T. M. Hall, "Classification of the North Devon Rocks": Trans. Devon Assoc., vol. xi, pp. 180–90, 1879.

[2] J. B. Jukes, "On the Carboniferous Slate (or Devonian Rocks) and the Old Red Sandstone of South Ireland and North Devon": Q.J.G.S., vol. xxii, p. 320, 1866, and his pamphlet, *Additional Notes on the Grouping of the Rocks of North Devon and West Somerset* (privately printed), Dublin, 1867; R. Etheridge, "On the Physical Structure of West Somerset and North Devon": Q.J.G.S., vol. xxiii, p. 568, 1867; W. A. E. Ussher, "On the Palæozoic Rocks of North Devon and West Somerset": Geol. Mag., Dec. II, Vol. VIII, 1881, and "Cornwall, Devon, and Somerset": Jubilee Volume Geol. Assoc., 1910, p. 859; J. E. Marr, "On some Effects of Pressure on the Devonian Sedimentary Rocks of North Devon": Geol. Mag., Dec. III, Vol. V, 1888; H. Hicks, "On the Morte Slates and Associated Beds in North Devon and West Somerset": Q.J.G.S., vol. lii, p. 254, 1896, and vol. liii, p. 441, 1897; Rev. G. F. Whidborne, "Preliminary Synopsis of the Fauna of the Pickwell Down, Baggy, and Pilton Beds": Proc. Geol. Assoc., vol. xiv, pt. ix, p. 371, 1896.

[3] Arber & Goode, "On some Fossil Plants from the Devonian Rocks of North Devon": Proc. Camb. Phil. Soc., vol. xviii, pt. iii, p. 89, 1915.

referred to by Professor J. Phillips in his *Palæozoic Fossils*,[1] published in 1841, as having been discovered at Baggy Point.

On the shore at Woolacombe Sands, about a quarter of a mile south of Woolacombe, an isolated patch of Pickwell Down sandstones and shale, dipping to the south at an angle of 60°, projects seaward from the foot of the sand-dunes. This outcrop, which is locally known as Mill Rock, measures 60 feet by 50 feet, and rises from 6 to 7 feet above the level of the tidal sands. I have not seen it myself, but Mr. J. G. Hamling, F.G.S., who has visited the spot, informs me that the exposure is fragmentary and covered by "head". In the year 1913 Dr. Thomas Young, of Colyton, then of Woolacombe, called my attention to there being an igneous vein about 2 inches thick in Mill Rock. I obtained a sample of it and recognized it as volcanic tuff. Eastward the vein is met with in a rock cutting leading to a large quarry opposite Fox Hunter's Inn on the Braunton road, three miles from Woolacombe. Here it is 18 inches in thickness and badly weathered. Three miles still further eastward it is well exposed in an old quarry a little south of Bittadon. Here the bed is 25 feet thick, fully crystalline, and much weathered. Mr. Ussher,[2] and also T. M. Hall,[2] refer to it as the Bittadon felsite. It extends to Bratton Fleming, another six miles eastward. Here I have not seen it myself, but Mr. Hamling, F.G.S., who has, informs me that it is fragmentary and probably not more than two or three inches in thickness.

Recently (May, 1918) I polished a piece of the tuff from Mill Rock. On closely examining it I detected to my surprise what appeared to be fish-remains and a tooth, whereupon I determined to obtain further samples of the rock. The result was I found not only that there were fish remains in the tuff, but that fragments of bones and teeth could be observed in almost every part of Mill Rock. One lenticle of redeposited tuff mingled with shale was discovered containing several scales, portions of scales, and bone plates, as well as many small bones. These proved to be the remains of typical Upper Devonian fishes — *Holonema*, *Bothriolepis*, *Holoptychius*, *Polyplocodus*. All the specimens were forwarded to Dr. A. Smith Woodward, F.R.S., for examination, and he has kindly sent me the subjoined report.

[1] J. Phillips, *Figures and Descriptions of the Palæozoic Fossils of Cornwall and Devon and West Somerset*, p. 133, 1841. See also Rev. D. Williams, "On the Killas Group of Cornwall and Devon": Trans. Roy. Geol. Soc. Cornwall, vol. vi, pp. 122–38, 1843; R. Etheridge, "On the Physical Structure of West Somerset and North Devon": Q.J.G.S., 1867, p. 156; W. Pengelly, "The History of the Discovery of Fossil Fish in the Devonian Rocks of Devon and Cornwall": Trans. Devon Assoc., vol. ii, pt. ii, p. 423, 1868; J. G. Hamling, "Recently Discovered Fossils from the Lower and Upper Devonian Beds of North Devon": ibid., vol. xl, pp. 276–80, 1908; "Excursion to North Devon, Easter, 1910": Proc. Geol. Assoc., vol. xxi, pt. ix, 1910.

[2] W. A. E. Ussher, "On the Palæozoic Rocks of West Somerset and North Devon": Proc. Som. Arch. and Nat. Hist. Soc., 1879, and "Cornwall, Devon, and Somerset": Jubilee Volume Geol. Assoc., 1910, p. 869; T. M. Hall, "Geology of the Ilfracombe Coast-line": Trans. Devon Assoc., vol. xi, p. 278, 1879.

Notes on the Fish-remains from the Pickwell Down Sandstones.

By A. Smith Woodward, LL.D., F.R.S.

The fish-remains discovered by Mr. Inkermann Rogers in the Pickwell Down Sandstones of Woolacombe Bay are merely scattered fragments. Some are sufficiently well preserved to exhibit their microscopic structure, but many are much obscured by the ferruginous infiltrations in the rock. A few appear to be generically determinable.

Holonema cf. ornatum, Traquair.—The most important specimens are two portions of dermal plates with an ornament much resembling that of the armour from the Upper Old Red Sandstone of Shetland named *Holonema ornatum* by Traquair.[1] The larger fragment is about as broad as long (measuring 9 cm. each way), but its borders are incomplete; and in both specimens the ornament is obscured by ferruginous stains which cannot be removed. The greater part of the plate is covered with low and rounded vermiculating ridges, which sometimes blend into a network; and the margin, to the width of about 2 cm., is ornamented with finer and closer straight ridges which are directed mainly at right angles to the edge. There are also some vague traces of tubercles on or between the ridges. The middle part of the larger specimen is 5 mm. in thickness; and a microscope-section of the smaller specimen shows that all the tissue is well preserved except that of the superficial ornament. The calcification is in almost structureless lamellæ, without bone-cells, and there are numerous irregular, horizontally-extended spaces between the lamellæ which give the plate a very open texture. The spaces are evidently all connected, for straight vertical canals are often conspicuous crossing the lamellæ. The structure of the plate is therefore similar to that of the Ostracoderms *Psammosteus* and *Drepanaspis*,[2] and very different from the true bone of Arthrodiran armour. This fact, indeed, suggests doubts as to whether the Shetland and Devon fossils are rightly ascribed to *Holonema*; for, although the microscopic structure of the original specimens of this genus from the Upper Devonian of North America remains unknown, the arrangement of the plates, so far as discovered, corresponds most closely with that of such an Arthrodiran as *Coccosteus*.

Bothriolepis.—The proximal end of the articular plate of an appendage and the remains of a posterior ventro-lateral plate belong to an Asterolepid, which other fragments of ornamented dermal armour seem to identify with *Bothriolepis*. The structure of the ventro-lateral plate, so far as preserved, agrees with that of the latter genus. The ornament of the other fragments is a coarse network of rounded ridges which often rise into low tubercles or are even subdivided into separate tubercles. In one specimen the most prominent ridges are concentric with the margin of the plate.

[1] Trans. Roy. Soc. Edinb., vol. xlvi, p. 327, pl. ii, 1908.

[2] J. Kiær, Rep. 2nd Norwegian Arctic Exped. *Fram*, 1898–1902, No. 33, pp. 28, 30, 35, text-figs. 5, 6, 8, 1915.

Some portions of the Asterolepid cancellous tissue belong to plates of considerable thickness. They may perhaps represent a *Bothriolepis* with a large dorsal crest, such as has been described by Traquair in a species from the Upper Old Red Sandstone of Elgin.[1]

Holoptychius.—One Holoptychian scale, shown in impression, is ornamented with very coarse rounded ridges, which are closely arranged and are not subdivided into tubercles. Another specimen, in which only a fragment of the original scale remains, shows by a clear impression that the inner face is destitute of a median tubercle.

Polyplocodus.—There are several isolated small Rhizodont teeth, which agree with those from the Upper Devonian of Russia and Scotland commonly named *Polyplocodus*.[2] They are not compressed to sharp edges, but rounded in section, and their outer face is marked by fine vertical grooves or striations. A microscope-section of two specimens shows the typical Rhizodont structure, and one broken tooth proves that the pulp-cavity extends upwards nearly to the apex. Part of the impression of one of these teeth is seen in a piece of Bittadon felsite.

Coccostean.—Some portions of tuberculated plates are probably Coccostean, but not sufficient for exact determination.

Conclusion.—The fish-fauna represented by the fossils from the Pickwell Down Sandstones is therefore typically Upper Devonian.

II.—The Facial Suture of Trilobites.

By Professor H. H. Swinnerton, D.Sc., F.G.S., F.Z.S., University College, Nottingham.

Introduction.

Trilobites in common with all other Arthropods shed their more or less rigid external covering or exoskeleton periodically. To accomplish this ecdysis it is necessary for this covering to split somewhere; and it is highly probable that the facial suture was the line along which such splitting took place. There seems, however, to be a tendency to assume that all lines which served this purpose are homologous. This has introduced unnecessary difficulties into the study of Trilobite classification. The object of this paper is to do something towards the elimination of this source of error.

The Segmentation of the Head.

A consideration of the segmentation of the cephalon will do much to give precision to our ideas of the position and homologies of the facial suture.

Bernard[3] considered that the number of segments in the head region was not fixed, and that within the order Trilobita new

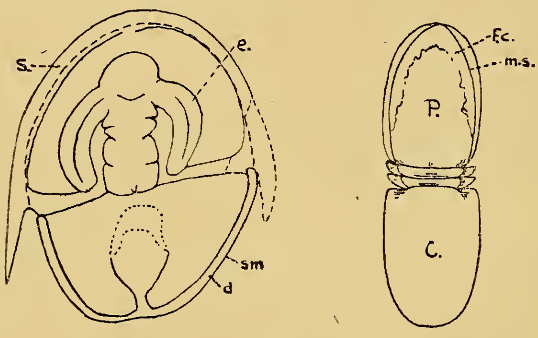
[1] *Bothriolepis cristata*, R. H. Traquair, *Fishes of the Old Red Sandstone* (Mon. Pal. Soc., 1906), p. 130, pl. xxxi.

[2] See R. H. Traquair in Brown & Buckley's *Vertebrate Fauna of Moray Basin*, 1896, p. 257.

[3] H. M. Bernard, "The Systematic Position of Trilobites": Q.J.G.S., vol. l, p. 414, 1894.

segments had been added to the posterior margin. He based this view upon two considerations: first, that the number of segments indicated on the axial portion of the dorsal side of the cephalon varied; second, that the last or occipital segment bears so close a resemblance to a trunk segment as to suggest that it had "been recently incorporated".

In discussing the former consideration, he observes that whilst the majority of trilobites show traces of five segments on the glabella, some, e.g. *Microdiscus* and *Triarthrus*, show only four. This line of reasoning is fallacious, for glabellar furrows are often reduced or smoothed out, so that if indications of four segments are left it is not safe to say that there are *not more* than four segments in the head, but it is safe to say that there are *at least* four. The presence of five segments on the glabella of *Eodiscus speciosus*[1] and the discovery since his day of five pairs of cephalic limbs in *Triarthrus* refute his first argument.



a *b*

Figures showing the position of the "facial suture" of Raymond and (?) Beecher in *Pædeumias* and *Agnostus*. *a.* Head-shield of *Pædeumias transitans* (Walcott) after Walcott (Smiths. Misc. Coll., vol. liii, pl. xxxiv, fig. 6). *b.* Carapace of *Agnostus nudus* (Beyrich) copied from Raymond (Amer. Journ. Sci., 1917, fig. 1). *d.* Doublure of *Pædeumias* reflected from underneath the head-shield. *s.m.* Sutural margin of the doublure. *s.* Approximate position of the marginal suture (facial suture of Raymond) on ventral surface. *e.* Eye. *c.* Cephalon of *Agnostus* according to authors. *p.* Cephalon of *Agnostus* according to Raymond. *m.s.* Marginal suture ("ventral facial suture" of Raymond and ?Beecher) of *Agnostus*. *f.c.* Ventral free cheeks according to Raymond and (?) Beecher.

With regard to the resemblance of the occipital segment to the trunk segments, it may be observed that this is merely an illustration of the principle that in segmented animals specialization of the posterior lags behind that of the anterior segments. Thus, within the Trilobita the glabellar furrows are obscure or absent most frequently in front, and again, it is this part of the glabella that varies most in shape and dimensions; compare for example, such forms as *Conocoryphe*, *Olenus*, *Paradoxides*, *Phacops*, *Staurocephalus*.

[1] Bull. U.S. Geol. Surv., No. 30, p. 154, 1886.

Nevertheless, amid all these changes the occipital, and sometimes the next segment in front of it, retain a close resemblance to a trunk segment.

The fixity or non-fixity of the number of cephalic segments cannot be definitely settled until the ventral surfaces of many more trilobites are known. Meanwhile it is significant that in such widely separated genera as *Triarthrus* and *Marella*[1] five pairs of cephalic appendages occur and that the last pair in each case resembles those in front more than it does the trunk appendages. The existence of this condition in so primitive a form as *Marella* suggests that the cephalic segments became marked off as cephalic *en bloc,* and proves that the posterior limits of the head-shield became defined and the number of its segments fixed at a very early stage in the evolution of the order.

In all trilobites, young or old, which possess eye-lines or eye-lobes as well as a clearly segmented glabella, the line or lobe is related to the palpebral segment that is the fifth from the posterior margin. This is another fact which indicates that these five segments are homologous in all typical trilobites, and that no new segment has been added to the cephalon since definitive trilobites came into existence.

How many segments lie in front of the palpebral it is quite impossible to say. An additional one is sometimes indicated on the glabella.[2] This must be the ocular segment whose pleural portion bears the visual area of the eye upon its hinder margin. The segmentation of the region in front of this is at present merely a matter for conjecture.

The Position of the Eye.

The position of the eye seems to be very variable. In the early stages of development of many trilobites it is first seen on the margin. In later stages it shifts on to the dorsal surface, and in the adult it may be quite close to the glabella and to the posterior margin of the cephalon. These facts led Bernard[3] to regard the eye as a lonely wanderer on the face of the trilobite, and to conclude that it "had no fixed hereditary locus on the dorsal surface". But in other animals an organ that wanders usually takes a train of other organs with it, that is to say it retains its major morphological relationships. Thus the eye of the flat-fish, *Pleuronectes*,[4] wanders during development from one side of the head over the dorsal surface on towards the other side, but throughout its wandering it is accompanied by its full complement of muscles, nerves, blood-vessel, and bones. That is to say, it retains a definite position in relation to the general morphology of the head. Bernard unconsciously recognizes this fact for the trilobites when he says, "The eye never

[1] C. D. Walcott, "Middle Cambrian Brachiopoda, etc.": Smithsonian Misc. Coll., vol. lvii, pp. 192, 193, 1912.

[2] C. D. Walcott, "*Olenellus*, etc.": Smiths. Misc. Coll., vol. liii, p. 277, pl. xli, fig. 9, 1910.

[3] 1894, p. 420.

[4] *Vide* F. J. Cole & J. Johnstone, L.M.B.C., Memoirs, No. viii: *Pleuronectes*, pp. 174 et seq., 1901.

crosses the cephalic suture."[1] Had we spirit specimens to dissect we should no doubt find that the trilobite's eye maintained equally stable relations to the nerves, vessels, and other organs vitally connected with it. The position of the eye, then, is a definite morphological point.

When, therefore, every worker from Burmeister to Raymond in describing the trilobite organization states that *the facial suture passes behind the visual area and in front of the palpebral lobe, he is giving to that part of the facial suture a very precise position in the trilobitic anatomy.*

The Ecdysial Line in Mesonacidæ.

In the Mesonacidæ there is no fully developed facial suture on the dorsal surface. Rudiments occur occasionally. Nevertheless, these trilobites must have undergone ecdysis. As long ago as 1891 Walcott in describing *Callavia Broggeri* wrote: "It is a very common occurrence to find the 'doublure' on the reflected under margin lying free from the other parts of the head and with the hypostoma attached. This fact leads to the conclusion that a suture passes around near the frontal margin."[2] He mentions that a similar suture is described by Holm in *Holmia Kjerulfi.* In 1910 the same worker figures an interesting specimen of *Pædeumias transitans* (see Figure), which further substantiates these observations.[3] Raymond, referring to this figure, describes the detached portion of the doublure as "swung back so that it presents its ventral face to the observer on the same block with and still attached to the head-shield".[4] This fortunate find makes it possible to determine the morphological relation of this ecdysial line to the dorsal facial suture. Though no true dorsal suture is present the eye-lobes are well shown. If one imagines the doublure replaced in its original position it becomes evident that its line of separation from the remainder of the head-shield must lie either marginally or submarginally, and in any case morphologically, far distant throughout its length from the eye. That is to say, no fraction of it passes between the palpebral and ocular segments, and therefore that no fragment of it is homologous with that portion of a typical facial suture which takes this course. To homologize this line with the facial suture and the detached portion with the free cheeks is merely to cause confusion. For the purposes of this paper these may be called the marginal suture and doublure respectively.

The Ecdysial Line in Agnostidæ.

The Agnostidæ are blind and show no suture dorsally. Beecher believed that they possessed facial sutures and free cheeks on the ventral side.[5] Raymond claims to have found these in *Agnostus nudus*[6] (see Figure). Before applying the results of the above

[1] 1894, pl. 420.
[2] C. D. Walcott, Tenth Ann. Rep. U.S. Geol. Surv., 1891, p. 638.
[3] 1910, pl. xxxiv, fig. 6.
[4] P. E. Raymond, Amer. Journ. Sci., vol. xliii, p. 208, 1917.
[5] Amer. Journ. Sci., 1897, p. 183.
[6] Ibid., 1917, p. 198.

discussion to this case it should be noted that the region which he calls the cephalon in this species has hitherto been unanimously regarded as the pygidium. The only reason he advances for disagreeing so utterly with previous workers is that he has discovered structures like free cheeks on the ventral side of the "pygidium". Until he brings forward independent evidence to prove that the pygidium is not a pygidium, or that the ventral structures are free cheeks, his discovery cannot be regarded as valid. Meanwhile, all independent evidence seems to be against him, and his discovery seems to prove only that *Agnostus* underwent ecdysis by way of the pygidium.

It is of course possible that Raymond may yet prove his case. When he does that his further deduction[1] will be valid, viz., that the suture and ventral linear "free cheeks" he has found in *Agnostus* are "analogous" with the marginal suture and detachable doublure of *Pædeumias.* But this can only prove that they cannot be homologous with the dorsal facial suture and dorsal free cheeks of other trilobites.

The fact that the closely allied but distinctly more primitive genus *Pagetia*[2] has both eyes and true facial sutures indicates that Agnostidæ have lost both these features, and have reverted secondarily to a marginal ecdysial line. This point of view receives support, on the one hand, from a consideration of the extraordinary degree of specialization attained by the Agnostidæ in all respects, and on the other hand from the existence of indications of eyes and true facial sutures in the allied but much more primitive genus *Mollisonia.*[3]

The Ecdysial Line in the Trinucleidæ.

The problem of the facial suture in *Trinucleus* has been very fully discussed by Reed,[4] who concludes that the true facial suture has disappeared, that the free cheeks have fused with the fixed cheeks, and that the suture which is present along the margin has come into being secondarily. Raymond disagrees entirely with these conclusions, and regards the marginal suture and ventral free plates of *Trinucleus* as facial suture and free cheeks respectively.[5] He rightly homologizes these features with those which he claims to have discovered in *Agnostus*[6] and, by implication, with the suture and free doublure of *Pædeumias.* In other words *Trinucleus* has nothing which is homologous with the true facial sutures and free cheeks, and Reed's conclusions are proved to be correct by Raymond's own evidence. Moreover, though Reed finds no satisfactory traces of dorsal facial sutures, he does find eye-lines and vestiges of eyes. When these occur they do not show that association with the marginal suture which would prove this to be a true facial suture.

Orometopus, if it be related to the ancestral stock of *Trinucleus*,

[1] Ibid., p. 208.
[2] C. D. Walcott, Smiths. Misc. Coll., vol. lxiv, No. 5, p. 407, 1916.
[3] Smiths. Misc. Coll., vol. lvii, p. 195, 1912.
[4] Geol. Mag., 1916, p. 175.
[5] 1917, pp. 201 et seq.
[6] p. 203.

supplies proof positive that Reed is right. Raymond,[1] however, denies the relationship because *Orometopus* has compound eyes, large free cheeks on the dorsal side, less specialized glabella, more than six free thoracic segments, and a square hypostome. The first two differences, being the subjects of dispute, may be left out of account. The remaining differences are not differential characters, but are such as are usually looked for between the earlier and later members of a genetically related series. The type of argument he thus applies to *Orometopus* would prove that *Mœritherium* had no relationship to *Elephas*, or *Hyracotherium* to *Equus*.

Incorrect Usage of Embryological Evidence.

Agnostus and *Trinucleus* are the typical representatives of Beecher's *Hypoparia*, which was founded upon inferences drawn from the study of the development of many trilobites. In this it was observed[2] that the eye appeared most frequently upon the margin, and travelled backwards bringing the facial sutures and free cheeks with them as development advanced. The occurrence of this phenomenon in so many trilobites was taken to indicate that the ancestors had marginal eyes, marginal or sub-marginal facial sutures, and ventral free cheeks.

In coming to this conclusion sufficient care was not taken to test the value of the developmental evidence by a comparative study of the adult structure. The larvæ to which Beecher attached most importance have, in addition to the marginal position of the eyes, a glabella which increases in calibre anteriorly and often extends to or even beyond the front margin of the head-shield. Compare this condition with that found in such primitive adult trilobites as *Conocoryphe*, *Ptychoparia*, etc., which were known to Beecher, and *Nevadia*[3] and *Nathorstia*,[4] which have been discovered since he finished his work. In these adults the eyes when present are dorsal in position, the glabella diminishes anteriorly, and does not approach the frontal margin. When the facts of embryology clash thus with those of comparative anatomy the former must be interpreted with extreme caution.

The conditions prevailing in less primitive trilobites throws a flood of light upon the conditions in these larvæ. Thus an increase in the width of the anterior segments of the glabella is frequently exhibited by the more advanced members of a progressive series, cf. *Olenellus* with *Nevadia*. It can only be concluded that the larvæ which exhibit this feature are specialized also, at least, in this respect. Again, in such a series as *Cheirurus*, *Sphærexochus*, and *Deiphon* the forward extension and inflation of the glabella are accompanied by an assumption of other features, such as the marginal position of the eyes and curious isolation of the pleuræ, which according to Dollo point to a planktonic mode of life. The peculiarities of the glabella and the position of the eyes in the

[1] p. 203.
[2] Amer. Journ. Sci., 1897, p. 184.
[3] C. D. Walcott, Smiths. Misc. Coll., vol. liii, p. 256.
[4] Ibid., vol. lvii, p. 194.

protaspis of certain trilobites are therefore not to be regarded as ancestral features, but, more probably, as adaptive characters associated with a planktonic habit.[1]

If this be the true interpretation of the facts, then the backward shifting of the eye during development has no phyletic significance, but is merely associated with the cessation of the larval planktonic mode of life and the assumption of the benthic habits of the adult.

Beecher was unfortunate in his choice of developmental evidence upon which to base his opinions. Had he given more attention to the larvæ of the Mesonacidæ he would never have instituted the division *Hypoparia*. These larvæ retain traces of several pleuræ in the cheek region, and thereby show themselves to be the most primitive of all known trilobite larvæ and therefore the most valuable indicators of ancestral conditions. But even in the youngest of these larvæ known the eyes are dorsal and the facial suture is absent. This agrees with the evidence of the comparative study of the adult and therefore outweighs the perhaps more abundant evidence from more specialized larvæ.

Raymond falls into the same error[2] as his great teacher when he hints at the resemblance between the young of *Trinucleus* and the adult of *Agnostus* as evidence of affinity. A trilobite with such forms as *Harpes* and *Dionide* closely allied to it could not possibly have descended from an *Agnostus*-like ancestor.

The Trilobita are Monophyletic.

Raymond finds difficulty in accepting my interpretation[3] of Mesonacid structure and development because it implies that "the anterior segment was not oculiferous"[4] in them as in other trilobites, and that therefore trilobites must be polyphyletic. Why he should consider it necessary that the oculiferous segment must be the anterior one he does not state, but as long as there are to be found annelids such as *Hirudo* having eyes on every segment as far back as the fifth there is no need to postulate the first segment as the only one that can be oculiferous in trilobites. It has been shown above that the ocular segment is the sixth from the posterior margin in all trilobites which exhibit sufficiently abundant traces of segmentation to enable an opinion to be formed. Whether this is the anterior segment or not does not matter; the essential point is that the segment which bears the eye is the same for all trilobites, so that from this standpoint the order is monophyletic.

Conclusion.

The trilobites are a compact group, the members of which at first underwent ecdysis along a line which may be called the marginal suture. "To facilitate the removal of the covering of the eye in moulting"[5] dorsal facial sutures appeared independently in several distinct lines of descent. It is necessary to emphasize the fact that taken as a whole the true facial suture is composite,

[1] L. Dollo, *La Paléontologie ethnologique*, Bruxelles, 1910, pp. 406 et seq.
[2] p. 204.
[3] Geol. Mag., 1915, p. 492.
[4] Amer. Journ. Sci., 1917, p. 208. [5] Ibid.

being made up of a new dorsal portion intimately associated with the eye, and an anterior portion which is probably a section of the marginal suture. The posterior section of the latter seems to have been completely replaced functionally by the newly instituted line running behind the visual area. The whole of the marginal suture was liable to be resuscitated in forms which, like *Trinucleus*, became blind secondarily and thus had no special use for a dorsal suture.

The position of the marginal suture, whether primarily or secondarily instituted, lay somewhere in the vicinity of the margin of the cephalon. For the present it may be left as an unsettled point whether the suture seen near the margin in such blind forms as *Conocoryphe* and *Ampyx* is a true facial suture or a marginal one. The line of reasoning followed above points to the latter as the correct interpretation.

The theoretic implications of the name *Hypoparia* render it unsuitable for describing those forms in which a dorsal suture has not yet appeared, and in which the marginal suture is of primary origin; hence the introduction of the name *Protoparia* for these. The *Protoparia* cannot include *Trinucleus*, for that is a highly specialized, not degenerate Opisthoparian, neither can it include *Agnostus*, for that is an even more highly specialized Proparian. This being the case Raymond's suggestion that the terms *Hypoparia* and *Protoparia* are practically synonymous cannot be accepted.[1]

III.—Notes on Yunnan Cystidea. III. *Sinocystis* compared with similar Genera.

By F. A. Bather, D.Sc., F.R.S.

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(PLATE III.)

B.—Comparison with *Megacystis* (*continued*).

3. *Structure of the Pores in Megacystis.*

ESSENTIALLY the pores of *Megacystis* are diplopores, for they are arranged in pairs. This is evident on the inner surface of a plate (E 16169, E 7671). Here each pore-pair lies in a shallow depression, and each pore again lies in a slight depression at the bottom of this (fig. 14). Compare *Sinocystis yunnanensis* (*antea*, p. 538).

From these inner openings the pore-canals pass outwards through the meso-stereom, still retaining their paired character. This can be traced in vertical sections, since the canals as a rule follow a fairly straight course normal to the surfaces; but it is more easily seen in horizontal sections of a plate (E 7675), or in the naturally worn surfaces. For instance, E 16169 shows the ω-channels in only a small region, while the remaining surface is worn, with the result that the structures manifest all over the theca appear to be ordinary diplopores. This effect is particularly obvious when the pore-canals have been filled with a dark matrix (e.g. E 7644, E 7641). Sometimes the matrix has been dissolved out, leaving the canals empty (E 16171).

[1] 1916, p. 209.

An outer surface that has been slightly worn, so as to uncover the ω-channels without obscuring them, shows the outer openings of the pore-canals connected by shallow channels on the following plan (fig. 15). The simplest arrangement consists of two channels, curved like the sides of an O, with a pore at each end. Next comes a doubling of these channels. Both of these arrangements are well shown near the base of E 7676 (fig. 16). It appears as though the doubling were due to, first, a broadening of each channel, and, secondly, a median up-growth of its floor. This process may take place on one side only, so as to yield a total of three channels; or it may be repeated on one side, yielding five channels (fig. 15), or, very rarely, on both sides, yielding six.

It is, however, unusual to find quite so simple a pattern: modifications arise in two ways. First, by simple irregularity in the curves of one or more channels. Secondly, by other up-growths of the floor so as to bar one or more channels (fig. 17). Each of these modifications seems to be subject to a special limitation. The irregularity is subject to the bounds which are set to the channel-system of a single pore-pair. The barring is subject, apparently, to the condition that such a channel-system must be continuous; thus, no part of a channel has been observed with a bar at each end; however irregular the labyrinth may become, it is always possible to track along every part of it.

Now as to the bounds of a channel-system. In no case does a system transgress the boundary of a plate; no pore-canal, and no channel, ever crosses a suture. Within each plate the diplopores are distributed over the whole surface—not regularly or according to any pattern, but at approximately equal distances. There are two plans of structure: the diffuse (figs. 16, 17, 18) and the concentrated (figs. 19, 20, 21). In the former the channel-system is diffuse and is separated from adjoining systems by a tract no wider than a single channel or, what comes to the same thing, no wider than a ridge between two channels. No wider is the space left at the sutural margin. Each channel-system spreads itself out until brought up against its neighbours; and, since the foci of each system are distributed irregularly, the boundaries also become irregular; did the systems start from equally-distributed centres, their boundaries would form regular hexagons, but, as it is, they form irregular polygons. It is therefore not easy to distinguish these boundaries from the other ridges, and so the whole thecal surface appears at first sight covered with a confused maze of channels. It seems possible that this complexity has misled even so acute an observer as Professor Jaekel (1899). His plate iv, fig. 2*a* shows in some cases as many as 5, 6, or 7 pores belonging to the same channel-system. There may in rare cases be more than one pore-pair to a system, but I am not convinced even of that. What does often happen is that the outer opening of one (or both) of the pores is crossed by a bar (fig. 17), so that externally the pore seems duplicated or even triplicated. There is also a deceptive appearance of pores at other bars.

Finally, the pores and their connecting channels are covered on the outer surface by a thin epistereom, so that on a well-preserved surface they are at first invisible, and all that one sees is the finely-vermicular ornament of the epistereom (E 7633). If, however, the surface be wetted, it is usually possible to see the channels beneath, looking much like the tunnels that a boring sponge or alga makes between the layers of a mollusc shell (fig. 18). The manifestation of the buried channels is generally increased by the fact that they are injected with a fine mud, which has reached them through the pore-canals from the interior of the test. It does not seem possible to explain the appearances as due to anything other than a complete coating of stereom. In thecas with diffuse channel-systems, the outer surface, when well-preserved, is equable and smooth, except for the fine ornament.

In thecas with concentrated channel-systems, the outer surface is raised into a little pustule over each system (E 7629, E. 7672, E. 7673, see fig. 19). When slightly worn, the ends of the channels are opened up and look like so many pores on the surface of the pustule (fig. 20). Further wearing shows that in every case there is only one diplopore to each pustule (fig. 21). Thus, Miller writes of *H. ornatus* (1878, p. 132): "Surface . . . pustulose . . . The pores open upon the summit of the granules, and where the granules are worn off, the plates show the pores, in pairs, passing through to the interior." So also of *H. splendens*, Miller & Gurley write (1894, p. 7): "The whole body is pustulose and every pustule is pierced by a pair of pores."

These pustules with their appearance of many pores may be compared with those vesicular multiperforate tubercles in *Caryocrinus*, of which so admirable an account was given by James Hall (1852, Palæont. N.Y., vol. 2, p. 220). There a single pepper-box pustule, as one may term it, may have as many as six outer openings, but only one pore-canal leads to the inner surface of the thecal plate. In older specimens the pustules of a single row enlarge till they coalesce, "forming a vesicular ridge."

The various modes of preservation and the differing amount of weathering produce a number of diverse appearances in these two plans of structure. Besides those already alluded to, one notes that in the diffuse pattern weathering frequently affects the area of the channel-system more than its boundary, so that the latter stands up as a ridge; possibly it is actually of denser stereom than the channelled area. On the other hand, the injected material may be more resistant than the stereom, and in this case the channels, and especially the pore-canals, stand out while the surrounding tract is weathered away. In some cases this eventually produces an irregular pustulation (E 7630), which must not be confused with the true surface-pustulation of the concentrated plan. It is plain that the thecas were often lying for some time on the sea-floor, and that their surface was then worn and overgrown in part by bryozoans and other incrusting organisms. When fossilization took place the open channels formed a key for the matrix, which ultimately became firmly bound to them by secondary calcification. In such cases the pattern shows up in sinuous ridges of pale light-reflecting matrix on the darker light-absorbing stereom, and it is hard to believe that these ridges really represent channels once covered by epistereom.

Even when one's mind is clear as to the facts, it is not easy to understand the origin of the channel-systems. There are two features to be explained: first, the number and sinuous extension of the channels; secondly, their closure by epistereom. The simplest pattern, as Professor Jaekel points out (1899, p. 413), seems but a modification of a single oval peripore[1] (Höfchen); when the outer covering is worn away, there is indeed little difference apparent. The channels connecting the two pores correspond to the moat of the peripore (fig. 16). How or why did they become covered? The answer to that question might also furnish the clue to their multiplication. To one who, like Prof. Jaekel, believes that the normal diplopore was covered (*antea*, p. 513), there should be no particular difficulty. Now the diplopore is obviously a complete unit. If it had a roof of epistereom, the development of a channel-system would take place by the union of the periporal floor with the roof—first between the two pores, leaving a channel on each side; then along the floor of each channel, thus splitting it into two; and so on. It is assumed by this hypothesis that the channels as they multiplied would move apart, at all events in the case of the diffuse pattern. This explanation is beautifully simple, but it provides no motive force. A diplopore seems so finished a structure, so obviously adapted to some function or other, that one cannot imagine why in this limited genus it should become broken up in this way.

Let us now suppose that the diplopore was not originally roofed over. The natural interpretation then seems to be that the pore-canals served to bring fluid (probably cœlomic) into osmotic connection with the surrounding medium, and that the fluid passed out by one canal and in by the other. The combined tube probably extended as a papula, and for the base of the papula the peripore afforded an attachment suggestive of retractile muscles. We have seen in *Sinocystis* how the central region of a diplopore is raised into a pustule, attaining sometimes considerable height. This implies deposition of stereom in the walls of the papular tube. Excess of deposition would interfere with the assumed function of the papula, and might lead to the closure of the pores, as Dr. Reed believes to have been the case. This calcification of the wall, with consequent reduction of the osmosis, would have to be counteracted, and that can be effected only by increasing the surface. Here then is the motive for the multiplication and extension of the channels. In the case of pustule-formation, the channels seem to have remained close round the original pustule, producing the concentrated plan. The diffuse plan can not have been preceded by pustule-formation, and we must suppose the calcification to have taken place round the margin of the peripore more rapidly than in its central area.

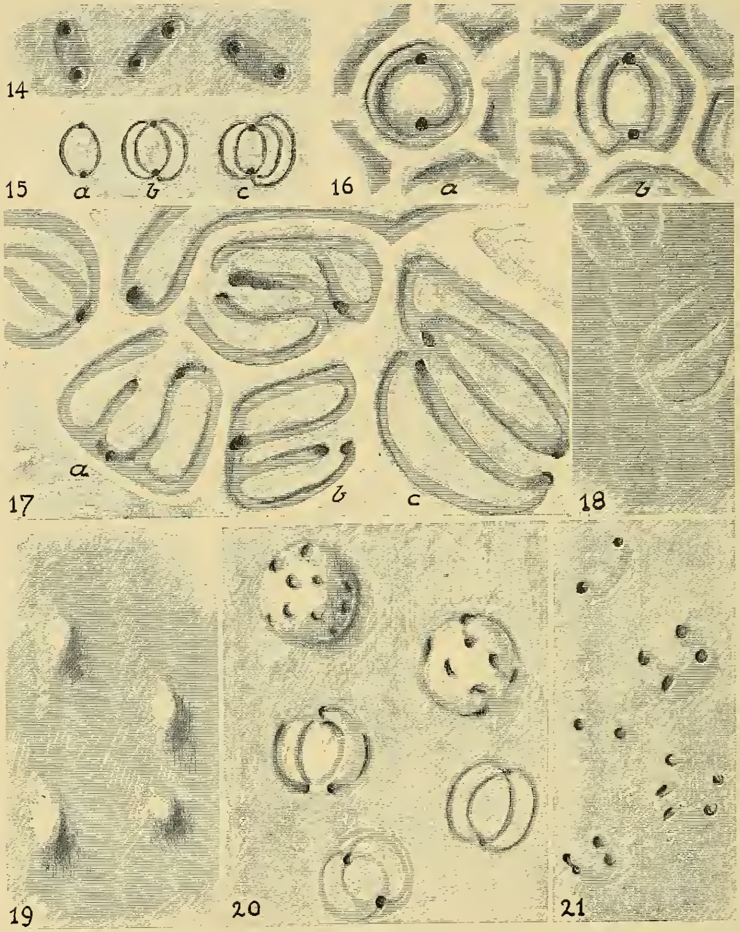
[1] The term "peripodium" was extended to these structures by Lovén (1883, Pourtalesia, p. 57), since he believed that tube-feet sprung from them as from the similar structures in Echinoidea. It seems advisable to drop this use of the term, along with the belief that it implies.

There is yet a third hypothesis. By placing his *Trematocystis* with *Aristocystis* in a family Aristocystidæ, Dr. Jaekel implies that the channel-systems were derived from the irregular groves of the latter genus. He says in effect:—In this family of *Diploporita* the peripores are lengthened in worm-fashion and form closed respiratory spaces beneath the epistereom. In *Aristocystis* the epistereom shows a smooth surface, and the pores are not visible till this is removed. They are then seen to be connected by irregular channels—the elongate peripores—and each channel may include two or more pores. One of Jaekel's drawings (p. 409) shows as many as four pores, three at the ends of a Y and one at the fork. One of Barrande's figures (1887, pl. 38, fig. 23) shows six pores in a channel. In *Trematocystis*, Jaekel continues, this tubular elongation of the peripores led to their duplication and combination, while the mesostereom also shared in their envelopment.

It is not quite easy to follow this account. In the first place there is still room for scepticism concerning the covering of epistereom. The outer layer seen in many of these Bohemian fossils has not yet manifested any structure, and may be nothing more than an adherent film of limonite induced by the decay of the organic stroma. Secondly, the account implies that the channel-systems of *Trematocystis*, or at any rate the more complicated ones, involve more than two pores; as already stated, I am unable to confirm this. Thirdly, the interposition of the peculiarly irregular stage represented by *Aristocystis bohemicus* between the normal diplopore and the simplest system seen in *Trematocystis* raises a gratuitous difficulty, and one apparently inconsistent with Jaekel's own comparison of the two latter.

Possibly Jaekel had in mind (though he did not mention them) the channel-systems of *Hippocystis* (*antea*, p. 72). There is an obvious resemblance between an omega and two horseshoes set side by side with the adjacent ends meeting in a single pore. But closer scrutiny of the facts renders it doubtful whether a system of this pattern is ever found in either *Megacystis* or *Hippocystis*: in the former, if the pattern resembles an omega, it is with a difference, and there are two pores to the system, not three; in the latter the horseshoes neither meet nor overlap, so far as one can judge from Barrande's figures and description. It is therefore no easier to derive the *Megacystis* system from that of *Hippocystis* than from any simple diplopore.

On the whole the second of the three hypotheses here discussed seems best to harmonize the various views that have been expressed as well as the greater number of the structural facts. The idea that the assumed papulæ tend to be calcified is confirmed by the lofty pore-pustules of *Sinocystis loczyi* and the pore-turrets of *S. yunnanensis*. The supposed clogging by excess of calcification is confirmed by the pepper-box pustules of *Caryocrinus ornatus*. Two large tubercles of similar nature appear, as a result of individual and local hypertrophy, in the holotype of *Megacystis hammelli* (Miller, sub *Holocystites*). Whether the elongation and sinuosity of the peripores in *Aristocystis* was due to a similar need for extending the respiratory surface, cannot be decided. At any rate the channel-



F.A.B. del. Bale & Danielsson.

PORES AND CHANNEL-SYSTEMS IN MEGACYSTIS.

16, 17, 18, Diffuse plan. 19, 20, 21, Concentrated plan.

All figures enlarged 20 diameters.

systems of *Megacystis*, each with its single diplopore, do not seem like direct modifications of the *Aristocystis* plan. It is curious that this type of channel-system should, to all appearance, have been confined to a single arm of a single sea during one relatively brief period of the earth's history.

EXPLANATION OF PLATE III.

Pores and Channel-Systems in Megacystis.

Fig. 14.—Openings of two diplopores on the inside of the theca in E 7671.

,, 15.—Three diagrams to show the multiplication of the channels from (*a*) the primitive two, through (*b*) four, to (*c*) five.

,, 16.—Simple channel-systems, corresponding to stages *a* and *b* of Fig. 15, seen in E 7676.

,, 17.—A portion of the worn thecal surface in E 7639, showing more complicated channel-systems. In *a* the two pores are distinct, but there is a deceptive appearance of a pore where the short channel ends on a bar. In *b* the pore to the right is divided by a bar. In *c* both pores are so divided.

,, 18.—A portion of the unworn thecal surface of E 7633. Two channel-systems are faintly seen beneath the epistereom.

,, 19.—A portion of the unworn thecal surface of E 7673, showing pustules. Here conditions of petrifaction are such that the underlying channels can nowhere be detected.

,, 20.—Pustules in various stages of weathering; from the deceptive appearance of many pores, through the exposure of the channel-system, to the beginning of its disappearance. Selected from E 7629.

,, 21.—Other stages in the wearing down of the pustules till the primitive diplopore is exposed. Selected from a single plate in the theca of E 7672.

The figure-numbers continue those of the text (Nov. and Dec., 1918). All figures enlarged 20 diameters.

IV.—Notes on Ammonites.

By L. F. Spath, B.Sc., F.G.S.

III.

In addition to the variability of the suture-line in a given species, mentioned previously, asymmetry of the elements on opposite sides of the same suture-line is very frequent and probably universal in so far as the minor frillings are concerned, which is only to be expected in organic beings. This phenomenon has lately been illustrated again in *Lioceras* by Horn,[1] and in *Dactylioceras* by Swinnerton & Trueman.[2] The latter authors also have some interesting observations on asymmetry associated with lateral displacement of the siphuncle which is of sporadical occurrence in Ammonites.

Canavari[3] had noticed that in some Spezia forms the siphuncle was asymmetrical in the young and then became central; and Solger[4] records a familiar excentricity in *Hoplitoides*. The

[1] "Die Harpoceraten der Murchisonæ-Schichten d. Donau-Rhein Zuges": Mitt. Grossherz. Bad. Geol. Land. Anst., vol. vi, pt. i, p. 264.

[2] Op. cit., Q.J.G.S., vol. lxxiii, pt. i, pp. 40, 51, 1917.

[3] "Beitr. z. Fauna d. Unt. Lias v. Spezia": Palæontographica, vol. xxix, pt. iii, p. 192, 1882.

[4] "Fossil d. Mungo-Kreide": Geol. v. Kamerun, ii, p. 217, 1904.

asymmetry here is lost when the venter becomes acute. On the other hand, when dissecting a specimen of, e.g., *Psiloceras erugatum* (Bean-Phillips) with asymmetrical suture-line it is found that on the innermost whorls the suture-line is quite normal and that the position of the siphuncle (and of the ventral lobe) shifted gradually away from the median plane, thus causing unequal development of the opposing halves of the suture-line. Swinnerton & Trueman remark that usually only the ventral features are affected, and enumerate many genera in which this sporadical displacement has been noticed.

These authors also point out that nearly every specimen in which this type of asymmetry has been noticed has a rounded or flat venter. The most notable example of the round-ventered shells is *Psiloceras*, several signs of instability in which have already been noticed. On a previous occasion[1] the writer attempted to demonstrate the *Monophyllites-Mojsvarites* ancestry of this genus, and in this original stock asymmetry apparently is unknown. In the Yorkshire representative *Psiloceras erugatum*, a particularly variable species-group, asymmetry may be associated with close or distant septation, or may be absent altogether. Again, there may be approximation of the last two to six septa or no approximation at all, with or without "reduction". The specimens are also generally smaller than the Somerset equivalent *P. planorbis* (Sowerby), which unfortunately is always squashed, or the Wurtemberg *P. psilonotum* (Quenstedt), and the Yorkshire examples remind one of the dwarf-forms of the Hierlatz, so that one might be tempted to compare them with organisms living under unfavourable conditions, such as the shells in the brackish waters of the Baltic. But the enormous development of the genus *Psiloceras* in the Alpine Hettangian, where asymmetry is very common, shows that it was a dominant and thriving stock. It may be assumed that there was a great "burst" when, with the extension of the sea over wide new areas, the Ammonites which in the Rhætic had nearly become extinct, were able to spread again. The one surviving family Phylloceratidæ, reduced to a few secluded localities of the Alpine Rhætic Sea, entered upon a new phase of development, and in its principal first Liassic descendant *Psiloceras* showed a strong adaptive radiation.

It might be asked whether this could not have affected the position of the siphuncle, and therefore the suture-line, in an attempt to change a bilaterally symmetrical swimmer into a crawling benthonic organism. For, as has already been pointed out, its probably nectonic contemporary *Phylloceras* (which, like the somewhat later "*Rhacophyllites*", *Euphyllites*, *Parapsiloceras*, *Pleuracanthites*, and *Analytoceras*, never migrated beyond the Alpine Hettangian Sea) does not show these signs of instability.[2] Diener, who thinks the

[1] L. F. Spath, "On the Development of *Tragophylloceras Loscombi*": Q.J.G.S., vol. lxx, p. 352, 1914.

[2] Canavari (op. cit., 1882, p. 69) has thought that asymmetry of the suture-line was not found in Phylloceratidæ, but he figures as *Amaltheus* (*Sphenodiscus*) *sinister* (ibid., pl. ii, xvi, fig. 17*a–c*) a form of "*Rhacophyllites*", that clearly shows this asymmetry; and both Pompeckj, and Swinnerton and Trueman mention it as occurring in *Tragophylloceras*, but these are not typical

asymmetry of no biological importance, would look upon such forms as "*Psiloceras*" *abnorme* (Hauer), "*Psiloceras*" *Suessi* (Hauer), and *Oxynoticeras Janus* (Hauer), as small forms, with limited geographical distribution, and probably adapted to a crawling mode of life.[1] The first two, in which apparently the asymmetry is fairly constant, are comparable to *Psiloceras*, with which genus, however, they cannot be united. The last, where the ornament also is affected, has a counterpart in *Amaltheus paradoxus* (Stahl), though here the suture-line may also be normal, and it seems that Diener's suggestion of a crawling mode of life may hold good for these abnormal forms. In helicoid shells that must be explained in this manner, the position of the siphuncle apparently is not affected, however.

In a round-ventered shell the position of the siphuncle in the median plane is, of course, not essential; and the functions of the indented septal edge, both as a strengthening feature and as a means of attachment of the animal to its shell, would not be interfered with by an unsymmetrical arrangement. It may be assumed that *Psiloceras*, though a dominant and thriving genus, was comparatively unstable owing to the instability of its conditions of existence. Neumayr[2] drew attention to this instability, and pointed out the variability of the Alpine *P.* (*calliphyllum* species-group) forty years ago, and Rothpletz[3] shows that even in a locality where there is a continuous transition from the Rhætic Kœssen beds with *Mojsvarites planorboides* to the variegated limestone facies of the *planorbis*-zone (Marmorgraben, near Mittenwald, Bavarian Alps), only brachiopods and lamellibranchs are found in the first six to twelve feet of Lower Liassic marls. Asymmetry of the suture-line in *Psiloceras* may then be looked upon as an abnormality that had attained a considerable degree of constancy, but which was due to constitutional instability. This was eliminated when an exceedingly strong radiation with production of keeled and grooved forms (both keel and groove being in part protection of the siphuncle) took place.

In the case of flat-ventered shells, such as *Hoplites splendens*, Swinnerton & Trueman think that "asymmetry is probably a growth-phenomenon associated with the tendency of the siphuncle to take up

Phylloceratids. It may be suggested for e.g. *Meneghiniceras* and other "*Rhacophyllites*", that, like many modern marine organisms, they were pelagic in the young and littoral when adult.

The form figured by Canavari affords a good illustration of the unsatisfactory results of a morphological classification of Ammonites according to the adult suture-line. Canavari wrote: "A remarkable circumstance in this species is the presence of three lateral lobes. Thus it lets itself be grouped in section B of the Amaltheids, according to Neumayr & Uhlig, which comprises the forms with three or more lateral lobes, and perhaps in the sub-genus *Sphenodiscus*, Meek, with complicated lobes." In 1888, Canavari ("Contribuzione alla Fauna del Lias inferiore di Spezia": Mem. R. Com. Geol. Ital., vol. iii, pt. ii, p. 34) assigned this form to the genus *Oxynoticeras*, but its suture-line shows it to be a Rhacophyllitid.

[1] Op. cit., 1912, p. 81.

[2] "Zur Kenntnis d. Fauna d. Unterst. Lias i. d. Nordalpen": Abh. k.k. Geol. Reichsanst., vol. vii, pt. v, p. 25.

[3] "Das Karwendelgebirge": Zeitschr. d. D. O. Alpenvereins, vol. xix, pp. 427–8, 1888.

a stable position along the angle bounding the venter".[1] Among Pseudoceratites, e.g., *Protengonoceras* and *Heterotissotia* belong to this group, and *Hoplitoides* in the young stage, though here the development of an acute venter in the adult causes the disappearance of the excentricity of the siphuncle. Solger saw an adaptation to a benthonic existence in the latter, but the great variability shown in the thirty-five specimens of *Hoplitoides*, quoted by Solger, points to unstable conditions. This author also adduces the reduction of the suture-line, the local restriction of the genus *Hoplitoides*, his discovery of a specimen with several destroyed air-chambers, and the similarity to the Triassic *Ceratites*, as evidence for the adaptation to a benthonic existence. The writer has already given his opinion on the first and third points, and the second does not now apply since *Hoplitoides* has been found, e.g. in Tunis (Pervinquière). With regard to the likeness of the Pseudoceratites of the Cretaceous to the real *Ceratites* of the Trias, Phillipi's conclusions on which Solger's theory of adaptation to a benthonic mode of life for both was based, have also been disproved (Diener).

Asymmetry in oxynote shells is very rare, and Swinnerton and Trueman mention that they have not detected one case of asymmetry in specimens with keeled venters (p. 54). The most notable example is *Garnieria heteropleura*. Neumayr & Uhlig[2] examined about fifty specimens of this and found the siphuncle excentric in each. It may be assumed that the function of an oxynote venter was, primarily, to assist rapid motion through the water, and only secondarily to act as protection for the siphuncle, which in an unstable stock might vary its position slightly, especially if the keel be hollow. Though this last case is doubtful, however, the writer is inclined to think that asymmetry of the siphuncle and suture-line cannot, by itself, be taken as sound evidence in favour of adaptation to a benthonic, crawling existence.

In connexion with a pathological or accidental case of asymmetry in a Perisphinctoid form, where the dorsal as well as the ventral features of the suture-line are affected, Swinnerton & Trueman refer again to the gas-pressure which, in Ammonites, was assumed to have been strong enough to impose upon the septum a marked convexity. They state (p. 52): "If this [septum-secreting area of the mantle] became hypertrophied on one side, it would still assume the form of a stretched membrane, but being more resistant to pressure from behind, would not become so concave forwards as the other half." And on p. 37 the authors suggest that the second septum of *Dactylioceras* already must have been formed under the influence of that pressure, though at the time of formation of the protoconch and even of the first septum, the mantle was strongly convex.

Brief allusion to this pressure has already been made in connexion with the phylogenetic "reduction" of the suture-line; but in Pseudoceratites, where the simplification is said to have been carried to such extremes, the septum is still convex forwards. It seems to

[1] Op. cit., p. 55.

[2] "Über Ammon. a. d. Hilsbild. Nordd.": Palæontographica, vol. xxvii, pp. 135–6, 1880–1.

the writer that the internal pressure of air, gas, or aerated fluid in Ammonoids need not have differed from that in Nautiloids of a corresponding type of shell and mode of existence, that it depended on the depth at which the septum was formed, i.e. external pressure, and that the differences in the position of the siphuncle, in the thickness of the shells, and in the methods of attachment, determine the shape of the septum. Mr. Crick[1] has shown that "not only was the Ammonoid animal, like the *Nautilus*, at least at some periods, attached to its shell by means of the lobes and saddles of the posterior portion of the body—corresponding to those of the edge of the septum of its shell—but it seems . . . that it was further provided with an annulus in addition to shell-muscles, as in the recent *Nautilus*. It would appear, therefore, as if the provision of an annulus were an absolute necessity to the animal in addition to the shell-muscles, and most probably Dr. Waagen's explanation of its occurrence is the correct one, viz. that the annulus and shell-muscles served not merely to hold the animal to its shell, but formed also an air-tight band around it, fastening the mantle to the shell." Since the muscles could probably easily become detached, as in *Nautilus*, it may be assumed that the protrusions of the mantle that went into the lobes tended to strengthen their adherence to the septum by progressive backward penetration of their fibres, thus causing the convexity of the septum. In a cylindrical shell like *Lytoceras*, where the elements radiate from the centre of the septum, the lobes would attach themselves more or less equally all round the shell-wall, and the more complex the septal edge the firmer the attachment. Such progressive complication is shown, e.g. in the first lateral lobe of the *Androgynoceras Henleyi–Bechei–nautiliformis* series, and on the other hand it has already been suggested that, on the adaptation to a benthonic existence in such forms as *Cochloceras* or *Rhabdoceras*, extreme simplification of the suture-line may result; for in these the need for firm attachment of the animal to its shell, while muscles and annulus shifted forward after completion of a new septum, was probably less great than in an active swimmer.

It has already been mentioned that "the tortuous windings of the foliated margin of the transverse partitions . . . strengthened the shell of Ammonites".[2] Buckland[3] examined at great length the "proofs of contrivance and design". Apart from the "use of giving

[1] "On the Muscular Attachment of the Animal to its Shell in some Foss. Ceph. (Ammonoidea)": Trans. Linn. Soc., vol. vii, pt. iv, p. 109, 1898.

[2] R. Owen, *Lectures on the Compar. Anat. and Physiol. of the Invertebr. Anim.*, 1843, p. 331.

[3] "Geology and Mineralogy, etc.": Bridgwater Treatise VI, vol. i, sect. iii, "Nautilus," pp. 310–32; sect. iv, "Ammonites," pp. 333–57; also sects. v and vi, pp. 357–60; and vol. ii, pp. 58, 59, 62.

This author (p. 62, vol. ii) also stated that the "course of the transverse plates was beneath the depressed and weakest part of the external shell, avoiding the bosses . . . which from their form were strong". This is not borne out by the specimen of *Hoplites auritus*, figured by Swinnerton and Trueman (op. cit., pl. iv, fig. 8), and it seems that in general the septal edge is independent of the position of the tubercles, which are also often irregularly spaced.

strength to the shell to resist the pressure", the "further use suggested by von Buch of affording points of attachment to the mantle", showed to him "the union of two beneficial results from one and the same mechanical expedient". Zittel[1] and Uhlig[2] held that the strongly ramified borders of the septa serve to increase the solidity of the shells, and the latter author showed (for *Lytoceras*) that "as the whorls only just touch one another they could offer little mutual support, and therefore every increase of resistance, if only slight, must have been of great value. Thus, physiologically, the sutural lobes would have served the same purpose that was attained in another genus with very evolute whorls, *Arietites*, by the external keel with its two accompanying grooves". It may be pointed out here that the septal surface, with excentric siphuncle, in both Ammonoids and Nautiloids, in spite of its anterior and posterior folds, is nearly enough at right angles to the whorl-surface to act as a strengthening feature. In the adult septum of *Dactylioceras*, fifty-two per cent of the area of the septum lies between contours only ·75 mm. apart, according to Swinnerton and Trueman (p. 32); and their graph shows that the area of the posterior folds is not much greater than that occupied by the anterior folds, i.e. that the convexity is comparatively slight.

In Nautiloids, provided with a simple suture-line, the shell in general is considerably thicker than in Ammonoids, where, ordinarily, it is "as thin as paper".[3] Diener[4] writes: "The shells of Phylloceratidæ, Perisphinctidæ, and Arcestidæ are always delicate, smooth shells of thickset build, more delicate than the *Nautilus* shell; Lytocerates are often as thin as paper and clear as glass, with feeble ornament." Boehm[5] found that the shells of *Nautilus*, washed up on the shores of the Sula Islands, were thicker than most Callovian Ammonites. On the other hand, the formation of septa by the nacreous layer of the shell and the periodical repetition of these during the progress of growth, concurrently with the formation of new layers which extend and expand the mouth of the shell, was probably the same in normal or irregularly coiled Ammonoids, as in the ancestral cyrtocone[6] or the present-day *Nautilus*. The material

[1] Op. cit., 1881–5, pp. 332 ff.

[2] "Die Cephalopoden Fauna d. Wernsdorf. Schichten": Denkschr. d. Math.-Naturwiss, Cl. d. k. Akad. d. Wiss., vol. xlvi, p. 61, Vienna, 1883.

[3] Op. cit., p. 332.

[4] Op. cit., 1912, pp. 67–89.

[5] "Beitr. z. Geol. v. Niederländ. Indien": I, 4, Palæont. Suppl. IV, 1912, p. 173.

[6] Whether the earliest representatives were active benthonic animals or attached and sedentary, is not known. But it is probable that from the ancestral capulicone, cyrtocones and orthocones arose, with elongation of the shell after the manner of tubular structures in Actinozoa, Polyzoa, Annelida, and Gastropoda ("Guide to the Fossil Invertebrata Animals in the Department of Geol. and Pal. in the Brit. Mus. (Nat. Hist.)," 1907, p. 147), and the formation of septa at the end of the cone only after a continued period of elongation and pulling away of the visceral hump from the cone, probably to give it buoyancy. But orthocones and cyrtocones cannot have been active swimmers. (See the interesting paper by O. Jaekel, "Thesen üb. d. Organis. u. Lebensweise ausgestorbener Cephalopoden": Z.d.g.G., vol. liv, p. 67,

of which the Ammonite septum was composed was probably of the same character and the same strength per unit cross-section as it is in the living *Nautilus*, and similarly deposited on a conchiolin membrane, starting in the region away from the siphuncle. Pfaff [1] found that in many well-preserved Gault Ammonites the pearly substance was quite similar and showed an identical structure of more or less parallel thin lamellæ, as in the septum of *Nautilus pompilius*. This author also shows in detail how in the case of *Nautilus* where the septa are concave forwards, as well as in Ammonites, external excess pressure would be transferred to the shell wall; and he comes to the conclusion that the arched septum of Ammonites need be only one-sixth of the thickness of the septum of *Nautilus*. But Pfaff [2] further assumes that one reason why the suture-line of *N. pompilius* is only curved as compared with the highly ramified suture-line of Ammonites is the thickening of the end-septum of the former. This is improbable, however, for as all the previous septa were capable of withstanding the external excess pressure, there was no need to thicken the last one, and it seems to the writer that this thickening is on a par with the occasional approximation of the last few septa when the animal had reached its full growth.

In *Nautilus* the siphuncle occupies exactly the centre of the supporting septal surface, though, as Dr. Foord has pointed out,[3] a change of position of the siphuncle during ontogeny is of frequent occurrence in fossil *Nautili*. The central siphuncular structure of these acted not only as a strengthening feature, as suggested already in 1854 by Pictet,[4] who thought it probable that in Ammonoids the complicated septa "were necessitated by the excentric position of the siphuncle", but the siphon also afforded an additional means of attachment.[5] In primitive Goniatites the earliest few septa are concave, and it has already been stated that the second septum of e.g. *Dactylioceras* also tends to be concave and is similarly associated with a simple suture-line and a sub-central siphuncle. When it is further found that e.g. in the Carboniferous *Subclymenia evoluta* (Phillips), the Triassic *Clydonautilus goniatites* (Hauer) or the Upper Jurassic *Pseudonautilus Geinitzi* (Pictet) a nearly external siphuncle is associated with an angular suture-line, it seems, indeed, probable that the shifting of the siphuncle to the external side first started the differentiation and convexity of the septal surface.

1902; also R. Ruedemann, "Structure of some Primitive Cephalopods": Report of New York State Pal. 1903, p. 334, for *Piloceras*.) They were probably benthonic, and it was only after the shell had become coiled upon itself and bilaterally symmetrical, that the Cephalopod animal could adopt a freely swimming mode of life.

[1] "Über Form und Bau d. Ammonitensepten und ihre Bezieh. z. Sutur-Linie": 4. Jahresber d. Niedersächs. Geolog. Ver., 1911, p. 212.

[2] Op. cit., p. 212.

[3] *Cat. of Foss. Ceph. in the Brit. Mus.* (*Nat. Hist.*), pt. ii; Nautiloidea, 1891, p. 322.

[4] *Traité de Paléont.*, vol. ii, pp. 666–7.

[5] Older authors (e.g. Vrolik & Van Breda, Ann. Mag. Nat. Hist., vol. xii, p. 173, 1843) even held that the animal was attached to the shell only by the siphon.

The writer would like to draw attention in this connexion to the interesting series of *Nautili* from the London Clay, which shows the close interconnexion of the various mechanical features of the shell. *Nautilus Parkinsoni*, Edwards, which has *Aturia* lobes (but the siphuncle farther away from the dorsum than e.g. the galeate-whorled *N. Sowerbyi*, Wetherell, with only slightly undulating septal edges) lacks the wide trumpet-mouthed funnels of typical *Aturiæ* where the siphuncle is dorsal. It might be suggested that apart from its connexion with the attachment of the animal to its shell, the differentiation of the septal surface in the neighbourhood of the siphuncle would afford protection for the latter. This would apply especially to the typical Ammonites in which elaboration of the suture-line begins at the siphonal lobe and progresses dorsally as is shown, e.g. in fig. 9 (p. 42) of Swinnerton & Trueman's paper, and in which external features such as a keel or a groove are similarly interpreted as contrivances for the protection of the siphuncle. It is probable, however, that this is partly also a case of retention of an original feature and gradual elaboration of the first ventral lobe or siphonal collar of the Goniatite radical, in such a manner that in a later Ammonite, e.g. the external saddle of stage 1 = the first lateral saddle of stage 2 = the second lateral saddle of stage 3 = the first auxiliary saddle of the (latest) stage 4.[1]

Pfaff[2] states that "as during growth the septal surface increases at the relatively quickest rate on the external side, differentiation must begin here". But in that case Clymenidæ, with an internal siphuncle, should not show greater elaboration of the suture-line on the dorsum. Here, also, protection for the siphuncle would have to be assumed, and the abnormal position of both siphuncle and deeper lobes suggests derivation of this stock, not from *Gyroceras* as Frech thinks, but from a Goniatite ancestor with a siphuncle, the position of which may have been unstable (as in the early whorls of most latisellate Ammonoids) but which had already become associated with the region of greatest differentiation of the septal surface.

It is necessary to distinguish between the progressive elaboration of the suture-line in the whole order Ammonoidea and the differentiation in certain stocks necessitated by e.g. whorl-shape. The *Dimorphoceras–Thalassoceras* lineage, e.g., seems to be the first one in which the minor details of the ventral lobe are elaborated, and from *Pronorites* onwards, and especially during the Permian and Lower Trias, first the lobes and then the saddles of all the stocks show progressive frilling. On the other hand, in more specialized lineages, such as the Devonian *Beloceras*, already differentiation is most pronounced in the lateral region, though it begins with the primitive ventral lobe. This applies to practically all compressed Ammonoids, as has already been stated, and demonstrates the impossibility of a morphological classification that groups together the above Devonian *Beloceras* and the Upper Triassic *Pinacoceras*, simply because these heterochronous homœomorphs possess a compressed shell.

[1] See L. F. Spath, Q.J.G.S., vol. lxx, fig. on p. 341, 1914, stages *e*, *f*, *h*, and *l*.
[2] Op. cit., p. 222.

V.—Pleochroism in a Tin-bearing Mineral from Siam.

By J. B. Scrivenor, M.A., F.G.S.

In 1915 a heavy concentrate of sand from an unknown locality in Siam was submitted to me for identification. The sand consisted of rather coarse grains of a dark mineral, and finer grains of ilmenite, monazite, tourmaline, zircon, and topaz, with some of the same dark mineral as that occurring in coarse grains.

The dark mineral was isolated and examined by partial chemical analysis and by optical methods, the results proving that it was a tin-bearing mineral with a remarkable pleochroism. The specific gravity was found to be 6·913.

The chemical examination, carried out by Mr. C. Salter, gave the following constituents: Sn, 74·50 per cent; TiO_2, 0·17 per cent; and some iron and alumina. Metallic tin was readily obtained on fusion with KCN.

Optically the mineral was found to be uniaxial and positive, and it exhibited a very marked pleochroism of deep red to green, suggesting the colours seen in hypersthene.

Unfortunately no crystals were available, therefore it was impossible to prove the mineral to be cassiterite, but the optical properties, apart from the pleochroism and the chemical composition, point to that identification.

I have little doubt myself that this dark mineral is cassiterite, showing abnormal pleochroism, because in undoubted specimens of that mineral I have frequently noted a less marked pleochroism of (E) carmine to (O) pale green or colourless. This pleochroism is not always equally distributed over a section, but may appear in irregular patches that suggest local variation in chemical composition. I have been informed that a similar pleochroism has been noted in a tin-bearing mineral from Nigeria, and have little doubt that it has been observed by mineralogists who have examined numerous tin-ore specimens from elsewhere. I published a note on this pleochroism in my Annual Report (Federated Malay States Government) for 1904, and have mentioned it in subsequent publications, but this specimen from Siam shows the phenomenon in a much more marked degree than any other specimen I have seen, and now that one has time to return to such matters I would suggest that the connexion between coloration, pleochroism, and chemical composition of cassiterite is a subject that might be pursued with some hope of arriving at interesting results. In crystals and in grains, viewed by reflected light, there is a wide range of colour; but in thin sections examined by transmitted polarized light the differences of coloration are more pronounced still. Pleochroism is sometimes present, sometimes not. The most distinct pleochroic effects I have seen are this deep red to green, deep brown to a lighter brown, and violet to almost colourless.

It would, of course, be necessary to examine large quantities of material before one could ascribe any particular coloration to a particular chemical constituent; but it is perhaps worth noting one point here in connexion with this Siamese mineral. One might surmise that the TiO_2 is responsible for the pleochroism, but a titaniferous cassiterite described in the *Mineralogical Magazine* for 1911 ("Notes on Cassiterite in the Malay Peninsula," pp. 188–20), showed the brown pleochroism noted above. On the other hand, this cassiterite contained so high a percentage of iron that it could be lifted by an electromagnet; and it is possible that the iron masked any pleochroic effect that the TiO_2 might produce were no iron present.

VI.—Note on the High-level Deposits on the Chalk at Little Heath, near Berkhamsted.[1]

By Reginald A. Smith, F.S.A., British Museum.

At a meeting of the Geological Society on January 22 a section at Little Heath, near Berkhamsted, was described[1] and discussed; but both in the papers and in the discussion attention was focussed on the lower part of the section, and the gravel, which is separated by about 6 inches of bull-head from the Chalk, was assigned to the Pliocene and correlated with the Westleton Beds of Prestwich. But the upper beds have an interest of their own, especially for the archæologist who is acquainted with the work of the late Mr. Worthington Smith; and it seems worth while to point out some striking resemblances to deposits in a line running north-east of the site in question. The Little Heath strata referred to are:—

6. Surface-soil with bleached flint-pebbles from the Reading Beds	about	2 feet thick.
5. Pebbly clay and other glacial deposits, varying from	2–20	,, ,,
4. Stratified loamy sand	5–6	,, ,,

A sharp break was noticed between the loamy sands and the underlying gravels, and analogy justifies the treatment of Nos. 4–6 as a series quite distinct from the Pliocene gravel below. The length of the interval may perhaps be determined by archæological data.

No. 4 is a stratified deposit of dark reddish-brown mottled loamy sand, the entire deposit being banded with very fine lines or partings of the grey clay. An abundance of sun-cracks throughout the stratum suggest genial climatic conditions, and indicate that each separate layer became exposed to the air after deposition.

Sun-cracks in brick-earth at Caddington, 7 miles distant, were noticed many years ago and illustrated in *Man, the Primeval Savage*, p. 80, fig. 49, the interstices being filled with later deposits of the same material, in which several floors or occupation-levels were noticed and examined with interesting results. Not only were flint implements of definite types and excellent workmanship collected in situ, but flakes capable of being fitted together again were recovered in quantities, proving that there had been no disturbance of the various surfaces when brick-earth was laid down from time to time. Above the brick-earth, which often

[1] See Reports and Proceedings, Geological Society of London, January 22, in this number of the Geol. Mag., pp. 138–41 (issued January 31, 1919).

reached a thickness of 20 feet, was what Mr. Worthington Smith called a contorted drift, evidently a glacial deposit, containing ochreous implements swept from a distant surface and perhaps of earlier date than the brick-earth specimens. The same sequence with corresponding implements was observed on two sites at Caddington (595–530 feet O.D. and 250–185 feet above the Lea); at Round Green, one mile north-east of Luton (530 feet O.D. and 178 feet above the Lea); at Whipsnade, 4 miles south-west of Luton (600 feet O.D. and 166 feet above the River Ver); and at Gaddesden Row, 3 miles north of Little Heath, on the other side of the Gade (544 feet O.D. and 184 feet above the Gade). Details of the above discoveries may be found in *Archæologia*, lxvii, p. 49, and in a paper about to be published by the Society of Antiquaries.

Little Heath is 550 feet O.D., about the average level of the other sites mentioned, which all have the same relation to the chalk escarpment, and are nearly 200 feet above the nearest river. It is a reasonable view that the present valleys have been cut down to that extent since the brick-earth was laid down and covered with glacial drift, on what are now the watersheds of several rivers.

The brick-earth implements show the beginnings of Le Moustier culture and are quite unabraded. If there is one point on which the authorities agree it is that the period of Le Moustier coincided with a cold climate, some would say a glaciation. Whether this "contorted drift" is connected with the Boulder-clay found in the immediate neighbourhood is at present undecided, but it may be recalled that James Geikie connected Le Moustier with the Boulder-clay.

It is perhaps too soon to expect the discovery of implements at Little Heath, but beds 4 and 5 seem (on paper) to correspond so closely to the implement-bearing deposits to the north-east that hopes may be entertained of eventual success; so that the newly opened pit may prove to have a human interest, and even a greater scientific value than was recognized at the meeting.

VII.—Some Recent American Petrological Literature.

For the last few years many geologists have been unable to keep in touch with the literature of their subject, partly owing to pre-occupation with war work of various kinds and partly owing to the spasmodic arrival in this country of non-British periodicals. The following short bibliographical notes on one limited branch of geological research have been put together in the hope that they may be of use to those who are now returning to their normal avocations, by affording them some idea of what has been done in America in the way of petrological investigation during the last few years. The list makes no pretence at completeness, since the compiler is himself suffering from the difficulties mentioned above, and the abstracts have purposely been made as short as possible, giving merely the barest indication of the contents of each paper, as a guide to readers who may desire to select what is of special interest to them. If the idea meets with approval it is hoped to publish from time to time similar compilations on other branches of geology.

"The System Anorthite-Forsterite-Silica," by O. Andersen. Amer. Journ. Sci., vol. xxxix, pp. 407–54, 1915.

A detailed experimental and theoretical discussion of this system, which must be treated as one of four components, in order to account for the formation of spinel in some of the ternary mixtures. The results are applied to actual rocks, especially to varieties that contain olivine.

"Crystallization-Differentiation in Silicate Liquids," by N. L. Bowen. Amer. Journ. Sci., vol. xxxix, pp. 175–91, 1915.

Experiments were undertaken with artificial melts to determine whether sinking or floating of crystals could be obtained. Olivine and pyroxene were found to sink and tridymite to float: the rate of sinking indicates a progressive increase of viscosity with increase of silica. The results obtained are applied to the observations of Lewis on the Palisade sill, and it is concluded that sinking of crystals is of importance even in acid magmas.

"The Crystallization of Haplobasaltic, Haplodioritic, and related Magmas," by N. L. Bowen. Amer. Journ. Sci., vol. xl, pp. 161–85, 1915.

The relations of diopside to the plagioclase series are studied by the quenching method of thermal analysis. The facts determined for artificial melts are applied to their natural analogues, and it is concluded that there can be little reason to doubt that crystallization controls the differentiation of the sub-alkaline series of igneous rocks.

"The Later Stages of the Evolution of the Igneous Rocks," by N. L. Bowen. Supplement to the Journal of Geology, vol. xxiii, No. 8, 1915. 91 pp.

In this long paper Dr. Bowen gives a summary of his conclusions based on an extensive discussion of the whole problem of the evolution of the igneous rocks, taking into account the results of investigations of the course of crystallization in artificial melts and the theoretical conclusions arising from them. Assimilation and direct refusion of sediments are regarded as unimportant, since they would lead to rock-types such as are never found. The decision is reached that differentiation is controlled entirely by crystallization, mainly by sinking of crystals and squeezing out of residual liquids, and it is shown that with slow cooling typical rock-series could be formed from basaltic magma, which is probably the primitive type.

"Differentiation in Intercrustal Magma Basins," by A. Harker. Journ. Geol., vol. xxiv, pp. 554–8, 1916.

This is mainly a criticism and review of Dr. Bowen's advocacy of differentiation in situ as opposed to differentiation before intrusion. It is pointed out that increase of viscosity in a cooling body of moderate size would soon stop sinking of crystals, and the frequency of small, separate, but obviously related intrusions is insisted on. It is also shown that the great majority of the crystalline schists of igneous origin belong to the calcic branch, indicating the connexion of calcic magmas with tangential thrusting movements.

"Genesis of the Alkaline Rocks," by R. A. Daly. Journ. Geol., vol. xxvi, pp. 97–134, 1918.

An examination of recent publications has led the writer to renewed faith in the general explanation for most of the alkaline rocks advanced in *Igneous Rocks and their Origins*. Doubts are expressed as to the validity of some of Bowen's conclusions on this subject.

"Internal Structures of Igneous Rocks, their Significance and Origin, with special reference to the Duluth Gabbro," by F. F. Grout. Journ. Geol., vol. xxvi, pp. 439–58, 1918.

A study of the significance and origin of banded structures, which are found to be in nearly every case parallel to the bounding surfaces of the intrusion. The banding is attributed to convection-circulation during crystallization.

"Two-phase Convection in Igneous Magmas," by F. F. Grout. Journ. Geol., vol. xxvi, pp. 481–99, 1918.

Banding and other parallel structures in igneous rocks indicate the occurrence of convection during cooling. The idea of convection becomes of practical service when applied to banding as an indicator of the form of the intrusion, assisting in locating and orienting bands of magnetite and other economic minerals and estimating their probable position and extent.

"A Study of the Magmatic Sulfid Ores," by C. F. Tolman, jun., and A. F. Rogers. Stanford University Publications, 1916.

A microscopic and metallographic study of ore-bodies of the Sudbury type, associated with basic intrusions. It is concluded that the magmatic ores in general have been introduced at a late stage as a result of mineralizers and that the ore-minerals replace silicates. The process, however, is distinguished from pneumatolysis, since quartz and secondary silicates are not then formed. Two main types are recognized, namely, nickeliferous pyrrhotite-chalcopyrite deposits in norite and gabbro, and chalcopyrite-bornite deposits in norite and diorite.

"The Nickel Deposits of the World," by W. G. Miller and C. W. Knight. Reprinted from the Report of the Ontario Nickel Commission, Toronto, 1917.

The origin of the Sudbury ores is fully discussed, with detailed descriptions of all the mines: in opposition to the views of Coleman and others the authors consider that the sulphides were deposited from heated waters at a period subsequent to the consolidation of the norite. It is pointed out that the commercial ore-bodies form the cementing and replacing material of breccias along crushed and sheared zones, not in the norite but in the country rock, often at some distance from the contact. Analyses of the norite show little or no evidence of differentiation.

"Magmas and Sulphide Ores," by A. P. Coleman. Econ. Geol., vol. xii, pp. 427–34, 1917.

A discussion of the work of the Ontario Nickel Commission and of Tolman and Rogers on the Sudbury ores. The author maintains that the field relations there seen are in good agreement with the theory of magmatic segregation under gravity, but inconsistent with the deposit of the ores by circulating solutions.

"Magmatic Ore Deposits, Sudbury, Ont.," by A. M. Bateman. Econ. Geol., vol. xii, pp. 391–426, 1917.

A description of the field relations and characters of the nickel-bearing ore-deposits of Sudbury, with a discussion of recent views as to their origin. The author's own hypothesis is that an intermediate magma was differentiated in a reservoir and a portion was extruded to form the "nickel eruptive". This portion then continued to differentiate, giving rise to the successive portions, which vary from granite to pyrrhotite-norite and ore-bodies.

"On the Geology of the Alkali Rocks of the Transvaal," by H. A. Brouwer. Journ. Geol., vol. xxv, pp. 741–78, 1917.

A detailed petrographical description of the Bushveld complex, with a special discussion of the possible origin of the nepheline syenites and allied rock-types of the Pilandsberg area, Leeuwfontein and Lydenburg. It is concluded that these highly alkaline rocks may have been derived by differentiation from the same magma as the granites and norites of the Bushveld.

"The Problem of the Anorthosites," by N. L. Bowen. Journ. Geol., vol. xxv, pp. 209–43, 1917.

The occurrences of anorthosite in the Adirondacks and in the Morin area are described, and it is concluded that the monomineralic rocks of the anorthosite group have probably been formed by gravity-separation of femic minerals from a gabbroid magma. The remaining plagioclase liquid again separates into a basic anorthosite layer below and a lighter syenitic or granitic phase above.

(*To be continued.*)

REVIEWS.

I.—La Face de la Terre. Tome III, 4e Partie (fin). Traduit et annoté sous la direction de E. de Margerie, avec un Épilogue par Pierre Termier. pp. xv and 1361–1724, with 3 coloured maps, 2 plates, and 115 figures. Tables générales de l'ouvrage, pp. 258. Paris: Armand Colin. 1918.

It is with great pleasure that we welcome the appearance of this the concluding instalment of the French version of *Das Antlitz der Erde*, and we congratulate M. de Margerie and his colleagues on the successful termination of their labours, in spite of the adverse conditions of the last four years. Although nominally a translation this work should be called rather an edition. It is true that the text follows as closely as the idioms of the two languages allow the wording of the original German, but it is enriched by such a mass of new references and notes, by so many new figures and maps, that it is almost a new book: in fact, Suess brought up to date. The index volume alone is a large work in itself, and it contains some very useful tables arranged to facilitate the finding of maps and figures referring to particular subjects and areas: these alone occupy 75 pages.

It is unnecessary at this time to review the book in the ordinary sense of the word, but it is perhaps permissible to make a few remarks on certain special points that suggest themselves on reading it. In the first place it is pleasing to find that the French editors have in some cases corrected injustices with regard to the assignment of ideas to their true authors: for example, it has been the fashion in German and other foreign petrological literature to attribute the conception of Atlantic and Pacific suites of rocks to Becke, whose work was published in 1902. An additional note on p. 1542 of this volume states that the idea, though foreshadowed by Iddings in 1892, was formulated clearly for the first time by Harker in 1896, six years before Becke wrote. Although probably unintentional on the part of Suess, this sort of thing is sadly too common in German scientific writings, and such statements are often copied without verification in other countries.

As is probably well known to most people, this part of the book contains a summary of the result of the author's lifelong work, and some of the conclusions here set forth differ somewhat from those reached in the earlier volumes. Such a study as this, extending over so many years, was naturally evolutionary, illustrating the development of the author's views as knowledge increased. Of special interest is the importance attached in the chapter entitled "Les Profondeurs" to the nature of the earth's interior and the genesis of the igneous rocks. The use of the rather barbarous manufactured terms like Crofesima and Nife is significant of the trend of modern petrological thought in the way of recognizing the desirability of studying the genesis of the metallic ores as well as of the silicates; the study of the sulphides is now becoming an important part of theoretical petrology, and in this way the work of Vogt, carried out nearly thirty years ago, is bearing good fruit.

The epilogue, by M. Pierre Termier, of the Académie des Sciences, partakes rather of the nature of a panegyric of Eduard Suess, and shows clearly the veneration of the French school for the great Austrian geologist, in spite of all the events of the last few years. It brings into strong relief the influence of his work on Bertrand and others, work which has largely substantiated and amplified the ideas of the master. The labours of the French editors have carried on this tradition, and there can be no doubt that geologists who wish to gain an insight into the structure of the earth will turn to this rather than to the original German or to the English translation as an exposition of the state of knowledge on this subject at the present time.

R. H. R.

II.—The Discovery of Diamonds in South Africa. By E. J. Dunn, formerly Director of the Geological Survey of Victoria. Industrial Australian and Mining Standard, vol. lx, p. 91, 1918.

THIS article, which was reprinted in the *Mining Magazine*, November, 1918, is a very interesting and readable account of the beginnings of the South African diamond industry, and especially so since the author was present in the very early days of the discoveries, and watched the gradual growth of the mining at first hand, while he also knew personally all the men who played the chief parts in the early development.

When he first arrived on the fields in 1871 the presence of diamonds had been known for four or five years, and a considerable amount of work had been done on the river diggings; but the exodus to the dry diggings was only just taking place; the site of the De Beers Mine was a low knoll, and no one had so much as scratched the surface at this place, where the shaft is now 3,520 feet deep.

The original discovery of the diamonds was quite accidental; the first was picked up by a Bushman herd-boy who gave the "blink klip" or bright stone to his master's children to play with, and it was only after some considerable time that its value was realized. After this finds became gradually more frequent till at last the rush took place and diamonds became a serious factor in the life of the country.

Before the discovery the trade and industries of South Africa were at a very low ebb and the country had become almost bankrupt, but the herd-boy's discovery on the Orange River was the beginning of a period of prosperity which is still continuing, and to which diamonds have contributed to a very considerable extent.

III.—The Geomorphology of the Coastal District of South-Western Wellington. By C. A. Cotton. Trans. New Zealand Inst., vol. l, pp. 212–22.

THE fertile coastal district of South-Western Wellington shows certain peculiar physiographic features of comparatively modern growth which appear to be explicable as the result of alternate retreat of the shore-line under wave-attack (retrogradation) and advance of the shore-line due to accumulation of land-detritus (progradation). The author gives an interesting theoretical discussion, with diagrams, of the growth of a coastal lowland under conditions of fluctuating waste-supply, and applies his conclusions to the features of the area under review. It appears that the dominant factor in this instance is a variation in the supply of sand coming from rivers further to the north-east, rather than a fluctuation in the gravel brought down by the local streams. Other possible explanations are also considered.

IV.—The Succession of Tertiary Beds in the Pareora District, South Canterbury. By M. C. Gudex. Trans. New Zealand Inst., vol. l, pp. 244–62, 1918.

THE Pareora district lies about half-way between Christchurch and Dunedin on the east coast of the South Island of New Zealand. The complete sequence of Tertiary beds includes representatives of the Oamaru and Pareora series, with a total thickness of about 1,250 feet. An enormous number of fossils have been collected, and their detailed occurrences are tabulated at the end of the paper. The lithological character of the beds is very variable, including sands, clays, marls, and limestones, and at the base a series of grits and conglomerates alternating with coal-seams. The coal is apparently inconstant and has a dip of 60°, so that it seems unlikely to be of commercial value: it appears to have been formed in an estuary or bay and not by growth in place.

V.—On the Age of the Alpine Chain of Western Otago. By James Park. Trans. New Zealand Inst., vol. l, p. 160, with plate, 1918.

THE Alpine chain of Western Otago consists of folded rocks of Lower Palæozoic age, but deeply involved in the eastern folds of the chain is a remarkable narrow strip of Tertiary strata which can be traced for some 25 miles. This has been involved to a depth of at least 4,500 feet. The beds consist of conglomerate, sandstone, clay, and limestone with badly preserved fossils, the maximum thickness being about 80 feet. The fossils indicate an Oamaruian (Miocene) age, probably belonging to the upper part of this formation. This occurrence affords satisfactory evidence that the mountain-building movements took place in post-Miocene times, probably early Pliocene.

VI.—Notes on the Geology of the Tubuai Islands and of Pitcairn. By P. Marshall. Trans. New Zealand Inst., vol. l, pp. 278–9, 1918.

THE Tubuai Islands are a scattered group situated near 23° S. lat. and 150° W. long. Little is known of their geology, and Professor Marshall has examined petrographically three stone implements brought thence: two of them are dense, rather acid basalts, while the third is a rather coarse-grained olivine basalt. None of them present any special peculiarities. An examination of a box of rock specimens sent by the Chief Magistrate of Pitcairn revealed the presence here also of fine-grained basalts, many being glassy and probably of submarine origin. Most of them contain a good deal of olivine, and are moderately basic, though less so than varieties described by Michel-Lévy, which were not represented in this collection.

VII.—The Building Stones of Queensland. By H. C. Richards. Proc. Roy. Soc. Queensland, vol. xxx, No. 8, pp. 97–157, 1918.

IN the Official Year Book of Australia for 1916 it was found necessary to remark that "there is not sufficient information available to permit of a detailed statement . . . in regard to the quantity and quality of Queensland Building Stones". This reproach is now largely removed by Dr. Richards, who has given in this paper the geological and physical characteristics of the stones available for constructional purposes. Numerous chemical analyses are quoted, and tables showing the resistance to crushing, specific gravity, absorption coefficient, etc., of many of the rocks, are provided. The paper contains many details of petrographical interest and is illustrated by eighteen photomicrographs.

VIII.—Report on the Clay Resources of Southern Saskatchewan. By N. B. Davis. Canada, Department of Mines. pp. 93, with 21 plates, 1 figure, and 2 maps. Ottawa, 1918.

THE Province of Saskatchewan contains abundant and excellent deposits of fireclay, and of clays suitable for the manufacture of all kinds of ceramic ware, especially bricks and tiles, a fact of much importance in a region devoid of building stone and with little timber. The most valuable clays are found in the lower and middle divisions of the Fort Union formation, of Eocene age, associated with silts, sands and lignite, the best of all being in the White-mud series. The Pleistocene and Recent deposits also include beds of clay suitable for making common bricks. In this report a very full account is given of the technology and properties of the clays with records of numerous tests, and a detailed description of the manner of occurrence and thickness of the beds in a great number of localities.

IX.—On the Intrusion Mechanism of the Archæan Granites of Central Sweden. By P. Geijer. Bull. Geol. Inst. Univ. Upsala, vol. xv, pp. 47–60, 1916.

THE older and younger Archæan granites of Central Sweden show characteristically different relations to the rocks invaded by them, the earlier intrusions being to a large extent connected with anticlinal structures, while among the younger batholiths two types can be discerned, the anticlinal and the transgressive. The former resemble in this respect the older gneissic granites, while the others, the Serarchæan granites of Högbom, furnish excellent examples of the features quoted by Daly in favour of the hypothesis of intrusion by overhead stoping. Many of these stoped batholiths occur in regions characterized by plateau structure, as defined by Harker; in others this relation is not so typically developed, but the structural relations are always those of the zone of fracture, with regional subsidence and faulting, in strong contrast to the conditions controlling the development of anticlinal batholiths which are associated with strong contemporaneous folding and compression of the surrounding stratified rocks.

X.—Swedish Archæan Structures and their Meaning. By P. J. Holmquist. Bull. Geol. Inst. Univ. Upsala, vol. xv, pp. 125–48, 1916.

FROM the evidence brought forward in this paper the following sequence of events seems probable: the porphyry-leptite rocks are the oldest known formation; they represent ashy volcanic deposits, comparable to the Keewatin. These sank in blocks into the underlying granite magma, being metamorphosed and partly assimilated. After the consolidation of this granite magma the whole was affected by dynamometamorphism, forming different varieties of gneissose and schistose rocks of varying grades of alteration, the highest grades of metamorphism being closely connected with pegmatitization. The latest eruptive masses of the Archæan consist of very acid granites, pegmatites, and aplites.

XI.—Department of Mines, Canada, Summary Report, 1917. Part B. 48 pages, with 1 text-figure. Ottawa, 1918.

THIS instalment of the Summary Report for 1917 contains accounts of geological reconnaissances and surveys in various parts of British Columbia and the Yukon Territory. Most of the areas dealt with contain minerals of economic value, especially gold, and mining is now being developed to a considerable extent. Most of the mineralization is evidently due to the intrusion in Jurassic and early Cretaceous times of the great igneous masses known collectively as the "Coast Batholith". More detailed work has shown the existence in many places of portions of the original sedimentary roof of this batholith in regions formerly considered to be entirely occupied by igneous rocks. This is of much importance, since most of the ores occur as contact deposits at the junction of the batholith with the older rocks.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *January* 8, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communications were read:—

(1) "On 'Wash-outs' in Coal-seams and the Effects of Contemporary Earthquakes." By Percy Fry Kendall, M.Sc., F.G.S., Professor of Geology in the University of Leeds.

The author differentiates two types of interruptions in coal-seams which have been confused under the general term of "wash-outs", "wants", "nips", or "dumb-faults". One type he believes to be due, as geological writers have mostly held, to erosion by contemporary or sub-contemporary streams which coursed through the alluvial area where the coal-material was accumulating as a species of peat. The channel thus cut was subsequently infilled with sedimentary materials.

He describes a number of examples of this type in the Midland Coalfield, some being sinuous in course and traceable over many miles; others being of great width and of irregular form, and due possibly to shifting and meandering streams.

Split seams of the type in which the seam rejoins are kindred phenomena, but in these cases the erosion was always contemporary, and, after a channel was filled up with sediments, peat-producing plants spread completely across the infilling.

Great diversity in the phenomena of splits and wash-outs arises from the differences in the ratios of shrinkage during consolidation of the various constituents, coal undergoing a shrinkage variously estimated from $\frac{9}{10}$ to $\frac{19}{20}$ of the peat from which it is formed; mud undergoing, as Sorby showed, a considerable though lesser degree of reduction; and sand undergoing almost no reduction at all. Thus the hog-back section of split seams is due to the shrinkage of the enclosing coal-substance letting down a relatively incompressible infilling of a channel deeper in the middle than at the sides. In the process the lower surface of the sedimentary mass would flatten to adjust itself to the floor, and the top would consequently assume a curve corresponding generally with the original lower curve, but reversed. The upper element of the seam has some species of seat-earth which arches over the hog-backed inclusion.

Cannel, which the author considers to be due to a kind of vegetable pulp that underwent most of its decomposition and chemical change coincidently with deposition, acts as a substance of little compressibility; and, whenever pools of cannel-pulp took the place of an equivalent thickness of normal coal stuff, they survive as swellings in the coal-seam.

The infilling of the erosion-channels, usually of muds and sands, which often show current-bedding, sometimes includes masses of conglomerate with, in exceptional cases, boulders measuring up to three feet in length. The pebbles are almost invariably of clay-ironstone, never much rounded, and presumably the product of the erosion of the measures through which the stream has cut its way.

Other disturbances of the coal-seams, commonly miscalled "wash-outs", the author believes to be due to earthquakes, and he holds that in Coal-measure times earthquakes had an importance which has never hitherto been suspected.

The area in which our Coal-measures accumulated he supposes to have resembled generally such alluvial tracts as were the scene of the great earthquakes of Assam and New Madrid described by Mr. R. D. Oldham and Mr. Myron Fuller, save that in the Coal-measures peat-beds were piled in a much more numerous suite, and were on a vaster scale both of thickness and of area than in any part of the modern world where earthquake phenomena have been studied. Some of the effects of earthquakes in Coal-measure times might be expected consequently to be of a magnitude greater than the effects of recent earthquakes, but the types of phenomena are similar.

The formation of permanent and transient ridges, troughs and fissures, the lurching out of place of belts of the superficial strata, great displacements by the subterranean flow of quicksand, traces of "sandblows" and of the caving-in of river banks have all been recognized by the author in coal-seams.

Disturbances of this character are frequent along the margins of erosion-channels, just as earthquake-formed fissures and ridges are often marked beside recent rivers in alluvial tracts.

A striking abnormality in coal-seams consists in the intrusion into the coal of sedimentary material, or the encroachment of masses of amorphous sandstone as "rock-rolls". The author attributes these to the invasion of sands rendered mobile by excess of water, and perhaps of gas, and moving under the impulse of waves of elastic compression produced by earthquakes.

An earthquake-wave would tend to push forward the water contained in a peat-bed enclosed beneath a cover of laminated clay or mud. Where this cover was impenetrable the effect would be merely transient; where the tenacity of the cover could be overcome, or where it came to an edge through erosion or failure of deposition, water would be ejected from the peat. If this passed into a sand-bed a quite small excess of water, whether accompanied or not by the gases generated in the peat by decomposition, would be sufficient to convert the sand into quicksand; and, in turn, wherever the sand-bed itself was not confined within impenetrable laminated muds there would under the elastic strains of the earthquake be an extravasation of quicksand into adjacent beds, or its expulsion as "sand-blows" at the surface of the ground. When impenetrable mud-beds occurred in a sufficiently yielding condition, such extravasation of sands might carry these beds with them in a more or less stretched condition, and so be perpetuated as solid rolls enveloped in a wrapping of stratified shales.

Lurching of the superficial strata took place on a considerable scale. The evidence is found in the gaps (often miscalled "wash-outs") of a type usually narrow and not sinuous, in respect of which the loss of coal is compensated for by swellings or folds of the seam, or by the overriding of the seam by great flakes of coal still retaining the characteristics of the seam. These flakes always show torn and ragged edges, which are sometimes splayed out and interpenetrated by tongues of sandstone or of amorphous "clunch", and the fine laminæ of the coal preserve their parallel arrangement to the extremities of the projections without contortion. In some cases the flake has been thrown in complicated folds, and in one instance completely inverted.

The inference is that the flake of coal was not moved ("over-thrust") by any tectonic stress, but that under the impulse of an earthquake a mass of unconsolidated, or but partly consolidated, peat-stuff or lignite was projected forward by its own inertia in a medium, usually of sand, which, through excess of water and gases, had only such resisting power as belongs to a fluid.

Such disturbances are (with some doubtful exceptions) always limited to single seams and their contiguous measures, and there is cumulative evidence that usually the coal-stuff, and always the measures, were unconsolidated at the time of the movement. In the overriding flakes the coal retains undistorted vegetable structures in its excessively tender "mother-of-coal" layers. The "cleat" in the overriding flakes follows the orientation general to the locality.

The gap left by the projection forward of the belt of seam is filled with an unstratified sludge-like substance, commonly containing angular masses of stratified argillaceous or arenaceous material. A very finely-contorted specimen of sandstone from a true "wash-out" shows quite plainly that the disturbance took place before the material was indurated.

In harmony with the contention that the overriding masses are not due to tectonic "overthrusts" is the fact that reversed faults are almost unknown in the coalfield, are never of considerable throw, and many collieries have never seen one.

In the roofs of many coal-seams and projecting slightly into the coal are very curious roughly conical masses of sandstone, familiar to the miners as "drops" (or by other names); but these have, so far as the author knows, hitherto escaped notice by any geological writer. They are commonly wrinkled on the surface as though partly telescoped, and often have a flange on two sides, showing that they were produced on the site of a crack. They are commonly ranged in long rows. These the author interprets as casts of the funnel-shaped orifices through which the sands surcharged with water have been expelled, an invariable accompaniment of earthquakes in alluvial tracts. The shape of these drops and their grouping negative the idea that they are infillings of orifices occasioned by escapes of gas arising from the decomposition of the peat.

Fissures filled with sand or other materials, the "sandstone dykes" of American writers, are not so common in the Midland Coalfield as in some other coalfields, as, for example, Whitehaven; but a number exist. They show contortion where passing through the seam—proving that the coal-substance had not undergone its full compression at the time when the fissure was produced.

Trough-shaped hollows, called "swilleys" or "swamps", to which some coal-seams are particularly prone, the author attributes to earthquake effects, such as the subterranean movements of sand, as quicksand. They are not tectonic, for exceedingly rarely, if ever, is more than one seam on the same vertical affected. Sometimes the formation of the swilley was coincident with the formation of the seam, as is proved by changes within the trough in the nature of the seam—particularly the occurrence of cannel.

All the phenomena here described were produced prior to the production of the larger faults of this coalfield; but minor faults, some affecting upper seams and not lower, others lower and not upper, are probably to be attributed to earthquake action.

A large number of examples of each type of phenomenon, drawn from the examination of over thirty mines in the coalfield, are discussed.

(2) "On Sandstone Dykes or Rock-Riders in the Cumberland Coalfield." By Albert Gilligan, D.Sc., B.Sc., F.G.S.

The occurrence of these sandstone dykes was brought to the notice of the author when engaged in investigations into the interruptions in the coal-seams of this area. They have been encountered at various times in pits distributed all over the Coalfield; but those more particularly examined were met with in the workings of the Bannock Band and Main Band Seams at Ladysmith Pit, one and three-quarter miles south of Wellington Pit, Whitehaven.

The pit-shaft is 1,080 feet deep, and has been sunk through the St. Bees Sandstone, Gypsiferous Marls, Permian, and Whitehaven Sandstone to the productive Lower Coal-measures. Splendid cliff-sections of the Whitehaven Sandstone and succeeding beds, which dip southwards, can be seen in a traverse of the shore from Whitehaven southwards round Saltom Bay. The coal-workings have been opened up south of the shaft, and therefore pass under St. Bees Head.

The dykes certainly pass through the Bannock Band and Main Band Seams and the intervening measures, which are about 54 feet thick; but their full vertical extent has not been determined. Their horizontal extent is variable: the longest has been traced for more than a mile. They all run practically parallel one to the other in a direction approximately north-north-west and south-south-east. The inclination of the same dyke is not constant, but the greatest deviation from the vertical was 10° south-westwards, and in general the amount was very small. In only one case was a dyke found associated with a small fault, the displacement being 2½ feet, and even this died out in a short distance. A noticeable feature was the presence of slickensiding, approximately horizontal, on the sandstone surface. Flutings, simulating ripple-marks, were present on the sides of the sandstone forming the dyke.

The average width of the dykes was from 2 to 4 inches, but sometimes they increase to 10 inches or dwindle down to mere films. Occasionally a lateral displacement was seen when the dyke passed from one type of rock to another. Splitting of the dykes was commonly seen. Veins of calcite and barytes traverse the dykes longitudinally and transversely, while lenticles of shale and coal are also of frequent occurrence in some portions of the dykes. The contact of the coal and dyke substance was very sharply defined, the coal preserving all the normal features even when adhering to the sandstone.

In discussing the origin of the fissures and the nature of their infilling, the author draws attention to the fact that the direction of the dykes at Ladysmith is that of the main system of faults in the Cumberland Coalfield. These north-north-west and south-south-east faults profoundly affect the Lower Coal-measures at Ladysmith Pit, but do not pass up into the overlying Permian and Triassic rocks.

An examination of the cliff-sections of Saltom Bay, where dykes of the same series as those at Ladysmith Pit should emerge, shows that they are not present in the Whitehaven Sandstone and succeeding beds. The inference was therefore drawn that they were of pre-Whitehaven Sandstone age. The probable conditions which obtained at the time of the formation of the fissures and their infilling were as follows: The coal-seams through which the dykes pass had been compressed to their present thickness, while they and the associated measures were sufficiently consolidated to take a more or less clean fracture. The sea in which the deltaic material of the Whitehaven Sandstone was accumulating covered the area. Fractures were produced by earthquake disturbances set up by movement along one of the north-north-west and south-south-east faults, and the sediment on the sea-floor ran in and sealed them up.

A mineralogical examination of the Whitehaven Sandstone and of the sandstone of the dykes shows that they have much in common, notably in the types of heavy minerals.

The sequence of events postulated supports the view of an unconformity at the base of the Whitehaven Sandstone. With regard to dykes in other parts of the Coalfield which show contortion in passing through the coal-seams, the author argues for their formation before consolidation of the enclosing measures.

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2. *January* 22, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The President announced that a Special General Meeting of the Society would be held on Wednesday, March 26, 1919, at 6 p.m., to consider the following Resolution of Council: "That it is desirable to admit women as Fellows of the Society."

The following communications were read:—

(1) "On the Occurrence of Extensive Deposits of High-level Sands and Gravels resting upon the Chalk at Little Heath, near Berkhamsted." By Charles Jesse Gilbert, F.G.S.

In a pit recently opened at Little Heath Common on a plateau of the Chiltern Hills, 550 feet above sea-level, the following section has been developed:—

	Thickness in feet.
6. Surface soil with bleached flint-pebbles from the Reading Beds . . . . . about	2
5. Pebbly clay and other Glacial deposits, varying from	2 to 20
4. Stratified loamy sand	5 to 6
3. Stratified coarse gravel	17
2. Dark clay, with black-coated unworn flints and small well-rounded pebbles	0 6 inches.
1. Chalk.	

The upper Glacial deposit is a pebbly clay. The pebbles, which are nearly all bleached and highly waterworn, are derived from the Reading Beds. The pebbles are almost always in a vertical position, or highly inclined, some being crushed in situ.

The clay matrix is tough and mottled, and the highly coloured tints of the clay leave little room for doubt that it has been derived from the upper part of the Reading Beds.

The Chalk flints, which are scattered in such profusion over all parts of the surrounding country, are almost entirely absent, while the small pebbles of white quartz and lydite, so abundant in the underlying gravel, are seldom met with. It seems probable that the ice must have derived its materials from a distant area. The deposit is very persistent, often cutting into and disturbing the beds beneath.

On the west side of the pit, underlying the pebbly clay, is a disturbed mass of Glacial sands and clay, of a very miscellaneous character. The whole deposit is suggestive of an englacial origin. It is introduced in the form of a wedge or V-fault cutting into the beds beneath, the pressure having come from the west. These Glacial beds were traced to a depth of about 20 feet, when the workings in this part of the pit were discontinued. At the apex of the wedge towards the east, the beds against which it had been forced showed signs of considerable disturbance.

No deposits have been found in any way corresponding to the stratified Glacial sands and gravels which are so extensively developed at Bedmond, about five miles away to the south-east, and contain a large percentage of rocks foreign to the district.

Beneath the Glacial beds is a stratified deposit of dark reddish-brown mottled loamy sand. The entire deposit is banded with very fine lines or partings of the grey clay. Some are ripple-marked, and others are covered by sun-cracks and apparent rain-spots, indicating that each separate layer became exposed to the air after deposition. The sun-cracks are very persistent throughout the deposit, and are suggestive of genial climatic conditions.

There is almost invariably a sharp break between the loamy sands and the underlying gravels.

The gravels have often an undulating surface, even where the bedding of the sands is horizontal, and strongly resemble a series of tidal beaches.

The laminæ of the loamy sands in the hollows of the beaches do not always follow the contour-line of the beach, but are deposited more or less horizontally, occasionally with a slight local unconformity. It seems probable that the water gained sudden access through one of the beaches at a distance, depositing first the heavier burden of sand, and then the lighter parting of clay in suspension, this operation being repeated by successive storms or high tides leaving the sands high and dry during the intervals. Hence the sun-cracks and rain-spots.

The fact that the surface of the clay-partings never shows signs of erosion, either from water or from subaërial agencies, suggests that the various layers of the sands were deposited at fairly frequent intervals, and in quiet water.

The underlying gravel deposit consists almost entirely of Reading pebbles and waterworn flints in approximately equal quantities, with an occasional pebble of puddingstone from the Reading Beds. Some of the pebbles of puddingstone and of the large waterworn flints show distinct evidences of noding. No rocks foreign to the district have been found.

As a general rule, the gravel becomes coarser in depth, the lower sections containing a high percentage of large waterworn flints. In no case are the pebbles crushed as in the Glacial beds, and they usually lie quite horizontally. The spaces between the pebbles are completely filled with loose sand and small stones. The small stones are mostly Reading pebbles and white quartz, with a few pebbles of lydite. The gravel is quite homogeneous.

Recent researches appear to indicate that the quartz and lydite pebbles in this district have been derived from the Lower Greensand (which crops out north and north-west of the Chilterns) after the final breach of the Chiltern scarp, in the gaps of which the quartz-bebbles are found in such abundance. If this be correct, it would indicate not only that the materials of which the gravels are composed came from the north, but also that the vast quantities of quartz-pebbles which are found everywhere in the upper plateau-gravels nearest to Little Heath are derived from the same source.

Reasons are adduced in support of the contention that the loamy sands and gravels are marine deposits laid down in a shallow sea; and that they cannot be of Glacial origin.

The area over which the gravels have been found extends for over a mile and a half south-east and north-west, by about half a mile north-east and south-west. They thin out towards the north-west, where they are only found in occasional outliers around which the Glacial beds rest directly upon the Chalk. It is clear that there must have been a considerable erosion of the pebble-beds before the Glacial beds were deposited.

As to the age of the loamy sands and gravels, the presence of the pebbles of puddingstone proves that they cannot be Reading Beds, and as they rest directly upon the Chalk the London Clay and Reading Beds must have been denuded before their deposition. They must be later than the Miocene movements, and are obviously pre-Glacial. They are apparently of marine origin, and their similarity to the high-plateau gravels farther south and to the beds at Headley Heath, Netley Heath, etc., suggests their contemporaneous deposition with these gravels. They are probably, therefore, of Pliocene age.

(2) "Notes on the Correlation of the Deposits described in Mr. C. J. Gilbert's paper with the High-level Gravels of the South of England (or the London Basin)." By George Barrow, F.G.S., M.I.M.M.

The gravels described in the preceding paper belong to a series of widespread deposits of which the harder constituents have usually been derived from two areas only: one within the Chalk escarpment (or local), the other beyond this escarpment, but within that of the Lower Greensand (neighbouring). The local constituents are Reading or other Tertiary pebbles, and flint; the latter is small in quantity where the gravels rest on Tertiary beds, but much increased where on the Chalk. In addition, pebbles of sarsen are not uncommon; they have been wrongly identified as quartzite. The pebbles to which the term "neighbouring" is applied consist of white quartz and lydite, all small; they have been proved to have been derived from the Lower Greensand, and this identification is corroborated by the fact that over considerable areas small fragments of chert from the Lower Greensand are associated with them.

"Far-travelled" stones, derived from the Bunter, Carboniferous Limestone, Red Chalk, etc., are entirely absent from these deposits as originally laid down.

So long as they are composed mainly of small pebbles the gravels keep at a nearly constant level over a very wide area, a little more than 400 feet above sea-level. This type has once covered the greater part of the Thames Valley that is now at or below this level. As they rise to a greater height the Tertiary pebbles (and flints if present) increase in size.

Outliers of the finer deposits have recently been met with near Chorley Wood, and on both sides of the Misbourne a little above Chalfont St. Giles. The steady increase in the proportion of small quartz pebbles in this area suggests that they must have entered the district by the Wendover gap, at the head of the Misbourne valley; this has been proved to be the case.

The coarser gravels of this composition occur on the south side of the Thames, at varying heights, up to above 600 feet; these all rest on the Chalk. The author has pointed out that there must be corresponding coarser gravels also resting upon the Chalk on the north side of the Thames, and the occurrence described by Mr. Gilbert now shows that this is the case.

The higher gravels on the south side of the Thames seem to be allied to the Lenham Beds, and this greater age is supported by the considerable denudation that has taken place since this series of gravels was deposited. The post-Glacial denudation of the area about London, away from the immediate neighbourhood of the Thames itself, is quite small in comparison with it.

II.—Edinburgh Geological Society.

December 18.—Dr. M'Lintock, Vice-President, in the Chair.

(Received January 18, 1919.)

1. "Lead and Zinc Mining in Scotland," or "Some Scottish Mineral Veins". By G. V. Wilson, B.Sc., F.G.S.

Metalliferous mining is an old Scottish industry of which few early records exist. Gold has been worked in many places, especially the Leadhills district. In considering the source of this gold we may suppose that some auriferous quartz veins were exposed in the district prior to the Glacial Period. By the ordinary process of erosion the gold weathered out of these veins and found its way into the river gravels of the streams. The whole country was then subjected to the action of glacier ice, which removed and mixed the gravels with other materials, and deposited the whole as a boulder-clay and drift over a wide area. Since then the local streams denuded the glacial deposits and concentrated afresh the gold in a new set of river gravels. A number of auriferous quartz boulders, including one found by the writer last summer, have been picked up in the Short Cleuch water.

Silver has been found and worked native at one or two localities—notably Hilderstone and Alva.

Copper has been worked in many places—the chief being Sandlodge in Shetland; others are Kilfinnan, Bridge of Allan, Tomnadshan, and Kirkcudbrightshire.

Nickel, cobalt, and antimony have been worked to a small extent. In connection with nickel a very interesting occurrence is that at Talnotry, near Newton Stewart, where the ore occurs as a magmatic segregation of niccolite and nickeliferous pyrrhotite, at the base of a small intrusion of hornblende gabbro near the margin of the Cairnsmore granite. The intrusion is of the nature of a sill, and thus it has affinities with the well-known Sudbury deposit in Canada.

Lead has been mined in almost every county, but in many cases the mines are now closed down. The chief mines are now at Leadhills and Wanlockhead. The veins of the Leadhills–Wanlockhead district can be divided into two main sets, one running about due north and south and the other about north-west. The north and south set are thought to be the later of the two. About seventy veins in all are known, but only three are now being worked. Leadhills mine (Glengonnar shaft) is about 230 fathoms deep, and works Brow and Brown's veins. Wanlockhead mine (Glencrieff shaft) is about 240 fathoms deep, and works the new Glencrieff vein in its west branch. At Leadhills only galena is worked, but at Wanlockhead both galena and zinc blende are obtained.

At the present time, in different parts of the new Glencrieff vein, various chemical changes are taking place: thus galena is being dissolved and calcite deposited, in others again calcite is being dissolved and hemimorphite deposited, and in others barytes is going into solution and witherite is crystallizing out. These secondary changes have much influence on the economic character of a vein, making it richer in ore. The Leadhills-Wanlockhead veins are supposed to owe their origin to the intrusion of a dome-shaped mass of granitic rock, which is not exposed, but whose presence is indicated by the numerous dykes of felsite in the area. Over the crest of the dome numerous fissures were formed in the country rock. In the final stages of the cooling of the mass large volumes of ore-bearing hot waters and gases were given off and permeated the whole area. These hot solutions found their way to the larger fissures, and there deposited their burden. Earth movements have disturbed these veins, forming fresh cavities, which have again been filled by secondary deposition of ore.

2. "The Bituminous Sands of Northern Alberta, Canada." By Lieut. S. C. Ells, 2nd C.E.R.B.

These bituminous sands, of which extensive outcrops occur in Northern Alberta, are of considerable commercial value as material for pavements of various classes. They are of Cretaceous age, and are found in a band overlying unconformably limestones of Devonian age. The sands, which vary much in quality, are always more saturated with bitumen in their lower layers, the amount decreasing upwards: from which fact it is supposed the bitumen has originated from below. A difficulty in the working of these bituminous sands is the considerable (but light in some districts) overburden of the Clear-water shales, also of Cretaceous age. Attempts have been made in the United States to separate the bitumen from the sands, to procure useful commercial products, but at present these have not been very successful. Lieut. Ells illustrated his remarks by a series of excellent slides, giving views of outcrops of the bituminous sands and the methods of working them.

III.—Mineralogical Society.

January 14.—W. Barlow, F.R.S., Past-President, in the Chair.

A. Hutchinson: "Stereoscopic Lantern Slides of Crystal Pictures." The twin pictures are projected by means of a double lantern through screens of complementary tints—red and green—and are viewed through similarly tinted screens, one for each eye. If the adjustment is correct a black and white picture stands out in relief. This method admits of the properties of crystals and of crystal structure being demonstrated simultaneously to a large number of students.—L. J. Spencer: "Mineralogical Characters of Turite (= Turgite) and some other Iron-ores from Nova Scotia." The mineral collection of the late Dr. H. S. Poole, which was presented to the British Museum in 1917, contains, amongst the iron-ores, specimens of magnetite, hæmatite, turite, goethite, limonite, chalybite, mesitite, and ankerite, from many well-defined localities in Nova Scotia. The dehydration curves and optical characters of turite ($2 Fe_2O_3 . H_2O$), goethite ($Fe_2O_3 . H_2O$), and limonite ($2 Fe_2O_3 . 3 H_2O$) prove that these, at least, amongst the large group of ferric hydroxide minerals are distinct species with crystalline structure; some others are colloidal. Turite (= turgite, an incorrect German transliteration from the Russian) is a hard, lustrous, black mineral, with a radially fibrous and concentric shelly structure, and gives a dark cherry-red streak; the fibres are optically birefringent and strongly pleochroic. Sharp brilliant crystals with the forms of goethite, but consisting of anhydrous ferric oxide, i.e. pseudomorphs of hæmatite after goethite, were described.

CORRESPONDENCE.

YUNNAN CYSTIDEA.

Sir,—In bringing (quite courteously) a general charge of inaccuracy against my observations on the Yunnan Cystids, Dr. Cowper Reed (Geol. Mag., February, 1919, p. 93) has confined his instances to two. (1) As regards the diplopores of *Sinocystis loczyi*, many of which certainly appear at first sight to be covered with tubercles of epistereom, I was able to detect the minute openings, just below the apex of the tubercle, even in unworn surfaces from which I myself cleared away the matrix (Geol. Mag., Nov. 1918, p. 512, fig. 5); Dr. Reed was not able to see the openings in such unabraded tubercles. Therefore, while maintaining that the pores normally opened, I have admitted that they might occasionally become clogged. (2) I am glad to assure Dr. Reed that I have never questioned the existence of the "runnels" on the surface of *Ovocystis mansuyi*. I have only denied that they are food-grooves. Those on which I made notes from the actual specimen were attributed to a combination of causes (Geol. Mag., 1918, p. 514).

When novelties are independently described by more than one student, contradictory conclusions and divergent observations are not uncommon. The matter is then generally decided by a fresh observer. He will be greatly assisted to a decision when the original describers have given the detailed evidence for each statement made. Anticipating the scrutiny of future workers, I have always enumerated the material studied and have supported each statement in turn by reference to precise specimens or even to a particular area on a specimen. The present case forms no exception, so any competent observer in Calcutta can soon check my account of the facts by using the same methods of examination.

F. A. Bather.

OBITUARY.

HENRY CHARLES DRAKE, F.G.S.

Born 1864. Died January, 1919.

We regret to record the death of H. C. Drake, F.G.S., of 10 Oak Road, Scarborough, at the age of 55, after a seizure. He was a keen palæontologist, a member of the Palæontographical Society, and made a large collection of vertebrate remains from the secondary rocks. At different periods he lived at Leicester, Hull, and Scarborough, and the museums at each of those places have been enriched by his collections, though possibly that at Hull is the most extensive, and includes a fine series of Saurian and other remains from the Oxford Clay. He also sent specimens to the British Museum (Nat. Hist.) at South Kensington. He wrote a number of papers in the *Naturalist* and in the publications of the Hull Scientific and Field Naturalists' Club, the Leicester Literary and Philosophical Society, and the Scarborough Philosophical Society.

T. S.

CHARLES RICHARD VAN HISE.

Born 1857. Died 1918.

Charles Richard Van Hise was born at Fulton, Wisconsin, and educated at the University of Wisconsin, of which he afterwards became president. The greater part of his life was devoted to teaching and research, and his geological work was chiefly connected with the development of the iron-bearing region of Lake Superior. His researches in this direction led to the publication of an important memoir entitled *Principles of North American Pre-Cambrian Geology*, but his name is perhaps most widely known as the author of a monumental work on Metamorphism, in which the subject is dealt with from many points of view, one of the most important underlying ideas being the conception of successive zones of the earth's crust characterized by different grades of metamorphism, both constructive and destructive, each accompanied by its characteristic type of rock-deformation. Van Hise also investigated the geological relations of the well-known and destructive landslides of the Panama Canal, while his later years were much occupied by administrative work and by special duties connected with the War, including a visit to this country and to France, whence he had only recently returned at the time of his death, following an operation.

R. H. R.

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EDITED BY

HENRY WOODWARD, LL.D., F.R.S.

AND

R. H. RASTALL, M.A., F.G.S.

ASSISTED BY

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APRIL, 1919.

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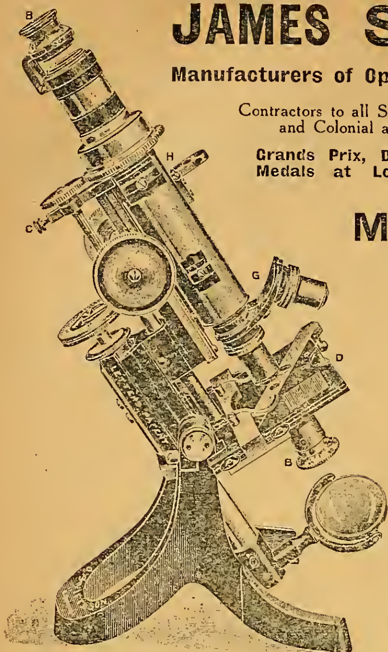

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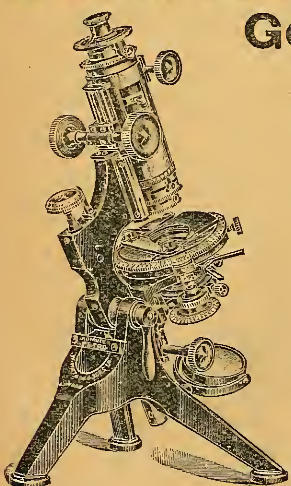

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THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. VI.

No. IV.—APRIL, 1919.

Smithsonian Instit. National Museum

EDITORIAL NOTES.

THE Editors of the GEOLOGICAL MAGAZINE desire to take this opportunity of thanking their friends and subscribers for the kindly expressions of good-will and promises of practical support that have followed the issue of the circular sent out with the December Number. They also wish to say that it is their hope and intention to make the Magazine of service to the geological world as a vehicle for the publication of original work, also as a review of the progress of the science and a means of intercommunication between fellow-workers in different parts of the world. In furtherance of this latter object, they appeal especially to geologists in the British Dominions beyond the seas and in foreign countries to continue to send copies of their publications for review. As a matter of fact, a large number of such publications are actually received, but it is feared that in the last three or four years a good many more never reached their destination. It is certain that a free interchange of ideas between widely separated parts of the world is one of the surest ways of forwarding the progress of knowledge. Geologists in the less developed countries where "fresh fields and pastures new" are constantly turning up, enjoy many opportunities denied to those in regions where field-work and mining investigations have been carried on for over a century and where the great fundamental principles of our science have long been applied and geological features mostly worked out. In new countries geologists and explorers also develop their own theories and represent fresh phases of thought, which should be disseminated as widely as possible for the benefit of mankind at large. The Editors trust that their readers will assist them in their ambition to help in the spreading of new light in the geological world.

* * * * *

THE Annual General Meeting of the Geological Society of London took place on Friday, February 21, when the medals and awards were handed to the recipients, whose names have already been announced in this Magazine. A portrait of Dr. Henry Woodward, F.R.S., painted by Miss Lancaster Lucas, was formally accepted as a gift to the Society. The President also delivered his annual address, the subject chosen being "The Structure of the Weald and Analogous Tracts". It was pointed out how deep borings have shown that the Wealden anticline is a superficial phenomenon imposed on a huge wedge of Jurassic and Lower Cretaceous rocks forming a deep syncline: the accumulation of the Mesozoic sediments took place in a gradually deepening trough with relatively stable sides, and the anticlinal structure was due to a slight reversal of the earlier direction of movement. Similar conceptions were extended to the Jurassic rocks of the Midlands and of Yorkshire; in both cases the recumbent wedge was found to be in evidence, and such structures can probably be traced in Triassic, Carboniferous, and even older rocks. It was also pointed out that where such formations lie above sea-level their outcrops represent areas of maximum development and coincide with the deepest parts of the old troughs. These considerations may be of wide application and have a practical bearing.

* * * * *

The Report of the Council of the Geological Society of London, presented at the Annual General Meeting on February 21, must be regarded as highly satisfactory considering all the circumstances of the time, since it shows that the Society has been able to keep most of its activities unimpaired. The number of Fellows shows, as might be expected, a slight decrease, and there are a good many vacancies in the list of Foreign Members and Correspondents. The financial position is satisfactory, in spite of the increased cost of nearly everything, and more especially of paper and printing. The production of volume lxxiii of the Quarterly Journal cost over £860 exclusive of postage. The generous action of the Council in remitting the annual contributions of those Fellows on active service has led to a diminution of receipts for some years, but that is now presumably a thing of the past. An increase of income may be expected in the future from the admission of women as Fellows, although this is not likely to be very great, at any rate for some time to come. It is well known that the Society's library has been found of the utmost value during the War to the Admiralty, the War Office, and many other Government departments, since it contains publications, and especially maps, not to be found elsewhere in this country. It is gratifying to observe that a small sum has been set aside from the Prestwich Trust Fund for the purchase of books on economic geology, in which the library is still somewhat deficient. It is certain that the demand for economic literature will increase greatly in the immediate future, and this is a step in the right direction.

* * * * *

The *Cambridge University Reporter* for February 18 last announces the subject for the Sedgwick Prize Essay for 1922 as follows: "The Petrology of the Arenaceous Sediments of Lower Cretaceous Age in England, with special reference to the Source of the Material." The prize, which is triennial and of the value of about £80, was not awarded in 1915 or 1918, as is natural under the circumstances, but even in normal times it has happened that no essays have been sent in. This is possibly owing to one of the conditions: that the prize shall be open to all graduates of the University who have resided in Cambridge for sixty days during the twelve months preceding the date at which the essay must be sent in. This greatly limits the number of possible candidates, since few geologists can afford the time to reside for a term in Cambridge for this special purpose.

* * * * *

The list of fifteen candidates selected by the Council for election to the Royal Society contains several names of interest to geologists. The many contributions of Dr. J. W. Evans to geology and mineralogy are well known to all, as well as his wide experience of travel and his activities at the Imperial Institute. He is also now taking a prominent part in the organization of the new Imperial Mineral Resources Bureau. Dr. W. D. Matthew is a Canadian palæontologist who has contributed largely to our knowledge of the fossil mammals of the North American Continent, especially by his generalizations as to the phylogeny of the Cervidæ, Felidæ, and other groups. Sir Charles F. Close, Director-General of the Ordnance Survey, is responsible for the excellent maps which are so invaluable for geological work of all kinds in this country. Mr. E. Heron-Allen, although primarily a protozoologist, recently gave a most interesting lecture before the Geological Society on the application of X-ray photography to the elucidation of the structure of minute fossils, especially Foraminifera, showing results of remarkable technical excellence.

* * * * *

The retirement of Sir Lazarus Fletcher, Knt., M.A., F.R.S., Director of the Natural History Museum, marks the disappearance from active service of the last of the four Keepers who under Professor Owen represented this great section of the old British Museum in Bloomsbury, and were responsible for the transfer of its several collections in 1880 from Great Russell Street, W.C., to their present home in Cromwell Road, South Kensington. Mr. Fletcher, who, after a remarkably brilliant career as a student and mathematician at the University of Oxford, entered the Museum as a First-class Assistant in Mineralogy in March, 1878, succeeded Professor Story Maskelyne as Keeper of Minerals in 1880, a post which he held for twenty-nine years, being made Director of the Museum in 1909, and retiring after ten years in the month of March. During this long period of forty-one years Sir Lazarus Fletcher has rendered important services to science and to the Museum; amongst others may be specially mentioned the arrangement of the entire Mineralogical Collection, and the preparation and publication of a most admirable series of Guide-books, namely, an Introduction to the Study of Meteorites, 1881; to Minerals, 1884; to Rocks, 1895; and, still earlier, an Optical Indicatrix in 1872. Numerous are the honours, medals, and awards which have been conferred upon Sir Lazarus Fletcher, but notwithstanding he is probably one of the most modest, reserved, and retiring scientific men of eminence in London.

* * * * *

The *Times* of March 13 last announced the appointment of Dr. Sidney Frederick Harmer, F.R.S., as Director of the Natural History Museum in place of Sir L. Fletcher. Dr. Harmer, who is the son of

Mr. F. W. Harmer, M.A., F.G.S., was formerly Fellow of King's College, Lecturer in Zoology, and Superintendent of the University Museum of Zoology at Cambridge. In 1907 he was appointed Keeper of Zoology at the Natural History Museum, and it is understood that he will continue to hold this post for a time, conjointly with the Directorship. Dr. Harmer has specialized in Invertebrata, especially Polyzoa, and with Dr. Shipley, now Vice-Chancellor of the University, he edited the Cambridge Natural History. Geologists may feel every confidence that in Dr. Harmer's hands the interests of their science will receive due consideration, and that every facility will be afforded to enable the specialists in charge of the different branches of the Museum to maintain the high standard of the collections and to continue their invaluable work of investigation and research. This appointment is very satisfactory also in that it shows the success of the protest put forward by many leading zoologists and geologists against the proposed appointment of a layman to this important post, which may be regarded as the blue ribbon of the biological world.

* * * * *

The *Mining Magazine* for February last contains a reprint of an interesting lecture by Mr. J. Morrow Campbell on the minerals of the Tavoy district of Burma, a region which has lately come into so much prominence as a producer of tungsten ores. As is well known, the origin and mode of occurrence of the ores in Tavoy have led to a good deal of controversy. Without entering in any way into the merits of the rival theories, it is perhaps permissible to point out the great interest which attaches to such investigations from the scientific as well as from the practical point of view. The origin of ore-deposits and the laws governing their formation are matters within the province of the theoretical petrologist just as much as the study of the silicates, and they possess the added advantage of possibly leading to results of practical value in the prospecting and locating of valuable mining areas. If it can be established, as seems possible, that ores of particular metals commonly show definite relations to one another and to certain types of igneous rock, it will become possible to draw conclusions as to the probability of successful development of metalliferous areas by exploration of a particular kind, such as diamond drilling, for example. As a concrete instance the well-known relations of copper and tin ores in Cornwall may be mentioned, or the association of platinum with serpentine, which actually led to the discovery, based on scientific reasoning, of platinum in the Serrania de Ronda in the South of Spain. In this way the theoretical and the practical geologist can work hand in hand for their mutual benefit and the good of the science in general.

* * * * *

After two years' interval owing to war conditions, the British Association for the Advancement of Science will resume its series of annual meetings this year at Bournemouth, from September 9 to 13, under the presidency of the Hon. Sir Charles Parsons, K.C.B., F.R.S.

ORIGINAL ARTICLES.

I.—Cambrian Hyolithidæ, etc., from Hartshill in the Nuneaton District, Warwickshire.

By E. S. Cobbold, F.G.S.

(PLATE IV.)

PROFESSOR CHARLES LAPWORTH, in his "Sketch of the Geology of the Birmingham District",[1] gives a list of species (pp. 343 and 349) from "the Hyolite Limestone" and the associated shales as provisionally determined by Miss E. M. R. Wood (Mrs. Shakespeare). He referred the beds generally to the Lower Cambrian and paralleled them approximately with the fossiliferous beds of Comley, the details of which had not then been worked out. The present study of the Hyolithidæ, etc., of Woodlands Quarry, fully confirms the reference to the Lower Cambrian, and it would seem that the position of the Hyolite Limestone in the faunal sequence is near to or a little below that of the *Olenellus* and Grey Limestones of Comley at the local summit of the Lower Cambrian. The evidence of this is indirect, for no species has yet been identified from both localities, unless it be *Micromitra labradorica*, Billings sp. Nevertheless, the Hyolithidæ, etc., found in North America that are nearest to, or representative of, those of Hartshill, are there associated more or less intimately with a number of trilobites and brachiopods that find their representatives in the Comley Limestones.

To put the matter in another way: the Hyolithidæ, etc., of Hartshill, combined with the trilobites of Comley, make up what is practically the same Lower Cambrian fauna that is found at North Attleboro', Massachusetts, in the exposures of Manuel's Brook, Newfoundland, and at many intermediate positions.

During the past four years Mr. L. J. Wills, F.G.S., has kindly sent me, for comparison with the forms found at Comley, a number of specimens that he had collected from Woodlands Quarry. This communication is the result of a critical examination of these specimens, without any previous reference to Mrs. Shakespeare's determinations above alluded to.

The specimens are preserved in the Birmingham University collection, and are found upon a number of pieces of red sandy limestone, specially characterized by plentiful tubes of *Coleoloides* and *Hyolithus*. A few other fossils occur and also some very obscure fragments of trilobites which are quite indeterminable. Where unweathered the rock is of a dull purplish-red colour, on which the white sections and fragments of shells stand out clearly. Usually the examples are very unsatisfactory for the shells break open tangentially and rarely show their surface characters. Where weathered the rock becomes brick-red and the fossils occur as casts or partially weathered exteriors, which may be more or less completely freed from the matrix.

Invagination of shells is very frequent, as many as three or four shells of the same species are sometimes found one within another,

[1] Proc. Geol. Assoc., vol. xv, pt. ix, 1898.

and, where they have the same orientation in cross section and are closely approximated, they give the appearance (noted by Billings[1] for *H. communis*) of the individual shell being "thickened by concentric laminæ, and thus approaches the structure of *Salterella*".

A few detached opercula occur, usually very indifferently preserved, and it is impossible to say, without reserve, to which species they belong.

Descriptions of Species.

HYOLITHUS, Eichwald.

Sub-genus ORTHOTHECA, Novak.

Hyolithus (*Orthotheca*) *de Geeri*, Holm. (Pl. IV, Figs. 1–6 and (?) 7–9.)

Hyolithus (*O.*) *de Geeri*, Holm, Sver. Geolog. Undersökning, ser. C, No. 113, p. 54, pl. i, figs. 25–7, 1893.

Orthotheca de Geeri, Holm, Lapworth, Proc. Geol. Assoc., vol. xv, p. 345, 1898.

Shells referred to this species are very plentiful in the collection. They agree closely with Holm's figures and description, the only difference observed being that the apical angle varies from 12° to 8° (taper 1 in 5 to 1 in 7) instead of from "9° to 8°".

The ratio of the sectional diameters also varies somewhat, but is always near to 3 to 2.[2] The surface has a texture as of ground glass, with very faint striæ of growth, which are transverse on both dorsal and ventral sides. The aperture is frequently seen, but in no instance has the apex been preserved. In two cases the internal cast has a smooth convex end representing a septal division below which the shell has been apparently decollated.

Operculum.—A few examples of opercula occur that are referred with reserve to this species. In outline they agree with the transverse section of the principal shell; the margin is practically in one plane; the nucleus is situated at about two-thirds of the diameter from the dorsal edge; the semi-conical portion is clearly marked off by two radiating lines, and in addition to these, on the exterior surface, two other radiating lines are seen, marking off triangular portions on each side similar to those of the opercula of *Hyolithus*, *sens. strict.*, at the places where the curvature changes from the conical (dorsal) portion to the upturned (ventral) part; at the bases of these triangles the margin is seen in a side view to be a little depressed from the general plane; the ventral margin is marked by a slightly raised, rounded fillet, between which and the nucleus there is a pit-like hollow.

H. (*O.*) *Johnstrupi*, Holm,[3] has a cross section that is somewhat similar, but the dorso-ventral diameter is proportionately greater and the surface marks are described as being rather strong.

H. primævus, Groom,[4] from Malvern, has a very similar cross section but a rather greater apical angle (10° to 11°) and indications

[1] Billings, *Canada Naturalist and Geologist*, ser. II, vol. vi, p. 214.

[2] Where the ratios of the diameters are mentioned in this paper it is intended to indicate those of the width to the dorso-ventral diameter.

[3] Op. cit., p. 56, pl. i, figs. 28–33.

[4] Q.J.G.S., vol. lviii, p. 116, 1902.

of longitudinal striæ; it is uncertain whether this species is an *Orthotheca* or *Hyolithus*.

H. (*O.*) *Emmonsi*, Ford,[1] appears to be the nearest American species; the cross section and rate of taper are very similar, the principal distinguishing feature being a shallow hollow all along the dorsal side, making it slightly concave.

Horizon and Locality.—Lower Cambrian : red sandy limestone of Woodlands Quarry, Hartshill.

(? Sub-genus) HYOLITHUS[2] (Holm).

Hyolithus (*H.*) *alatus*, sp. nov. (Pl. IV, Figs. 13–15 and (?) 16.)

? *Hyolithus* cf. *obscurus*, Holm, Lapworth, Proc. Geol. Assoc., vol. xv, pt. ix, p. 343, 1898.

Type-specimen [34].[3]

Diagnosis.—Shell slightly curved toward the ventral side, taper about 1 in 4 (equivalent apical angle 14°); greatest length about 24 mm., diameter of aperture 6 mm.; apex having the same rate of taper as the remainder of the shell, often filled with calcite, but no septa have been observed. Section, dorsal face gently convex centrally, almost concave towards the lateral angles which form rounded projections, ventral face strongly convex centrally, slightly concave towards the lateral angles, ratio of axis 1 : ·6. Surface, resembling ground glass, but marked with striæ of growth, which are transverse on the ventral side, but convex forwards on the dorsal. Aperture in two planes, dorsal lip projecting to a distance equal to about two-thirds of the longer diameter; ventral lip a little sinuous, with a rounded notch on the centre line.

Operculum (?): several examples occur which are assigned with little hesitation to this species. In the view of the operculum as usually seen the outline is nearly circular (Fig. 16), but when the plate is tilted so as to bring the dorsal margin parallel to the line of sight the outline conforms very closely to the section of the shell. In the circular view the nucleus is distant about four-fifths of the diameter from the dorsal margin, and the sides of the conical part meet at an angle of 110° to 120°; the ventral portion is strongly concave and rises in front (the upper side in the figure) like an upturned brim to a soft felt hat to about twice the height of the nucleus. The curve joining the ventral to the dorsal margin is slightly indented in correspondence with the alate lateral angles of the shell.

Comparisons with other species.—The section of *H. alatus* is of the same character as that of *Hyolithus* sp. *a*, Groom,[4] but is not provided with a "blunt keel", and the proportion between the diameters is different. The species is readily recognized by its alate cross section.

H. obscurus[5] has two impressed lines on the dorsal side close to

[1] *Amer. Journ. Sci.*, ser. III, vol. v, p. 214, figs. 3*a–e*.

[2] It seems doubtful whether Eichwald's genus *Hyolithus* can be used, *sens. str.*, also as a *sub-genus*.—H. W.

[3] Numbers in square brackets are those attached to the blocks on which the specimens are found.

[4] Groom, op. cit., 1902, p. 116.

[5] Holm, op. cit., 1893, p. 76, pl. v, figs. 29–33.

each lateral angle; these cause the angles to project something like those of *H. alatus*; the ventral side is, however, bluntly keeled.

Horizon and Locality.—Lower Cambrian: red sandy limestone of Woodlands Quarry, Hartshill.

Hyolithus (*H.*) *biconvexus*, sp. nov. (Pl. IV, Figs. 10–12.)

? *Hyolithus* cf. *lenticularis*, Linnarsson, Lapworth, Proc. Geol. Assoc., vol. xv, pt. ix, pp. 343, 349, 1898.

Diagnosis.—Shell straight, taper 1 in 3 to 1 in 4 (equivalent apical angle 18° to 14°), length of type-specimen 14 millimetres, diameter of mouth in another specimen 5 mm. Section biconvex, dorsal face moderately convex, ventral strongly convex, ratio of diameters 1 to ·66, lateral angles rather sharply rounded; aperture in two planes, dorsal lip projecting but little; surface marked by fairly strong ridges of growth, spaced about eight to the millimetre in the body of the shell, but closer near the aperture, and having a tendency to be alternately strong and weak; the ridges are strongly bent forwards on passing the lateral angles; interior, surface apparently smooth.

Operculum (?): one or two examples of opercula that may belong to this species have been found. They are constructed on the same general lines as those assigned to *H. alatus*, but are more oval in outline as usually seen in the rock, the ventral margin does not rise to so great a height above the convex conical portion of the plate, and the sides of the conical portion meet at an angle of about 90°.

Comparison with other species.—*H. biconvexus* has a similar section to that of *H. acadica* (Hart MS.), Walcott,[1] which, however, has faint longitudinal striæ and a greater apical angle.

The Middle Cambrian form *H. socialis*, Linnarsson,[2] has a somewhat similar section, but a smaller apical angle, and is provided with a rounded keel on the ventral side.

H. lenticularis, as figured by Holm,[3] has its dorsal and ventral sides equally convex.

Horizon and Locality.—Lower Cambrian: red sandy limestone of Woodlands Quarry, Hartshill.

Hyolithus (*H.*) *Willsi*, sp. nov. (Pl. IV, Figs. 17, 18.)

? *Hyolithus* cf. *princeps*, Billings, Lapworth, op. supra cit., pp. 343, 349.

The type-specimen [27 and 28] exhibits a fragment of the dorsal face together with (on the other side of the piece of limestone) the much-weathered ventral face, from which the outline of the shell may be reconstructed; two oblique sections are also visible.

Diagnosis.—Shell large, straight, tapering at the rate of 1 in 2·6 (equivalent apical angle 22°). Section uncertain (the specimen

[1] U.S. Geol. Surv., Bull. 10, 1884, p. 20, pl. ii, fig. 5.
[2] Holm, op. cit., 1893, p. 78, pl. i, figs. 72–7.
[3] Id., p. 77, pl. v, figs. 23–8.

has uneven surfaces, indicating some amount of damage or compression when freshly embedded in the matrix), ratio of axes (as preserved) 1 to ·5; aperture in two planes, dorsal lip projecting a distance equal to one-third of the width (in the type-specimen it is somewhat emarginate at the central line); surface marked near dorsal lip with obvious lines of growth, elsewhere unknown; internal surface finely granular; dimensions, the complete shell (as reconstructed) would be about 63 millimetres long and the width of aperture (as preserved) is about 20 mm.

Comparison with other species.—*H. Willsi* is only exceeded in size by the Bohemian species *H. giganteus*, Novak[1] (Ordovician), and *H. maximus*, Barrande (Middle Cambrian).[2] It is of about the same length as *H. princeps*, Billings,[3] which, however, is much more acuminate.

H. Willsi agrees closely in some respects with *H. excellens*, Billings,[4] from the Red Limestone of Trinity Bay, Smith's Sound, Newfoundland. The Hartshill species has the same length, width, rate of taper, and projection of dorsal lip, but its other characters (convexity and surface marks) are unknown, and until further material is available from Hartshill it seems best to describe it under a new specific name.

Horizon and Locality.—Lower Cambrian: the red sandy limestone of Woodlands Quarry, Hartshill.

Hyolithus (*H.*) *æquilateralis*, sp. nov. (Pl. IV, Figs. 21, 22.)

Type-specimens [25, 2].

Diagnosis.—Shell straight and tapering uniformly, so far as known, at a rate of about 1 in 5 (equivalent apical angle about 12°), apex not preserved. Section, dorsal face very gently convex, lateral angles rounded, ventral face consisting of two surfaces which are very slightly, if at all, more convex than the dorsal and are joined by a rounded angle, the whole forming an equilateral triangle; aperture in two planes, dorsal lip projecting to a distance of about one-quarter of the diameter, exterior not known.

Remarks.—This species seems somewhat scarce; where the cross section can be observed it is easily recognized, but otherwise it is difficult to distinguish it from some views of *H.* (*O.*) *de Geeri*, with which it agrees in the rate of taper. It is near to *H. Americanus*, Billings,[5] which has a similar triangular section, but is not so equilateral; the projection of the dorsal lip also appears to correspond. The exterior of that species is marked by transverse lines of growth and longitudinal striæ.

Horizon and Locality.—Lower Cambrian: the red sandy limestone of Woodlands Quarry, Hartshill.

[1] K. Böhm. Gesell. der Wissensch., Folge vii, Band iv, No. 4, p. 19, pl. iv, figs. 40–50, 1891.

[2] *Sil. Syst. de Bohème*, vol. iii, p. 5, pl. x, figs. 22–9, 1867.

[3] *Can. Naturalist and Geologist*, N.S., vol. vi, p. 216, 1872.

[4] Id., p. 471.

[5] Billings, op. cit., 1872, p. 215.

SALTERELLA, Billings.

Salterella (?) *curvata*, S. & F. (Pl. IV, Figs. 16*a*, *b*.)

Salterella curvatus, S. & F., Bull. Mus. Comp. Zool. Harvard, vol. xvi, p. 34, pl. ii, fig. 22, 1888.
,, ,, ,, Walcott, Tenth Ann. Rep. U.S. Geol. Surv., p. 625, pl. lxxix, figs. 3, 3*a*, 1890.
,, ,, ,, Grabau, Occ. Papers Boston Nat. Hist. Soc., vol. iv, p. 660, pl. iii, 1900.

Two specimens on one block [38] in the collection suggest a reference to Shaler and Foerste's species; they lack, however, the cone-within-cone structure of shell that characterizes the type species for the genus *Salterella rugosa*. They are curved tapering tubes with a rounded or somewhat oval section, scarcely three millimetres long and less than one mm. in diameter. The aperture is not seen, the open ends being fractured. The shell is thick; its outer surface is smooth but marked near the apex with very faint transverse striæ spaced about eight to the millimetre. The interior is also smooth, and though filled with calcite shows no trace of annulations or septal divisions. The rate of taper is about 1 in 4, equivalent to an apical angle of 14°.

Horizon and Locality.—Lower Cambrian: the red sandy limestone of Woodlands Quarry, Hartshill.

COLEOLOIDES, Walcott.

Coleoloides typicalis, var. *multistriata*, var. nov. (Pl. IV, Figs. 30, 32.)

Coleoloides typicalis, Walcott, U.S. Nat. Mus. Proc., vol. xii, pl. xxxvii, 1889.
,, ,, ,, U.S. Geol. Surv., Tenth Ann. Rep., p. 624, pl. lxxix, figs. 6, 6*a*, 1890.
,, ,, ,, Lapworth, Proc. Geol. Assoc., vol. xv, pt. ix, p. 343, 1898.

Straight tubes of circular section with very slight taper are plentiful in the rock specimens to hand, but very rarely preserve the original surface.

In two instances [15 and 38], however, the external surface marks are perceptible: they are very closely set spiral lines, numbering about seventy in the whole circumference of the tube, which is one millimetre in diameter; they are inclined at such an angle as to make one complete circuit of the tube in a length equal to about 10 diameters.

C. typicalis, Walcott, as figured, has much fewer spiral lines and they are set at a more acute angle.

The tubes vary in diameter from 1 to 1·3 millimetres.

Horizon and Locality.—Lower Cambrian: red sandy limestone of Woodlands Quarry, Hartshill.

BRACHIOPODA.

MICROMITRA (Meek), Walcott.

Micromitra cf. *Phillipsi*, Hall, sp. (Pl. IV, Fig. 25.)

Obolella Phillipsi, Holl, Q.J.G.S., vol. xxi, p. 102, figs. 10*a–c*, 1865.
O. (?) *Phillipsi* (Holl), Davidson, Pal. Soc. Mon. British Fossil Brachiopoda, vol. iii, pt. vii, p. 62, pl. iv, figs. 17–19, 1866.

Kutorgina cingulata, Davidson, id., p. 342, pl. i, fig. 25, 1871.
K. cingulata Phillipsi (Holl), Matley, Q.J.G.S., vol. lviii, p. 145, 1902.
Micromitra (*Paterina*) *Phillipsi* (Holl), Walcott, U.S. Geol. Surv. Mon., vol. ii, p. 351, pl. iii, fig. 8, 1912.

One external cast of a ventral valve and a few obscure fragments are very like specimens obtained at Malvern and Comley.

The general outline and surface characters agree with Holl's species, but, in the absence of further specimens and particularly those showing the false area and pseudodeltidium, the reference is made with considerable reserve.

Horizon and Locality.—Lower Cambrian: the red sandy limestone of Woodlands Quarry, Hartshill.

GASTEROPODA.

Platyceras, Conrad.

Platyceras cf. *primævum*, Billings. (Pl. IV, Fig. 34.)

Platyceras primævum, Billings, Can. Nat., n.s., vol. vi, p. 220, 1871.
,, ,, ,, Walcott, U.S. Geol. Surv., Bull. 30, p. 130, pl. xii, figs. 5, 5*a*, 1886.
,, ,, ,, Grabau, Occ. Papers Boston Nat. Hist. Soc., vol. iv, pt. iii, p. 628, pl. xxxi, figs. 7*a*, *b*, 1900.

A single specimen [37] consisting of an internal cast of a whorled shell with oval aperture appears to be nearly allied to or, possibly, identical with Billings' species. In the absence of better preserved specimens the reference must remain doubtful.

Horizon and Locality.—Lower Cambrian: the red sandy limestone of Woodlands Quarry, Hartshill.

Helcionella, Grabau & Shimer.

Helcionella (?) *emarginata*, sp. nov. (Pl. IV, Figs. 26, 27.)

The type-specimen [46] shows two internal casts, from one of which a fragment of the external cast was preserved during development, indicating the character of the surface.

Diagnosis.—Shell strongly recurved so that the apex projects beyond the limit of the posterior margin; aperture almost circular, slightly flattened anteriorly owing to the presence of a rhomboidal notch; apex (in the cast) somewhat blunt; exterior with many irregular raised lines of growth, some of which are more pronounced than others; all conform in shape to the apertural notch; no radiating striæ detected in the material to hand; interior marked with several, irregularly arranged raised concentric lines, seen as depressions in the cast, in addition to which there are in one of the specimens (Fig. 26) two symmetrically arranged rounded and ill-defined depressions, that simulate muscle-scars of Brachiopoda, but it seems more probable that they are somewhat fortuitous and possibly connected with the trace of the apertural notch.

Dimensions.—Length of aperture about 4·5, width 5, height 2·5 mm.

Observations.—So far as known to the writer the aperture of *Helcionella* is entire. The notch in this species is suggestive of

Bellerophon, and it is possible that it should be relegated to a new genus and placed among the Heteropoda. The general form is suggestive of the ventral valve of an elevated Brachiopod, but the notch being at the anterior margin cannot be a pedicle opening.

Pelagiella, Matthew,[1] and *Watsonella*, Grabau,[2] have similar notched margins, but are very different in other respects.

Horizon and Locality.—Lower Cambrian: the red sandy limestone of Woodlands Quarry, Hartshill.

Stenotheca (Salter), Grabau & Shimer.

Stenotheca abrupta, Shaler & Foerste (?). (Pl. IV, Figs. 28, 29.)

Stenotheca rugosa, var. *abrupta*, S. & F., Bull. Mus. Comp. Zool., vol. xvi, p. 29, pl. i, figs. 9*a*, *b*, 1888.
S. (?) *rugosa*, var. *abrupta* (S. & F.), Walcott, Tenth Ann. Rep. U.S. Geol. Surv., p. 617, pl. lxxiv, figs. 6, 6*a*, 1890.
S. abrupta (S. & F.), Grabau, Occ. Papers Boston Nat. Hist. Soc., vol. iv, pt. iii, p. 637, pl. xxxi, figs. 12*a*–*c*, 1900.

A few internal casts agreeing closely with Walcott's figures seem to indicate the presence of this form.

They show from six to ten rounded corrugations; the section is an elongate oval with the axes in the proportion of 1 to ·5; the apex is curved over so as to stand approximately above the posterior margin of the aperture. Exterior not observed; no thickening of the ventral margin, such as is spoken of by Grabau (op. supra cit.) has been detected. Dimensions (of largest specimen): length 5, width 2·5, height 4·5 mm.

In the absence of good exteriors of these shells it seems doubtful whether they should not be referred to *Helcionella*, the genus proposed in 1910 by Grabau & Shimer for forms congeneric with *Metoptoma rugosa*, Hall. It is consequently necessary to give the specific reference with reserve.

Locality and Horizon.—Lower Cambrian: the red sandy limestone of Woodlands Quarry, Hartshill.

LAMELLIBRANCHIATA.

Fordilla, Barrande.

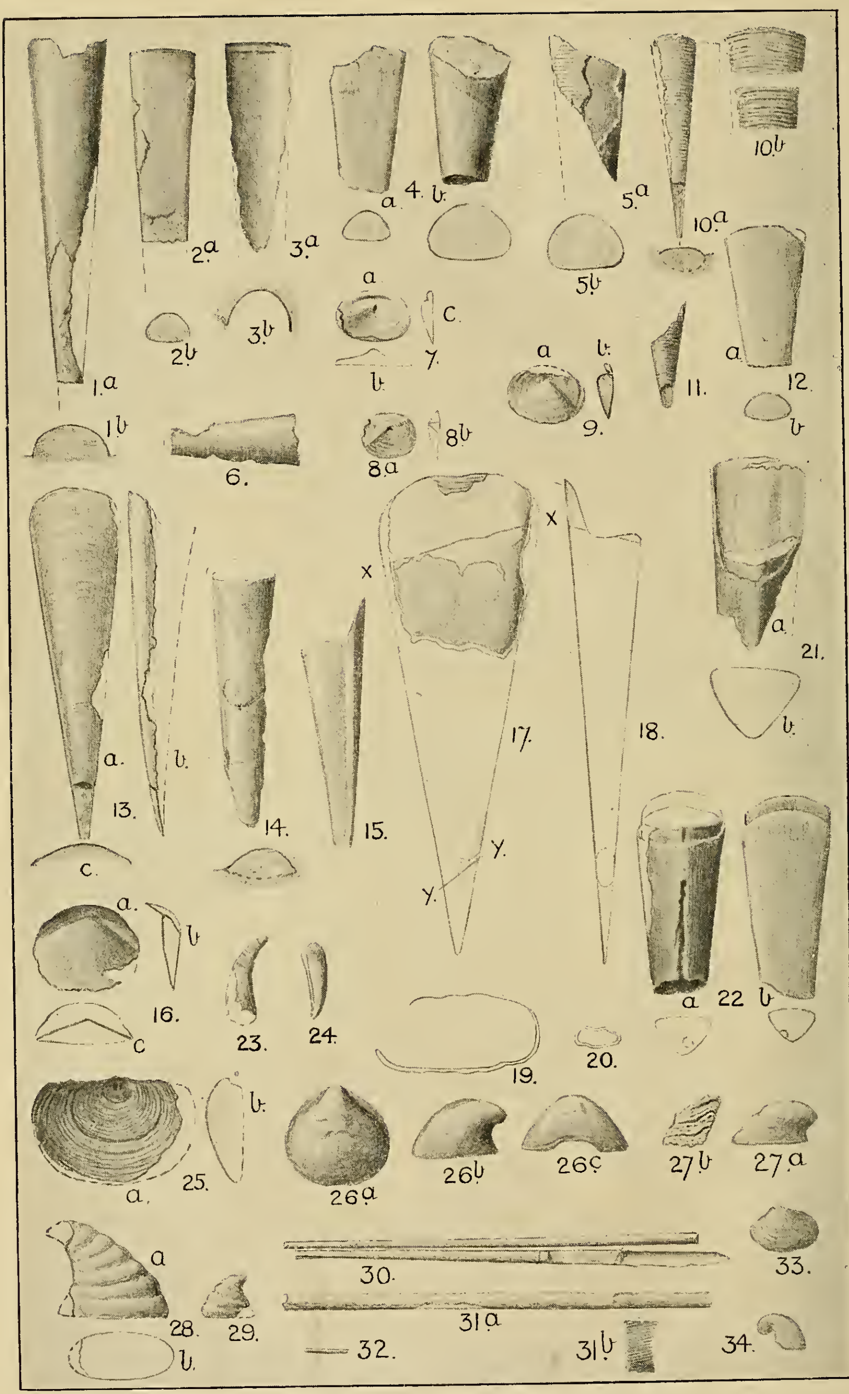
Fordilla troyensis, Barrande (?). (Pl. IV, Fig. 33.)

Fordilla troyensis (Barrande), Walcott, Bull. U.S. Geol. Surv., No. 30, p. 125, 1886.
,, ,, ,, Walcott, Tenth Ann. Rep. U.S. Geol. Surv., p. 615, pl. lxxiii, figs. 2, 2*a*–*c*, 1890.
,, ,, ,, Grabau, Occ. Papers Boston Nat. Hist. Soc., vol. iv, pt. iii, pp. 610, 611, 633, 1900.

A single shell occurs with the Hyolithidæ from Woodlands Quarry agreeing in many respects with Walcott's figures for this species.

It appears to be the somewhat worn exterior of a left valve, and is about 3 mm. long with the umbo situated a little in advance of the mid-length. No radial striæ are preserved, and the concentric lines of growth are not so thickly set as those shown in Walcott's figures.

[1] Trans. N.Y. Acad. Sci., vol. xiv, p. 131, 1895.
[2] Op. cit., p. 631, 1900.


1.a
1b
2.a
2b
3.a
3b
4. a b.
5.a
5b
6.
7. a b c.
8a
8b
9. a b.
10.a
10b
11.
12. a b
13. a. b. c.
14.
15.
16. a. b c
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x
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21. a. b.
22 a b
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26a
26b
26c
27a
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28. a b.
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30.
31a
31b
32.
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34.

Horizon and Locality.—Lower Cambrian: the red sandy limestone of Woodlands Quarry, Hartshill.

I desire to express my gratitude to Mr. L. J. Wills for allowing me to study and describe his specimens, and also to Dr. F. A. Bather for much kind help in reference to the literature of the genera *Salterella*, *Stenotheca*, and *Helcionella*.

EXPLANATION OF PLATE IV.

NOTE.—The numbers in square brackets are those attached to the blocks on which the specimens are found. All belong to the collection of the Birmingham University.

Hyolithus (*Orthotheca*) *de Geeri*, Holm. × 2. (See p. 150.)

FIG.

1 [37]. Ventral side; *a*, exterior; *b*, section.
2 [36]. Dorsal side, showing transverse lip; *a*, internal cast; *b*, section.
3 [34]. Ventral side, showing transverse lip; *a*, external cast; *b*, section.
4 [29]. A detached internal cast; *a*, dorsal; *b*, ventral; with sections at ends.
5 [31]. Fragment showing sculpture; *a*, ventral side; *b*, section.
6 [20]. An internal cast, showing form of septum.
7 [12]. Interior of operculum
8 [14]. External cast of operculum } referred with reserve to this species.
9 [18]. Internal cast of operculum

Hyolithus biconvexus, sp. nov. × 2. (See p. 152.)

10. Type-specimen [31]; *a*, exterior of dorsal side, with *b*, enlargements to 4 diameters to show character of sculpture.
11 [36]. Fragment of exterior of ventral side.
12 [34]. Internal cast; *a*, dorsal side; *b*, section.

Hyolithus alatus, sp. nov. × 2. (See p. 151.)

13. Type-specimen [34]; *a*, dorsal side exterior; *b*, side view; *c*, section.
14 [37]. Ventral side, showing lip slightly notched, with section.
15 [33]. Internal cast, side view.
16 [14]. *a*, internal cast of operculum referred with reserve to this species; *b* and *c*, side and axial views in outline.

Hyolithus Willsi, sp. nov. Nat. size. (See p. 152.)

17. Type-specimen [27 and 28]. An exfoliated dorsal side with form of shell shown by the weathered ventral side.
18. Same specimen, side view in outline, reconstructed.
19, 20. Same specimen, diagonal sections at fractures XX and YY.

Hyolithus æquilateralis, sp. nov. × 2. (See p. 153.)

21. Type-specimen [2]. *a*, exterior ventral side and interior dorsal side; *b*, section.
22. Co-type [25]. Internal casts of two invaginated shells; *a*, ventral side; *b*, dorsal.

Salterella (?) cf. *S. curvata*, S. & F. × 4. (See p. 154.)

23 [38]. Exterior.
24 [38]. Internal cast of a second specimen.

Micromitra cf. *Phillipsi*, Holl, sp. × 5. (See p. 154.)

25 [37]. External cast, with side view of a squeeze.

Helcionella (?) *emarginata*, sp. nov. × 3. (See p. 155.)

26. Type-specimen [46]. An internal cast. *a*, summit view; *b*, side view; *c*, anterior view.
27. Co-type [46]. *a*, internal cast of a second specimen, side view; *b*, fragment of the external cast showing character of sculpture.

Stenotheca abrupta, S. & F. (?). × 3. (See p. 156.)

28 [3]. *a*, internal cast; *b*, outline of aperture.
29 [5]. Internal cast.

Coleoloides typicalis, Walcott, var. *multistriata*, nov. × 2. (See p. 154.)

30 [38]. Two specimens, showing slight taper.
31. Type for var. [38]. *a*, exterior; *b*, character of sculpture. × 6.
32 [30]. A very minute tube, × 2.

Fordilla troyensis, Barrande (?). × 3. (See p. 156.)

33 [15]. Exfoliated exterior.

Platyceras primævum, Billings (?). × 4. (See p. 155.)

34 [37]. Internal cast.

II.—Cyclones and Climate.

By R. Mountford Deeley, M.I.C.E., F.G.S.

FROM time to time I have been given an opportunity to discuss in the Geological Magazine the question of the cause or causes of climatic variations. The subject is one of deep interest to the geologist. Even Lyell, in the first edition of his *Principles of Geology*, gave a good deal of space to it, but contented himself with merely pointing out that variations in the distribution of the land would lead to changes in the climate. He wisely limited himself to this aspect of the question, for, at that time, the directions of the winds in middle latitudes were not such as meteorological theory would have led us to expect.

The view was held in Lyell's time that the winds were the result of the varying temperature of the air from place to place. The centre of a cyclone came to be considered as consisting of a column of warm air with cooler surroundings. The central warm air rose, became chilled by expansion, and threw down its moisture in the form of clouds, rain, hail, snow, etc. But the two great permanent cyclones of the earth lay over or in the neighbourhood of the two poles of cold, just where it seemed impossible, or very unlikely indeed, that a warm column could exist. This was the great "stumbling-block" to all progress. Indeed, it was held by many that, as further information of the climatic conditions of the polar areas was obtained, it would be found that there were really polar anticyclones within the polar cyclones. But the barometric pressures found within the Arctic Sea, and at the most southerly portion of the Ross Antarctic Barrier, show that such polar anticyclones do not exist, and the strength and constancy of the "brave south-westerly winds" of the southern oceans continued to be one of the greatest of scientific puzzles.

At the end of the nineteenth century meteorologists began to turn their attention to the study of the conditions obtaining in the upper air. Small balloons, having attached to them self-registering thermometers and barometers, were sent up to sound the atmosphere, and very unexpected results were obtained. It was found that up to a variable height of about ten kilometres the temperature gradually fell at such a rate as very nearly to establish a condition of convective equilibrium. This condition is one such that air moved from one height to another, owing to the expansion or compression it undergoes, changes its temperature so as to agree with that of the surrounding air. This layer of the atmosphere has been named the troposphere. Above it the temperature conditions are quite different, for the temperature either varies little with increasing height or actually becomes much warmer. This upper layer has been called the stratosphere.

In the troposphere the conditions of temperature are such that the free flow of the air is possible in re-entrant paths, both horizontally and vertically. But such is not the case in the stratosphere. Here rising air would be chilled and find itself on a level with air warmer than itself, and air falling would rise in temperature and be on a level with air colder than itself. For this reason vertical air currents of any strength must be almost entirely absent in the stratosphere, but horizontal movements may take place freely, or the whole may rise or fall bodily.

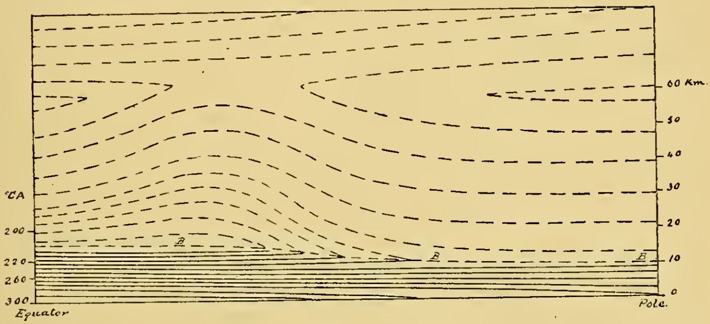


Fig. 1.

Many thousands of self-registering balloons have been sent up and much detailed information obtained concerning the temperature conditions of the atmosphere in different latitudes and at various heights.

The point of supreme interest is, of course, the temperature difference between cyclonic and anticyclonic areas. Strange to say, there has proved to be little difference between the temperature conditions existing in the great polar cyclones and those of the smaller wandering ones, which affect our climate so much from day to day.

The most astonishing feature of the cyclone proved to be that, in the troposphere, the centre of the cyclone was colder than its margins, just the opposite to what had been considered likely. Far too much importance was at first attached to this peculiar fact, for it unduly discredited the broad teaching of the "temperature gradient" theory of cyclones. Indeed, Aitkin has shown that although in the troposphere the temperature is lower in the centre of the cyclone than at its margins, owing to its lower pressure, the air is really lighter.

Anticyclonic areas are now regarded as being the normal conditions of the atmosphere in which cyclones move, rather than as special features of the atmospheric distribution of temperature and pressure.

Fig. 1 is a diagrammatic section of the atmosphere from the equator to the pole. The isothermal lines drawn in full are in accordance with the teachings of registering balloon soundings, but the dotted lines are purely theoretical. The great rise of the isothermals over latitude 30° is probably more pronounced in the diagram than it should be. B B is the line of separation between the stratosphere and the troposphere. Discussion now centres itself mainly on what takes place where these two portions of the atmosphere meet.

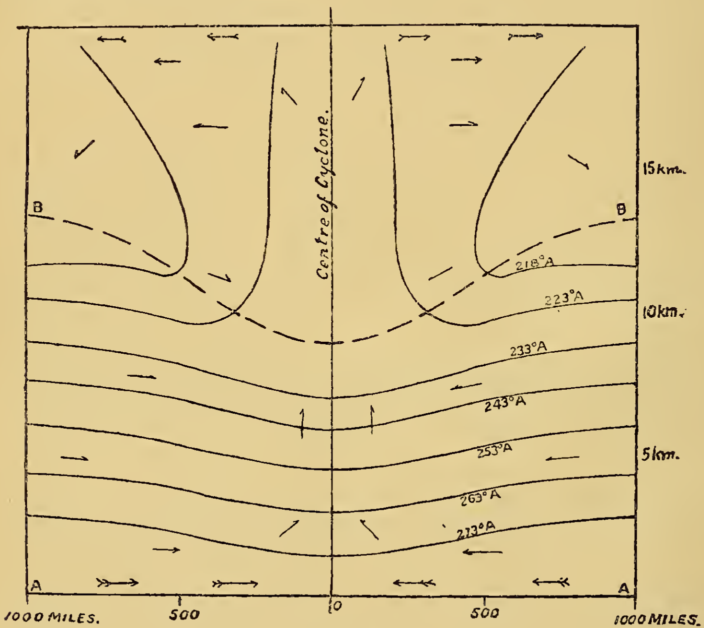


Fig. 2.

As a result of the consideration of a large number of atmospheric soundings Dines has drawn a diagram showing the temperature conditions obtaining in the average cyclone. It is shown in Fig. 2. Here the arrows indicating the probable nature of the very slow general circulation of the air, to and from the centre of the cyclone, have been added by the writer. The similarity of the temperature distribution shown by these two diagrams is very striking. The line of junction B B separating the stratosphere from the troposphere dips down in the travelling cyclone just as it does in the polar cyclone.

Such are the facts, as near as they are known, with regard to the temperature distribution in the atmosphere. It remains to consider the cause of this peculiar distribution and its bearing upon the theory of cyclones.

The temperature of the earth's surface and of the atmosphere is much above that of space, owing to the radiations received from the sun, and also very probably owing to the bombardment of cosmic matter to which the atmosphere is subjected at its upper limit. Not only do we receive heat from the sun in the form of heat and light rays and X radiations, but it has been shown that electrons are being shot out from the sun at enormous velocities. These electrons, when they reach the magnetic field of the earth, are captured and are directed in long spirals towards the poles, where they give rise, among other phenomena, to the auroral lights. Meteors, both large and small, strike the atmosphere at high velocities and heat it, and there would seem to be pencils of high velocity cosmic matter, which are also arrested by the atmosphere.

The energy thus directed earthwards is mainly either arrested by the upper atmosphere or by the lower portion of the troposphere and the earth's surface. The radiant energy which is arrested by the upper atmosphere heats the air, and this heat passes downwards to the lower portions of the stratosphere by radiation and conduction, not by convection. The undulations, to which the clear atmosphere is transparent,and which pass through it, are intercepted by the earth's surface and by clouds, water vapour, and carbonic acid. This lower warmed stratum of air then rises and cools by expansion, with the result that the troposphere assumes the condition of convective equilibrium.

Balloon ascents show that above cyclones the air of the stratosphere is warmer than it is above anti-cyclonic areas, and that the lower boundary of the stratosphere is lowest near cyclonic centres. But in Fig. 2 the air is shown to be rising in the centre of the cyclone, and it has been suggested that if the air is rising in such areas the line B B should bulge upwards.

As already remarked, Aitkin, in a paper read before the Royal Society of Edinburgh in June, 1916, showed that although the core of a cyclone is colder than the surrounding regions of high pressure, yet the air in the cyclone is lighter. This low density is due to the air being under a lower pressure, and this more than compensates for the lower temperature; so that though the air in cyclones is colder, yet it is lighter than the surrounding air, and the central core, therefore, tends to ascend both in the troposphere and the stratosphere.

In *Nature* for January 30, 1919, Dines remarks: "Mr. Deeley's suggestion (*Nature*, January 16, p. 385) that the cyclone is caused by the high temperature of the stratosphere does not seem to me to be feasible for the following reason: Owing to the temperature inversion, or, at least, to the cessation of the lapse of temperature with height, the boundary between the troposphere and stratosphere is, in general, perfectly definite, as definite almost as the boundary between oil and water would be. If then any sort of sucking action

—to use an incorrect but convenient expression—were exercised by the lightness of the air above the boundary, it ought to draw up the boundary itself as well as the air below it. This is exactly the reverse of what happens; the boundary bulges downwards in the cyclone and upwards in the anticyclone."

However, the air in the stratosphere and troposphere does not differ as do oil and water. The difference is merely one of temperature, and if the heat of the stratosphere is flowing downwards in the direction of the temperature gradient, faster than the air is rising, then, in spite of rising air, the boundary will bulge downwards. The bulging downwards of the isotherms right up to the boundary of the troposphere above proves that the air is rising there. To refer again to the letter in *Nature* by Dines, it will be seen that he says, "But if we postulate an outward radial sucking force acting horizontally on the water just below the common boundary, the water will rise from below at the centre, the common boundary will fall, and the layer of oil will thicken, and this is just what occurs in the layers of air . . . *but I do not see how an outward acceleration can be applied horizontally to the layers of air at the top of the troposphere.*" The italics are my own. Considering that the downward bulge of the isotherms of the troposphere occurs close up to the stratosphere, there is no room for such an outward flow, nor has such a flow ever been detected.

Owing to the large diameter of the cyclone and its thinness, even if there should be a considerable flow inwards the rise of the air over the whole area would be small. When much rain is thrown down in a cyclone it is not due to a general rise of the air, it is due to one current mounting another current locally. It is more reasonable to suppose that the explanation of the downward bulge of the boundary is due to the downward penetration of heat being more rapid than the upward rise of the air.

It is impossible to account for the existing climatic conditions of the earth on the assumption that the winds are produced entirely by the temperature distribution in the troposphere; for the direction of the winds of middle latitudes is opposed to the temperature gradient. It is the heating of the upper side of the stratosphere (the upper limits of the atmosphere) that results in the winds flowing in the troposphere towards the poles from middle latitudes, in spite of the ground temperature gradient.

A polar sea, with low land or islands, well connected with the great oceans, would remove to a large extent the present surface temperature gradient, which tends to lessen the force of the ground winds flowing polewards, and would enable the effect of the high temperature of the stratosphere (over the poles) to strengthen the winds flowing towards the poles. These winds would induce ocean currents flowing in the same direction. Indeed, given fairly open water connexions between the Arctic Sea and the great oceans, there is no reason why the Polar area should not be tropical in its climate.

III.—On Borings at Cotefield Close and Sheraton, Co. Durham (Permian and Coal-measures).

By David Woolacott, D.Sc., F.G.S.

DURING the last year I have examined, through the kindness of Mr. E. O. Forster Brown, Min. Eng., borings that have been put down by Messrs. Bell Bros., at Cotefield Close and Sheraton, near the southern limits of the Northumberland and Durham Coalfield. They are situated about 5 miles west of Hartlepool, and about 8½ miles east of the Permian escarpment at Ferryhill. The boring at Cotefield Close lies about 1½ miles east of Hurworth Burn station, and about the same distance south of that at Sheraton. The details of the former are from my own notes which were taken when the hole was finished, but those of the Sheraton cores are by Dr. C. T. Trechmann, who examined them as they were brought up from time to time, it thus being possible to obtain a very full record. I also desire to thank this geologist for some notes on the Sheraton boring which are incorporated in this paper. Both of the boreholes passed through the superficial deposits and Permian strata into the Coal-measures, but as that at Sheraton has just entered the last-named series and is not yet completed, the remarks on the Carboniferous rocks refer only to the strata pierced at Cotefield Close. The examination of these cores adds to our knowledge of the Permian, confirming some of the points that Dr. Trechmann and I have enunciated in previous papers dealing with the Magnesian Limestone. The boring at Cotefield Close is also of interest because it penetrated the Lower Coal-measures beneath the Brockwell Seam and gives a section of the little-known Ganister Series. It is hoped in a subsequent note to deal with any noteworthy features that may arise in connection with the Carboniferous rocks of the Sheraton borehole.

It is known that the Coal-measures in the south of Durham rise to the south beneath the Permian and are cut by the Butterknowle fault, which throws them down to the south so that a small area of northerly and steeply dipping measures lies on the south of this fracture.[1] It was to obtain the limits of this area, which has been proved to contain workable coal at Fishburn and Trimdon, that the Cotefield Close boring was put down, while that at Sheraton was to get information regarding the nature of the coalfield to the north of the fault.

As the particulars regarding the boreholes will doubtless in the course of time appear in the volumes of the Borings and Sinkings of the North of England Institute of Mining Engineers, it is not proposed to give the minute details regarding each bed, but to describe the general characteristics of the strata and discuss the points of geological interest. In many cases it is impossible to give the exact thickness of a bed as only the more solid portions were brought up in the core, the softer granular beds being ground down.

[1] Sections of *The Coal Seams of Northumberland and Durham Coal-field*, by J. B. Simpson, 1877; section in Lebour's *Geology of Northumberland and Durham*, 1886, etc.

These rocks came to the surface as loose dolomitic grains and were recorded as "Sand" by the borers.

Details of the Boring at Cotefield Close (Permian).
Altitude, 340 feet.

Boulder-clay, etc., 106 feet.

Middle Magnesian Limestone. Total thickness about 240 feet.

a. Grey cellular and spongy limestone, the calcium carbonate having segregated out of a dolomitic rock, leaving cavities filled with soft yellow dolomite. Bands of crystalline calcium carbonate also occurred. About 85 feet.	Segregated Limestone
b. Soft yellow bedded dolomitic limestone. About 39 feet.	
c. Bed consisting of loosely cemented dolomitic rhombs. This bed was ground down and came to the surface as a yellow granular sandy-looking powder, being called "sand" in the records. About 36 feet.	Granular Dolomite
d. Dolomitic roestone, an oolitic limestone with geodes containing crystals of dolomite and calcite. About 80 feet.	Dolomitic Oolite

Lower Magnesian Limestone. Thickness about 270 feet.

e. Soft and hard dense yellow limestone, with streaks and specks of manganese dioxide (about 33 feet), passing gradually into *f.* Brown dolomitic limestone (about 118 feet), graduating by alternating irregular bands into	Dolomitic Lower Limestone
g. A hard grey highly calcareous rock with carbonaceous partings. The surfaces between the layers were irregular and knobbly, a peculiarity due to pressure solution. Parts of this rock had a brecciated appearance, being crowded wifh numerous irregular fractures. About 100 feet.	Calcareous Lower Limestone
h. Brown dolomitic limestone. About 20 feet.	
i. Hard grey calcareous laminated bed, resting unconformably on Coal-measure Sandstone. 1 ft. 3 in.	Marl Slate

Total thickness of Permian, 513 feet.

Details of the Boring at Sheraton (Permian). Supplied by Dr. Trechmann.
Altitude, 380 feet.

Drift gravel and boulder-clay. 187 feet.

Middle Magnesian Limestone. Total thickness about 213 feet.

a. Hard whitish spongy brecciated calcareous rock, with small cavities filled with powdery dolomite. About 90 feet. *b.* Brownish-yellow spongy-looking rock with small cavities filled with crystals of dolomite and calcite, a good deal of soft dolomitic rock interbedded with it.	Segregated Limestone
c. Dark yellowish-brown dense crystalline rock.	
d. Spongy-looking yellowish-brown crystalline rock, largely made up of dolomitic rhombs.	Granular Dolomite
e. Yellow, dense, rather soft dolomitic rock, with many small irregular oolite grains and small cavities filled with calcite crystals interbedded with hard brown thin bands without oolitic structure, changing in places into a spongy looking rock. *f.* Dark-yellow dolomitic oolite, with calcite-lined geodes. This bed is very thick, and merges into	Dolomitic Oolite
g. Fine-grained light yellowish-brown soft but dense dolomite, in which very dwarfed specimens of the following fossils occurred: *Bakevellia ceratophaga*, small serpulids, and ostracod valves. This rock is a fine dolomite. *h.* Similar to above, but no fossils, passing down into	Equivalent of bedded dolomites on the west side of reef as exposed in Castle Eden Dene

Lower Magnesian Limestone. 286 feet thick.

i. Hard yellow dense dolomitic rock.	Dolomitic and Calcareous Lower Limestone, 166 feet
j. Ditto, brecciated with sparry cavities, passing gradually down into	
k. Hard grey calcareous limestone, with carbonaceous partings and calcite-filled geodes (about 5 feet), passing down into	
l. Brown dolomitic limestone, brecciated in places. About 7 feet.	
m. Calcareous grey limestone with sparry cavities.	
n. Hard brown dolomite.	
o. Calcareous grey limestone.	
p. Brown brecciated dolomite.	
q. Hard brown dolomite, with patches of calcareous limestone.	Calcareous Lower Limestone, about 120 feet
r. Brown brecciated dolomite with sparry cavities.	
s. Hard grey calcareous rock, brecciated in places.	
t. Hard grey calcareous rock with sparry geodes.	
u. Grey calcareous rock, brecciated in places.	
v. Hard dark laminated Marl Slate. 1 foot.	Marl Slate
w. Grey hard dark calcareous limestone. 3 inches.	"Yellow" Sands, 3 ft. 6 in.
x. Coarse grit, small irregular chips and fragments of crinoidal limestone and chert in a matrix of rounded quartz grains interspersed with pyrites crystals.	
y. Grey sandstone with rounded grains.	
z. Grey shale, the rounded grains of the Yellow Sands impressed on the surface of the shale at the junction.	Coal-measures

Total thickness of Permian, 504 feet.

The first rock met with under the drift was apparently in both of the borings the Middle Magnesian Limestone, there being no trace of the typical upper beds as they appear in the area nearer the coast, such as the Hartlepool and Roker dolomites (dolomitic oolites and soft yellow dolomite) with the typical fauna of the Upper Magnesian Limestone, nor the Concretionary and the Cannon-ball Limestones, nor the bed which I have taken as the base of the Upper Limestone series, viz. the Flexible Limestone. These upper beds occur on the east of the Shell Limestone reef and also on the top of the reef in some places; for instance, Dr. Trechmann records the cannon-ball limestone as occurring on the top of the Shell Limestone in the Blackhall Colliery sinking. We are of opinion that owing to the shrinkage of the sea in later Permian times the upper beds were not deposited much to the west of the Reef.[1]

In neither of the borings was any trace of the richly fossiliferous Bryozoa Reef of the Shell Limestone found. At Blackhall Colliery sinking $3\frac{1}{2}$ miles to the north-east nearly the full thickness of this bed—335 feet—was pierced, and Dr. Trechmann was able to study the zones of it.[2] Both of these borings are west of the Reef and pass through a series of beds which are the western equivalent of it. The Sheraton boring is probably less than a mile from it. In Castle Eden Dene, $3\frac{1}{2}$ miles to the north, rather high beds of the Reef are exposed at Ivy Rock. They are here full of fossils and merge westwards into a fine-grained, very pure, dolomitic bedded rock, which if

[1] Woolacott, "Stratigraphy and Tectonics of the Permian of Durham (Northern Area)": Proc. Univ. Durham Phil. Soc., vol. iv, pt. v, p. 268, 1911–12. Trechmann, "On the Lithology of certain Durham Limestones": Q.J.G.S., vol. lxx, p. 260, 1914.

[2] Q.J.G.S., vol. lxix, p. 213, 1913.

carefully searched yields a very scanty and dwarfed fauna, consisting of *Bakevellia antiqua*, Munst., *B. ceratophaga*, Schl., *Schizodus truncatus*, King, *Pleurophorus costatus*, Brown, *Astarte vallisneriana*, King, and *Spirorbis permianus*, King. The bed marked "g" in the Sheraton boring with *Bakevellia ceratophaga*, small serpulids, and ostracod valves, is the exact equivalent of these beds. The reef-like nature of the Shell or Fossiliferous Limestone thus receives further confirmation from these borings.

The sections of the Middle Limestone given in these boreholes are therefore of much interest as they add considerably to our knowledge of the little-known western equivalents of the Reef. In the northern part of the county the remnant of them occurs as a bedded fossiliferous magnesian limestone, the main mass having been everywhere denuded, but in the south they are found as a series of cellular segregated rocks and granular, oolitic, and bedded dolomites over 200 feet thick. The segregated part of the former rocks are nearly pure calcium carbonate with powdery dolomitic infilling in the cavities, while the latter beds are almost pure dolomites.[1] In both borings thick beds of dolomitic oolite occurred. Such beds are of much more frequent occurrence in the Magnesian Limestone than is generally thought to be the case.

These segregated, oolitic, and granular dolomites are the in-shore equivalents of the Bryozoa Reef. To the east the Reef is replaced by the off-shore beds consisting of segregated and yellow bedded rocks, from which no fossils have yet been recorded, and which are often more pseudo-brecciated and brecciated than the rocks on the west. The Middle Magnesian Limestone thus presents two distinct types of bedded rocks with the shell-bank of the Bryozoa Reef lying between.

The top of the Lower Limestone is fairly well marked in each borehole by the merging of the Middle beds into a hard dense yellow dolomite with carbonaceous partings. The bedded series beneath consists of 280 feet of yellow and brown dolomitic and grey calcareous limestone. These at one or two horizons alternate in irregular bands, but beds over 100 feet thick of both types occur. The grey calcareous rocks are among the purest of the whole of the Magnesian Limestone series, containing over 98 per cent of calcium carbonate, and are very similar in composition and appearance to Carboniferous Limestone. They are distinctly hard and solid, but in places have suffered a process of brecciation, generally apparently more or less contemporaneous with the deposition of the beds. Some of the more pronounced brecciation in these beds has, however, been

[1] A. D. N. Bain, B.Sc., has analysed these rocks and supplied me with the following figures:—

Granular Dolomite.

Dolomite	62·38
Calcite	30·10
Ferric oxide	3·88
Insoluble residue	3·46
	99·82

Oolitic Dolomite.

Dolomite	82·47
Calcite	17·46
Ferric oxide	·4
	100·33

brought about by causes that have operated later.[1] At Raisby Hill Quarry, near Trimdon, a few miles to the west, these dolomitic and calcareous rocks are well exposed in a face 100 to 180 feet high.[2] At the quarry the highly magnesian rocks are called "Basic Dolomite or Crusher Stone", and the purer rocks are called "Bluestones".[3] The grey limestones are often fossiliferous. Although no fossils were found in the cores, yet at Raisby Hill they yield fossils, and further west at East Thickley a bed 10 feet in thickness yields a well-preserved and fairly rich fauna of the Lower Limestone. The borings confirm the discontinuous and lenticular nature of these calcareous beds, which Dr. Trechmann has noticed in connection with the field exposures.

[In the Sheraton boring the limestone became more impure and passed down into the Marl Slate (1 foot thick), beneath which the yellow sands (3½ feet) occurred. The former bed was hard and compact, and beneath it was, as is frequently the case, a band of grey calcareous limestone. No fish-remains were noted in the samples brought up. The Yellow Sands formed the base of the Permian series. At the surface outcrops along the escarpment this consists of a bed of incoherent rounded grains, plentifully stained with iron oxide and irregularly bedded. In its original unweathered condition the bed is here a solid rock with a remarkable quantity of iron pyrites disseminated through it. The upper layers at Sheraton are noticeable for the quantity of other fragments of rock embedded in the matrix of rounded quartz grains. Among these pieces of Carboniferous crinoidal limestone, fragments of chert and bits of grey sandstone occur. A similar rock is recorded from Blackhall Sinking, but such fragments do not occur in the north of the county nor along the escarpment.[4]—C. T. T.]

The decrease in the thickness of the Yellow Sands at Blackhall

[1] e.g. the thick irregular coarse dolomitic breccias occurring in the calcareous limestone of Raisby Hill Quarry.

[2] The section of the Lower Limestone at Raisby Hill is :—

	Feet.
Soft Dolomite	50–90
"Crusher Stone" (hard and pure dolomite, 10–40 feet)	
"Mixed blue" (dolomitic limestone)	0–28
"Bluestone" (highly calcareous rock)	28–54
Dolomite	10
Marl Slate	1
Top of Yellow Sands.	

A coarse irregular dolomitic breccia occurs in the "Bluestone".

[3] The following analyses of these rocks have been forwarded to me by T. A. Saint, B.Sc., assistant quarry manager :—

Basic Dolomite ("*Crusher Stone*").		*Bluestone.*	
$CaCO_3$	53·58	$CaCO_3$	98·75
$MgCO_3$	44·64	$MgCO_3$	·77
Silica	·10	Silica	·54
Ferric oxide	·88	Alumina and peroxide of iron	·30
Alumina	·8		100·36
	100·00		

[4] [In an arenaceous limestone at the base of the Lower Limestone on Tynemouth Cliff, stems of Carboniferous Limestone crinoids occur.]

Colliery, Sheraton, and Cotefield Close confirms the view that the Yellow Sands die out in the South of Durham. This thinning out is irregular but continuous. The fragments of Lower Carboniferous rocks occurring in the Yellow Sands, and the thinning out of this bed southwards, prove that the ridge of Carboniferous rocks that lay to the south was exposed at the time of the deposition of the basal beds of the Permian, and was being denuded until rocks of the limestone facies were laid down. It is interesting to compare the Permian in the boring at Cotefield Close with that at Sheraton about 1½ miles to the north-east and at Blackhall Colliery 2 miles further in that direction. Thicknesses are given in feet.

	Blackhall Colliery.	Sheraton.	Cotefield Close.
Upper Limestones	82	Absent.	Absent.
Middle Limestones	335 feet of fossiliferous rock, forming the Bryozoa Reef.	213 feet of segregated, granular, and oolitic dolomite, fossiliferous on one horizon.	240 feet of unfossiliferous rock similar to that at Sheraton.
Lower Limestones	240	286	271
Marl Slate	5	1	1¼
Yellow Sands	26	3½	Absent.
Total thickness of Permian	688	504	513

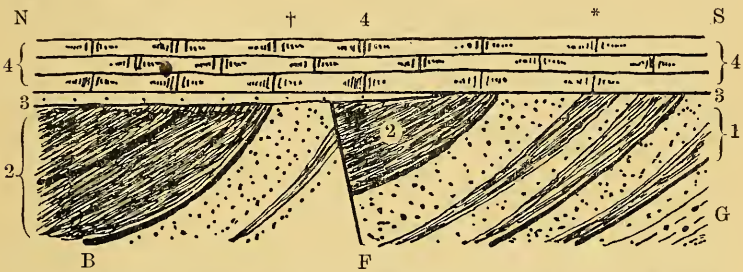
While the boring was being put down at Cotefield Close, after a depth of about 250 feet had been reached the air rushed in to the borehole and at other times out of it. This it did for days at a time, varying with the height of the barometer, and proving in a noticeable manner the porous and cavernous nature of the Middle Magnesian Limestone.

Coal-measures (Cotefield Close).

The borings at Cotefield Close and Sheraton entered the Coal-measures at a depth of 278 and 311 feet respectively beneath sea-level. As the line of the Butterknowle fault runs between them the Permian here is not affected by this fracture, which has a considerable throw to the south in the Coal-measures beneath. At Butterknowle, 20 miles to the west, this fault has a downthrow to the south of from 80 to 90 fathoms.[1]

[1] Kirkby & Duff, "Geology of Part of South Durham": Nat. Hist. Trans. of Northumberland and Durham, vol. iv, pt. i, 1871.

The unconformity between these series was distinctly marked at Cotefield Close. The Permian beds were lying without any marked dip, but the rocks below were dipping at about 1 in 4 (15°), probably in a northerly direction. They were penetrated by the boring for 470 feet. For about 370 feet they were a series of yellow, brown, and red sandstones, and felspathic grits, alternating with beds of grey, greenish, and reddish shales, and fireclays. A fairly coarse conglomerate occurred near the top. At one point contemporaneous erosion of the shales had taken place, as fragments of shale were interbedded with the sandstone, the laminations of the pieces lying at various angles in regularly bedded sandstone. Interbedded with this series were five thin seams of coal (the thickest being 11 inches). Remains of the ordinary Coal-measure plants were common in the shale, such as *Lepidodendron*, *Stigmaria*, *Calamites*, but no trace of any characteristic fossil such as *Aviculopecten papyraceus*[1] was found.



Diagrammatic Section showing Termination of the Coal-measures in South Durham.

1. Ganister Series: beds of sandstone, felspathic grits, shales, fireclays, and thin coal-seams with beds of Ganister (*G*) at base. The sandstones probably thicken northwards, and these beds on north side of fault are chiefly sandstones.

B. Brockwell Seam.

2. Coal-measures.

3. Yellow Sands thinning out southwards and overlaid by Marl Slate.

4. Magnesian Limestone. Only the lower part of this bed is shown.

No attempt is made to draw the beds to an exact scale.

F. Butterknowle Fault.

* Approximate position of Cotefield Close borehole.

† Approximate position of Sheraton borehole.

The length of the section is about 4 miles.

Below these rocks several beds of Ganister alternating with beds of shale and finely bedded micaceous sandstone were proved. The thickest bed was 4 feet, and was of the "pencil" variety. The occurrence of this Ganister is of some interest, because the beds between the Brockwell Seam and the Millstone Grit are called the Ganister Series, and are taken as the equivalents of the true Ganister-bearing rocks of Yorkshire and Lancashire. It is proved

[1] Professor Lebour found this fossil along with other marine fossils in beds occupying a similar position to these at Whittonstall (Geol. Mag., 1878, p. 144).

by this boring that there are over 300 feet of Coal-measure strata beneath the Brockwell in South Durham which do not contain any Ganister. This rock only occurs in the lower part of the series.[1]

Samples of the most interesting rocks brought up in the Cotefield Close boring are deposited in the geological laboratory of the Armstrong College.

I should like here to lay stress upon the necessity for the examination of all cores of borings by geologists. The record given by the borers, especially in such rocks as the Magnesian Limestone, is often of little value for exact scientific work, and valuable information is thus lost.

IV.—Notes on Ammonites.

By L. F. Spath, B.Sc., F.G.S.

IV.

The variability and occasional instability of the Ammonoid suture-line, to which attention has been drawn, the recurrence of similar types, and the frequent asymmetry of the opposing halves of a given suture-line, which is apparent not only in the *Dactylioceras commune*, figured by Swinnerton & Trueman (fig. 9 on p. 42), but also in the development of the suture-line in e.g. *Pseudosageceras multilobatum*, Noetling,[2] in *Indoceras baluchistanense*, Noetling,[3] or in *Oxynoticeras oxynotum*, Quenstedt, sp.,[4] to mention only a few well-illustrated examples, might be thought to impair the usefulness of the suture-line for the classification of Ammonoids. Yet, long before there was any subdivision of "*Ammonites*" at all, the greatest importance had been attached to the foldings of the suture-line, and Pictet stated in 1854 that "the lobes in their essential traits furnished very constant and very valuable characters".[5] Von Buch's group of "*Arietes*" was well characterized by the general plan of the suture-line, namely, the deep siphonal lobe and the short external saddle, only most authors would put more reliance on the ornamentation of the shell and put such a form as *Asteroceras sagittarium*, Blake, sp., into the genus "*Aegoceras*". The writer would even go so far as to say that the type of suture-line given by Mr. Buckman[6] for "*Defossiceras*" *defossum*, Simpson, sp., should not be found at the horizon stated,[7] and that the form probably will turn out to be an Arietid (*Agassiceras*) of *semicostatum* age.

[1] The borehole at Sheraton appears also to have entered the Ganister Series. Thick beds of sandstone have been penetrated dipping at an angle of 45°, probably northwards, as shown in section.

[2] "Untersuchungen ü. d. Bau d. Lobenlinie v. *Pseudosageceras multilobatum*, Noetling": Palæontographica, vol. li, pts. v, vi, 1905.

[3] "Die Entwicklung v. *Indoceras baluchistanense*, Noetling": Geol. u. Pal. Abh. v. Koken, N.F., vol. viii, pt. i, 1906.

[4] "Die Entwicklung v. *Oxynoticeras oxynotum*, Que.": Geol. u. Pal. Abh. v. Koken, N.F., vol. viii, pt. iv, 1908.

[5] Op. cit., vol. ii, p. 669.

[6] *Yorkshire Type Ammonites*, vol. ii, pt. x, p. 76, pl. lxxvi, 1913.

[7] Definitely given as "*capricornum* zone" in Mr. Buckman's "Palæontological Classification, etc.", in *The Geology of the Country between Whitby and Scarborough* (Mem. Geol. Surv.), 2nd ed., 1915.

Wright[1] expressed the opinion that von Buch had considered the suture-line of much greater importance than was justified by later observations, and he stated : "In adult life, however, the form of the suture-line is a valuable character." H. Douvillé,[2] ten years later, took an exactly opposite view. He thought that the best family characters would have to be furnished by the plan of the suture-line, i.e., its general course in the post-goniatitic stage before it was masked by the complication of the lobes and saddles. Fischer,[3] on the other hand, thought that "the suture-line was of real value for classificatory purposes only when used in conjunction with other characters of a 'higher' order, such as the general form of the shell, its ornament, mouth-border, or aptychus. If the suture-line were the absolute basis for a classification of Ammonites, this would have been accomplished long ago, since from von Buch's time onward all palæontologists had kept this character in view. Unfortunately no one could affirm to-day that there exists a satisfactory classification of this group of cephalopods".

Noetling[4] also thought that the systematic value of the suture-line was not very great, since the protrusions of the visceral hump that went into the lobes were of no importance. Opinions may differ on this latter point, for in living animals even specific differences are often very fundamental and extend to quite minor internal structures or to the convolutions of the brain.[5]

It is not the writer's intention to give a complete history of the alternate favouring and disfavouring of the suture-line as a basis for the classification of Ammonoids, but it is surprising that, though opinions on its value were freely given, little research as to the nature and origin of the folded septal edge was carried on. It must be admitted, however, that among modern workers on Ammonoids many look upon the suture-line as the dominant feature, and Hyatt[6] even went so far as to say that "all classifications were necessarily based upon sutural peculiarities". In view of the importance of this statement it seems advisable to examine the other features of the Ammonoid shell that have been used for classificatory purposes.

With regard to the form of the shell and the coiling, their value for a natural classification of Ammonoids is strictly limited. Few authors would now group certain Inferior Oolite forms (*Patoceras*)

[1] *Monograph of the Lias Ammonites*, Pal. Soc., 1880, p. 219. Only seven years after the compilation of Wright's work, hailed at the time of its appearance as a "masterly monograph" (A. Geikie, *Text-Book of Geology*, 1882, p. 786), Professor Blake ("The Evolution and Classification of the Cephalopoda, etc.": Proc. Geol. Assoc., vol. xii, p. 292, 1892) had to say with regard to the classification adopted by Wright, namely that of Neumayr, originally published in 1875 : "Its author, were he happily still with us, would certainly regard it as quite inadequate and out of date at the present time."

[2] "Sur la Classification des Cératites de la Craie": Bull. Soc. géol. France, ser. III, vol. xviii, pp. 280, 291.

[3] Discussion on above, ibid., pp. 291–2.

[4] Op. cit., 1905, pp. 59–60.

[5] A. v. Tschermak, "Über d. Entwicklung d. Artbegriffs": Tierärztl. Zentralblatt (34), Vienna, 1911, pp. 351, 381.

[6] In Zittel-Eastman, *Textbook of Palæontology*, 1st ed., vol. i, p. 546, 1900.

with the Cretaceous *Ancyloceras* or *Toxoceras*, as, e.g., d'Orbigny and Pictet did, simply because they are of a similar shape. There is no generic connexion among most of the scaphitoid or other "aberrant" forms that appear at a number of horizons and may originate from very distant stocks, though they have a similar form. De Loriol[1] describes an aberrant form that occurs together with *Cardioceras cordatum* as *Œcoptychius Christoli*, Beaudouin. It is evident that this form has no connexion with the earlier type of *Œcoptychius*, namely *Œ. refractus* (de Haan), from the *anceps* zone. There is not even similarity of shape, and the form is probably a modified development of some contemporaneous group of Ammonites such as *Pachyceras*. It has also been mentioned already that it is impossible to group together the Devonian *Biloceras* and the Triassic *Sageceras*, or the Cretaceous *Garnieria* and the Liassic *Oxynoticeras*, simply because they are similar in appearance. It will be noticed that geological occurrence is a determining factor in the separation of many of these lineages based on a modified whorl-shape; *Spiroceras* is strictly Callovian, *Ancyloceras* confined to the Lower Aptian. Unfortunately this has given rise to a multitude of new names, but the creation of separate genera for the various abnormal whorl-shapes antedates the splitting up of the genus "*Ammonites*" by Suess, Hyatt, and Waagen.

Impossible as it may be to use form and coiling of the shell for a general classification, certain Ammonites (e.g., *Phylloceras*) can at once be recognized by their form, and when this is modified (e.g., in *Sowerbyceras*) a separate name is given to the new stock. The same thing applies to the coiling in *Lytoceras* where evolution gives rise to, e.g., *Costidiscus* and *Macroscaphites*. In the great majority of Ammonites, of course, form and coiling vary considerably within a genus; e.g., in *Cadoceras* there are compressed shells and greatly depressed cadicones, in *Morphoceras* there is involution and evolution, in *Schlotheimia* the whorl may become almost oxynote (*S. Greenoughi*). When form and coiling change within a species group, what older authors termed thick and thin, evolute or involute "varieties" of the species are produced. But the term "variety", which has a definite zoological meaning, is not favoured by modern palæontologists, who, on the other hand, often do not make enough allowance for individual variation within a species. It may be inadvisable to give a new name to every form that differs, often only very slightly, from the type in thickness or involution; but it seems to the writer equally objectionable to identify, e.g., a Yorkshire *Psiloceras* with an Alpine form only because their dimensions agree (for in both the *erugatum* and the *calliphyllum* species-groups similar variations would probably have occurred), or, as Hyatt has done, identify an *Amioceras* from Peru with *A. ceras*, Giebel, sp., when there is such a distinct change in the *Amioceras* fauna even from Gloucestershire to Dorset on the one hand and to Yorkshire on the other. It is known from the study of living mollusca that in the sea each locality gives its

[1] "Etude sur les Mollusques et Brachiopodes de l'Oxfordien Supér. et Moyen du Jura Bernois," Supplément I: Mém. Soc. Pal. Suisse, vol. xxviii, pp. 20–2, 1901.

inhabitants its own peculiar stamp; but when an Ammonite is described as, e.g., *Phylloceras mediterraneum* (Neumayr) race *indica*, Lemoine, or as *Protogrammoceras cornacaldense* (Tausch) var. *zeugitanum*, Spath, it is not certain that it really represents a horizontal variant or race, and not a vertical mutation. In fact, these terms can rarely be safely employed, and an attempt to trace the mutations of, e.g., *Quenstedtoceras* through R. Douvillé's beds H_1 to H_6 shows the unsatisfactory and difficult nature of their use. But on the examination of many hundreds of specimens of a variable species such as *Hystrichoceras varians* (Sowerby), *Cardioceras cordatum* (Sowerby), or *Xipheroceras planicosta* (Sowerby) (out of one block or bed, and, therefore, apparently contemporaneous) and as an alternative to using the term "variety" or creating new names, the use of the trinomial nomenclature suggests itself for these thick and thin, involute or evolute, weakly or strongly ornamented variations, as employed by, e.g., Solger for *Hoplitoides ingens nodifer*, *H. ingens costatus*, and *H. ingens lævis*. Wepfer[1] also reintroduces Quenstedt's trinomial nomenclature, but in a different sense. The genetic relationship between the Bajocian *subradiata*-group and the Tithonian *lingulati* is too uncertain to include them all in the genus *Oppelia*, and, moreover, even such names as *Glochiceras lingulatus carschtheis*, *Gl. lingulatus lævis*, and *Gl. lingulatus crenosus*, covering forms from different facies and different horizons between the *bimammatum* zone and the Tithonian, would not be admissible.

What has been said with regard to the form and coiling applies also to the use of the ornamentation of the shell for classificatory purposes. Von Buch's sections with a keeled or grooved venter, or Mojsisovics's divisions of Liostraca and Trachyostraca, were soon found to be unnatural groupings. "*Aegoceras*" *sagittarium*, Blake, is an *Asteroceras*, though it has no keel; "*Oxynoticeras*" *Greenoughi* (Sowerby) is a *Schlotheimia* though it has no ventral groove. An Argovian *Neumayriceras*, e.g., may have a groove on the ventral region of the chambered portion which, generally with the beginning of the body-chamber, changes into a keel. This passes into an interrupted line of tubercles which, disappearing abruptly, may again give way to a groove. According to whether this groove or the dentation is more pronounced, there are several combinations; at the same time the sides are often conspicuously smooth and the body-chamber often becomes abnormal and depressed.[2] And all this in one and the same form. Again, the presence of a hollow carina, though occasionally constant, and the thickness of the siphuncle—at one time considered a distinction between "*Harpoceras*" and Oppelids—cannot be used for classificatory purposes.

Mojsisovics had at first[3] considered all post-Triassic Ammonites, except *Phylloceras* and *Lytoceras*, to be descendants of the

[1] "Die Gattung *Oppelia* im süddeutschen Jura": Palæontographica, vol. lix, pp. 1–68, 1912.

[2] Wepfer, op. cit., p. 17.

[3] "Die Cephalop. d. Mediterr. Triasprovinz": Abh. k.k. Reichsanst., vol. x, 1882.

Trachyostraca. In his later work,[1] however, he assumed, conformably to the general opinion, that the whole of the Jurassic and Cretaceous Ammonites issued, by branching, from the family of the Phylloceratidæ, i.e. Liostraca. Steinmann,[2] on the other hand, still maintains a purely artificial classification into Trachyostraca, Hemiostraca, Liostraca, and Heterostraca. J. Boehm[3] also emphasizes that from the study of *Kossmaticeras* it was clear that the systematic division of Cephalopoda according to the mode of ornamentation was an artificial one, and that stress was to be laid above all on the ontogenetic development.

But though unsuitable for general purposes, the ornamentation or carination may be of considerable value for the minor groupings of Ammonoids. The course of the radial line in certain Hildoceratids,[4] the different types of costation in the Perisphinctids, an important classificatory character, and in the ribbed descendants of *Psiloceras*, the tendency to differentiate costation either on the venter (with first thickened and then interrupted ribs) or on the side (with eventual carination of the ventral area) separate the two important families of Schlotheiminæ and Arietidæ. In the former, the development that leads up to a grooved periphery (in the ontogeny of the later forms) is separated generically(as *Waehneroceras*) from the forms of the succeeding hemeræ that have a similar tendency to lead back from a grooved periphery to a rounded venter (*Schlotheimia*). The terms anagenesis and catagenesis are avoided by the writer not only because, for example, a smooth (so-called catagenetic) form may show elaboration of all its other characters, but also because he considers the smooth oxycones in many stocks to be specialized

[1] "Die Ceph. d. Hallstätter Kalke": Abh. k.k. Reichsanst., vol. vi, 1873–93, 2 vols.

[2] *Einführung in die Palaeontologie*, 2nd ed., 1907.

[3] *N. Jahrb. f. Miner.*, etc., ii, p. 463, 1912 (in review of Kilian & Reboul's paper on certain neo-Cretaceous Ammonites).

[4] The writer used this character in the subdivision of the Middle Liassic (Domerian) Hildoceratids ("On Jurassic Ammonites from Jebel Zaghuan": Q.J.G.S., vol. lxix, pp. 547–52, 1913) and separated the Flexiradiata from the rectiradiate forms that constitute the genus *Seguenziceras*. The genus *Protogrammoceras* was created for the former, and two divisions were recognized within that genus; but one of these, characterized by dionase in peripheral projection and including subanguliradiate and angulirursiradiate forms, is covered by the genus *Fuciniceras* created just prior to the publication of the writer's paper. The genus *Protogrammoceras* will, therefore, have to be restricted to the forms of the first subdivision, including subfalciradiate and falciradiate forms (type "*Grammoceras*" *bassanii*, Fucini, "Apenn. Centr.," pl. x, fig. 6, 1900). Apart from their Domerian age, both the Rursiradiata (*Fuciniceras*) and the Falciradiata (*Protogrammoceras*) are distinguished from the Toarcian Harpocerates by their combination of evolute whorls with a tendency to change the periphery from fastigate to carinatisulcate and back again to fastigate. The form described and figured in that paper as gen. nov. sp. nov. (?) (pl. lii, fig. 2, p. 556) belongs to the group of forms wrongly referred to *Harpoceratoides* by Haas, and the new genus *Lioceratoides* (type "*Lioceras* (?)" *Grecoi*, Fucini, "Apenn. Centr.," Pal. Ital., vol. vi, p. 65, pl. xi, fig. 4, 1900) is now proposed for this development, characterized by a type of costation very distinct from that of the other Domerian Hildoceratids.

adaptations, corresponding to elaborately ornamented sphærocones or uncoiled shells in other lineages.

In the family Arietidæ, the hastening in development of one character of the whorl or its ornamentation faster than another, or the delaying of a feature, afford valuable indications of the beginning of diversity of lineages. During the acme of the group, certain Alpine forms of *Coroniceras* show a tendency to retard the development of the keel and to flatten the periphery, which tendency probably leads to the Microderocerates. Other Alpine *Coroniceras*-forms hasten the development of the keel and foreshadow the somewhat later *Aetomoceras*, which seems to be a corresponding development of the bituberculate *Agassiceras*. In the later genus, again, the tendency to omit the keel and to continue the costation across the venter probably leads to *Xipheroceras* and thus starts the family Aegoceratidæ, from which the *Microderoceras* development, mentioned above, would, obviously, have to be excluded. It will be seen that the tendency of a lineage to develop or specialize in a certain direction (adaptative in response to changes of environment or intrinsic and aiming at diversity) is here favoured as the basis of lineal independence and generic classification, as opposed to the morphological method of grouping together forms that fit the generic diagnosis of the textbooks, or to the cyclical method which assumes that stocks should develop according to a given "cycle" and show periods of "anagenesis" and "catagenesis".

Suess,[1] when first venturing on the subdivision of Ammonites, thought the length of the body-chamber and the shape of the mouth-border characters of systematic value. The former generally depends on shape and coiling, and Buckman and Bather[2] have pointed out that in *Stephanoceras* the body-chamber "varies in length from about half a whorl in the thick forms (the supposed females) to very nearly two whorls in the thin forms (the supposed males)". As a specific distinction this character alone has been used by Pompeckj,[3] who described as *Psiloceras brevicellatum* an Ammonite that differs from *P. planorbe* only in having a shorter body-chamber. On the other hand, G. von Arthaber[4] bases what appears to the writer to be a very artificial classification of Triassic Ammonites into Microdoma and Macrodoma, on the length of the body-chamber. He also states that "much more important than generally assumed seems to be the convergence of forms", but groups such heterochronous homœomorphs as *Beloceras* and *Sageceras* together.

As regards the shape of the mouth-border, great variability is shown even in one genus, e.g., *Phylloceras*, as H. Douvillé[5] pointed out. Of course, it might be objected that this genus really ought to be subdivided into a number of genera, but Douvillé thinks even the ornament of the sides "perhaps more important for classificatory

[1] "Über Ammoniten": Sitzungsber. d. Wiener Akad., vol. lii, p. 71, 1865.
[2] *Nat. Sci.*, vol. iv, p. 428, 1894.
[3] "Beitr. z. einer Revis. d. Amm. d. Schwäb. Jura," 1893, pt. i (T).
[4] "Grundzüge einer Systematik d. Triad. Amm.": Centralbl. f. Min., etc., 1912, p. 245.
[5] "Cérat. de la Craie": loc. cit., pp. 278–9.

purposes than the shape of the aperture". The presence or absence of lateral lappets at the mouth-border is used for classification by Mascki,[1] who put *Parkinsonia* and *Strenoceras* into the family Otoitidæ, *Baculatoceras* into Stemmatoceratidæ, *Garantiana* and *Subparkinsonia* into Stephanoceratidæ. But Wetzel[2] has found "ears" in a small form of *Garantiana* and only very slight lateral processes in larger forms, and he thinks that probably—as is the case also in *Parkinsonia*—in certain series the "ears" disappeared with age, earlier in some series and later in others. Again, in *Hecticoceras*, *Glochiceras*, and other Oppelids "ears" are often confined to the younger stages, "vary in form and size from one specimen to another, and show by this alone an impress of individuality that seems to deny them any usefulness for systematic purposes."[3]

When Waagen, in 1871, combined the Ammonitid genera in eight groups, he attributed "great importance to the presence or absence of the shell-plates termed *Aptychus* and *Anaptychus*, and to the particular structure of these remains".[4] Wright[5] also expressed the opinion that "the *Aptychus* played an important part in the organic functions of this large extinct group of tetrabranchiate Cephalopods". But it had been shown long before that, in the case of Gastropods, as the operculum sometimes varies in structure in species of the same genus, as it is present in some volutes, cones, mitres, and olives, and absent in other species of these genera, and as some genera in a natural family, as *Harpa* and *Dolium* among the Buccinoids are without an operculum, whilst the other genera of the same family possess that appendage, it obviously affords characters of very secondary importance.[6] H. Douvillé[7] thought that "there was nothing to show that in one and the same family one might not find *Aptychi* of the same form that could have been either horny or else more or less impregnated with calcareous matter, the former would have disappeared during fossilization, at least in the majority of cases, whereas the latter would be preserved. The absence of the *Aptychus* might, therefore, be only apparent, and it was a character of little importance". The assumption that the operculum of Cephalopods has a greater systematic value than that of Gastropods, even if not homologous, is not justified. Apart from this our scanty knowledge of *Aptychi* found together with their parent Ammonites has proved a great practical difficulty, and Waagen's classification was, from this point of view, unsuccessful.

Mr. Crick[8] thought that the traces of muscular attachment of the

[1] "Die *Stephanoceras*-Verwandten der Coronatenschichten von Norddeutschl.": Dissertat., Göttingen, 1907.

[2] "Beitr. z. Pal. u. Stratigr. d. nordwestdeutschen Jura, ii, Faunistische u. stratigr. Untersuch. d. *Parkinsoni*-Schichten d. Teutoburger Waldes bei Bichfeld": Palæontographica, vol. lviii, p. 159, 1911.

[3] Wepfer, op. cit., p. 40.

[4] Zittel, *History of Geology and Palæontology*, English trans., 1901, p. 403.

[5] Op. cit., 1880, p. 176.

[6] R. Owen, *Lectures on the Comparative Anatomy and Physiology of the Invertebrate Animals*, 1843, p. 296.

[7] "Cérat. de la Craie": loc. cit., p. 278.

[8] "On the Muscular Attachment of the Animal to its Shell in some Fossil Cephalopoda (Ammonoidea)": Trans. Linn. Soc., vol. vii, pt. iv, p. 109, 1898.

Ammonoid animal to its shell afforded important characters for the purposes of classification, but both on account of the comparative scarcity and the indefinite nature of these impressions they have not proved of value yet in the classification of Ammonites.

On the whole, then, the Ammonoid suture-line may be considered to be a more useful feature for classificatory purposes, especially of the larger groups and families, than any of the above characters, though, like any other character, it cannot be used by itself as the sole basis for the natural classification of organisms that are made up of an almost infinite number of characters, each of which is in a continuous state of movement, either originative, progressive, or retrogressive.[1] Holzapfel[2] stated long ago that one single character, such as the shape of the first suture, the direction of the siphonal funnel, or the shape of the peristome, cannot well be used for classification. In his paper on the genus *Oppelia*[3] Wepfer stated: "In palæontological works the question is often asked, which characters in Ammonites are decisive, the lobes, the length of the body-chamber, etc., etc.? I believe they all are, to a certain extent' but one cannot formulate general rules. All characters are liable to variation, and what decides is the general appearance, at any rate we get further with this than with following some one-sided character." Hyatt's classification of the Nautiloids[4] according to the structure of the septal neck, though more attractive than the previously existing classifications, cannot be really natural, and when it is found that Hyatt[5] included, e.g., in his family Estonioceratidæ, based on the shape of the whorls, beside the Ordovician genus *Estonioceras*, also the Jurassic *Digonioceras*, that is two genera that almost certainly have not the remotest affinity, the artificial character of his classification becomes evident. The same applies to his classification of Ammonoidea, as is shown, by the inclusion in, e.g., his *Leptocampyli* of such a heterogeneous mixture of Ammonoids belonging to widely removed stocks, or his separation of such closely allied genera as, e.g., *Reineckeia* and *Erymnoceras*, *Sigaloceras* and *Kepplerites*, not only into different families, but even different super-families.

It seems to the writer that the development of the Ammonite suture-line has to be studied from its first "angustisellate" beginning, and used as a basis for classification only in conjunction with the development of all the other characters of the shell. The use for general classification of, e.g., the symmetrical or asymmetrical arrangement of the first lateral lobe, the changing width of the external saddle, the number of auxiliary lobes, or any other similar peculiarity of the suture-line, by itself, is unsatisfactory.

[1] H. F. Osborn, "Origin of Single Characters as observed in Fossil and Living Animals": Presidential Address Pal. Soc. Amer., 1914 (see *Nature*, November 11, 1915, pp. 284–5).

[2] "Die Cephalopoden-führenden Kalke d. Unt. Carbon v. Erdbach-Breitscheid bei Herborn": Pal. Abh. v. Dames u. Kayser, vol. v, No. 1.

[3] Loc. cit., 1912, p. 30.

[4] *The Genera of Cephalopods*, etc., 1883.

[5] In Zittel-Eastman, op. cit., 1900.

V.—Some Recent American Petrological Literature.

(*Continued from p. 128.*)

"Structure of the Anorthosite Body in the Adirondacks," by H. P. Cushing. Journ. Geol., vol. xxv, pp. 501–8, 1917.

A criticism of Dr. Bowen's conclusions as to the field relations of the different rock-types of the area.

"Adirondack Intrusives," by N. L. Bowen. Ibid., pp. 509–12, and H. P. Cushing, ibid., pp. 512–14.

A continuation of the discussion on the two preceding papers.

"The Relation of the Titaniferous Magnetite Ores of Glamorgan Township, Haliburton County, Ontario, to the Associated Scapolitic Gabbros," by W. G. Foye. Econ. Geol., vol. xi, pp. 662–80, 1916.

It is concluded that gases given off by the acid and intermediate magmas collected beneath the gabbro, oxidizing its iron to titaniferous magnetite and depositing this below the laccolith; the chlorine and other gases thus set free scapolitized and recrystallized the overlying gabbro.

"The Relation of the Titaniferous Magnetites of North-Eastern Minnesota to the Duluth Gabbro," by T. M. Broderick. Econ. Geol., vol. xii, pp. 663–96, 1917.

The gabbro has developed magnetite-bearing rocks along its contact with the Gunflint iron formation, including coarse-textured fayalite-pyroxene-magnetite rocks, hitherto mistaken for marginal facies of the gabbro. Several types of magnetic ores within the gabbro are partly magmatic segregations and partly inclusions of the Gunflint formation.

"The Geology of Pigeon Point, Minnesota," by R. A. Daly. Amer. Journ. Sci., vol. xliii, pp. 423–48, 1917.

A re-examination of the occurrence of micropegmatite (red rock) in a basic intrusion. The intrusion is considered to be a sill, not a dyke, as supposed by Bayley, and the variation in composition is due to differentiation, mainly by gas-action, after stoping and assimilation of Animikie quartzite.

"Petrography of the Pacific Islands," by R. A. Daly. Bull. Geol. Soc. Amer., vol. xxvii, p. 325, 1916.

The available data lead to the conclusion that the primary Pacific magma is basaltic and that andesites and ultrabasic lavas have been differentiated from this: certain alkaline types may be limestone syntectics.

"A Contribution to the Petrography of the South Sea Islands," by J. P. Iddings and E. W. Morley. Proc. Nat. Acad. Sci., vol. iv, pp. 110–17, 1918.

Analyses are given of rocks from Tahiti and other islands of the Georgian and Society groups, many of which are profoundly eroded volcanoes, consisting mainly of basalts rich in augite and olivine, with little felspar: at five of them are late trachytic and phonolitic lavas, while two show coarsely crystalline cores of gabbro or theralite and in one case syenite and nepheline-syenite.

"Age of the Igneous Rocks of the Adirondack Region," by A. P. Cushing. Amer. Journ. Sci., vol. xxxix, pp. 288–94, 1915.

The orthogneisses which have been metamorphosed along with the Grenville rocks have been invaded by the anorthosite-syenite group, which contain inclusions of the gneisses. It is held that the orthogneisses and the anorthosite-syenite group are distinct and should not be classed together.

"The Composition of the Average Igneous Rock," by A. Knopf. Journ. Geol., vol. xxiv, pp. 620–2, 1916.

Using the data given in Daly's *Igneous Rocks and their Origins,* the writer calculates a new average igneous rock, taking into account the actual volume of each type, so far as known. This average is found to agree very closely with that previously given by Clarke.

"The Summation of Chemical Analyses of Igneous Rocks," by H. H. Robinson. Amer. Journ. Sci., vol. xli, pp. 257–75, 1916.

An application of the laws of probability to the determination of errors of summation, as a guide to the quality of the analytical work.

"Use of the Slide-Rule in the Computation of Rock Analyses," by J. H. Hance. Journ. Geol., vol. xxiii, pp. 560–8, 1915.

The author gives two tables of the percentage composition of rock-forming and ore minerals with a method of use applicable to an ordinary slide-rule for the conversion of analyses into the corresponding mineral compositions.

"Suggestions for a Quantitative Mineralogical Classification of Igneous Rocks," by A. Johansen. Journ. Geol., vol. xxv, pp. 63–97, 1917.

The basis of the proposed classification is a figure in the form of a double tetrahedron, each corner representing certain mineral constituents of the rock, the composition of any type being represented graphically in its proper position in the figure. The minerals are divided into groups and a large number of new rock-names are proposed.

"Types of Prismatic Structure in Igneous Rocks," by R. B. Sosman. Journ. Geol., vol. xxiv, pp. 215–34, 1916.

Several types of prismatic structure are distinguished as due to thermal contraction, convection in the still liquid magma, and internal expansion respectively.

"The Microscopical Characters of Volcanic Tuffs, a Study for Students," by L. V. Pirsson. Amer. Journ. Sci., vol. xl, pp. 191–211, 191 .

A discussion of the origin and characteristic structures of tuffs, with a description of the criteria for their recognition when altered, weathered, and metamorphosed.

REVIEWS.

I.—New and little-known Gastropoda from the Upper Cretaceous of Tennessee. By Bruce Wade. Proc. Acad. Nat. Sci. Philadelphia, vol. lxix, pt. ii, pp. 280–304, pls. xvii–xix, 1917.

We have referred in a previous issue (Geol. Mag., 1917, p. 471) to the notable results of Dr. Bruce Wade's study of the Gastropod fauna from the Upper Cretaceous Ripley formation of Coon Creek, in McNairy County, Tennessee. The fossils from this locality are in a remarkable state of preservation, and consequently afford excellent material as a basis for the establishment of new generic types. We have now before us a second contribution, in which further new forms are established. Among them is *Conorbis mcnairyensis*, a new species founded on a single specimen, which is the only member of the Conidæ in the fauna. This record is important on account of its being the first typical representative of the genus in the Upper Cretaceous; it shows all the salient features exhibited by Sowerby's *Conus dormitor*, the type of the genus *Conorbis*, from the Eocene of Western Europe.

Three new genera in the Volutidæ are established, and a new species is assigned to Grabau's *Falsifusus* and to Conrad's *Linosoma*, also of this family. *Hyllus* is a genus (type, *H. callilateras*, n.sp.) of large, unornamented volutes, with expanded bodies and low spires. The characteristics of this genus resemble those of *Liopeplum*, but there are differences in the form of the spire and the disposition of the columellar plaits. The new genus *Boltenella* (type, *B. excellans*, n.sp.) includes a group of well-defined forms of fulguroid shells, with large paucispiral protoconchs and subdued ornamentation, probably intermediate between the Busyconidæ and the Fusidæ. *Scobina* is a generic name given to a number of shells similar in general shape to *Hercorhynchus*. The strongly inflated body resembles Conrad's *Rapa cancellata* from the Cretaceous of India, but in the new genus there is a marked increase with age in the spiral angle. *S. bicarinata*, n.sp., is the genotype. The new species assigned to the genus *Falsifusus*, *F. mesozoicus*, is a fragile, slender shell, marked by spinose terminations of the axials along the shoulder angle. This form and Kaunhowen's *Fusus bicinctus* are the first two species from the Upper Cretaceous to be referred to *Falsifusus*. In another genus, *Lirosoma*, a new species (*cretacea*) is again recorded for the first time from the Cretaceous. This form resembles the generic type from the American Miocene.

The Buccinidæ are represented by one new genus, *Seminola* (type, *S. crassa*, n.sp.), named after a tribe of Indians who formerly inhabited the south-eastern coastal plain. The genus resembles Meek's *Odontobasis*, of which the fusiform outline distinguishes it from the globose form of *Seminola*.

An elegant little pyriform shell, with a depressed spire, *Ecphora proquadricostata*, n.sp., has again the interest of being the first representative in the Cretaceous of a genus well known in the Upper Tertiary of the Atlantic Coast district. Belonging to the same family, the Purpuridæ, is a new genus, *Paramorea* (type, *P. lirata*, n.sp.), which can be distinguished from *Morea* by the presence of a narrow, oblique chink instead of a well-defined umbilicus, by an acute spire, and by the absence of the strongly reflected inner lip.

Two genera new to the Cerithiidæ are also established. *Nudivagus* (type, *N. simplicus*, n.sp.) includes a group of simple, elongately conical shells, with no external ornament. To this genus, moreover, Stoliczka's Indian Cretaceous *Cerithium* (*Fibula*?) *detectum* and Hudleston's *Pseudomelania astonensis*, from the Inferior Oolite of England, are also referred. *Astandes* (type, *A. densatus*, n.sp.), a small trochoid shell, resembles Conrad's *Cerithioderma* in outline, but its spire is less acuminate and the umbilicus imperforate. By its short anterior canal, also, it can be distinguished from Gardner's *Paladmete*, which otherwise it resembles. Included in this new genus is Holzapfel's *Tritonium cretaceum*, from the Aachen Cretaceous.

Acirsa and *Hemiacersa* belong to the Scalidæ; of the former two new species are described and one of the latter. The form named *Chemnitzia cerithiformis* by Meek and Worthen is now considered to be an *Acirsa*, and Kaunhowen's Maestrichtian *Scalaria dense-striata* is probably comparable with *A. corrugata*, n.sp. De Boury's *Hemiacersa* is enlarged by the inclusion of *H. cretacea*, n.sp., of which the single example is notable on account of its being the first recorded from the Upper Cretaceous. The present contribution to the systematic study of this fauna ends with the establishment of the new genus *Creonella*, belonging to the Pyramidellidæ. The genotype, *C. triplicata*, n.sp., is a small, slender, conical shell, like *Pyramidella*, and is characterized by three conspicuous folds on the inner lip.

We await with interest the results of Dr. Bruce Wade's further studies on this fauna.

C. P. C.

II.—A Bibliography of Indian Geology and Physical Geography, with an Annotated Index of Minerals of Economic Value. Compiled by T. H. D. La Touche, M.A., F.G.S., F.A.S., Bengal. Published by Order of the Government of India. and printed in Calcutta for the Geological Survey of India. London: Kegan Paul & Co. Imp. 8vo. Part I (1917), pp. xxviii + 571, price 5*s.* 4*d.*; Part II (1918), pp. 490, price 6*s.*

The author of this important work is a man well qualified for the task, having served for thirty years upon the staff of the Geological Survey of India, to the "Records" of which he was himself a frequent contributor. During his long service he was a careful and diligent compiler of references bearing upon both geology and physical geography and on the mineral resources of India. He had also the advantage of being able to make use of Mr. R. D. Oldham's very complete bibliography, presented to the Geological Survey of India in 1888. The earlier additions made by the author to Mr. Oldham's work have been largely due to his long English residence in Cambridge, by which he had access to the libraries of the Cambridge University, the Geological Society of London, the India Office, the British Museum, the Imperial Institute, the Science Museum, the Royal Geographical Society, and the Institute of Civil Engineers. Thanks are also recorded by the author for assistance given him by many State Geologists who have aided in his work.

The first volume (dated 1917) is devoted to a Bibliography of Indian Geology and Physical Geography, under authors' names, prefaced by 23 pages of abbreviated titles used in the work (all alphabetically arranged).

The second volume (dated 1918) contains an "Annotated Index of Minerals of Economic Value"; this is intended to be used in conjunction with the bibliography (which, indeed, is included and really forms part of this work).

The figures inserted in brackets after the observer's name correspond to the serial number allotted to each author, followed by the number of the page on which the reference will be found.

A list of works dealing generally with the distribution of economic minerals in India is given under provinces and authors, for India, Burma, Madras, Punjab, and Rajputana, the names of minerals being arranged alphabetically: e.g. Alum, Amber, Chromite, Coal, Copper ore, Corundum, Diamonds, etc., so that no separate index is required.

Much information relating to the mineral resources of the country collected within recent years is stored up in the progress reports and correspondence files of the Geological Survey Department in Calcutta, where it may be studied by those who are interested in the subject, either in its scientific or commercial aspects.

The matter comprised under the general heading "Building Materials" (pp. 27–62) is of course very complex in its nature, embracing descriptions and localities for limestones, sandstones, slates, quartzites, granites, marbles, basalts, gneissic rocks, laterites, serpentinous limestones, dolomites, etc., in great variety.

By this valuable compilation Mr. T. la Touche has conferred a great service on all who are seeking information on Indian geology. He has given us in these volumes a ready reference to the authors of all books and papers, not only relating to the geology and physical geography of our Indian Empire, but also to its economic minerals and rocks and the localities in which they are found. It is a book which should find a place in the reference works of every scientific library, but is much too large to carry in one's handbag.

III.—A Mystery Crinoid.

On *Mysticocrinus*, a new genus of Silurian Crinoidea. By Frank Springer. Amer. Journ. Sci., xlvi, pp. 666–668, pl. ii, Nov. 1918.

THE genotype is *Mysticocrinus wilsoni*, of which the holotype and a fragment were obtained by Dr. Herrick E. Wilson from the Laurel formation near St. Paul, Indiana, and are in the Springer Collection at the U.S. National Museum. The crown, with stumpy infolded arms, is like a wrinkled pea in size and shape. The cup consists of 3 unequal infrabasals (the small one right posterior), 5 basals, 5 radials, a radianal (forming the lower part of r. post R.), and a long anal *x*. This last rises in a spearhead between the adjacent arms; the other arms are separated by similar spearheads, formed from both shoulders of the anterior radial and the right and left shoulders of the right and left posterior radials; the antero-lateral radials have no such processes. The arms consist of 2 primibrachs followed by equal rami of 3 secundibrachs, except in the antero-lateral rays, which have but one primibrach. The tumid cup-plates and the short square brachials of the short arms give the crown a massive appearance, despite its small size.

Dr. Springer assigns this new genus to no Family, and is, indeed, uncertain as to the Order, though describing it as a Dicyclic Inadunate "intermediate between the Larviforma and the Fistulata". If by this he means phylogenetically intermediate, he is deriving dicyclic forms from monocyclic, which is unjustified. He excludes it from the Flexibilia because there is "no indication of loose suture or flexibility in cup or tegmen". None the less *Mysticocrinus* would seem better placed in that Order. The tegmen in any case is unknown, and in so small a cup it would be hard to see any indications of loose suture. The anal *x* recalls that of *Lecanocrinus*, as Dr. Springer says, also that of *Anisocrinus*. The tightly-closed arms resemble those of *Lecanocrinus* and still more those of *Mespilocrinus*. The inadunate character of the arms is primitive and is paralleled by *Pycnosaccus*, which has wide interbrachial areas occupied by small irregular plates. That genus and *Lecanocrinus* also display a tendency to have a single primibrach instead of the two usual in the early Flexibilia. The primitive position of the radianal is retained also in the Silurian Flexibilia, *Clidochirus* and *Ichthyocrinus*.

When Dr. Springer's great Monograph of the Flexibilia reaches this country we shall see to which of his Families *Mysticocrinus* might be referred. Its "mysterious" characters are due partly to its primitive stage of development and partly to conditions, probably of a reef-like nature, such as have so often produced similar forms.

F. A. Bather.

IV.—Notes on the Geological Structure of the Vale of Kingsclere. By H. L. Hawkins. Proc. Hampshire Field Club, vol. viii, pp. 191–212, with 4 plates, 1918.

The author gives an interesting sketch of the stratigraphy of the Vale of Kingsclere, with a general account of the development of the Cretaceous and Tertiary deposits. As a result of his palæontological work in the Upper Chalk, he proposes to subdivide the *coranguinum* zone, which is of unwieldy proportions, by marking off the upper portion as the "sub-zone of *Conulus albogalerus*". Some modifications are also suggested in the reading of two well-sections, affecting the assignment of certain beds to the London Clay and Reading Beds respectively. The most important part of the paper. however, is concerned with the tectonics of the district. A detailed study of the strike of the strata indicates that the periclinal structure of the district is modified by the interference of two anticlines and a syncline having a N.N.W.–S.S.E. strike and parallel to the East London ridge. These folds, though of very slight amplitude, nevertheless produce a marked effect on the strike of the Cretaceous rocks and are possibly due to slight posthumous movements of the Charnian fold-series. Hence it is possible that Palæozoic rocks may underlie the district at no great depth.

V.—Geological Observations in Fiji. By W. G. Foye. Proc. Amer. Acad. Arts and Sci., vol. liv, pp. 1–145, with 1 plate and 40 figs., 1918.

PROFESSOR FOYE spent seven or eight months of 1915–16 in a geological expedition to the islands of the Fiji group, chiefly for the purpose of studying coral-reefs at first hand, and this long paper gives an account of his observations and the conclusions drawn from them. The first part, entitled "Geological History of Fiji", describes the physiography and stratigraphy of the islands, and discusses the living and raised reefs in considerable detail. The larger islands possess a plutonic core and two series of sedimentary rocks, the older, probably Miocene, being folded along trend-lines parallel to those described by Suess in other parts of Oceania, the younger unfolded and apparently post-Tertiary. Four separate volcanic phases are recognized with a regular gradation in acidity, namely, (1) rhyolite, (2) andesite, (3) andesite, (4) basalt. The elevated limestones rest unconformably on eroded volcanic rocks, and there is abundant evidence of great instability of relative level throughout the group, partly due to uplift and subsidence and partly to return of water after the Glacial period. Hence the conditions are very favourable to the formation of reefs according to Darwin's theory. The reduction of masses of elevated limestone to sea-level has in some cases been accomplished by atmospheric solution, and slight submergence initiates the growth of reefs and atolls on these platforms. The present coral-reefs have been developed on surfaces formed by integration of a number of processes: (*a*) atmospheric erosion, (*b*) wave-cutting, (*c*) sedimentation, and (*d*) volcanic aggradation. On the other hand, it is demonstrated that the older limestones developed on a subsiding basement of eroded volanic rocks, but no evidence could be found in Fiji for the existence of Pleistocene benches; the platforms are much more modern in their development.

The second part of the paper gives a petrographic description of the rocks collected, including plutonic, hypabyssal, volcanic, pyroclastic, and sedimentary types. The igneous rocks are exclusively Pacific in their character, the most acid rock observed, with 70 per cent of SiO_2, called tonalite by the author, being composed of quartz, plagioclase, biotite, and hornblende. This appears to grade into diorite and gabbro, while the volcanic rocks are characterized by hornblende, augite, and hypersthene. It is suggested that the hornblende-hypersthene rocks have been formed by submarine eruption, the retention of gases allowing these minerals to form, whereas subaerial eruptions without water gave rise to augite. The volcanic vents of the region appear to have been extremely persistent in their localization, since the later basalts came from the same craters as the andesites.

This paper must be regarded as a valuable contribution to the ever-growing American literature of the reef-problem and of the petrography of the Pacific Islands.

VI.—Asbestos in the Union of South Africa. By A. L. Hall. Geological Survey of the Union of South Africa, Memoir No. 12. pp. 152, with 15 plates, 16 text-figures, and a map. Pretoria, 1918. Price 5*s*.

OF late years the Union of South Africa has become an important producer of asbestiform minerals for the world's market. It possesses deposits of chrysotile, tremolite, and crocidolite, and a new and important variety, here called amosite, has recently been developed on a commercial scale in the Transvaal. In this memoir Mr. Hall gives a full account of the properties and occurrence of all these varieties. Chrysotile is found in workable quantities in the Carolina district of the Transvaal in the upper part of the Dolomite Series, a few feet above a large basic sill. It also occurs in the Tugela Valley in Natal, as described by Dr. Hatch in 1910. Crocidolite is found in very large quantities in the banded ironstones of the Lower Griqua Town Series, which are equivalent to the lower part of the Pretoria Series of the Transvaal. Amosite is an amphibole, rich in ferrous iron and pale grey or nearly white in colour, and remarkable for the great length of its fibres, which can be obtained in quantity averaging 6 inches. It is found in the Lydenburg and Pietersburg districts of the Transvaal, near the base of the Pretoria Series. The genesis of crocidolite and amosite is discussed in detail and attributed to metamorphism of ferruginous and siliceous sediments associated with rocks containing magnesia and soda. The origin of the amosite deposits is believed to be connected with the intrusion of the Bushveld complex. The industrial aspects of the subject are also dealt with.

VII.—On Sections in the Lower Permian Rocks at Claxheugh and Down Hill, Co. Durham. By David Woolacott, D.Sc., F.G.S. Trans. Nat. Hist. Soc., Northumberland, Durham, etc., n.s., vol. v, pp. 155–162, with 4 plates and 2 figures, 1918.

THE author discusses the various ways in which brecciation has been produced in the Permian rocks and describes sections showing that local disturbances have been produced by horizontal movements due to thrusting from west to east, by which part of the Marl Slate and Lower Limestone have been displaced and cut out. No suggestions are offered as to the cause of the thrusting, but reference is made to the work of Trechmann on deposits of anhydrite at Hartlepool and to the presence of sulphates in the Permian rocks of other parts of North-East England. It is suggested that the removal of these by solution would at any rate lead to an accentuation of the effects of such movements, if produced by other agents.

VIII.—Summary Report of the Mines Branch of the Department of Mines, Canada, for the year 1917. 153 pp., with 4 figures. Ottawa, 1918. Price 15 cents.

THIS publication contains a summary of the work of the various divisions of the Mines Branch and gives evidence of great activity in several directions. Among the work of properly geological character may be mentioned reports on the iron-ores of the Rainy River district, on the limestones of Ontario, and on certain sands and sandstones. The Fuels and Fuel-testing Division investigated a large number of peat bogs in various localities, while the Ore-Dressing and Metallurgical Division carried out tests on a large number of ore samples, including gold, silver-lead, iron, manganese, chromite, tungsten, and molybdenum. The Ceramic Division examined into resources of clay and shale in several provinces, and an account is given of the manufacture of magnesite products, an industry of growing importance.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

February 5, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communication was read—

"The Geology of the Marble Delta, Natal." By Alexander Logie Du Toit, B.A., D.Sc., F.G.S.

The paper deals with the crystalline dolomitic marbles of Port Shepstone, Natal—rocks that have already been the subject of several communications to the Society; but its main object is to demonstrate that certain "boulders" of alkali-granite, formerly regarded as inclusions, are in reality parts of intrusive tongues, and to discuss the mutual relations of the igneous rocks and the adjacent dolomites.

The main area of Marbles covers a tract of about eight square miles. It is not a solid block surrounded by granite and gneiss, but a bent and twisted mass enveloped and underlain by igneous material, and cut into several distinct portions by great intrusive sheets.

The Marbles, almost wholly dolomitic in composition, are medium to coarse-grained rocks that have their bedding-planes marked out by various contact-minerals. They reach a total thickness of about 2,000 feet, and are divided into an upper and a lower portion by a narrow belt of quartz-schist.

The plutonic rocks are, for the greater part, coarse-grained biotite- or hornblende-orthogneisses, with streaks and belts of hornblendic gneisses, schists, and granulites at or near the contacts with the Marbles. A conspicuous feature of the igneous rocks is that, for a distance of two to eight miles from the contact, they contain red and brown garnets.

In addition to the normal type of metamorphism produced by the gneiss and the granitic offshoots therefrom, there is also developed at the contacts a phase almost identical with that presented by xenoliths of limestone in volcanic rocks. Through the action of magmatic emanations, zones possessing more or less regularity have been produced in the adjacent dolomitic marble, of which the innermost is commonly rich in diopside and often in scapolite, with forsterite, phlogopite, chondrodite, and spinel farther away. The dedolomitization is usually perfect.

In the contact-zone forsterite and chondrodite are antipathetic minerals, the latter being invariably farther removed from the intrusion.

In certain cases the marble beyond the silicate-zone has been deprived of the bulk of its magnesia, and has been changed into a mass of coarsely crystalline calcite. This phenomenon has probably been due to the action of carbonated waters during the cooling of the plutonic masses.

The absorption of marble by the magma at the contacts has caused the development of pyroxene in the intrusive rock, but there is no evidence in this area of large-scale assimilation of marble by the gneiss.

II.—Liverpool Geological Society.

February 11, 1919.—W. A. Whitehead, Esq., B.Sc., in the Chair.

The following papers were read:—

1. "The Ancient Settlements in Wirral in relation to the Surface Geology." By William Hewitt, B.Sc.

A study of the geological drift map of the Wirral peninsula in relation to the early settlements in the area revealed certain points of interest. For the purpose of the inquiry the peninsula was considered as extending beyond the existing boundaries of the "hundred of Wirral" to a line running from the River Dee at Chester to the opening of the River Weaver into the Estuary of the Mersey. Of the surface so defined, approximately 64½ per cent is covered with boulder-clay and 1½ per cent with drift sand; 19 per cent is made up of various patches of Triassic rocks free from glacial deposits, while the remaining 15 per cent is covered with recent deposits. The 77 ancient settlements in the area which are either mentioned directly in the Domesday Survey Record (viz. 52) or are known from early records to have been in existence at the time of the Conquest, are situated as follows: 41 or 53 per cent on exposed rock surfaces free from drift, 2 on blown sand, 10 on drift sand, and 24 or 31 per cent on boulder-clay, this distribution showing a marked preference for a pervious foundation. A detailed classification of the settlements was given, and many particulars of interest both to the archæologist and to the geologist are recorded.

2. "Some Borings through the Marshes bordering the Southern Shore of the Mersey Estuary." By F. T. Maidwell.

In this paper full details are given of a large number of borings made in recent years by the firm of E. Timmins & Sons, Ltd., Runcorn, in the neighbourhoods of Frodsham, Ince, and Ellesmere Port, some of which reached a depth of over 900 feet below the surface. At Ellesmere Port evidence has been obtained of an important trough fault, and the thickness of the drift has been proved to be as much as 113 feet. None of the boreholes passed beyond the Lower Bunter Sandstone.

III.—Edinburgh Geological Society.

January 22, 1919. (Received February 14.)—Professor Jehu, President, in the Chair.

1. "The Origin of Terrestrial Vertebrates." By the President, Professor T. J. Jehu.

The ancestry of vertebrates is still an unsolved problem, and palæontology can throw little light on the subject. One theory traces their descent through a series of primitive Chordate forms represented by *Amphioxus*, the *Tunicata*, and *Balanoglossus*. The peculiar ciliated larva of *Balanoglossus*, known as *Tornaria*, shows marked resemblances to the larvæ of the echinoderms, and a form similar to this larva may possibly have been the common ancestor of echinoderms and vertebrates. Another hypothesis derives the vertebrates from the Annelida, the organs of which show a curious correspondence, but with a general reversal of the relation of the various parts to one another. A recent theory seeks the vertebrate ancestor amongst the more primitive arachnoids, now represented by *Limulus*, and formerly exhibited by the extinct group of *Merostomata*. Chamberlin's theory is that the vertebrates originated in flowing land waters as a response to the influence of strenuous dynamic conditions impressed upon a primitive animal aggregate towards the close of pre-Cambrian times. The return of migratory fishes to rivers for spawning purposes is an argument in favour of regarding flowin land waters as their ancestral home. Primitive armoured fishes are found in Ordovician sediments in Western America, and more typical fishes appeared in Europe towards the close of the Silurian period and became abundant in Old Red Sandstone times. The appearance of fishes which utilized the air-bladder for respiratory purposes at this period was the result of adaptations to oscillations of climate leading to alternate seasons of drought and rain. The life-habits of Dipnoans and fringe-finned Ganoids which have survived as relic fauna to the present day were described. These afford a clue to the conditions of life which, during Devonian time, led to lung-breathing in the Dipnoans and Ganoids of that period. Increasing aridity of climate eventually led to the emergence of vertebrates from their aquatic habitat and their adaptation to life on land. This transition is illustrated in the Amphibia which appeared at the close of the Devonian period and developed into diverse forms during the Carboniferous. The fact that the early life of amphibians is aquatic and that for a time they breathe by means of gills, shows that they were not completely adapted to a terrestrial life. The *Stegocephalia* show more resemblances to the fringe-finned Ganoids than to the Dipnoans, especially in the structure of the limbs, and more probably evolved from that Order. At the beginning of the Permian the *Stegocephalia* gave rise to the reptiles which were able to survive more completely arid conditions and were adapted to an entirely terrestrial life. Reference was made to Broom's theory that the evolution of mammals from reptiles was rendered possible when the Theromorphs developed limbs which enabled them to carry the body off the ground. The aridity of climate during Permian times served as an incentive to speed, and the extensive glaciation, which supervened during that period in the Southern hemisphere, favoured the acquisition of warm blood and of heat-retentive clothing. In their anatomical features the Theriodonts of the Permian and Triassic bridge the gap between reptiles and mammals. This was illustrated by a description of the origin of the paired occipital condyles of the mammal from the tripartite single condyle of Theromorphs, by the gradual reduction of the bony elements of each half of the lower jaw in these reptiles, by their heterodont dentition, by the structure of the shoulder and hip girdles and other features.

2. Specimens of native gold from Rhodesia were exhibited by Dr. M'Lintock.

IV.—Geologists' Association

The annual general meeting of the Geologists' Association was held at University College, Gower Street, W.C. 1, on February 1, 1919, when the following lecture was delivered :—

"The Nimrud Crater in Turkish Armenia." By Felix Oswald, D.Sc., F.G.S.

The Nimrud volcano, situated on the west coast of Lake Van in Turkish Armenia, has a perfect crater nearly five miles in diameter. The precipices of the crater-wall rise two thousand feet abruptly from a deep lake which fills half the area of the crater. The lecturer described the external and internal features of this great volcano, which he visited and surveyed some years ago, and he gave a summary of its geological history down to its last eruption in 1441.

The lecture was illustrated by lantern-slides, photographs and drawings.

March 1, 1919.

"Some Suggestions on the Flaking and Evolution of Flint Implements." By S. Hazzledine Warren, F.G.S.

The paper dealt with the following points:—

Characteristics of the fracture of flint under internal molecular strain, flexion, tension, compression, etc. The planes of least resistance—what they are and what they mean. The designed flake and the accidental chip. Normal flaking at about 75° tending to cuneiform flakes. High angle and low angle edge-flaking tending to incurved flakes. The Levallois-Pressigny method. Suggested evolution of the Neolithic axe and double axe from special forms of palæoliths. Possible development of the Neolithic arrow-point, scraper, sickle-knife and certain other implements from the Mousterian racloir along divergent lines of evolution. The importance of wood and bone for implement making in past human industries.

CORRESPONDENCE.

TOPAZ AS A ROCK CONSTITUENT.

Sir,—When a paper on the Gunong Bakau topaz and cassiterite [1] appeared in this Magazine for 1916, it was sufficient for the time being to ask you to publish a report [2] to which the author referred in order to show that before I worked out the structure of Gunong Bakau [3] he held the view that the quartz-topaz rock was "topazised granite", and attempted to explain the horizontality of one of the ore-bodies by faults, thrusts, and a landslip, although in his paper he writes of the "important veins intrusive in the porphyritic granite", and argues that because certain topaz-bearing rocks in Germany and elsewhere are considered to be altered granitic rocks, the same origin should be accepted for the Gunong Bakau quartz-topaz rock. I do not propose to repeat the evidence on which my opinion that the topaz is a primary mineral was based, but there are two points of general interest that might be mentioned in connexion with topaz as a rock constituent.

On pp. 300 and 301 of *The Natural History of Igneous Rocks* Dr. A. Harker writes: "Closely bound up with the greisens are the tinstone veins, the cassiterite probably resulting from reaction between the volatile tin fluoride (SnF_4) and water. The destructive action of fluorides is exceedingly energetic. At Geyer, in Saxony, granite is locally converted to a rock containing more than 90 per cent of topaz," and quotes as his authority regarding the Geyer rock Salomon & His' paper in the Zeit. deutsch. geol. Gesellschaft, vol. xl, pp. 570–4, 1888. Dr. Jones follows Dr. Harker in making a similar reference to these authors; but the fact remains that whatever may be the truth about the origin of the topaz they described, Salomon & His did not write anything in that paper that justifies their being quoted as authorities for its formation by the destructive action of fluorides. On the contrary, Salomon and His made it clear that they considered the topaz in the greisen to be the primary topaz that occurs in the granite. They mentioned topaz as being widely distributed as a constituent of the granite stocks, although it seldom becomes a prominent constituent. They said that one must expect the topaz, so characteristic of the granite, in the greisen as well, and on pp. 573 and 574 they described aggregates of topaz with a little felspar and mica which become converted by decomposition into aggregates of 90 per cent topaz with a little kaolin and ferrite. According to these authors the topaz was not formed by pneumatolysis. Never having seen the Geyer or indeed any German greisens in the field, I am not in a position to say whether Salomon & His were correct in their view or the reverse.

[1] Dr. W. R. Jones, "The Origin of Topaz and Cassiterite in Malaya": Geol. Mag., 1916, pp. 255–60.

[2] Loc. cit., pp. 453–6.

[3] Quart. Journ. Geol. Soc., vol. lxx, pp. 363–81, 1914.

On p. 379 of my paper on the Gunong Bakau rocks I pointed out that without segregation one could not expect to have a rock very rich in topaz. In a pure orthoclase magma the 18·4 per cent of alumina could only produce 32·6 per cent of topaz if attacked by fluorine unaccompanied by more alumina. Dr. Jones produces evidence to show that alumina was introduced into some greisens.[1] I do not know how the rock-sampling was carried out in the cases quoted, nor on how many analyses the results are based; but I do not wish to question the increase of alumina in any of the altered rocks in the table on p. 260 as compared with the unaltered granite. The greatest increase is 2·09 per cent, which, added to the alumina of a pure orthoclase rock, gives a possible 36·3 per cent of topaz, which is still very far short of 90 per cent, and we are not dealing with pure orthoclase rocks. There can be no question that topaz does occur as an original rock constituent. The Meldon aplite, for instance, has been described anew recently,[2] in which topaz is associated with lepidolite, tourmaline, and fluorspar, among other minerals. There is no doubt in my mind that it occurs also as a pneumatolytic alteration product. Each case must be decided on the local evidence.

J. B. Scrivenor.

YUNNAN CYSTIDEA.

Sir,—A few comments are necessary on Dr. Bather's letter in the March number of this Magazine (p. 143) in reply to my remarks on his articles on Yunnan Cystidea. Especially is this the case with regard to the diplopores in *Sinocystis*. Firstly, it must be borne in mind that the figured specimens which were lent to him for a short time for the purpose of making casts for the British Museum constitute the only material on which he can base his conclusions, while I had three times the number of specimens for study for two years. Secondly, it has not been mentioned that these figured specimens before being drawn or sent to him had been cleaned under my eyes with a weak acid solution, which I then observed attacked and partially dissolved a few of the tubercles, so as to remove the thin covering layer of epistereom in some cases and thus expose the pores. Thirdly, the other specimens of *Sinocystis*, numbering over twenty, which Dr. Bather never saw, were examined by me as they came fresh from their limestone matrix, unaffected by weathering, untouched by any solvent, and often only partly exposed. These did not show any pores on the hundreds of tubercles which I scrutinized, except where the tubercles were obviously injured. Fourthly, his statement that on removing a piece of the matrix from one of my figured specimens there was disclosed a tubercle exhibiting the minute pores completely confirms my experience that there is extreme difficulty in getting rid of the closely adherent matrix without damaging the surface, and thus his discovery is of

[1] Op. cit., pp. 259–60.
[2] Geol. Mag. 1919, pp. 41–2.

no value in support of his views. As I was ignorant that he was intending immediately to publish a detailed critical re-description of the species which I had established, and that all his evidence would be obtained from the few figured specimens which were lent for another purpose, the rest of the material was not put into his hands, and the unfortunate errors to which allusion has been made have thus appeared in his otherwise valuable articles on these interesting fossils.

F. R. C. Reed.

Cambridge.
March 14, 1919.

OBITUARY.

ARTHUR EDWARD VICTOR ZEALLEY, A.R.C.S., F.G.S.

Born March 1, 1886. Died October 28, 1918.

A most promising career has been cut short by the death of A. E. V. Zealley from pneumonia following influenza in the epidemic which visited Rhodesia in October, 1918. Zealley received his geological training at the Royal College of Science, London, and afterwards was appointed Demonstrator in Geology there. At this time he worked upon the metamorphosed limestones of Donegal, and published a short note in the Geological Magazine for 1909, but the complete work is still in manuscript.

In 1909 Zealley went out to Southern Rhodesia as Curator to the Rhodesia Museum. In that capacity he saw the collections housed in the first part of a building specially designed for a museum. He made important contributions to the Museum Reports on the minerals, on the mineral resources, and on the gold-bearing rocks of Rhodesia; and wrote articles and papers on the local minerals and rocks.

Zealley joined the Geological Survey of Southern Rhodesia in 1911, shortly after it was started, and remained in that service until the time of his death. His work lay chiefly amongst the metamorphic rocks, and he took part in the mapping of several of the goldfields. He was particularly interested in the ore-deposits, their genesis, and the association of minerals in them.

He had gained a wide knowledge of the mineral deposits of the country, and his work was inspired by the belief that for their efficient development a thorough and exact study of them was necessary. When, after the War broke out, the systematic mapping of the Geological Survey was suspended, he threw himself wholeheartedly into the task of assisting prospectors with the determination of minerals and with advice as to the nature of the deposits they had found. He also took an active part in the work of the Rhodesia Munitions and Resources Committee, which has done much to spread a knowledge of the mineral wealth of the Territory. His ever-ready willingness freely to give his geological knowledge was much appreciated by prospectors and mining men, and will be greatly missed.

H. B. M.

TABLE of BRITISH STRATA

Compilers :

HENRY WOODWARD, LL.D., F.R.S., F.G.S.

HORACE B. WOODWARD, F.R.S., F.G.S.

MANY years have elapsed since the publication of a Table of British Strata. The Table of British Sedimentary and Fossiliferous Strata by Messrs. H. W. BRISTOW and R. ETHERIDGE and that by Mr. BRISTOW, showing the Relative Thickness of the Strata, date back to 1873.

Meanwhile many changes have been made in nomenclature, and many new local subdivisions have been marked out in the series of Strata. To represent these in tabular form as an aid to the memory is one object of the present publication.

The student should bear in mind that Nature does not draw the hard and fast lines which appear in the Table, and that the divisions, like those in human history, are epochs artificially limited for the convenience of grouping events. In many cases it is possible to indicate only the general position of the minor divisions in the great series of geological formations. Minute correlation of strata, dependent on organic remains, cannot here be attempted.

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AND

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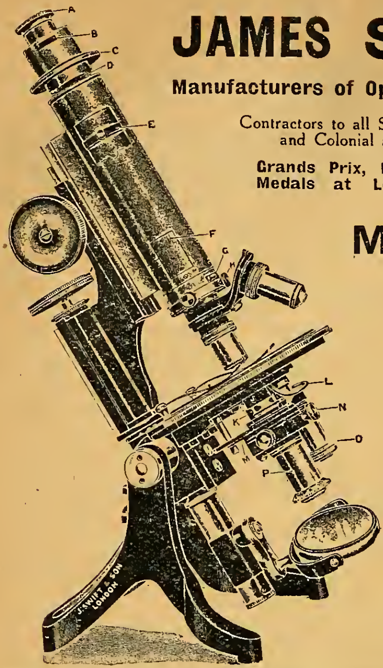

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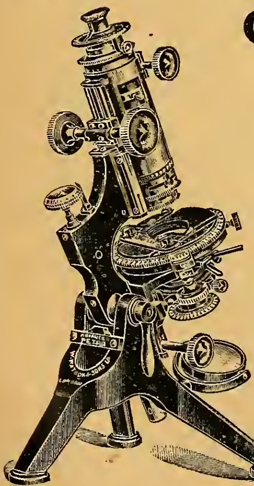

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THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. VI.

No. V.—MAY, 1919.

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EDITORIAL NOTES.

As will be seen from the official report reprinted elsewhere in this issue, the Geological Society has decided at a Special General Meeting to admit women as Fellows. It was generally believed that the result was a foregone conclusion, and the figures of the ballot indicate that this belief was justified. As the President pointed out in his opening remarks, the Society has in the past pursued a rather hesitating policy with regard to this matter, and it is satisfactory to find that a clear and definite decision has at last been made on a motion initiated by the Council. The work done in the past by a number of women geologists has been of a high order of merit, and the recognition of its worth will doubtless stimulate others to follow in similar paths and even to surpass the achievements of the pioneers. Ere long we shall doubtless see ladies occupying seats on the Council and possibly even the presidential chair.

*   *   *   *   *

We have much pleasure in calling special attention to the paper appearing in this number of the Magazine under the title of "Foliation and Metamorphism in Rocks". In this Professor Bonney gives a summary of the conclusions reached by him after an almost lifelong study of the subject both in the field and in the laboratory. It so happens that Professor Bonney's active geological life nearly synchronizes with the existence of microscopic petrology; he was one of the pioneers in this field and has had unrivalled opportunities of examining the gneissose and schistose rocks of many parts of the world, and especially those of the Alps. Again, he has devoted much attention to the origin of serpentine and cognate questions, both in Britain and abroad, with important results. Among other achievements Professor Bonney was one of the band of geologists who set British stratigraphy free from the incubus of "altered Silurian", and assisted to exorcise many other bogeys surviving from an earlier day. We feel sure that our readers will welcome this summary of the conclusions reached by one of the masters of petrology after nearly half a century of research, all the more because the observations on which the results are founded are entirely first-hand and independent of textbooks or preconceived ideas of any kind.

*   *   *   *   *

Following a deputation to the Board of Trade from the Joint Industrial Council for the Tin-mining Industry of the United Kingdom, the Government delegated to the Imperial Mineral Resources Bureau the duty of making a preliminary inquiry into the position of the industry, which is, as is well known, in a parlous condition owing to the high cost of labour and material, without a corresponding increase in the price obtained for the main product of the mines, namely black tin or cassiterite. A committee was formed to undertake the work, Sir Lionel Phillips being appointed Chairman, and Dr. F. H. Hatch and Mr. W. Forster Brown, on behalf of this Committee, have recently visited the principal mines in the Camborne–Redruth area as well as those near St. Just and St. Agnes. At their request they were supplied with full data relating to the operation of the mines in the years 1912–18 inclusive. We understand that the report of the Committee, after approval by the Bureau, has been placed in the hands of the Government, and will be considered as soon as possible.

*   *   *   *   *

The lecture recently given by Professor Edgeworth David before the Geological Society gave food for a considerable amount of reflection on the importance of geology in warfare and the extraordinary inability of our military authorities to appreciate this importance. It was, however, fully realized by the Germans, who had a geologist for every 20 kilometres, as against one geologist for the whole of the British western front. This responsible post was held by Captain W. B. R. King, of the Geological Survey of Great Britain. On occasion Professor David also assisted with advice on geological matters, especially with regard to water supply, but as a rule no geologist was consulted until borings in unsuitable places had failed to find water, thus wasting time, labour, and money. Expert geologists were also urgently needed to advise with regard to tunnelling and mining operations; owing to ignorance of the position and depth of the water-table tunnels were frequently drowned out. A water-table map of most of the western front was eventually constructed, but it was impossible for the small staff to deal adequately with this and many other matters, such as prospecting for road-metal and other necessary supplies. Although many geologists were actually serving in the Army in various capacities on the western front, Headquarters did not seem to think that their services could be usefully employed; some of the Engineers high in authority did, however, realize the value of geology and would have liked more help, as is made manifest in a paper entitled "The Work of the Miner on the Western Front", read by Major H. Standish Ball before the Institution of Mining and Metallurgy on April 10, and published in the Bulletin of the Institution for last month. This contains some brief but highly appreciative remarks on the geological work of Professor David and others. The general conclusion to be drawn is that professional geologists ought to be permanently attached to all armies.

*   *   *   *   *

Owing to the unprecedented demand for houses, a large amount of indiscriminate building will take place in the immediate future. A recent issue of the *Observer* contains a most timely article, signed "Silex", on the necessity for geological advice and control in these matters. There are few subjects on which more nonsense is talked and written than on the question of the suitability or otherwise of various soils for residential districts. The general public has acquired some vague ideas as to the advantages of gravel soils and the supposed evil effects of clays, but the importance of taking into account other conditions as well is hardly ever realized. The man in the street is by no means aware that a gravel site in a hole, such as the Thames Valley, may be infinitely wetter and more unhealthy than a clay site on a hill, and similar instances might be multiplied indefinitely. It is highly desirable that local authorities before giving their consent to building schemes, at any rate on a large scale, should consult an expert as to the suitability of the area suggested for the special purpose in view, and that they should refuse their consent in the case of an unfavourable report. Neither municipalities nor the State can afford to allow the health of the people to be endangered or money tc be wasted in unprofitable and possibly injurious enterprises, when this can be prevented by sound scientific and technical advice.

* * * * *

Mr. T. Sheppard has again earned a debt of gratitude for a remarkably interesting sketch of Martin Simpson and his career. He provides a pedigree, bibliography, and detailed description of his books and a variety of personalia now difficult to obtain, a facsimile of his writing and the well-known portrait. The paper appears in the Proceedings of the Yorkshire Geological Society, xix (4), 1918.

* * * * *

Dr. H. S. Washington contributes to *Art and Archæology*, vii (7), August, 1918, 256–63, a description and figures of a medal he acquired in Rome. Of Leonello Pio, Count of Carpi, it is cast in lead, and dates from about 1500. The artist is unknown. The special interest of this medal lies in the fact that it represents a volcanic eruption, with "lightning-charged" clouds, falling bombs, and lava-flow in realistic fashion, and Washington, from a most careful and elaborate investigation, thinks that it must represent the eruption of Vesuvius of 1500, described by Ambrosio Leone in *La Storia di Nola*, 1514, which contains the oldest known figure of Vesuvius. If that is so, then the medal is probably a little earlier in date than the book. The legend on the reverse, surrounding the design of the mountain, reads MELIUS PUTATO, which Washington interprets as "more powerful (or active) than I have been thought to be", and he further points out that as the records of earlier eruptions are 1036, 1049, and 1139, the motto would be appropriate to the popular idea that the volcano was then extinct.

ORIGINAL ARTICLES.

I.—Foliation and Metamorphism in Rocks.

By Professor T. G. Bonney, Sc.D., LL.D., F.R.S.

Introductory.

THE application of the microscope to petrology made it possible to investigate effectively the history of the foliated rocks and of metamorphism. This was done, as it happens, only a very few years before I began any special study of such rocks, so that the account of my own work almost corresponds with that of the general progress in a knowledge of them. I was led, after some preliminary efforts, into investigating two distinct problems, each of which, as I soon discovered, presented rather exceptional difficulties. These were the pre-Carboniferous rocks of Charnwood Forest and the serpentines of the Lizard. The problem involved in the one was how far some of them were or had been igneous in origin, lavas, tuffs, and agglomerates, or were stratified rocks, which by pressure and mineral changes had been so altered as to be indistinguishable from some of the former. The other introduced the question of the origin of serpentine, about which in 1873 the utmost uncertainty existed.[1] This, from its associations, led on to investigating the nature and origin of gneisses and schists, so that the history of my own studies during the last forty-five years happens to illustrate some important aspects of the progress made during that period. So I have thought that even now, notwithstanding the multiplication of textbooks and special memoirs (nay, perhaps because of it), some younger students may find it both interesting and useful to read the conclusions which I have been led to adopt, and to have their attention directed to investigations which were, to a large extent, independent and unbiassed.

As my first paper depending on microscopic work was published early in 1877, anyone who consults those which have since appeared must not be surprised to find that my conclusions have been reached by degrees, and that some have had to be retracted. The former should be forgiven, because one frequently resembled a man feeling his way through a dense forest and the latter was often due to misleading information. More than once I have found that the old saying "put not your trust in princes" is true even in science. Of both these defects my work in Charnwood and at the Lizard affords instances. In the latter it was long before the real history,

[1] The following remarks appeared in *Rocks, Classified and Arranged* (B. von Cotta; translated by P. H. Lawrence and published in 1866 with author's preface of same date). After stating that serpentine is "probably the product of the metamorphosis of some other rock", he continues (p. 317): "In some places . . . its transmutation from other rocks is very evident, as, for instance, from gabbro at Siebenlehn, near Freiberg; from dykes of granite traversing serpentine rocks near Böhrigen and Waldheim in Saxony, where the main serpentine itself is not improbably a transmuted granulite; from chlorite-schist at Zell in the Fichtelgebirge, where the change does not appear to be yet complete; and from gneiss (probably) or an eclogite rock in the gneiss at Zöblitz in the Erzgebirge."

as I believe it to be, of its gneisses and hornblende schists came home to me. The same holds good of the Alps, but in one paper relating to them, that on *The Carboniferous Gneiss at Guttannen*,[1] I doubt if I have not fallen into one error while trying to correct another. Besides studying the slab supposed to contain two small tree stems in the Berne Museum, I visited Guttannen in 1891, 1895, and 1897, and in the last year saw an outcrop of the "Carboniferous gneiss" in the Urbach-thal. But it has since been proved that these objects are not fossils of any kind.[2]

How the Problems arose.

On beginning to give lectures in Geology just half a century ago, I soon discovered how little I knew about that part of it which is now called petrology, and that the authors of the textbooks then in use were in much the same position. In England De la Beche, in Scotland Macculloch[3] had done most valuable work, but with their deaths not only had progress been arrested but also a movement had begun in a reverse direction.

The application of the microscope to the study of thin slices of rocks, for which we are indebted to the inventive genius of H. C. Sorby,[4] arrested this movement and gave the student a surer footing. I began to work with this instrument about 1870 (tentatively at first, because at that time my eyes were far from strong), and for a while restricted myself to the igneous rocks, but I was soon drawn into those of the metamorphic group and was speedily confronted by statements which, as I was not long in finding, rested on very uncertain evidence. This forced me to enlarge my field of examination. Charnwood, as I have said, soon presented one set of problems, the Lizard another. The difficulties of the Llanberis district resembled the former, those of Anglesey to some extent approximated to the latter. Specimens sent to me by friends directed my attention to the alleged metamorphism in South-Western Ayrshire and in the North-Western Highlands, and I sought light on the difficulties of the latter by studying the gneisses and schists of the Alps, among which I often spent a summer holiday.

Thus having done what I could, for nearly forty years, by work in the field and with the microscope, to solve some of the problems presented by the metamorphic rocks, I have thought that perhaps a short record of the results might be useful. It contains, I fear, nothing new; probably everything in the following pages "has been said by somebody somewhere", but I may at any rate plead that my conclusions have not been taken "second-hand". As a rule,

[1] Q.J.G.S. xlviii, p. 390.

[2] The story of this "Comedy of Errors" is told in "Plant Stems in the Guttannen Gneiss", Geol. Mag. 1900, p. 215.

[3] J. Macculloch died in 1835, H. T. De la Beche in 1855, but the clouds were gathering again before the latter date. An excellent account of the difficulties which had to be encountered by those who were living and working in the earlier half of the nineteenth century is given by Sir A. Geikie in *The Founders of Geology*, ch. viii.

[4] He began this work, for some years little appreciated, about 1850.

I have consulted memoirs and textbooks only so far as to obtain a statement of the problems and to ascertain what places were likely to throw light upon them, and on this account ask my readers, if they think my conclusions wrong, before rejecting them contemptuously because they are unorthodox, to "go and see"—to examine nature for themselves, to collect their own specimens, and to study them with the microscope.

Foliated Rocks.

Foliation denotes a structure due to a more or less parallel ordering of certain of the mineral constituents in a rock which is not a direct consequence of its stratification. Such rocks are commonly called metamorphic, but that structure, as we shall see, is more often an original one than was once supposed. In a certain sense all rocks, except recent volcanic ejections and such sedimentaries as wind-blown sands and dusts, or diatomaceous earths, coral-reef limestone and even pure chalk, are metamorphic, because they have undergone some amount of mineral change since the time when they were first deposited. In a sandstone, for instance, the fragments are cemented by a little secondary quartz or iron-oxide; in a limestone those of calcareous organisms are united by calcite; in an igneous rock the less stable minerals have undergone some change, but we do not consider this as amounting to metamorphism. To justify the use of that term, the bulk of the constituents, all in fact which are small in size, should have lost the aspect which was once characteristic; for instance, in a limestone the calcareous organisms should be no longer recognizable as such, and any constituent mud should have been converted into a mica or some other authigenous mineral. This may, however, happen, as we shall presently see, without resulting in a definite foliation. But in certain igneous rocks such a structure may be, not a superinduced, but an original one.

Foliation, then, is produced by a parallel ordering of the authigenous platy or acicular constituents in a rock, and may or may not be associated with mineral banding.[1] In the simpler case, when the constituents are not thus grouped, we find that the foliation is the result of movements in the mass, before it has become completely solid, though after most of its component minerals had segregated. Banded foliation, however, proves to be due, at any rate in many cases, to the movement of two associated magmas, different in chemical composition, both of which are in a somewhat plastic condition, though one may be more nearly liquid than the other. The two are forced along, sometimes without mixing, as two differently coloured glasses may be in the hands of a glassblower. Many varieties of rock, from acid to basic, from vitreous to holocrystalline, afford examples of this structure.

I have studied its various stages in several places, of which the following may serve as examples. (*a*) On the southern half of Kennack Cove (Lizard) we can see veins of a grey granite breaking up a dark slightly foliated biotite-diorite, which it partly melts

[1] See *Manual of Geology*, J. B. Jukes, 1872 (ed. A. Geikie), p. 142.

down, till a well-banded gneiss results from the movement of the imperfect mixture (**1**).[1] (*b*) A similar gneiss occurs in Kynance Cove and the cliffs to the south, though here the first stage is not so well illustrated (**2**). (*c*) In Sark, on both the east and west coasts, we find a similar banded gneiss, produced by the intrusion of an aplitic granite into a basic diorite or hornblendite (**3**). The hornblende schists of the Lizard and of Sark also suggest a similar origin, viz., that after a moderately basic magma has been separated by differentiation into a more acid and a more basic part, the two, while still in a pasty state, have been forced to flow together (**4**). The different stages (*d*) of this process are very well displayed on the ice-worn rocks at the foot of the Allalin Glacier in the upper part of the Saasthal (**5**). Here a rather fine-grained aplite breaks into a mass of *grüner Schiefer* (probably a pressure-modified diabase). Sometimes the one rock simply forms veins in the other; sometimes the former breaks off fragments from the latter; sometimes it melts part of these, producing locally a fine-grained green-streaked gneiss. A process generally similar may be studied (*e*) in the rocks under Castle Cornet, Guernsey (**6**). Thus, as gneisses and hornblende-schists, exactly resembling those of which the genesis can be observed in the field and under the microscope, are by no means rare, we seem to be justified in concluding that this production of banded gneisses by partial mixture of more or less plastic magmas is one of frequent occurrence.

b. Foliation also may be produced in an ordinary holocrystalline rock by the action of pressure, more or less definite in direction, and sufficiently great to cause a partial crushing of the mass, which is succeeded by the formation of new minerals. Sharply folded rocks, such as often abound in mountain ranges, afford many examples of this kind of foliation. Here the quartz is more or less crushed; so also is the felspar, but this mineral, by the subsequent action of water (doubtless when the pressure was diminishing), is replaced by a mixture of granules of quartz and small scales of a white mica, the latter generally lying at right angles to the direction of pressure. Thus a granite may exhibit all stages from an ordinary gneiss to a mica-schist (**7**), and a porphyritic granite those from an augen-gneiss to one characterized by thin and rather minutely crystalline bands (**8**). The so-called protogine of the Alps, which, instead of being the "first-born" of their crystalline rocks, is intrusive into great masses of a more or less banded gneiss (sometimes rather rich in biotite), affords excellent examples of this, as in the Mont Blanc range (**9**), on the upper part of the St. Gotthard Pass (**10**), and in more than one district of the Engadine (**11**).

One form of "pressure-gneiss" deserves special notice, because, till about thirty-five years ago, its origin was a geological puzzle. Of this the so-called Newer Gneisses of the North-West Highlands are an historic example. These appear to overlie the basal Cambrian quartzite and some other sedimentary rocks belonging to the rest of that period and perhaps a little of the Ordovician. They form an

[1] Figures in heavy type refer to the bibliography at the end of the paper.

escarpment, often very conspicuous, which runs from the southern end of Loch Maree to the north of Loch Eriboll, the members of which are generally "slabby" in structure, composed mainly of quartz, felspar, and mica, though the minute scales of the last appear to have been formed in situ.[1] This group of gneisses was asserted to represent a set of metamorphosed stratified rocks, approximately of Silurian age. Difficulties in this interpretation became graver as the knowledge of petrology increased, till, in the summer of 1882, the problem was finally solved by Professor Lapworth (**12**), who demonstrated that some of the pre-Torridonian crystalline rocks had been carried by overfolding and overthrusting above sedimentaries of later date, and had been greatly crushed in the process. So these "Newer Gneisses" are really Archæan Gneisses, which have undergone pressure-modification, a clastic structure (followed by a certain amount of mineral development, as described above) having been imposed on them at some epoch subsequent to the latest Cambrian and distinctly before the Devonian periods (**13**). A similar origin was claimed by Professor Lehmann in 1884 (**14**) for certain slabby gneisses in Saxony, but in this region the gneiss appears to have been more completely reconstituted, so perhaps the crushing may have occurred at an earlier date, or some local cause have favoured the repairing process.

Rocks of a dioritic or doleritic nature also exhibit a pressure-foliation. The felspathic and ferro-magnesian constituents are crushed, and to a certain extent "rolled out", after which they undergo a process of reconstitution, analogous with that which has been described in the case of granite rocks, but the original augite or hornblende is replaced by an acicular and generally rather smaller form of the latter mineral. The rock becomes, in fact, an actinolitic schist, examples of which are common in the Alps (**15**). The more coarsely crystalline hornblendic gneisses, such as occur in the Lepontine Alps for some distance eastward from the south side of the St. Gotthard Pass (**16**) and in one or two parts of the Tyrol, also afford examples of a coarser form of pressure-foliation.[2]

The bulk of gneisses, especially the banded kinds, were formerly supposed to be metamorphosed sedimentary rocks. That was confidently stated less than half a century ago in textbooks of authority (**17**), and I well remember how often sedimentary rocks were said to pass (i.e. be melted down in situ) into igneous rock (**18**); nay, a metamorphic origin was sometimes attributed even to granite, because, as the specific gravity of its quartz was 2·65, and that of quartz which had been melted was only 2·25, the rock could not have been truly fused.[3] It is now not too much to say that the *onus*

[1] Similar gneissoid rocks occur on the southern border of the Highland complex from near Stonehaven northward for some miles.

[2] Certain minerals, such as hornblende, biotite, chloritoid, ottrelite, dipyr, couseranite, and a plagioclase felspar, seem to form with comparative ease, as will presently be described, in some crushed gneisses and hornblendic rocks.

[3] The advocates of this notion appear to have forgotten that normal crystalline quartz is a frequent constituent of felsites, rhyolites, etc.

probandi lies on anyone who claims a sedimentary origin for a gneiss, whether banded or not, and in the few cases where this can be proved the gneiss is usually limited in thickness and not quite normal in character; sometimes, indeed, the supposed gneiss is found on closer study to be merely a rolled out sill or vein of intrusive granite (**19**). Thus it is prudent, in dealing with gneisses which show no signs of passing, on the one hand, into schists by a gradual transition, on the other into indubitable granites, to carry them for the present to a "suspense account".

I pass on now to those crystalline schists which can be proved to be metamorphosed sedimentary rocks, viz. the group of the quartz-schists, quartz-mica-schists, calc-mica-schists, and crystalline marbles (or dolomites). These sometimes overlie, with marked unconformity, the above-named gneisses, though occasionally it is difficult to divide them. The same may be said of their relation to the overlying hypometamorphic or unmetamorphic strata, but in many cases their division from the one or other is not quite so clear.

The sedimentary origin of these crystalline schists, if we except the *grüner Schiefer* (and we must not exclude the possibility of some of these being metamorphosed tuffs), is unquestionable. In chemical composition they agree with corresponding members of the stratified rocks, and are associated in exactly the same way. Of these associations striking instances may be found in the Val Canaria, Val Piora, on the Nufenen and the Gries Passes, in the neighbourhoods of Binn, Saas, Zermatt, and at sundry localities in the French, Italian, and Austrian Alps (**20**). Here we can find dark or lead-coloured mica-schists, sometimes containing garnets (which may be as large as peas) interbanded with quartz-schists or passing rapidly into calc-mica-schists and marbles. They show the effects, often conspicuously, of subsequent pressure (**21**), but careful study makes it obvious that before this acted they had been well metamorphosed, that change having been due to the joint action of pressure, water, and heat, of which probably the last agent was most above the normal. We infer this from the fact that stratified rocks, which must have been depressed to very considerable depths from the earth's surface, and have been kept for a long time sodden with water, do not exhibit this kind of metamorphism. Its occurrence has often been confidently asserted, but every instance, such as the "fossiliferous schists" of more than one part of the Alps and the "Devonian schists" of the Start district, has broken down, on careful study in the field and with the microscope, like the "Newer Gneisses" of the Highlands.

A quartz-schist consists mainly of grains of quartz, but usually contains small flakes of white or lead-coloured mica, which occasionally form distinct and rather conspicuous bands (**22**). The purer varieties are almost white and slightly slabby (perhaps a superimposed structure. When this schist rests on gneiss its lower part occasionally contains some fragments of felspar and (in a few cases) pebbles of vein quartz or some compact rock resembling a hälleflinta (**23**). Evidently the purer varieties much resemble quartzites, but they present under the microscope a different structure.[1] The quartzites consist of distinct grains, angular or rounded, cemented together by a secondary deposit of quartz, often in crystalline continuity with the original grain, but those in a quartz-schist are rather more irregular and indefinite in outline, so as to give the matrix a slightly streaky structure and even to suggest the possibility that, like the mica, they are authigenous. The quartz-schists frequently pass up into mica-schists, and in one part of the Val Piora a fairly normal example is associated with a mica-schist containing many rather large staurolites (**24**). In this district masses of very dark mica-schist are abundant, and their lower part is sometimes repeatedly interbanded with a not very pure quartz-schist. Garnets occur in both these rocks, but are more abundant and rather larger in the mica-schist. The same garnet-bearing dark mica-schist occurs at the Alp Vitgira on the Lukmanier Pass (**25**) as well as on the Nufenen Pass (**26**) and in the Binnenthal (**27**). The dark mica-schist in the Val Piora apparently passes locally into calc-mica-schist, and it is found in a ravine on the western side of the Val Canaria, associated with a pale-coloured schist, largely composed of two species of mica, and with a calc-mica-schist, locally passing into a white marble.[2] In fact, these different kinds of schists may be seen to pass one into another, just as sandstones, clays, and limestones do among the ordinary sediments, so there cannot be any doubt that they are the metamorphic representatives of such rocks.

In the Alps the overlying slates and other sedimentary rocks, as a rule, are readily distinguishable from the above described schists, but at one or two localities, authigenous garnets and staurolites have been asserted to occur with belemnites, joints of crinoids, and other fossils, which prove the supposed schists to belong to the Lias (**28**). This assertion finds a merely superficial support from field evidence and breaks down wholly when tested with the microscope. The minerals associated with those organisms and called garnets and staurolites are neither the one nor the other, but only some silicates too impure to be identified with certainty; but probably allied to dipyr and a colourless chloritoid, which, under certain circumstances, form with comparative ease[3] and do not indicate sufficient metamorphic action to obliterate any organism, though this is generally one of the first things to disappear before a marked rise of temperature. Nature has, in fact, been setting traps for the unwary petrologist.

In some localities the apparent passage from a dark crystalline

[1] The pressure-modified quartzites of the Scotch Highlands, such as those of Glendhu in Sutherland, present the nearest resemblance to a true quartz-schist.

[2] Descriptions of these schists, together with analyses quoted from an article by Dr. Grubenmann (Mitth. Thurg. naturf. Ges., Heft viii, 1888), are given in a paper on "Crystalline Schists and their Relation to Mesozoic Rocks in the Lepontine Alps" (Q.J. 1890, pp. 187–236). The garnets appear to be an impure representative of the alumina-lime variety. They are sometimes about one-third of an inch in diameter.

[3] They had already been analysed (see Q.J.G.S. 1890, p. 233) by Fritsch (Beiträge zur Geol. Karte der Schweiz, Lief. xv, p. 127) and the impossibility of identifying his *knoten* and *prismen* with *garnet* and *staurolite* implicitly demonstrated.

schist to a slate is due to exceptionally severe pressure having locally converted the slate into a phyllite and so far crushed the schist that it is hardly distinguishable from the latter rock. This may be seen, for instance, in the Tyrol on the ascent from Mittersill to Kitzbühel (**29**), and in the cliffs south of Torcross in Devon (**30**).

(*To be continued.*)

II.—On the Highest Coal-measures or "Zone" of *Anthracomya Phillipsi* in the Durham Coalfield.

By C. T. Trechmann, D.Sc., F.G.S., and D. Woolacott, D.Sc., F.G.S.

(PLATE V.)

It has been known for some considerable time that the highest beds of the Northumberland and Durham Coalfield lie approximately beneath the town of Sunderland.[1] The great syncline of the Coal-measures of this area is distinctly accentuated in North-East Durham, so that a secondary basin-like depression is formed, in the centre of which these high beds occur.[2] Beneath Sunderland, where the top layers also exist, the Carboniferous rocks are concealed by the overlying Permian strata, but at a place called Claxheugh on the Wear, about two miles west of Sunderland, the Coal-measures are exposed for a short distance on both the north and south banks of the river.

These beds represent the horizon known as the zone of *Anthracomya Phillipsi.* It is not generally known among British geologists that these specially high beds occur in the northern coalfield, so that we consider it desirable to put this fact definitely on record, and to add some details on the stratigraphy and palæontology of the beds in question, the result of several visits to the locality. The section described is exposed on the north bank of the Wear, and is the one that is specially fossiliferous. The shale, with the bands of clay ironstone from which most of the fossils are obtained, does not occur in the section on the opposite side. The small section of Coal-measures, about 90 yards long and about 15 feet high, is cut off by a fault on the west which throws down the Permian Yellow Sands. This is the same displacement that brings down the Permian rocks, which are so well exposed in the Claxheugh escarpment.[3] The Carboniferous rocks consist of argillaceous sandstones at the base, a layer of dark fissile shale, 3 feet thick, with two or three irregular nodular bands of clay ironstone, and beds of grey sandy micaceous shale. The sequence is shown in the section, Fig. 1. During one of our visits to the locality, Dr. Woolacott observed that the exposure, besides the four

[1] J. W. Kirkby, "On the Occurrence of Fossils in the Highest Beds of the Durham Coal-measures": Trans. Tyneside Nat. Field Club, vol. vi, pt. ii, pp. 220–5, 1864.

[2] D. Woolacott, "Stratigraphy and Tectonics of the Permian of Durham (Northern Area)": Proc. Univ. Durham Phil. Soc., vol. iv, pt. v, p. 246, 1911–12.

[3] D. Woolacott, "On Sections in the Lower Permian Rocks at Claxheugh and Down Hill, Co. Durham": Trans. Nat. Hist. Soc. Northumberland, Durham, and Newcastle-upon-Tyne, N.S., vol. v, pt. i, p. 155.

FIG. 1.—SECTION SHOWING POSITION OF FOSSILIFEROUS IRONSTONE BANDS AND THRUST-PLANE. (Drawn by D. Woolacott.)

1. Light-coloured argillaceous sandstone stained yellowish-brown along irregular fractures.

2. Shale (3 feet thick) with ironstone bands, above which is a layer of slickensided clay and ground up and broken shale $1\frac{1}{2}$ in. in thickness. To the west of the small displacement *XY* it is on the top of the shale, but to the east it is continued straight on at the same level in the shale towards *C*, not being faulted by *XY* (see Fig. 2). It is a plane of thrusting.

3. Grey sandy micaceous shale.

4. Yellow Sands (Permian), much fractured.

5. Boulder-clay.

F. Fault throwing the Yellow Sands against the Coal-measures.

F_1. Minor faults.

or five faults that occur in it, includes a peculiar layer, 1½ inches thick, of slickensided, broken up, and powdered shale, which occasionally splits and does not maintain a constant horizon in the shale (see Fig. 2). This disturbed band marks a plane of thrusting, the beds above having moved on the upper layers of the shale, the powdered and broken up material acting as a lubricant. It is impossible to say whether the displacement is of large or small magnitude owing to the faults which cut out the beds, but it seems probable that the movement to which this slickensided layer is due was produced by the same forces that caused the extensive series of horizontal movements, which have been proved to have occurred in both the Coal-measures and the Permian rocks of South-East Northumberland and North-East Durham,[1] the results of which are so well exposed in the Permian rocks of Claxheugh.[2]

These fossiliferous Coal-measures are the highest visible in the northern coalfield. Those situated immediately under Sunderland are inaccessible to research, and any evidence available from borings or pit-sinkings can yield little palæontogical evidence of value, but it can be fairly safely asserted that those that occur in this section cannot be more than 50 or 60 feet below the top of the Coal-measure floor, as it existed just previously to the deposition of the overlying Permian. Also our knowledge of the lie of the coal-bearing rocks beneath the east of Durham enables us to assert that they are near the top of the highest Carboniferous strata, as these occur in Northumberland and Durham. This zone, therefore, is of importance, since it marks the upper limit of the Coal-measures of these two counties.

Evidence bearing upon the height of these beds above the chief workable seams of the district has been obtained from details of the sinkings at Hylton Colliery, which is situated about a quarter of a mile to the east and Monkwearmouth Colliery about 2 miles in the same direction. No intervening faults of any great magnitude occur. At the former colliery the thickness of the Coal-measures to the main coal of the Wear is about 1,300 feet, and to the Maudlin or Bensham seam about 1,375 feet, while at the latter the thickness to the main coal is about 1,170 feet, and to the Maudlin 1,265.

Near the top in the Hylton sinking some bands of clay ironstone are recorded, which may very well be the same as those at Claxheugh, as the beds dip gently in an easterly direction.

Palæontology of the Claxheugh Beds (C. T. T.).

"*Ancylus*" *Vinti*, Kirkby. (Pl. V, Figs. 1–4.)

This problematical fossil occurs in great numbers in the layers of clay ironstone. Generally the specimens are more or less crowded together along certain bands in the rock to the exclusion of other fossils, but occasionally they occur scattered about on the surfaces that yield the bivalves of the group of *Anthracomya Phillipsi*.

[1] The evidence is detailed in "Stratigraphy and Tectonics of the Permian of Durham": op. jam cit., pp. 288–99.
[2] Op. jam cit., p. 159.

One of my specimens measures 2 mm. in length and slightly over 1·5 mm. in height; another is 3 mm. long and 2 mm. high.

Kirkby wisely declined to arrive at any definite decision as to the real nature of this organism and stated clearly his reasons both for and against regarding it as an *Ancylus*, a *Discina*, an *Estheria*, or a bivalve mollusc.

Some later geologists have, however, adopted a less cautious attitude, and Dr. Wheelton Hind has definitely described and figured specimens from Claxheugh as a lamellibranch, calling them *Carbonicola Vinti*.[1] *Carbonicola* is a genus which bears hinge-teeth.

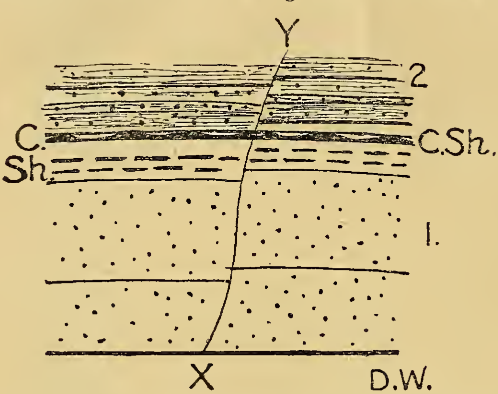


Fig. 2.—Section at *XY* in Fig. 1. (Enlarged.)

Sh. Shale with fossiliferous ironstone bands, slightly faulted along *XY*; the fault dies out in the upper beds.

C. A band of slickensided clay and broken shale (1½ in. thick), which on the west of the section runs along the top of the ironstone band beneath the sandy shale, but is not faulted by *XY*, being continued straight on in the bed of shale. This layer lies along a thrust-plane.

1. Light-coloured argillaceous sandstone.
2. Thinly bedded sandy micaceous shale.

He regards the Claxheugh specimens as "the closely compressed remains of the periostracum of a large number of shells". My examination of a large series of specimens, however, reveals difficulties in accepting this view. They show no trace of calcareous matter and seem to have consisted entirely of chitinous material, but on the same slab one observes numerous valves of *Anthracomya*, and of small entomostraca still retaining their calcareous nature, so that it is not easy to believe that the valves of "*Carbonicola*" *Vinti* have become decalcified, while those of other equally delicate calcareous organisms have remained unaffected. The Claxheugh specimens are clearly not shells which have been partly decomposed or decalcified.

However, a speaker at the discussion on the above-mentioned paper assumed that the bivalve nature of the fossil was decided. It is clear to me from examination of my specimens that the organism

[1] "On three New Species of Lamellibranchs from the Carboniferous Rocks of Great Britain": Q.J.G.S., vol. lv, p. 365, 1899.

was bivalvular and cannot be either an *Ancylus* or a *Discina*. It seems unfortunate, however, that a shell from the Upper Coal-measures of the North Staffordshire Coalfield, which from the illustration and description seems beyond doubt to be a true and adult form of *Carbonicola*, should have had the specific name of "*Vinti*" attached to it on the assumption that it is identical with the chitinous organism from Claxheugh.

The name has now found its way into Continental publications. E. Haug,[1] speaking of the Coal-measures of Great Britain, says: "The Upper series is characterized by intercalations of beds of *Anthracomya Phillipsi* and *Carbonicola Vinti*, lamellibranchs generally regarded as freshwater forms." Kirkby, as his habit was, gave an accurate description of the organism, and one can add little to his diagnosis, which is as follows: "length one-twelfth to one-eighth of an inch, breadth one-fourteenth to one-tenth, sub-oval or nearly circular, with the posterior margin straight, flatly patelliform, with an eccentric reflexed apex posteriorly placed, shell delicate, surface ornamented with several rather coarse concentric plaits."

I am much indebted to Mr. H. Bolton, M.Sc., F.G.S., to whom I submitted some of the specimens for the suggestion that these organisms are the "spat" of *Anthracomya Phillipsi*. He writes: "I have examined the fossils you sent me, especially the example of '*Ancylus* (*Carbonicola*)' *Vinti*, and have found them of more than usual interest. In the first case I fail to see any *Carbonicola* character at all in any of them: what I do see, is that so far as my experience goes, you are dealing with 'spat' and not with adult forms of mollusca. I gave a long time to the study of the life-history of *Anthracomya Phillipsi*, and had the advantage of a great series of specimens from several coalfields, whilst I had the experience of thirty years to aid me. I feel convinced that your speeimens and the *Ancylus* ('*Carbonicola*') *Vinti* are nothing but the spat of *Anthracomya Phillipsi*. As you will see by my paper,[2] I have linked three former species, viz. *Anthracomya lævis* var. *Scotica*; *A. minima*; and *A. Phillipsi*. The first is the 'spat' stage, the second the adult stage, and the third the senile stage of the one species. I shall be interested to learn whether your *Ancylus Vinti* ever occurs away from the *Anthracomya Phillipsi*. Of course it may, but I think you will find the other two speeies not far off. The 'spat' stage has usually a short straight hinge-line, and the valve is perfectly symmetrical to it and not oblique at all; the obliquity comes in with the '*minima*' stage. Until the latter is reached the central and youngest part of the umbones remains fairly elevated and convex. As the '*minima*' stage increases the new shell matter is added to the ventral-posterior border at a much greater rate than elsewhere, and as a result there is an increasing obliquity, which reaches its maximum in the '*Phillipsi*' stage. I have seen shells so well preserved that you can mark off the three stages on the surface on the one shell."

[1] *Les Périodes Géologiques*, vol. ii, p. 764.

[2] "Fauna and Stratigraphy of the Kent Coalfield": Trans. Inst. Mining Engineers, vol. xlix, pt. iv, p. 33, 1915.

On my inquiring further in this matter Mr. Bolton writes: "With respect to the shell of *A. Vinti*, I think that in the 'spat' stage there was little or no calcification. I would not be sure, but I rather fancy that the shell is little more than a top integument, and may possibly be represented by the periostracum at a later stage. I am assuming this from the Glochidia larva of the common Swan Mussel. I have not seen the latter for some years, but I think the valves are well domed and hooked at one end, so that the larvæ can hang on to the gills of the parent; afterwards calcification takes place in regular concentric layers around the umbonal point, and the hooked condition is left together with the tegumentary-like appearance; and the shell assumes more or less the appearance of the adult stage."

It was, therefore, a matter of interest to me to try and observe whether on any of the Claxheugh specimens one could see the "spat" form in the act of growing into the *A. lævis* form or whether the umbones of the larger shells showed any trace of the wrinkled stage of the spat. I examined all the available specimens with this point in view. Certainly there are no specimens of *Anthracomya* on the slabs of smaller size than "*Ancylus*" *Vinti*, which is a fact in favour of the latter being actually the young stage of the *Anthracomyas* associated with them.

In one or two instances there seemed to be evidence of the wrinkled periostracum of the "spat" stage remaining on the umbo, though in nearly all the specimens after the calcification of the interior of the valves of the spat, the character of the shell seems to change rapidly and the periostracum to disappear. (See Pl. V, Figs. 6 and 7.)

Notwithstanding these difficulties I am quite inclined to agree with Mr. Bolton's interesting suggestion that all the bivalvular organisms in this bed belong to different stages of growth of one and the same shell, commencing with "*Ancylus*" *Vinti* and ending with *Anthracomya Phillipsi*.

One slab shows clear evidence of an "*Ancylus*" *Vinti* with incipient calcified growth-lines developing round the anterior, posterior, and lower margins.

I may here remark that the apex of "*Ancylus*" *Vinti* does not correspond with the beak of the more adult form *Anthracomya minima*. In the former, in well-preserved examples, the rounded and rather indefinite apex never occupies the hinge-line but is situated well below it, and anterior to the middle of the shell, or eccentric, as Kirkby described it.

Anthracomya Phillipsi (Williamson). (Pl. V, Figs. 5–7.)

Bivalves having the appearance of this form occur in great numbers more or less crushed in the two bands of clay-ironstone in the Claxheugh section.

My specimens vary in size from 6 mm. long and 3 mm. high to 32 mm. long and 14 mm. high, and certainly appear to me to represent various stages of growth of one and the same species.

No other bivalves have been found in these beds, consequently the group of shells appears to mark a definite horizon in the Durham Coalfield.

Not much zonal collecting of the fossils has been done in the Coal-measures of this district, but I have a fair number of bivalves, mostly collected at different times from pitheaps, and the Newcastle Museum also has a number of specimens. From these it is possible to ascertain roughly the sequence of the "mussels" in the main Coal-measures of Durham and Northumberland.

Kirkby, in 1864, mentions the shell that occurs at Claxheugh as *Anthracomya acuta*, a species which is now placed in the genus *Carbonicola*, but he gives no description of it.

I submitted some of the smaller Claxheugh shells to Mr. Bolton who returned them to me labelled "*Anthracomya minima* stage of *A. Phillipsi*", and he remarks in a letter, "I have been breaking up the ironstone nodules you sent and am extremely interested to note that they contain beautiful examples of *A. minima*, the intermediate stage between *A. lævis* var. *scotica* or 'spat' and the adult *A. Phillipsi*."

I am not sufficiently well acquainted with the mollusca of the Coal-measures to be able to discuss whether Mr. Bolton's views on the various growth stages of this shell are in every instance correct or not.

It is also very difficult on reading the various publications on the question to determine whether or not *A. Phillipsi* represents a distinct zone in the English Coal-measures, and its recorded distribution offers some points that require further elucidation.

In the North of England its horizon seems to be a well defined and restricted one. In Yorkshire it is reported, so far as I can ascertain from one locality only,[1] namely, from a cutting near Conisborough, in a band of soft ironstone about two inches thick among clays and sandstones underlying the Permian. In the Nottingham area Messrs. Lamplugh and Gibson[2] say that "the range of the distinctive species of the genus *Anthracomya* has not been definitely fixed but *A. Phillipsi* occurs in the top beds of the middle Coal-measures at Gedling", and Mr. R. D. Vernon informs us that *A. Williamsoni* (Brown) invariably accompanies the roof shales of the "Top Hard Coal".

In the concealed coalfield of Yorkshire and Nottinghamshire its horizon seems also to be a definite one where it has not occurred below the Top Hard or Barnsley Coal, and is regarded as characteristic of the Middle Coal-measures above that seam.[3]

Matters, however, in the South of England, are much less clear and Mr. H. Bolton[4] states that "*Anthracomya Phillipsi* is equally abundant in the lower Coal-measures of the Bristol district and in the upper series of Radstock".

In the Kent Coalfield a similar uncertainty seems to prevail. Mr. Bolton, referring to *Anthracomya lævis*, *A. lævis*, var. *Scotica*,

[1] H. Culpin & G. Grace, *Naturalist*, No. 577, February, 1905, p. 40.
[2] *Geology of Nottingham* (Geol. Surv. Mem.), 1910, p. 17.
[3] Walcot Gibson, Geol. Surv. Mem., 1913, p. 25.
[4] Q.J.G.S., vol. lxvii, No. 267, p. 329, 1913.

A. minima, and *A. Phillipsi*, says they are the dominant fossils of the Kent Coalfield and occur in countless numbers and at many horizons.

The remaining animal fossils at Claxheugh require little notice. On a recent visit I was fortunate to collect in the sandy shales above the clay-ironstone bands a small limuloid crustacean, which Dr. H. Woodward has described as a new species of *Bellinurus* under the name of *B. Trechmanni*.[1] The specimen is now in the British Museum (Natural History).

Insect remains were found here many years ago, but no one has since succeeded in finding any more of them. Kirkby records them as *Etoblattina Mantidioides*, Goldenb.; *Lithomylacris Kirkbyi*, H. Woodw.[2]

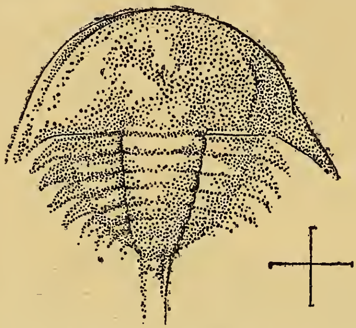


FIG. 3.—*Bellinurus Trechmanni*, H. Woodw., sp. nov. × 4. Upper Coal-measures: Claxheugh on the Wear, Sunderland.

Fish-scales are fairly plentiful. Dr. A. Smith Woodward was kind enough to examine those I collected and reports that they are "Well-preserved specimens of the scales of *Rhizodopsis sauroides* (Williamson)".

Ostracoda are common but have not been examined in recent times. Kirkby recorded the occurrence here of *Beyrichia arcuata*, Bean, and another small entomostracan related to *Cythere* or *Cypris*.

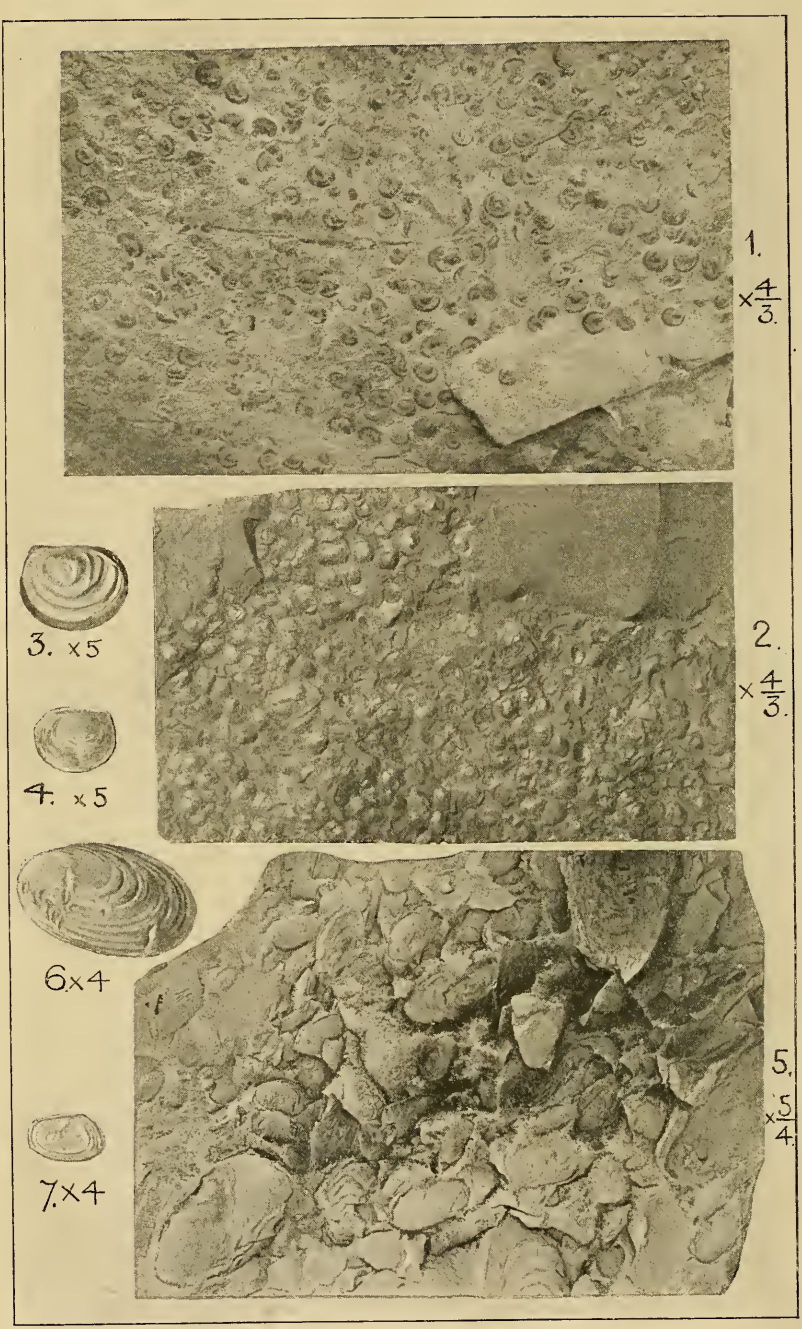
PLANT REMAINS.

Plant remains are rather scarce at Claxheugh, but occur in the ironstone bands. Hoping to obtain some results I kept all the specimens I collected from time to time and have recently sent them to Dr. Kidston, F.R.S., who has very kindly identified them, and has given me the following list of species and the results of his examination of them.

"Those that are sufficiently good for determination are

Neuropteris gigantea, Sternb.
Calamites suckowii, Brongt.
Lepidodendron simile, Kidston.
Lepidophyllum triangulare, Zeiller.
Sigillaria discophora, König sp.

[1] GEOL. MAG., Dec. VI, Vol. V, p. 470, 1918.
[2] GEOL. MAG., Dec. I, Vol. IV, p. 390, Pl. XVII, 1867.



C.T.T. photo. *Bale & Sons, imp.*

SLABS OF CLAY-IRONSTONE FROM THE HIGHEST COAL-MEASURES, CLAXHEUGH, CO. DURHAM.

"It is difficult, owing to the small number of species collected, to give a definite horizon. There are no specially characteristic species contained, but it is either Westphalian or possibly the Black Band group of the Staffordian series which immediately overlies the Westphalian. There is nothing in the collection to enable one to decide this."

EXPLANATION OF PLATE V.

Slabs of clay-ironstone from the highest Coal-measures at Claxheugh, co. Durham.

FIG. 1.—Surface with a number of individuals of "*Ancylus*" *Vinti*, Kirkby. Supposed to be the "spat" of *Anthracomya Phillipsi* (*fide* Herbert Bolton).

,, 2.—Ditto, the individuals more crowded together.

,, 3.—A specimen of "*Ancylus*" *Vinti*, Kirkby, from slab (Fig. 1). × 5.

,, 4.—Another specimen of same, from same slab. × 5.

,, 5.—Slab covered with lamellibranchs. The largest specimens are *Anthracomya Phillipsi* (Fig. 6); the smaller ones are *A. minima*, Ludwig, the younger stage of *A. Phillipsi*. Some of these have the umbones wrinkled and incompletely calcified, recalling "*Ancylus*" *Vinti*. Specimens of *A. vinti* occur also on this slab.

,, 6.—*Anthracomya Phillipsi*, from slab 5. × 4.

,, 7.—Another younger specimen of same, ditto. × 4.

III.—The Mineral Composition of the Lower Greensand Strata of Eastern England.

By R. H. Rastall, M.A., F.G.S.

In the year 1913 the author formed the intention of carrying out a comprehensive investigation of the mineral composition of the Lower Greensand strata of England, in order to ascertain whether any definite conclusions could be drawn as to the sources of the material and the geographical conditions that existed while the deposits were being formed. A large number of specimens were collected along the outcrop from the Wash to the borders of Buckinghamshire and examined by the usual laboratory methods. This work was interrupted by the outbreak of war, and on returning to Cambridge after an absence of nearly four years on Government service circumstances proved to be unfavourable to a continuance of the work on the scale originally contemplated. The district already dealt with forms in itself a fairly well-defined unit, and it was decided to publish an account of the results already attained, in the hope that they may be of service to future workers in this interesting field of petrological and stratigraphical research.

Introduction.

The formation generally known as the Lower Greensand attains a considerable development in the eastern midland counties of England. It has an almost continuous outcrop from the shores of the Wash to the western borders of Bedfordshire, but further to the west it is discontinuous and does not appear at the surface over long stretches of country, being overlapped by the Gault. It is a question still undecided whether it was ever deposited continuously in this region and afterwards removed by inter-Cretaceous denudation, or whether, on the other hand, there were from the beginning gaps in the succession owing to intervening land-areas. At all events, it is certain that the Lower Greensand thinned out towards the south against the high ground of the London Palæozoic plateau, which was first completely submerged in Gault times, as shown by the records of numerous deep borings. The thickness of the Lower Greensand within the district as above defined undergoes certain remarkable and more or less regular variations, and the present author has already put forward reasons for believing that this variation is due to the existence in Lower Cretaceous times of a ridge of land running in a general north-west to south-east direction, parallel to the known strike of the Charnian rocks, and probably due to posthumous movements of an ancient fold-line.[1] Repeated movements of this axis have been clearly demonstrated in other instances by Professor Kendall,[2] although he expressly disclaims any belief in its influence on the Lower Greensand. On that point the present author ventures to maintain his own opinion. It is at any rate a striking fact that the strongly marked diminution in thickness of the Lower Greensand takes place just over the district where it might be expected on this supposition. In the west of Bedfordshire it is 250 feet thick, in Norfolk about 150 feet, whereas at Upware and Ely there are only a very few feet, and it is possible that in places it is absent altogether. These facts can only be accounted for by overlap against a land-surface, apparently an isthmus dividing two seas, which was gradually being submerged and was finally overflowed at the beginning of Upper Cretaceous times, since there is no doubt that the outcrop of the Gault is continuous, although the thickness of this formation diminishes greatly towards the north-east.

The stratigraphy and palæontology of the Lower Greensand present many problems of great interest and difficulty; some of them are still matters of discussion, as, for example, the true age and origin of the so-called "derived" fossils, which are so common in the pebble-beds of some districts. The present author is not competent to deal with this and other cognate matters, nor with the question of the exact correlation of the strata of the midland and eastern counties with those seen elsewhere. The object of the present paper is merely to set forth the results of a mineralogical examination of the sands of certain areas in the hope that the facts ascertained may assist in throwing light on some factors of a larger problem, which must eventually be dealt with by others.

1. Carstone, Hunstanton.

The general character of the rock forming the lower part of the cliff section at Hunstanton is so well known as scarcely to require detailed description. It must suffice here to say that the finer beds consist of a highly ferruginous sand, each grain being coated by a pellicle of iron oxide, and the whole more or less cemented by the same substance. Owing to this circumstance the preparation of the material for minute investigation presents considerable difficulties.

[1] Rastall, *Geology in the Field*, 1909, pp. 140–4.

[2] Kendall, Report Coal Commission, 1905, pt. ix, p. 30.

Even after very prolonged digestion with strong hydrochloric acid it is difficult to get rid of all the brown iron oxide, which clings very closely to the grains, and often forms oolitic structures apparently possessing a skeleton of silica.[1] This sand also contains a good deal more carbonate than those from most other localities, though in this respect it does not approach the calcareous sandstone of the Ely outlier.

When the residue from the preliminary panning, so very necessary in this instance, is digested for a long time with acid, it is found that a large proportion of the separated material consists of brown grains of oxidized glauconite; owing to their low density most of these can be got rid of by shaking and washing in a watch-glass or shallow dish before the bromoform separation. This is an advantage from the point of view of economy of bromoform. Even while the separation in the heavy liquid is in progress it is evident that the average size of the grains that sink is greater than usual, and especially greater than in those specimens from the western and southern areas. This is abundantly confirmed in the microscopic examination of the material, when the difference is very noticeable at the first glance.

Several distinct samples from different horizons in the cliff were separated with the most careful treatment adapted to the special circumstances; all were, however, so closely similar that one general description will suffice. The characteristic minerals are kyanite, staurolite, rutile, zircon, tourmaline, and garnet. The inevitable ilmenite was abundant, and both hornblende and diopside were present in small quantities, as well as an immense number of minute flakes of muscovite.

The crystals of kyanite are abundant and large and as a rule not much rounded, some being quite angular and blade-like; they show clearly the normal extinction angle of 30° and the emergence of a negative bisectrix normal to the principal cleavage, on which the crystals always lie. Staurolite is common in angular chips, much larger than usual, and also in grains of smaller size and more rounded form; it is of the ordinary bright orange colour, with distinct pleochroism. Rutile is abundant in large grains, generally much rounded, varying in colour from a bright orange to a deep blood-red; some show good twin-lamellæ on the common law. Tourmaline is moderately abundant; it is usually in small rounded grains of a greenish or brownish colour, but there are also a few larger and more angular individuals of a greenish-blue; these generally show little crystal form, but possess very sharp angles: they have evidently not travelled very far from their source.

Zircon is very common and it is very difficult to give a comprehensive general description, since it shows so much variation; on the whole, however, it may be said that the great majority of the crystals belong to the granitic type of Krushtchov.[2] They vary much in size,

[1] Phillips, "On the Constitution and History of Grits and Sandstones": Q.J.G.S., vol. xxxvii, p. 17, 1881.

[2] Mem. Acad. Imp. Sci. St. Petersb., ser. VII, vol. xliii, No. 3, 1894; Min. Petr. Mitth., N.S., vol. vii, p. 423, 1886.

some individuals being as much as 0·3 mm. in length, though most are smaller. Many of them show very fine examples of the spherical and tube-like inclusions described by the above-mentioned author. Apart from these the substance is usually quite clear, and zoned and coloured forms are exceedingly rare. The larger crystals are generally quite sharp, but many of the smaller ones are much rounded.

The hornblende is mostly in the form of rounded and rolled grains, or as much rounded as this mineral is capable of becoming owing to its good prismatic cleavage. The colour is greenish blue, with strong pleochroism, and the mineral is undoubtedly a variety rich in soda, approaching arfvedsonite in composition; it may have come from Scandinavia.

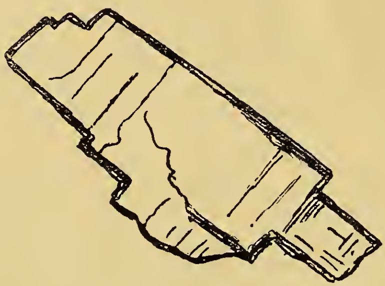


Fig. 1.—Kyanite, Sandringham Sands. × 60.

The most interesting feature of these specimens is the presence of a considerable amount of garnet, a mineral conspicuously absent from most localities. It occurs both in angular chips and in well-rounded grains, the former being distinctly the larger, and includes both brownish-pink and colourless varieties. The significance of the occurrence of garnet in Norfolk will be dealt with later.

2. Sandringham Sands, Castle Rising, Norfolk.

These specimens were taken some years ago from a sand-pit near Castle Rising, on the west side of the high road from Kings Lynn to Hunstanton. The sand, which is quite loose and incoherent, is pale grey in colour, evidently containing very little iron. A considerable amount of black carbonaceous vegetable material, probably decayed roots, is present. A slide of heavy materials prepared from this sample (No. 10641 in the Sedgwick Museum Collection) was figured by Dr. Hatch and the present author.[1]

The slide has been again carefully examined. The principal minerals found were kyanite, tourmaline, staurolite, rutile, with a small proportion of zircon and green biotite. The characteristic and dominant minerals are kyanite and tourmaline, which are both unusually large and well developed.

[1] Hatch & Rastall, *The Petrology of the Sedimentary Rocks*, London, 1913, p. 44, fig. 5.

The kyanite occurs in prisms, blades, and shapeless grains, the majority being very little rounded, while some are of very peculiar forms, with conspicuous re-entrant angles (Fig. 1).

Tourmaline shows much variation in size, shape, and colour. It is mostly in good crystals of the usual prismatic forms with flat rhombohedral terminal faces; the edges are, as a rule, only slightly rounded, if at all. The ordinary well-rounded drop-like forms are much less common. The commonest colour is a brownish green, with resinous lustre; a few crystals are pure brown. Some more remarkable grains show a brilliant blue colour at the maximum absorption with one nicol prism, while one in particular shows strong pink and blue tints. This is very uncommon.

Staurolite is as usual in shapeless yellow fragments, nearly always angular in form, a few only showing traces of crystal-faces. Apart from their unusually large average size there is nothing remarkable about them. Rutile, which is not very common, forms red and orange prisms and grains, small and much worn. A few rounded flakes of green mica are a rather unusual constituent. Zircon is rather rare, only a few comparatively large crystals being seen. The other constituents noted in this specimen are, besides ilmenite, brown, yellow, and red opaque grains, presumably consisting of some oxide of iron; the treatment with acid seems to have been rather incomplete, as compared with specimens of later date, treated by standardized methods.

Other slides prepared more recently from material from the same pit showed all the minerals mentioned above, with in addition a few crystals of dark-green and bluish hornblende, and colourless and pale-green pyroxene, together with flakes of muscovite.

One specimen is specially interesting, since it contains a considerable number of rather large grains of garnet, varying from colourless to brownish pink, some being much rounded, while others are very sharply angular and of remarkable forms. These angular chips of garnet are characteristic of many sands of later geological date in the east of England,[1] though it would be hazardous to assume that these were derived from the Sandringham Sands or Carstone.

One sample from this locality was sufficiently clean and free from iron to be separated and mounted without any preliminary treatment by acid. The chief object of this special examination was to determine the presence or otherwise of minerals soluble in acid, such as might be missed in the ordinary ferruginous samples. This specimen yielded some interesting minerals. Tourmaline was remarkably abundant, most of the grains being brown in colour, but a few were bright blue and one of a clear rose-red. The grains are partly of the usual rounded type, but some are sharply angular, suggesting recent derivation from the parent rock at no great distance. Kyanite and staurolite are common and show nothing unusual; zircon is rather rare, while rutile occurs frequently both as the usual shapeless bright red grains and as clear prisms with

[1] Rastall, "The Mineral Composition of some Cambridgeshire Sands and Gravels": Proc. Camb. Phil. Soc., vol. xvii, pp. 136, 138, etc.

lamellar twinning: these are of a very deep red colour. Bluish-green hornblende and various pyroxenes, probably including both rhombic and monoclinic varieties, are frequent. Only one undoubted crystal of apatite was found: this is of the usual prismatic form, showing high refractive index, weak birefringence, straight extinction, and negative optical character. The surface shows the usual speckled appearance of this mineral. The presence of several other minerals was suspected though not definitely proved, including anatase, sillimanite, and barytes. Only one crystal of each was seen, and the determinations could not in any case be made with certainty. The horse-shoe magnet extracted nothing from this sample, so that magnetite is absent and even ilmenite is by no means abundant. No garnet was found.

When compared with specimens from localities to the west of Cambridge all these samples from Castle Rising are notable for the much larger size of the heavy mineral grains, which also show more pronounced angularity.

3. Ely.

The Lower Greensand covers a considerable area around the city of Ely, forming the capping of the higher ground of the "island". The beds are certainly very thin, perhaps not more than 9 or 10 feet, although it is not certain that this is the whole original thickness, since part may have been removed by recent denudation. For the most part they consist of a rather ferruginous sandstone or pebbly grit, which in places become conglomeratic. This is the general character of the rock as used for building stone around the cathedral and elsewhere.

The specimens selected for examination came from the well-known exposure in Roswell Pit. This particular band is in a highly inclined position and has certainly slipped. It is in places a good deal weathered and decomposed to soft and crumbly sandstone, but the fresher portions form an unusually good example of a calcareous sandstone, with a cement of crystalline calcite.

A sample of the soft weathered sandstone, when broken up and washed, is found to consist of fairly large and rather angular grains of quartz, with a large number of grains or small pebbles of ferruginous and cherty rocks, lydianite and other allied types. The quartz grains are estimated roughly to constitute about one-half of the total.

The heavy minerals in separated samples do not show a great amount of variety, but there are one or two special points of some interest. The characteristic, and in fact almost the only, constituents are zircon, tourmaline, kyanite, and staurolite, with a smaller amount of rutile. The zircon crystals, which are the most abundant mineral, present no features of any special interest, beyond the fact that most of them are broken: doubly terminated crystals are very rare. Tourmaline is common, the larger crystals being usually bluish, while the smaller ones are brownish or olive-green and much more rounded. Kyanite is quite abundant, both as large angular flakes and as smaller and more rounded grains. Staurolite also occurs in the usual small angular chips and fragments, which are common, while larger grains are less frequent. Rutile includes the usual deep red prisms as well as orange and brownish varieties. The most interesting feature, however, is the presence of garnet and blue amphibole in exceedingly small quantity: in fact, the typical sample contained only one grain of each. In their characteristic features, shape, size, and degree of rounding these exactly resembled crystals from the sands of Hunstanton and West Norfolk. The significance of this fact will be dealt with later.

4. Great Gransden.

This interesting exposure is somewhat difficult to find, as it is situated in a small orchard behind a cottage in the straggling village of Great Gransden, some 3 miles N.E. of Gamlingay. The orchard is really an old quarry, but most of it is now overgrown. On one side, however, the rock is well exposed and appears to show a very sharp dip of some 40°. It is clear, however, that this is in reality current-bedding.[1]

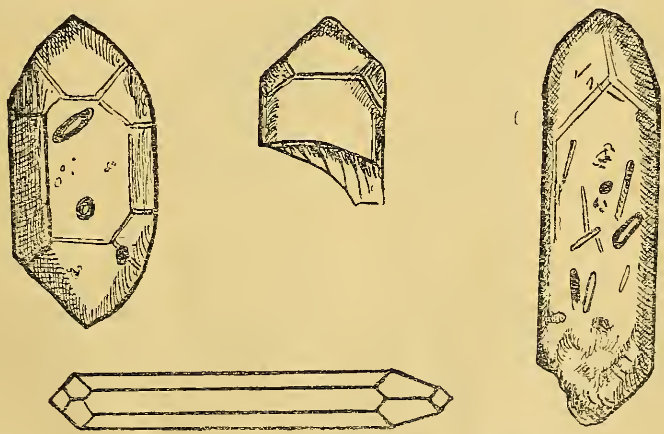


Fig. 2.—Zircons, Great Gransden. × 200.

The rock here is of a yellowish colour, and rather coarse in texture, some layers being almost conglomeratic, with small and well-rounded pebbles of quartz, chert, and lydian-stone. There is nothing remarkable about these or about the lighter portion of the finer constituents, but the heavy minerals after separation are interesting, and as might perhaps be expected from the generally coarse texture of the rock, they are of fairly large size. In particular, some of the staurolites reach a diameter of 0·5 mm.

The most abundant mineral is zircon in numerous varieties, to be hereafter described, while rutile is also very common. Staurolite, though in large pieces, is not very abundant, and the same remark

[1] Fearnsides, *Natural History of Cambridgeshire* (Brit. Assoc. Handbook), Cambridge, 1904, p. 22.

applies to tourmaline. Muscovite is common in small flakes. Among the rarities may be mentioned a very few crystals of orange sphene, a few bits of colourless pyroxene, and a single very angular colourless isotropic fragment, apparently garnet. A large pale-orange flake with slight pleochroism, distinct striations, and straight extinction, is doubtfully identified as brookite, but it may be an unusual form of rutile. A black metallic-looking mineral in prismatic crystals is ilmenite.

Zircon is remarkably abundant and shows a great variety of forms. Nearly all the types described by Krushtchov may be recognized, together with a good many intermediate forms. The commonest habit appears to be the square prism with pyramidal terminations, 100, 111, while similar prisms with their edges bevelled by narrow 110 faces are also abundant. In many cases the angle made by the edges of the pinakoid or prism and pyramid can be measured with sufficient accuracy to determine the form. The horizontal edge

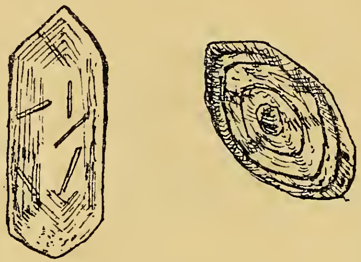


FIG. 3.—Zoned Crystals of Zircon, Great Gransden. × 200.

made by the intersection of 110 and 111 is very rare here, though common elsewhere. Another common type is the square prism terminated by the bipyramid 311, the gneissic type of Krushtchov. One very remarkable crystal showed a very long prism with 100 and 110, the terminations being different at the two ends. At one end 311 is dominant, while the other appears to show a simple pyramid (Fig. 2). However, in these very small crystals with high refractive index, it is difficult to be certain of the forms, owing to the strong internal reflection and the rounding of the edges and corners. Pale-pink and pale-brown crystals, often much rounded and with strongly developed zonary structure, are also very common. According to the latest researches these may be xenotime, which appears to be isomorphous with zircon and even to form parallel and alternating intergrowths with it. These zoned crystals are on the whole more rounded than those without zonary structure. Fig. 2 shows a number of sketches of interesting forms, some with conspicuous inclusions of various kinds, including both crystals and spherical or spheroidal bodies, which Krushtchov believes to be glass, while Fig. 3 shows zoned crystals of zircon or xenotime, one of them being very much rounded by attrition.

This specimen also contains several interesting forms of rutile, especially those showing twin-lamellæ. The colour of the crystals of this mineral varies from yellow to orange-brown and deep red. One conspicuous elbow twin on the common 101 law is of a quite pale yellow colour, but most are darker than this. Fig. 4*a* shows a deep-red, rounded crystal with twin-lamellæ making an angle of 61° with the prism zone, while Fig. 4*b* shows a remarkable resemblance to a crystal figured by Dr. Teall from the Bagshot Sands of Hampstead Heath.[1] The arrow-head twins there figured have, however, not been observed in the Greensand. It is clear that rutile varies very widely in many of its physical characters, especially in colour and crystallographic development, and its discrimination from the other TiO_2 minerals is not always easy, especially in the case of brookite. The latter mineral, however, does not appear to form twins, which are so common and characteristic in rutile.

The other minerals from this locality do not show any noteworthy features.

5. Gamlingay.

A few years ago the large brick pit at Gamlingay afforded a very good section showing the unconformity of the Lower Greensand on the Ampthill Clay, but it is now a good deal overgrown and obscured. The sands are somewhat ferruginous, fine, and very uniform in texture, without pebble-beds.

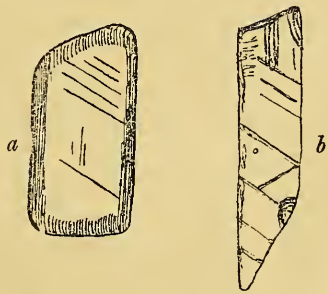


Fig. 4.—Crystals of Rutile, Great Gransden. × 200.

From an examination of washed but unseparated samples it is clear that heavy minerals are unusually abundant here, since specimens mounted without any concentration show a large number of grains of most of the characteristic species. In samples from most other localities it is rare to find more than half a dozen grains in any one slide. The quartz grains vary much in size and shape: some are quite angular, but the majority are more or less rounded, while a few are very round indeed. The characteristic heavy minerals in separated samples are zircon, kyanite, staurolite, tourmaline, and rutile.

Zircon is found in many varieties; some are fairly large, having the form of long prisms with the usual inclusions, but the majority

[1] Teall, *British Petrography*, London, 1888, pl. xliv, fig. 4.

are rather short and stumpy. Some pinkish zoned crystals enclose what appear to be prisms of rutile. The smaller zircons are generally very well rounded. Staurolite is generally seen as small angular pieces, but a few rather larger grains show well-marked striations, probably due to cleavage. Rutile is common, the orange-red variety being the more abundant in rather irregular but often well-rounded grains. Tourmaline is less frequent than usual, chiefly as the olive-green variety; one large piece is of a curious brick-red colour. The kyanite is quite normal; there are a few large prisms, but most are rather small, and some unusually well rounded. Pale-green pyroxene is rare, and no other transparent minerals were identified. Ilmenite is abundant in the usual brilliant black or metallic grains. A prolonged search did not lead to the detection of either garnet or sphene.

(*To be continued.*)

IV.—Notes on Ammonites.

By L. F. Spath, B.Sc., F.G.S.

V.

As an illustration of the difficulties encountered in basing the classification on some peculiarity of the Ammonoid suture-line the case of the two families Macroscaphitinæ and Crioceratinæ may again be referred to, the former of lytoceratid, the latter of hoplitid origin. Distinction between these two families was based on the bifid or trifid characters of the first lateral lobe. *Hamulina nitida*, v. Koenen,[1] which shows very nearly equal-sized suture elements, has the trifid first lateral lobe of the type-species of *Hamulina*, namely *H. dissimilis*, d'Orbigny, but the plain shell of the lytoceratid *Anahamulina*. Hyatt[2] put the latter into his family Macroscaphitidæ, but the former, and also the clearly lytoceratid *Pictetia*, into Ancyloceratidæ, i.e. even into a different sub-order.[3] But *Anahamulina subcylindrica*, d'Orbigny, sp., i.e. the type-species itself, has a nearly trifid first lateral lobe, though it is connected through *A. Lorioli*, Uhlig, sp. (with a sub-bifid first lateral lobe), with typically lytoceratid forms. In ornament and coiling also *Hamulina* resembles certain lytoceratid forms (compare e.g. the various forms of Macroscaphitinæ figured by Uhlig[4]).

Sarasin and Schöndelmayer[5] wrote in this connexion: "After having believed, for a moment, that the similarities shown by the

[1] Op. cit., p. 396, pl. lii, figs. 3–5.

[2] In Zittel-Eastman, *Textbook of Palæontology*, vol. i, pp. 371, 588.

[3] The inclusion in Macroscaphitinæ again of *Hamulina*, withdrawal of *Anahamulina*, the inclusion of *Spiroceras* in Crioceratinæ, and many other alterations introduced by Professor J. P. Smith in the chapter on Ammonoidea in the second edition of Zittel-Eastman's *Textbook of Palæontology* (1913), and evidently not based on additional research, cannot be considered improvements on Hyatt's classification.

[4] "Cephalop.-Fauna d. Wirnsdorfer Schichten": Denkschr. d. Math.-Naturw. Cl. d. k. Akad. d. Wiss., vol. xlvi, Vienna, 1883.

[5] "Etude Monogr. d. Ammon. du Crét. Infér. de Chatel-Saint-Denis," pt. ii: Mém. Soc. Pal. Suisse, vol. xxix, p. 154, 1902.

suture-lines of *Hamulina* and *Crioceras* might indicate a real relationship between these two genera, we have convinced ourselves that we have here a simple case of convergence. The first lateral lobe, which at first sight appears to be trifid in certain forms of *Hamulina*, is in reality a bifid lobe, deformed by the reduction of its internal branch." The writer is inclined to doubt, however, whether many of the apparently lytoceratid forms described as "*Crioceras*" by Sarasin and Schöndelmayer "enter into the great family of Perisphinctidæ".

Here the adult suture-line alone has been utilized and the result is far from satisfactory, but even where the ontogenetic development has been worked out, one special peculiarity of the suture-line cannot always be regarded as proof of even generic affinity. The writer has shown[1] that, e.g., in *Psiloceras* and *Tragophylloceras* the external saddle has throughout ontogeny a monophyllic ending, whereas in *Rhacophyllites stella* there are two terminal leaflets. It was assumed, therefore, that *Tragophylloceras* was more nearly related to *Psiloceras* and what were grouped as Pleuracanthitidæ[2] than to the contemporaneous *Rhacophyllites*. Apart from the wide separation, geologically, of *Tragophylloceras* from the Hettangian genera, the fact that not all "*Rhacophyllites*" have a diphyllic external saddle, and the comparative insignificance of these differences in the endings of the external saddle, make it probable that *Tragophylloceras* must be derived from its Mediterranean Rhacophyllitid contemporaries. On the other hand, the phylloid character of the suture-line shows that these genera as well as *Psiloceras* are descendants of the great family Phylloceratida, though few families offer such a striking characteristic of the suture-line for classificatory purposes.

The variability of the symmetrical or asymmetrical arrangement of the folioles of the lobes and saddles is well illustrated in the sutural development of *Polymorphites* cf. *jupiter* given by A. E. Trueman[3] and also in that of *Cymbites globosus*, reproduced from Branco for comparison.[4] In the former the external saddle of stage *h* is trifid on one side and bifid on the opposite half of the same suture-line. Similarly the first lateral lobe is unequally developed on the two sides. In *Cymbites globosus* the first lateral lobe is bifid at first and trifid afterwards, whereas the reverse is the case with the external saddle. Also the first lateral saddle of the last stage and especially the second lateral saddle are not monophyllic like the external saddle of the earlier stage, and therefore do not repeat the progressive complication of the saddles in the manner shown by *Tragophylloceras Loscombi*.

But these two sutural developments are instructive from another point of view. The very deep ventral lobe of *Cymbites* from the third suture onwards shows this genus to be an Arietid, and

[1] "The Development of *Tragophylloceras Loscombi*": Q.J.G.S., vol. lxx, 1914.

[2] The family Pleuracanthitidæ, Hyatt em. Diener, provisionally accepted in the paper mentioned above, cannot be upheld.

[3] Op. cit. (Geol. Mag., 1917), p. 445, Fig. 10.

[4] Loc. cit., p. 447, Fig. 13.

geological occurrence and general resemblance suggest, at least for the *lævigatus* group, to which the genus *Cymbites* should be restricted,[1] modification of an *Agassiceras* development. On the loss of the typical Arietid venter the first lateral lobe tends to assume larger proportions, just as in *Oxynoticeras* the Arietid suture-line shows an enlarged first lateral lobe and first lateral saddle in compensation for a wide lateral area. *Polymorphites*, on the other hand, has the first lateral saddle indicated already in the second suture, and though in the later suture-lines, owing to carination and the swinging forward of the umbilical portion, which has been shown to occur similarly, with time, in a number of stocks, the first lateral lobe is smaller than the ventral lobe, the tendency here is in an opposite direction, suggesting a round-ventered, Deroceratid ancestor.

Even in cases where the suture-line development has been worked out in detail, widely antagonistic explanations of the affinity of the Ammonites can thus be given. Apart from the striking disagreement shown in the classifications of Ammonoids hitherto proposed, there is also the extraordinary increase in the number of genera created in some of these and adding to the difficulties of the student, and it is not surprising perhaps that none of these classifications has found universal adoption. To give an illustration of the divergence of opinion, the four genera *Grammoceras*, *Hudlestonia*, *Dumortieria*, and *Hammatoceras*, from the *jurense* zone of the Upper Lias, may be taken. Hyatt[2] puts the first and the third into the family Hildoceratidæ, and the others into Pœcilomorphidæ and Phymatoidæ respectively. These three families again belong, according to this author, to two super-families, Arietida (the first two) and Phymatoida. Mr. Buckman,[3] on the other hand, puts these same four genera into four families, and only one genus, *Grammoceras*, is in the same family to which Hyatt had assigned it, i.e. Hildoceratidæ. The remarkable part about these four genera, however, is that they are all, and the first three of them closely, allied. This is almost a return to the classifications of the older authors, for, e.g., Pictet[4] in 1854 grouped *Ammonites radians*, *levesquei*, and *insignis* together in "Falciferi". It is not intended to suggest that these old divisions represent natural groups; but the example tends to show that the scepticism of most general palæontologists towards the modern classifications of Ammonites was not unfounded.

A more permanent and uniform classification of Ammonoids may appear desirable to the general palæontologist and collector who are interested in seeing cleared up the generic nomenclature which, apparently, has drifted into a state of hopeless confusion. But to the stratigrapher it may still seem of little consequence whether a form

[1] Certain aberrant forms, occurring e.g. in the *marmorea* and *margaritatus* zones, and resembling the *globosus-lævigatus* group superficially, cannot be included in the genus *Cymbites*, which is confined to the *Birchi-obtusus* zones.

[2] In Zittel-Eastman, vol. i, pp. 576–7, 1900.

[3] "On the Grouping of some Divisions of so-called 'Jurassic' Time": Q.J.G.S., vol. liv, pp. 442–62; also in *A Monograph of the Ammonites of the "Inferior Oolite Series"*, Supplement, Pal. Soc., vols. 1898–1907, p. cxcviii.

[4] *Traité de Paléontologie*, vol. ii, p. 673.

is referred to the old genera "*Goniatites*" or "*Ammonites*", or to a modern small subdivision. For stratigraphical purposes a much more exact definition than in the past of the horizon of each form will be necessary. Here, again, clearness and uniformity of nomenclature, facilitated by a natural classification, would be of great advantage. Since Mr. Lang[1] has shown that in the case of *Deroceras armatum*, at least at Charmouth, there probably is "an example of the zonal fossil lying entirely outside the zone that bears its name", it will be admitted that this revision of the horizons of Ammonites is of importance. Moreover, little value now is placed on specific identifications for zoning purposes. With regard to graptolites, Dr. Elles[2] wrote recently: "Detailed knowledge of the different species is in no way necessary for the recognition of the different horizons. The nature and value of a Graptolitic zone depends on the assemblage of characteristic forms." And with regard to Ammonites, Mr. Buckman[3] had stated five years previously that "one did not ascertain the date of a deposit so much by the actual species as by the general facies, in the case of Ammonites. Coarse-ribbed *Dumortieriæ*, fine-ribbed *Dumortieriæ*, Ammonites of *aalensis* pattern, Opalinoids, showed the dates as well as more exact identifications, because the successive Ammonites of different genera assumed certain developmental facies".

As important as a revision of nomenclature and horizons seems, to the writer, to be the elucidation of the phylogenetic problems presented by the Ammonites, and the consideration of their evolutionary significance in relation to research done in other branches of modern science. Developmental palæontological research has taken an active part in the establishment of modern evolutionary theories, and with Waagen and Blake[4] one may consider "to have here the true basis of palæontology as an independent science". As Zittel[5] stated: "The character of palæontological literature has been correspondingly modified; the purely stratigraphical treatment of palæontological results has been held more and more distinct from the biological systematic treatment, and the latter places the genealogical direction of research more and more in the foreground."

Since the Ammonite animal is unknown, many important factors of evolution can only be imperfectly inferred and not demonstrated by those structures that alone are preserved to us. The writer would favour, for the fossil forms of Cephalopoda, the division into three main orders, without reference to gills. The Nautiloidea and Belemnoidea are outside the scope of the present paper; with regard to the Ammonoidea, the division into "Ammonitidæ" and "Goniatitidæ" is, of course, as little justified as was the original

[1] "The Geology of the Charmouth Cliffs, Beach, and Fore-shore": Proc. Geol. Assoc., vol. xxv, p. 321, 1914.

[2] Proc. Geol. Assoc., vol. xxvi, p. 267, 1915.

[3] "Certain Jurassic [Lias-Oolitic] Strata of South Dorset, and their Correlation": Q.J.G.S., vol. lxvi, p. 53, 1910.

[4] "The Evolution and Classification of the Cephalopoda, an Account of Recent Advances": Proc. Geol. Assoc., vol. xii, p. 278, 1892.

[5] *History of Geology and Palæontology*, London, 1901, p. 380.

grouping by von Buch into the three sections of Goniatites, Ceratites, and Ammonites, or, by Wright, into three corresponding families. As the discovery of rich Triassic faunæ showed the impossibility of separating the Ceratites from the Ammonites, so the interesting Permian forms dealt the death-stroke to the division into Ammonitids and Goniatitids. Professor Haug[1] stated already in 1894 that "a classification of Ammonoidea into Goniatites and Ammonitids, or into Retrosiphonates and Prosiphonates, would not be really natural, except if all were descended from a single Goniatite family. Permian Ammonites showed, however, that several families were evolved, more or less in a parallel manner, and passed through the Goniatite into the Ammonite stage". Thus, complication of the suture-line, change of the protoconch from latisellate to angustisellate, and modification of the septal necks took place in the different stocks of "Goniatites" that persisted into the Permian and Triassic periods, at different times; and since it is possible that the Goniatites themselves did not originate from one single Nautiloid stock (for in the Devonian several very distinct groups can be recognized) it is clear that the subdivision of Ammonoidea into Goniatites and Ammonitids cannot be upheld.

Haug, in his admirable textbook,[2] indeed, divides the Ammonoidea from the Devonian onwards into several great "phyla": Anarcestidæ and Glyphioceratidæ (the latter with many Triassic families), Agoniatitidæ, Prolecanitidæ (with Ceratitidæ), and Gephyroceratidæ. This last "phylum" includes the Phylloceratidæ and is therefore the root-stock of the host of the Jurassic and Cretaceous Ammonites. The writer[3] had to differ from Haug on this latter point and also from that author's interpretation of the genera *Nomismoceras*, *Dimorphoceras*, and *Thalassoceras*,[4] and there can be no doubt that a good deal of research is necessary yet before this classification of Haug's can be said to rest on a secure foundation; but it marks a splendid advance in the right direction. The same cannot be said for the three "phyla" Belocerata, Tomocerata, and Gephyrocerata, proposed in his work on the Triassic of Albania by G. v. Arthaber.[5] These "phyla", widely separated already in the Devonian, are "assemblages of heterogeneous elements", as Diener[6] has already pointed out, and show the greater value, for classification of the larger groups, of the suture-line compared with other characters.

The Liassic and later families of Ammonites are then looked upon, not as being subordinate to a sub-order "Ammonitidæ" of the order Ammonoidea, but as being, with some Triassic groups,

[1] "Les Ammonites du Permien et du Trias": Bull. Soc. Géol. France, ser. III, vol. xxii, p. 386.

[2] *Traité de Géologie*, vol. ii, fasc. 1, 2, Paris, 1908–11.

[3] Op. cit., 1914, p. 353.

[4] Op. cit., vol. ii, fasc. 1, pp. 754–5.

[5] Beitr. z. Geol. u. Palaeont. v. Oesterr.-Ung., etc., vol. xxiv, 1911.

[6] *Triassic Faunæ of Kashmir* (Mem. Geol. Surv. India), N.S., vol. v, i, p. 3, 1913.

subordinate to the super-family Phylloceratida, which, like the earlier and probably ancestral super-family Glyphioceratida, belongs to some great "phylum" ranging up from the Devonian. These four or five stocks or "phyla", of which one at least begins already in the Silurian, and only one of which transgresses the Trias–Jura border, comprise for convenience the order Ammonoidea.

In tracing these "phyla", based so far mainly on the adult suture-line, stress will have to be laid on the ontogenetic development, as has already been pointed out. Branco,[1] as far back as 1879–80, had dissected sixty-four species of Ammonites; but with a few exceptions, among which Professor J. Perrin Smith's paper on the "Development of *Lytoceras* and *Phylloceras*"[2] may be mentioned, observations on the less obvious features such as the earliest chambers and the gradual development of the various characters, were neglected by palæontologists. When Michaelski in 1890,[3] relying on the differences in the ornament of the inner whorls of the various species of so-called *Virgati*, separated these into the two genera *Olcostephanus* and *Perisphinctes*, he met with opposition, at first, even from A. Pavlow,[4] who wrote, "The older specimens have absolutely the same type of suture and are so much alike in shape and ornament that it is extremely difficult to distinguish them if the ontogenetic development of each cannot be studied." Since then, practically on differences in shape and ornament of the adult shell alone, some twenty new genera have been created for various forms formerly included in *Perisphinctes*, but the ontogenetic development of most of them is still unknown. The writer's personal research has been connected chiefly with Lias Ammonites, and the study of the ontogeny of most of their principal types has now been concluded. The phylogenetic conclusions arrived at differ considerably from the interpretations of the relationship of these Ammonites given by other authors, and prove that until the development of the more important types at least of other periods as well has been studied in detail, there seems little hope of arriving at a satisfactory classification of Ammonoidea.

In conclusion, the writer would like to express his obligation to all those who have helped him with material for research or with valuable suggestions. His thanks are especially due to Dr. A. Smith Woodward, the late Mr. G. C. Crick, and Dr. W. D. Lang, of the British Museum (Nat. Hist.); also to Dr. Wyatt Wingrave, Dr. A. Morley Davies, and Mr. C. P. Chatwin.

[1] "Beitr. z. Entwicklungsgeschichte der Fossilen Cephalopoden": Palæontographica, vol. xxvi, pts. i, ii, 1879.
[2] Proc. Calif. Acad. Sci. [3], i, 1898.
[3] "Die Ammoniten der Unt. Wolga-Stufe": Mém. du Comité Géol. St. Pétersbourg, vol. viii, No. 2.
[4] In Pavlow & Lamplugh, *Argiles de Speeton*, etc., Moscow, 1892, p. 114.

V.—Some Recent American Petrological Literature.

(*Continued from p. 179.*)

"The Igneous Geology of Carrizo Mountain, Arizona," by W. B. Emery. Amer. Journ. Sci., vol. xlii, pp. 349–63, 1916.

This region includes various intrusive bodies: sheets, sills, dykes, and a large laccolith of diorite-porphyry. The presence of six volcanic plugs also indicates extrusion, though all flows have been removed by erosion.

"Contributions to the Geology of Java and Celebes," by J. P. Iddings and E. W. Morley. Journ. Geol., vol. xxiii, pp. 231–45, 1915.

The rocks from Java described in this paper include leucite-tephrite, leucitophyre, shoshonite, basalt, and varieties related to kentallenite and borolanite. Those from Celebes comprise nepheline-syenite, kentallenite, trachyte, and marosite. Full petrographical descriptions and analyses are given.

"Contributions to Sardinian Petrography. I. The Rocks of Monte Ferru," by H. S. Washington. Amer. Journ. Sci., vol. xxxix, pp. 513–29, 1915.

A detailed petrographical description, with analyses, of certain trachytes, phonolites, basalts, and analcite basalts from this well-known locality.

"Primary Analcite of the Crow's Nest Volcanics," by J. D. Mackenzie. Amer. Journ. Sci., vol. xxxix, pp. 571–4, 1915.

A reply to criticisms on some previously published work, the point at issue being as to whether the analcite is primary, or formed by alteration of leucite by sodium solutions in salt lakes.

"Relation of Ore Deposits to different types of Intrusive Bodies in Utah," by B. S. Butler. Econ. Geol., vol. x, pp. 101–22, 1915.

The ore deposits associated with laccoliths and more deeply truncated stocks are of little commercial importance, while those connected with apically truncated stocks are of great value. This is attributed to the concentration of mobile metal-bearing vapours or solutions near the apex of the stocks, in which differentiation was more complete than in the laccoliths. In the case of the more deeply truncated stocks the metalliferous portion has been removed by erosion.

"The Ternary System $MgO–Al_2O_3–SiO_2$," by G. A. Rankin and H. E. Merwin. Amer. Journ. Sci., vol. xlv, pp. 301–25, 1918.

The temperature-concentration relations of crystalline phases in equilibrium with liquid are discussed and represented by diagrams and a model. A ternary compound, $2MgO.2Al_2O_3.5SiO_2$, was found in two forms with a transition point at about 950° C. It is very like cordierite. The effects of FeO on magnesian minerals and rocks are also considered.

"The Ternary System $CaO-MgO-SiO_2$," by J. B. Ferguson and H. E. Merwin. Proc. Nat. Acad. Sci., vol. v, pp. 16–18, 1919.

A very brief summary of a hitherto undescribed portion of this system by the quenching method. The phases found include, among others, cristobalite, tridymite, pseudowollastonite, periclase, forsterite, monticellite, diopside, and various solid solutions. One hitherto unrecorded compound is probably åkermanite. The temperature-concentration relations are shown in a triangular diagram.

"Temperature Viscosity Relations in the Ternary System $CaO-Al_2O_3-SiO_2$," by A. L. Field & P. H. Royster. Trans. Amer. Inst. Min. Eng., vol. lviii, pp. 658–68, 1918.

A study of the viscosity of slags, with reference to blast-furnace work. Measurements of viscosity show the existence of definite compounds in slags and even indicate their fields of stability. The maxima of viscosity occur at quintuple points and the minima at the binary eutectics.

"The Significance of Glass-making Processes to the Petrologist," by N. L. Bowen. Journ. Wash. Acad. Sci., vol. viii, pp. 88–93, 1918.

Observations during war-work at the Bausch-Lomb glass plant are applied to elucidate inhomogeneity in silicate melts. Liquid immiscibility and the Gouy-Chaperon principle are regarded as inapplicable, and differentiation is referred to rising of crystals and sinking of heavy liquid.

"A Type of Igneous Differentiation," by F. F. Grout. Journ. Geol., vol. xxvi, pp. 626–58, 1918.

The rocks of the Duluth intrusions fall into two series, gabbroid and granophyric (red rock). The evidence suggests an immiscible separation of acid and basic portions, the variations in the gabbro being produced by convection. The evidence is strong that differentiation of two kinds may occur in a single magma-chamber.

"The Lopolith: an Igneous Form exemplified by the Duluth Gabbro," by F. F. Grout. Amer. Journ. Sci., vol. xlvi, pp. 516–22, 1918.

The Duluth gabbro differs from typical laccoliths in that its central part is sunken, not raised. It is about 140 miles across, covering an area of about 15,000 square miles, and its volume is estimated at 50,000 cubic miles. It is intruded along the base of the Keweenawan. It is compared to the igneous masses of Sudbury and the Bushveld, and possibly of Skye and Julianehaab. For such saucer-shaped masses the name "lopolith" is suggested.

"The Charnockite Series of Igneous Rocks," by H. S. Washington. Amer. Journ. Sci., vol. xli, pp. 323–38, 1916.

Analyses, supplementary to Holland's descriptions, are given of five specimens of typical rocks of the Charnockite series, selected by the Indian Geological Survey. The relations of the Charnockites to the rocks of similar petrographic provinces are discussed somewhat fully.

"Geological Observations in Fiji. Part II: Petrography of Fiji," by W. G. Foye. Proc. Amer. Acad. Arts and Sci., vol. liv, pp. 97–145, 1918.

Petrographic descriptions are given of a large number of rocks collected by the writer in the islands of the Fiji group. They include tonalite, gabbro, porphyrite, pitchstone, andesite, basalt, and various pyroclastic types. Besides the plutonic intrusions four periods of extrusion are recognized, grading from acid to basic, all types being subalkaline and probably differentiates of a basaltic magma.

"The Nepheline Syenites of Haliburton County, Ontario," by W. G. Foye. Amer. Journ. Sci., vol. xl, pp. 413–36, 1915.

A petrographic description of two differentiated laccoliths of nepheline syenite, together with a discussion of the origin of such rocks in general: it is supposed that the solutions that gave rise to them were produced by the reaction of limestone with granitic magma.

"Eruptive Rocks at Cuttingsville, Vermont," by J. W. Eggleston. Amer. Journ. Sci., vol. xlv, pp. 377–410, 1918.

This small complex includes a large number of alkaline types ranging from essexite to nordmarkite, with their accompanying apophysal and complementary dykes. They are very similar to the rocks of Mount Ascutney, Red Hill, and Essex County in New England, and to the bosses of the Monteregian province, Quebec.

"The Origin of Serpentine: a Historical and Comparative Study," by W. N. Benson. Amer. Journ. Sci., vol. xlvi, pp. 631–731, 1918.

Chrysotile and antigorite serpentines are alteration products of peridotites, more or less pyroxenic; the hydration being often brought about by waters from the same magma. Sometimes it is due to water from later intrusions or to the general underground circulation. An extensive bibliography of serpentine is appended.

"Magmatic Differentiation in Effusive Rocks," by S. Powers and A. C. Lane. Trans. Amer. Inst. Min. Eng., vol. liv, pp. 442–57, 1917.

An investigation of gravitative differentiation-phenomena in effusive rocks shows a concentration of leucocratic minerals near the top and of melanocratic minerals near the base of the flows, while chilled margins show the original composition.

"Triassic Igneous Rocks in the vicinity of Gettysburg, Pennsylvania," by G. W. Stose and J. V. Lewis. Bull. Geol. Soc. Amer., vol. xxvii, pp. 623–44, 1916.

Subsidence and faulting of Triassic sediments was followed by intrusion of prevalently diabasic magma, its products ranging from olivine diabase through hypersthene diabase to quartz diabase, or even nearly pure quartz-felspar micropegmatite rocks.

" Hypersthene Syenite and Related Rocks of the Blue Ridge Region, Virginia," by T. L. Watson and J. H. Cline. Bull. Geol. Soc. Amer., vol. xxvii, pp. 193–234, 1916.

This petrographic province, which is probably of pre-Cambrian age, comprises a batholith about 150 miles long by 20 miles wide, composed of differentiates of a syenitic magma; the chief types are quartz-hypersthene syenite, granite, norite, gabbro, pyroxenite, and a quartz-felspar-epidote rock.

" Zircon-bearing Pegmatites in Virginia," by T. L. Watson. Trans. Amer. Inst. Min. Eng., vol. lv, pp. 936–42, 1917.

Pegmatites from Amelia County contain zircon, with beryl, helvite, allanite, columbite, and monazite, while those from Hanover County are specially characterized by zircon and rutile.

" The Emerald Deposits of Muzo, Colombia," by J. E. Pogue. Trans. Amer. Inst. Min. Eng., vol. lv, pp. 910–34, 1917.

A detailed description of the emerald deposits and their associated minerals with an account of the present state of the mining industry. The origin of the emeralds is ascribed to mineralization associated with intrusion of pegmatites.

REVIEWS.

I.—Les Echinides des "Bagh Beds". By R. Fourtau. Records Geol. Surv. India, vol. xlix, pt. i, pp. 34–53, pls. i, ii, 1918.

THE age of the marine Cretaceous series of the lower part of the Narbada Valley, generally known as the Bagh Beds, has long been regarded as Cenomanian, a view based to a large extent on Duncan's researches on the Echinoids. Other views of their age have been expressed, notably those of Stoliczka and of Bose, who both considered that more than one Cretaceous horizon was represented. At the time of Duncan's writing the Echinoids were the only group of fossils from these beds that had been critically examined, but Mr. E. W. Vredenburg has since studied the Ammonites, although he found that they did not help in determining the exact age of the beds.

The specimens upon which Duncan based his conclusions have lately been re-studied by M. R. Fourtau, whose results are valuable because they determine more accurately the relationships of these Echinoids, and also fix the age of the beds with more certainty. Duncan was so convinced by the general facies of the Echinoids that he was dealing with an undoubted Cenomanian fauna, that he did not find it necessary to make comparisons with older forms. M. Fourtau, on the other hand, was much puzzled by the record of two of the species, *Salenia fraasi* and *Echinobrissus goybeti*, since they belong to an horizon which R. P. Zumoffen has recently shown to be synchronous with the Aptian of the Mediterranean border. He has therefore made comparisons with a wide range of species in the Cretaceous, and he concludes that the Echinoids have affinities with the Early and Middle Cretaceous forms, that the Bagh Beds are of

Albian age, and that only one horizon is represented in the series. He thinks that the presence of *Placenticeras mintoi*, Vredenburg, confirms the reference of the beds to the Albian stage, since this Ammonite is related to *P. uhligi*, Choffat, from the Bellasian of Portugal, and to *P. saadense*, Peron & Thomas, from the Vraconnian of Northern Africa.

M. Fourtau gives a careful description of the eight species found in the Bagh Beds. He identifies Duncan's *Cidaris namadicus* [*sic*; the termination should be feminine] as a true *Dorocidaris*. In the case of *Salenia fraasi* the original diagnosis by Cotteau was not precise, hence later workers were misled, but M. Fourtau now shows that the form from the Bagh Beds is not the same as that from the Aptian of Lebanon. The new name *S. keatingei* is proposed for the species described by Duncan, which is regarded as closely comparable with *S. mamillata*, Cotteau, from the Aptian of France. The *Cyphosoma* from the Bagh Beds, which Duncan determined as *C. cenomanense*, Cotteau, is now called *C. namadicum*, n.sp., and the nearest related species is *C. peroni*, Cotteau, from the Barremian of France and Switzerland. The name *Orthopsis indica*, Duncan, still stands; the species is now compared with *O. repellini*, Desor, from the Barremian and Aptian of France, Switzerland, and Portugal. M. Fourtau regards the two large specimens of *Echinobrissus goybeti*, Duncan *non* Cotteau, and the two small deformed *E. similis*, Duncan *non* d'Orbigny, as of the same species, and proposes the new name *E. haydeni*. The nearest allied species is *E. eddissensis*, Gauthier, from the Aptian and Albian of Algeria and Tunis. *Hemiaster cenomanensis*, Duncan *non* Cotteau, is redescribed as *H. oldhami*, n.sp., and the most closely related species is *H. luynesi*, Cotteau, from the Cenomanian of Palestine. Other examples of *Hemiaster* were referred by Duncan to *H. similis*, Orbigny, of which a figure was subsequently reproduced by Mr. R. D. Oldham in his *Geology of India*. Of the five specimens sent to M. Fourtau, three are separated and described as *Opisaster subsimilis*, n.sp., and regarded as related to *O. morgani*, Cotteau and Gauthier, from the Senonian of Persia. The other two are described as *Opisaster*, sp. indet., a form related to *O. vignesi*, Cotteau, from the Cretaceous of Palestine.

C. P. C.

II.—Yacimientos Carboníferos de las Provincias de Pallasca, Huaylas y Yungay. By Juan M. Yañez Leon. Boletin del Cuerpo de Ingenieros de Minas del Peru, No. 90, pp. 85, with 5 plates and 2 maps. 1918.

THE stoppage of the import of foreign coal into Peru has served to call attention to the potential value of native supplies, and in this memoir the author gives an account, both scientific and economic, of the large supplies of high-grade coal that exist in the provinces of Pallasca, Huaylas, and Yungay. The coal occurs in strata of Lower Cretaceous (Wealden) age, forming three seams averaging about 1, 2, and 1 metres respectively, separated by varying thicknesses of sandstones, shales, and limestones. As shown by the sections given the strata are considerably folded, and in some localities the dips are as high as 60°, though over a considerable area the beds are nearly flat. The coal is of anthracitic character, averaging about 79 per cent of fixed carbon, 10 per cent of volatile matter, and 6 per cent of ash, with a calorific power of about 13,770 B.T.U. It is of good quality, well suited for industrial uses, although possessing poor coking properties. A highly conservative estimate gives a workable quantity of 152,900,000 tons, allowing an abundant margin for all contingencies in working.

A brief account is also given of the tungsten ores of Huaura, and of a newly discovered region in the neighbourhood of Tarica, as well as of the copper deposits of Magistral.

R. H. R.

III.—Special Reports on the Mineral Resources of Great Britain. Vol. VII: Lignites, Jets, Kimmeridge Oil-shale, Mineral Oil, Cannel Coals, Natural Gas. Part I: England and Wales. By A. Strahan. Mem. Geol. Survey, pp. 69, with 1 plate and 3 text-figures. 1918. Price 2*s.* 6*d.*

DURING the last four years there has been a vast amount of irresponsible talking and writing about the possibility of the discovery of workable sources of oil and other natural fuels, other than coal, in the British Isles. It is, therefore, highly satisfactory to find that the Geological Survey has collated all known information on the subject, examining the records of past operations so far as available, and in the case of present explorations, carrying out independent investigations on the spot. The scope of the Memoir is sufficiently indicated by its title. The most important sections deal with the lignites of Bovey Tracey, the explorations made in them by Germans and others, and the uses to which they have been put; the distribution of Kimmeridge Oil-shale throughout the country; the principal known occurrences of mineral oil, cannel coal, and natural gas. It may be said at once in general terms that a careful perusal of this volume does not lend any notable amount of support to the highly optimistic views set forth in the daily papers during the last year or two.

A very full description is given of the well-known lignite and clay deposits of Bovey Tracey, and of the somewhat obscure operations of the German company, which mysteriously vanished two days before the declaration of war. It appears that the products of their industry were not of satisfactory quality, owing to the fact that the lignite consists mostly of highly resinous *Sequoia* wood, which seems to be unsuitable for the manufacture of paraffin wax and similar materials; the chief product of distillation being an evil-smelling yellow tar, a wholly unsaleable substance. Detailed sections are given of several borings put down in this area; these show the presence of a large amount of lignite, which is apparently only of poor quality and much mixed with clay. It is also shown that lignite has a wide distribution in Tertiary, Cretaceous, and Jurassic rocks, but nowhere in workable quantities. A brief account is given of the almost extinct Whitby jet industry.

A chapter of seventeen pages is devoted to a consideration of the Oil-shales of the Kimmeridge series, which have lately been the subject of much discussion. The observations here recorded are largely founded on the results of borings made by the Department for the Development of Mineral Resources. The possible oil-yielding bed, locally known as the "Blackstone", forms part of the upper division of the Kimmeridge, and was probably never laid down over much of the distance between Dorset and Cambridgeshire, coming in again as bituminous shales in Lincolnshire and Yorkshire. Numerous analyses are given of samples from Kimmeridge and Corton, in Dorset, and from Donnington-on-Bain, in Lincolnshire. The yield of oil varies from 13 to 39 gallons per ton, and of sulphate of ammonia from 11 to 32 lb. per ton in Dorset, the figures for Lincolnshire being much lower.

The well-known occurrence of natural gas at Heathfield, in Sussex, is described, as well as other instances met with in borings at Calvert, in Bucks, and near Middlesbrough, which appear to be unimportant. From a statement in the preface it appears that this memoir is to be regarded as an instalment, and that a further publication on the subject of mineral oil in Britain is in contemplation.

R. H. R.

IV.—Eindverslag over de Onderzoekingen en Uitkomsten van den Dienst der Rijksopsporing van Delfstoffen in Nederland, 1903–1916. 664 pp. Amsterdam, 1918.

THIS immense volume contains the final report on the investigations that have been carried on in the Netherlands in search of coal and other useful minerals, chiefly under the direction of Mr. W. A. J. M. van Waterschoot van der Gracht, a geologist well known in England. In 1903 the Government made a grant of 3,000,000 gulden for this purpose: the total cost for 25 deep bores and all expenses was about 2,500,000 gulden. Coal-measures were actually reached in three areas: (1) In the Peel district in the middle and north of Limburg coal was proved at a less depth than 1,200 m. over an area of 19,500 hectares; it is estimated that seams of workable thickness contain 1,766,000,000 tons, while a further 799,000,000 tons below 1,200 m. may possibly be workable in the future, though not immediately available. (2) In the Winterswijk district in East Gelderland 300,000,000 tons of coal exist at depths not greater than 1,400 m., and an enormous amount of rock-salt was also proved. (3) The most important coalfield is, however, in South Limburg, where coal occurs at a less depth than 1,200 m. over an area of at least 37,000 hectares. The coal is classified according to its gas content, in the German manner, and the reserves are estimated as follows:—

	Tons.
Over 35 per cent gas content . .	206,000,000
35–30 ,, ,,	483,000,000
30–20 ,, ,,	1,396,000,000
20–14 ,, ,,	927,000,000
below 14 ,, ,,	1,541,000,000
	4,553,000,000

Hence the whole coal reserves of the Netherlands, probably workable under present engineering and economic conditions, amount to 5,256,000,000 tons, without taking into account supplies that may become available at a later date. In the Buurse-Hengele district in the south-east of Overijssel, the coal was found to lie too deep, but important beds of rock-salt were encountered. The vast deposits of salt found both here and in the Winterswijk district suggest the possibility of finding both potash salts and petroleum.

The report gives a detailed account of the stratigraphy and palæontology of the beds passed through by the borings, the palæobotany being dealt with by Dr. W. J. Jongmans. The local development of the strata is carefully compared with those seen in France, Belgium, and Westphalia. The Upper Carboniferous is divided into four groups, respectively designated the Maurits, Hendrik, Wilhelmina, and Baarlo stages, in descending order. Each of these appears to be characterized by a special assemblage of fossil plants.

The whole investigation affords an admirable example of far-seeing and well-directed enterprise, and both the Government and the staff employed are to be congratulated on the results obtained, which seem likely to lead to important commercial developments in the near future, possibly rendering Holland economically independent of foreign supplies of coal. The sufferings of the country in the last four years will doubtless stimulate efforts in this direction in view of a possible repetition of such conditions in the event of a future war.

R. H. R.

V.—Note on the Aquamarine Mines of Daso, Baltistan. By C. S. Middlemiss and L. G. Parshad. Rec. Geol. Surv. India, vol. xlix, pt. iii, pp. 161–172, with 5 plates, 1918.

IN 1915 an important deposit of aquamarine was located at Daso, on the Braldu River, Shigar Valley, Baltistan, Kashmir, and it is now being actively exploited. The country rock for miles round is biotite-gneiss with big veins of coarse pegmatite, consisting of quartz, orthoclase with some albite, tourmaline, muscovite, garnet and beryl. The best and most transparent beryls are found in drusy cavities, and the prisms are often up to 3 inches long, while crystals of opaque varieties may be as much as 6 inches in length. The colour of the best specimens is not very deep, but of the true aquamarine shade. The available supply appears to be very large, but mining is somewhat handicapped by high transport charges for stores and equipment.

VI.—Observaciones Geológicas en la Isla de Gomera (Canarias). By L. F. Navarro. Trab. Mus. Nac. Cien. Nat., Geological Series No. 23, pp. 87, with 34 text-figures and a map. Madrid, 1918.

THE author has paid several visits to this little-known island, of which he describes the topography and geology in some detail. The island is remarkable for the abruptness of its shores and the general steepness in its slopes. It is deeply dissected by a large number of "barrancos", steep valleys of characteristic form with passes at their heads affording means of access from one part of the island to another. The author also discusses with particular care the origin of the peculiar isolated peaks and platforms of phonolite, locally called "roques" and "fortalezas", and discourages the tendency to explain them all without discrimination as spines of the Peléan type, although admitting that a few of them may be such. Petrographic descriptions are given of the rock-types observed, which include augite-andesite, basalt, ægirine-phonolite, trachy-phonolite, trachyte, sanidinite, and trachyandesite, with corresponding tuffs and breccias.

R. H. R.

VII.—Petrographische Beschreibung einiger Basalte von Patagonien, Westantarktika und den Süd-Sandwich Inseln. By O. Baeckström. Bull. Geol. Inst. Univ. Upsala, vol. xiii, pt. ii, p. 115, 1916.

An elaborate petrographical description of basalts from various localities in Southern Patagonia, from Ross Island, Cockburn Island, Paulet Island, and other localities in the western part of Antarctica, together with the South Sandwich Islands. The general characteristics of most of the area described are somewhat indefinite from the petrographic point of view, since calc-alkali basalts are widely distributed, but commonly associated with rocks of distinctly alkaline and Atlantic type. In the South Sandwich Islands, however, alkaline rocks are wholly wanting, indicating a connexion with the calc-alkaline Pacific province.

VIII.—Scope and Significance of Paleo-ecology. By Frederic E. Clements. Bull. Geol. Soc. Amer., vol. xxix, pp. 369–74. June 30, 1918.

The title of this paper is promising, but the performance is unsatisfying. "Paleo-ecology," says the author, "is characterized by its great perspective, due chiefly to the absence of a large body of facts." The meaning of this is obscure, unless it is that the wood is easily seen because there are so few trees. The author's chief points, so far as we can extract them from an abundance of words, are that vegetation should first be studied because it is the connecting link between the topography and the fauna; secondly, that valuable results may be expected from the study of successive floras and faunas in a limited area. It will be gathered that Mr. Clements' attention is focussed on epi-continental formations (forgive the mongrel term!), such as the badlands and lacustrine deposits of North America. From there some interesting facts and inferences are cited.

IX.—Mineralogy of the H.B. Mine, Salmo, B.C. By T. L. Walker. University of Toronto Studies, Geol. Ser., No. 10, 1918.

The minerals, calamine, spencerite, hopeite, and parahopeite, formed by the oxidation of zinc ores in a marmorized limestone are described. From an examination of the optical properties spencerite had previously (*Min. Mag.*, **18**, 76, 1916) been classed as monoclinic, and this is now confirmed by goniometrical measurements. The relationships of the various hydrated zinc phosphates are briefly discussed. A. S.

X.—NOTES ON MIMETITE, THAUMASITE, AND WAVELLITE. By E. T. WHERRY. Proc. U.S. Nat. Mus., **34**, 373–81, 1918.

THE crystals of mimetite described are of unusual habit and rich in forms, several of which are new. A "prism" determination of the mean refractive index gives the value 2·14, agreeing with previous values obtained by the immersion method. New forms were also observed on thaumasite, which is regarded by the author as a sulphate. Wavellite rarely occurs in measurable crystals, but in this instance the development is sufficiently good for the crystals to be measured, the axial ratios being 0·345 : 1 : 0·404. The refractive indices and chemical composition are also determined.
A. S.

XI.—AUGITE FROM STROMBOLI. By S. KOZU and H. S. WASHINGTON. Amer. Journ. Sci. (4), **45**, 463–9, 1918.

THE results of chemical and optical examinations of the augite, occurring in the ashes round Stromboli, are given. In chemical composition it closely resembles other Mediterranean augites, as 80 per cent consists of the diopside molecule, the remaining molecules being acmite, hypersthene, and an aluminous compound in nearly equal proportions. The refractive indices for sodium light are, α 1·693, β 1·699, γ 1·719, while the optical axial angle (2V) is 57° 39. A. S.

XII.—UNITED STATES NATIONAL MUSEUM.

THE annual report on the United States National Museum for the year ending June 30, 1917, published by the Smithsonian Institution, includes an account of the additions made to the Department of Geology during that time. The Department was specially fortunate in the acquisition of meteorites, having received by bequest the well-known and important Shepard Collection. Other noteworthy accessions were specimens of ores of metals used for hardening steel, namely tungsten and vanadium. A large number of good mineral specimens and gem-stones were transferred from the Geological Survey, and the palæontological collections were enriched by the addition of a large number of type-specimens.

REPORTS AND PROCEEDINGS.

I.—GEOLOGICAL SOCIETY OF LONDON.

1. Parts of the Report of the Annual General Meeting on February 21, 1919, having already appeared in the GEOLOGICAL MAGAZINE (see March Number, pp. 97, 98, and April Number, pp. 145–6), it is obviously needless to repeat them in further detail here.—EDITOR.

2. *February* 26, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The President said in accordance with the Special Notice it was proposed to change the subject previously announced for the afternoon's meeting, and he hoped the change would be approved, namely, that Colonel T. W. Edgeworth David, D.S.O., C.M.G., D.Sc., F.R.S., would deliver a lecture on "Geology at the Western Front".

After the lecture a vote of thanks was unanimously accorded to Colonel David for his lecture.

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3. *March* 12, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communication was read by Mr. R. D. Oldham, F.R.S., in the absence of the author:—

"The Early History of the Indus, Brahmaputra, and Ganges." By Lieut. Edwin Hall Pascoe, I.A.R.O., M.A., D.Sc., F.G.S., Superintendent Geological Survey of India.

The occurrences of marine Nummulitic rocks show that in Eocene times a gulf of the sea extended up the Indus valley and the hill country to the west of it, and eastwards along the southern margin of the Himalayas at least as far as the neighbourhood of Naini Tal. In the Himalayan region the marine deposits are succeeded by a series of red clays with intercalated sandstones and occasionally marine beds, regarded by the author as having been deposited in a series of lagoons. The Upper Tertiary deposits consist of a great series of conglomerates, sandstones, and silts of freshwater origin, which are known to extend along the whole of the southern face of the Himalayas. From these geological indications the author concludes that the first effect of the commencement of the Himalayan uplift was the establishment of a great westward-flowing river along the southern face of the range, for which he proposes the name of Indobrahm. The distribution of Tertiary rocks on the northern side of the range suggests that here also a westward-flowing river was formed, which discharged either round the end of the range into the same sea as the Indobrahm, or flowed westward into the region of Turkestan and the Caspian Sea. The subsequent history of the drainage system consists of the capture of the upper waters of this river by a tributary of the Indobrahm, a cutting-back along the valley to form the eastward flowing Tsangpo, now the upper waters of the Brahmaputra, and the capture of the lower reaches in part by the Sutlej and in part by the Attock tributary of the Indobrahm, to form the Himalayan portion of the Indus valley. Meanwhile, on the southern side of the range, some of the tributaries on the eastern side of the Lower Indobrahm had cut back from the Sind region and cut off the original bend near Attock, to form the present plains of the Punjab; and farther east, a river cutting back along the present line of the Gangetic delta and lower course of the Ganges and Brahmaputra, had captured the upper waters of the Indobrahm to form the present Brahmaputra. The same system of capture had worked westwards, until the tributaries of the Indobrahm had been successfully diverted from a westerly to an easterly drainage up to and including the Jumna River. The author finds proof of the recent date of the separation between the drainage-system of the Indus and that of the Ganges in certain historical evidence, indicating that the Jumna was a tributary of the Indus within the human period; in the occurrence of the same species of freshwater porpoise in the two river-systems and nowhere else outside of them; and in the identity of the freshwater Chelonia of the two river-systems, the species being either peculiar to these drainage-areas or represented outside of them by distinct varieties.

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4. *March* 26, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

At 6 p.m. a special general meeting was held in order to consider the following resolution of Council: "That it is desirable to admit Women as Fellows of the Society."

The President said: It will be within the recollection of most of the Fellows that the question of the admission of women to candidature for the Fellowship of the Society has been raised on more than one occasion in the past. It was considered in 1889 and 1901, and again, more systematically in 1908–9, when a poll of the Fellows was taken and three special general meetings were held, with inconclusive results.

It is generally recognized that the course of events since these dates has materially changed the situation. Women have been welcomed to our meetings as visitors, and we have had many examples of their qualifications for Fellowship in the excellent papers which they have from time to time contributed to the Society. The value of these papers has been appreciated by all geologists, and has been repeatedly acknowledged by the Council in its awards.

Therefore, in the opinion of the Council, it is no longer reasonable to maintain a sex-bar against qualified candidates for the Fellowship of the Society, and I am empowered by the Council to submit the above-mentioned resolution for your consideration.

A ballot was then taken, and the resolution was declared carried by 55 votes against 12.

II.—The Royal Society.

March 27, 1919.—Sir. J. J. Thomson, O.M., President, in the Chair.

The following paper was read:—

"The Morphology and Evolution of the Ambulacrum in the Echinoidea." By H. L. Hawkins, M.Sc., F.G.S. (Communicated by Dr. Henry Woodward, F.R.S.)

A summarized account of the ambulacra in non-Holectypoid orders is given. *Bothriocidaris* shows the simplest type of structure, and the most efficient for coronal strength. As podia increased, ambulacral plates multiplied, and the areas became mechanically weak. The main podial function in Regular Echinoids being adhesive, coronal weakness demanded modification. In most Palæozoic types, general flexibility neutralized local weakness; but with the adoption of rigidity the problem reappeared. Hence arose "plate-complexity".

The formation of compound plates is discussed. "Grouping" precedes, and is distinct from, combination. Plate-reduction is due to "growth-pressure"; combination to tubercle-growth. Elaboration of combination culminates in the Echinometridæ, where the compounds regain "Bothriocidaroid" proportions.

In irregular Echinoids no combination occurs; grouping is often developed. Secondary specialization in Spatangids produces "Palæozoic" structures.

The Holectypoida show four ambulacral types:

(1) Plesiechinid (triad-groups adorally, primaries adapically);
(2) Pygasterid (primaries throughout);
(3) Pyrinid (triad-groups throughout);
(4) Discoidiid (triad-groups adorally, dyad-groups adapically).

Plesiechinid is primitive, and resembles the early Acrosaleniid type. Pygasterid indicates simplification, being morphogenically transitional from Diademoid to Spatangid structure. Pyrinid is persistent, resembling the "Echinoid" structure of Diademoids. Discoidiid is exceedingly elaborate, showing extreme plate-reduction.

The Cassiduloidea are divided into Nucleolitoida and Cassiduloida (restr.). The former order is related to the Pygasteridæ; its simpler members have Plesiechinid ambulacra, and Holectypoid structures appear in later forms. The Cassiduloida evolved through the Echinonëidæ.

There are three main trends of evolution in Echinoid ambulacra: (i) Diademoid, attaining plate-combination; (ii) Clypeastroid, attaining plate-destruction; and (iii) Spatangoid, reversionary.

III.—Edinburgh Geological Society.

February 19, 1919.—Professor Jehu, President, in the Chair.

1. "A Historical Sketch of the Iron Industry in Scotland." By M. Macgregor, M.A., B.Sc., of H.M. Geological Survey.

Mr. Macgregor sketched the rise and development of iron-working in Scotland, more particularly in regard to the raw materials used. The small primitive furnaces of early times known as *Bloomeries* were described, and an account was given of the iron-works in operation in the Loch Maree district during the first half of the seventeenth century. The later furnaces in the central and west Highlands during the eighteenth century were then noticed in some detail. In all these charcoal was used as fuel. The smelting of Scottish Carboniferous clayband ores by means of coke and coal came into vogue soon after 1750, the year in which the Carron Ironworks began their long career. Since that time there had been three main stages in the development of the modern iron industry. These were as follows: (1) Rise of the Clayband Industry, 1760–1830; (2) Rise of the Blackband Industry, 1830–60; (3) Rise of the open-hearth Steel Industry, and period of imported ores, 1850 onwards.

2. Exhibition of Specimens of Norwegian Nepheline Syenite (Laurdalite) Boulders from Flotta, Orkney. By Dr. J. S. Flett, F.R.S.

IV.—Mineralogical Society.

March 18.—Sir William P. Beale, Bart., K.C., President, in the Chair.

L. J. Spencer: "Curvature in Crystals." The curvature of crystals is evidently of many different kinds, and due to as many different causes. Numerous examples, figured in the literature and illustrated by specimens in the British Museum collection of minerals, are grouped under the headings: curved crystallites and feathery microlites, capillary habit, aggregations of crystals, interfacial oscillation, vicinal faces, bent crystals and plastic deformation, twisted crystals, cylindrical (?) and spherical (?) crystals (a supposition leading to a *reductio ad absurdum*).

Lieut. A. B. Edge: "Siliceous Sinter from Lustleigh, Devon." The district round Lustleigh, near Bovey Tracey, is mined on a small scale for a very fine quality of micaceous hematite, which occurs there in well-defined lodes traversing the granite. At the Plumley Mine (now disused), on the walls of one of these lodes, is found a peculiar banded material, somewhat resembling lithomarge or halloysite, which on analysis proved to be a siliceous sinter or opal, with an approximate percentage composition of silica 70, water 21, hematite 6, alumina, soda and potash 3, and a low specific gravity, 1·73. It is hard and compact, and shows a beautifully banded structure, the layers being tinted to varying degrees by limonite and finely divided flakes of micaceous hematite. The general appearance of the material and the presence of delicately overfolded ripples in the banding suggest that it was originally deposited on the walls of the lode in the form of a jelly, and solidified by loss of water. Such loss continues at a very slow rate when specimens are kept in a dry atmosphere, and after some years the surface becomes soft and powdery. The sinter is very fragile, breaking conchoidally even when most carefully handled; this may be caused by the shrinkage strains set up during solidification. The source of this hydrated silica is rather doubtful; it probably formed part of the aqueous injection which deposited the hematite, but may possibly have been leached from the granite during the formation of the lode.

A. F. Hallimond: "An Anorthic Metasilicate from Acid Steel Furnace Slags." A description of the slags will be communicated to the Iron and Steel Institute. The substance is a metasilicate of iron, manganese, calcium, and magnesium, and appears as flat, elongated crystals with the following characters: Forms $b\,(010)$, $m\,(110)$, $M\,(1\bar{1}0)$, $p\,(1\bar{1}2)$, $l\,(10\bar{1})$, $n\,(3\bar{1}0)$, constants α 99° 37′, β 110° 57′, γ 82° 3′; a : b : c = 1·156 : 1 : 0·497; perfect cleavages parallel to m and M, $mM = 95°\,9\frac{1}{2}'$; colour clear amber yellow, not pleochroic; optical characters, $2V = 65\frac{1}{2}°$, negative, $\beta = 1{\cdot}701$, axial plane nearly normal to the cleavage zone, extinction on a 5°, acute bisectrix nearly normal to a.

Dr. C. T. Prior: "On the Meteorites Adare and Ensisheim." The percentage amount of nickeliferous iron and the ratio of iron to nickel in it were found to be respectively 18 and 13 in the case of Adare, and $3\frac{1}{2}$ and $3\frac{1}{2}$ in the case of Ensisheim, which results support the view that in chondritic meteorites the less the amount of nickeliferous iron the richer it is in nickel.

Dr. G. F. Herbert Smith: "A Student's Goniometer." This instrument, which was made by Messrs. J. H. Steward, Ltd., is of the type in which the direction of reference is given by the reflection of some distant object in a mirror, and in which the axis of the graduated circle is horizontal. A ball and socket joint provides the mirror with all the necessary adjustments in direction, and it is also movable vertically in the plane of the axis of the circle. The crystal holder is provided with a simple and convenient form of adjustment which enables a crystal to be measured, as regards one-half, without removal from the wax. A pointer on a swinging arm facilitates the setting of the crystal in the axis of the circle.

CORRESPONDENCE.

MOUSTERIAN FLAKE-IMPLEMENTS.

Sir,—Mr. Henry Dewey, in his note "On some Palæolithic Flake-implements from the High Level Terraces of the Thames Valley" (Geol. Mag., February, 1919, pp. 49–57), in dealing with the fact that flint-implements of what is known as the "cave" period, are generally made from flakes, states, on p. 55, that "some are carefully worked on a disc-face, a facetted platform prepared, and by a single blow on this platform a complete implement detached from the core. By this means half the work expended on their manufacture was saved . . ." The comparison here is with the earlier Palæolithic "cave" implements exhibiting flake-scars on both faces. But the view, which for some unaccountable reason seems widely held, that the flake-implement of Mousterian man was a labour-saving device is erroneous. The process of making a flake-implement was as follows: a large nodule or block of flint was first carefully shaped by flaking into a tortoise-like form, and this process almost certainly took as long as the manufacture of a normal Chellean or Acheulean cave - implement. But when Mousterian man had made what may be regarded as his core-implement, he proceeded to detach a flake from it, and after trimming it round the edges, to use this flake as an implement. And in many cases the core, over which so much labour had been spent, was thrown away as useless. I fail to understand how it is possible to regard this method of implement-making as demonstrating that Mousterian man was able to produce his flake-implements with half the labour expended by the earlier Palæolithic people on their pointed and ovate artefacts. In fact, I see no connexion between the Chellean and Acheulean core-implements and the flake-implements of the Mousterians. The technique of the latter is totally different, and was probably practised by a different race of people from the Acheuleans.

J. Reid Moir.

One House, Ipswich.
March 27, 1919.

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Henry Woodward, LL.D., F.R.S., F.G.S.

Horace B. Woodward, F.R.S., F.G.S.

MANY years have elapsed since the publication of a Table of British Strata. The Table of British Sedimentary and Fossiliferous Strata by Messrs. H. W. Bristow and R. Etheridge and that by Mr. Bristow, showing the Relative Thickness of the Strata, date back to 1873.

Meanwhile many changes have been made in nomenclature, and many new local subdivisions have been marked out in the series of Strata. To represent these in tabular form as an aid to the memory is one object of the present publication.

The student should bear in mind that Nature does not draw the hard and fast lines which appear in the Table, and that the divisions, like those in human history, are epochs artificially limited for the convenience of grouping events. In many cases it is possible to indicate only the general position of the minor divisions in the great series of geological formations. Minute correlation of strata, dependent on organic remains, cannot here be attempted.

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JUN 25 1919
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HENRY WOODWARD, LL.D., F.R.S.

AND

R. H. RASTALL, M.A., F.G.S.

ASSISTED BY

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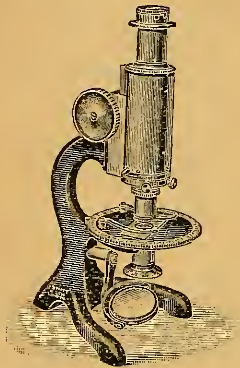

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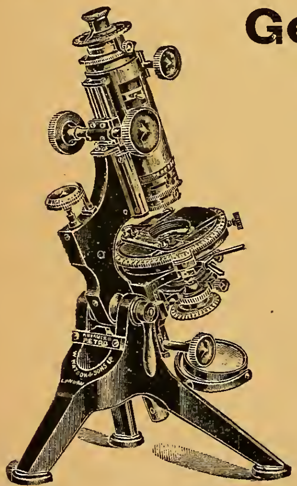

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THE
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No. VI.—JUNE, 1919.

Smithsonian Institution JUN 25 1919 National Museum

NOTICE OF CHANGE OF ADDRESS.

On and after June 1 all communications for the Editor of the "Geological Magazine" should be addressed to R. H. Rastall, Esq., M.A., F.G.S., Christ's College, Cambridge. Letters for Dr. Henry Woodward, F.R.S., to be sent to Tudor Cottage, Clay Hill, Bushey, Herts. Books and parcels to be directed to Messrs. Dulau & Co., 34–36 Margaret Street, Cavendish Square, W. 1.

EDITORIAL NOTES.

BY the death of Sir Frank Crisp, Bart., on April 29, in his 77th year, science in general has lost a very generous supporter and a valuable fellow-worker. Late senior partner in the well-known City firm of Ashurst, Morris, Crisp & Co., solicitors, Throgmorton Avenue, he devoted fifty years to law, but gave all his leisure and much of his income to scientific pursuits. He was a keen student and lover of microscopic research, and was an ardent supporter and honorary secretary of the Royal Microscopical Society, for which Society he obtained a Royal Charter. From 1879 to 1889 Crisp wrote the bulk of the invaluable bibliographical abstracts in the Journal R.M.S., and generously supported the publication by every means in his power. He formed, with much knowledge and at great expense, a most instructive and remarkable collection of instruments from the very earliest known microscopes to those of the most modern and costly construction provided with a great series of lenses of every kind. These he presented to the nation for the new Science Museum at South Kensington, the delay in the completion of which (caused by the War) has hitherto prevented their exhibition to the public. Sir Frank was also a Fellow of the Linnean Society, on the Council of which he served for nearly forty years, filling the various offices of Treasurer, Vice-President, and Solicitor. He procured the modification of the Society's charter to cover the admission of women as Fellows in 1904. He was pre-eminent as a botanist and collector of rare and remarkable living plants, to procure which he spared no expense. In Alpine plants alone he has brought together upwards of four thousand different species. His rock-garden at Friar Park, Henley, crowned with an accurate model of the Matterhorn, needed for its construction no less than 20,000 tons of Carboniferous Limestone from Yorkshire, and with the other gardens, caves, lakes, and cascades renders this beautiful spot one of the finest gardens in England. At the time of his death he was preparing a great work on *Gardens, Ancient and Modern*, for which he had gathered an ample library of rare and curious books.

* * * * *

Now that Belgian scientific publications are beginning to reappear, we are not surprised to see, accompanying those of the Académie Royale, a "Rapport succinct sur l'Etat du Palais des Académies après le Départ des Allemands". This has been compiled by M. Louis le Nain, Secrétaire de la Commission Administrative, whose duty it was to report on the work necessary for restoring the apartments to a condition fit for their original purposes. From this report it is clear that the work of restoration will take some considerable time, as the building and its contents had suffered during the German occupation. Certain rooms had been used as hospital wards, one even being set aside for tubercular cases, others as store-rooms, and so on, thus necessitating some structural alteration. Everywhere M. le Nain found the utmost confusion, disorder, and filth; and the photographs accompanying his report show this to be the case.

The Library too had suffered; some books had disappeared, others were misplaced, but when found were in a damaged condition. This was particularly the case with the Stassart Collection. Certain Belgian busts and paintings had been disfigured, the portrait of Leopold I being decorated with an iron cross; others had been damaged.

M. le Nain therefore considers that the building must be thoroughly cleansed and repaired before it can be again used, and that the number of objects stolen, lost, or misplaced must be discovered. Some time must elapse before this can be accomplished.

* * * * *

An oil-painting of Gideon Algernon Mantell has recently been presented to the Geological Society of London, by subscription among a number of the Fellows. Unfortunately, the history of this painting is not known. The collection of oil-paintings in the possession of the Society is very small, consisting of only nine, including the portrait of Mantell, and that of Dr. Henry Woodward, referred to in these notes in the April number. The other oil-paintings, at present hung in the Society's Meeting Room, consist of the portraits of William Smith, Buckland, Lyell, De la Beche, Phillips, Huxley, and Prestwich. There is also the painting of the group of geologists at the meeting of the British Association at Newcastle in 1838. On the walls of the Council Room are hung the portraits of the former Presidents of the Society. This series is complete, and consists chiefly of engravings, with large photographs of the later Presidents.

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The veteran Swiss geologist, Albert Heim, attained his 70th birthday on April 12, 1919. The event has been duly commemorated by the publication of a Festschrift, issued by a special committee, with Dr. Paul Arbenz as chairman, as a double number of the Vierteljahrschrift der Naturforschenden Gesellschaft in Zurich. This is a handsomely prepared volume of 518 pages and 12 plates, and contains 24 separate contributions, besides a complete catalogue of Professor Heim's publications. Most of the contributions to this Festschrift naturally deal with various branches of the geology of Switzerland; other subjects, however, have received attention. Thus, A. Hartmann deals with the hydrology of the Magdalena Bay district, in Lower California; L. Zehnder contributes a short discussion on the causes of geological epochs; E. Blumer reviews the principal petroleum deposits; E. Bloesch gives an account of the tectonics of the Front Range in Colorado; while W. Staub presents the results of recent geological exploration in Eastern Mexico. The value of Albert Heim's own work is well recognized in this country; he was elected a Foreign Correspondent of the Geological Society of London in 1887, and was made a Foreign Member in 1896. It will be remembered that he was one of the six distinguished geologists on whom the University of Oxford conferred the honorary degree of D.Sc. on the occasion of the Society's Centenary in 1907.

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The views set forth in the Report of Sir Joseph Thomson's Committee on Scientific Education (*Report of the Committee of the Privy Council for Scientific and Industrial Research for the Year* 1917–18) are evidently endorsed by opinion in the Colonies. In the recently established New Zealand Journal of Science and Technology (the organ of the New Zealand Board of Science and Art), the matter is discussed by the editor under the title of "Training Research Workers". Certain passages are quoted from the Privy Council Report, and particular stress is laid on the prefatory exhortation to prompt action. In the opinion of the editors of this New Zealand Journal, even if scientific research were adequately endowed in the Dominion a dearth of investigators would be at once apparent. Granted that the true research spirit is a matter of natural ability rather than the result of training, it still remains that the potential worker must be able to get proper facilities for development. The War has made us aware of many deficiencies: one of these is the need of adequate scientific training of a University type. The feeling of the natural independence of the New Zealand youth is not confined to that Dominion; he wants to find himself as independent financially while pursuing his University course as he would if starting a business career. An extension of the scholarship system is the only means of attaining this except in the case of the rich.

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Geology and geography have so much in common that it is not always easy to draw the line between them. It is accordingly a matter of some interest to the geologist that the University of Cambridge has recently established a Tripos in Geography. Hitherto geography has not been recognized by any British University as a subject for a degree in honours, and the highest distinction awarded was a Diploma, such as that of Cambridge or Oxford. The Diploma in Geography has proved a very valuable and useful qualification to teachers, but it did not carry with it an honours degree.

The new Tripos is divided into two parts. Part I corresponds very closely with the old examination for the Diploma, and will probably still remain the most useful qualification for teaching purposes. It covers a wide ground, and no candidate can pass it creditably without showing a sound and broad knowledge of all the different branches of geography. Part II is designed more for the specialist, and the man who intends to undertake original research takes up one or two sections only, but is required to study these more deeply and to be acquainted with the other branches of knowledge which bear upon the section which he selects. There is, for instance, a section "Geomorphology", and the student who chooses this must be a geologist. There is, however, a geographical side to geology, and it is to this, and its influence on surface features, rather than to details of stratigraphy, palæontology, and petrology, that he will devote most attention.

The other subjects in Part II are Geodetic and Trigonometrical Surveying, Oceanography and Climatology, Historical and Political Geography, and Economic and Commercial Geography.

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We referred recently in our Editorial Notes to the question of the existence of workable quantities of petroleum in England; since that date another important contribution to the subject has come to hand in the shape of a paper read to the Manchester Geological and Mining Society by Mr. T. Sington on "The Search for Petroleum in Derbyshire now in Progress". This paper describes the exact situation of the seven boreholes now being put down to the south-east of Chesterfield and their relations to the geological structure of the district. The author points out in the clearest terms that if any considerable amounts of oil or gas now exist in the rocks to be penetrated by these bores they have had every opportunity to show themselves, owing to the abundance of colliery workings in the neighbourhood, and he feels confident that none will be found. In the discussion that followed this view received the support of every speaker, including the weighty authority of Professor Boyd Dawkins, who pointed out that while petroleum is often found in the Coal-measures, it is always in quantities to be measured by a tea-spoon rather than a bucket, and that it is extremely improbable that at lower levels it will occur in any larger proportion. This entirely agrees with the views of the authorities already quoted. In this connexion the Editors are pleased to be able to say that they have in hand a valuable paper by Mr. V. C. Illing, which will be published in an early issue of the Magazine, after the conclusion of the paper on Potash by Dr. Holmes begun in the present number.

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Arising out of the previous question, as they say in Parliament, it is perhaps permissible once more to draw attention to a most important subject, namely, the proper examination, treatment, and preservation of the cores from borings. According to the details given by Mr. Sington, there will be no cores from the Derbyshire borings; nevertheless the principle is the same: all material obtained from deep bores should be inspected by competent geologists and the results carefully recorded. Cores are frequently treated in the most haphazard fashion, being examined only by the borer, who often records their character in jargon intelligible only in the district where they happen to be, and totally useless anywhere else. It is rarely that a core is inspected by a competent geologist and the results published in a scientific form. It is, of course, obvious that it may be necessary in certain cases that the details of a boring should be kept secret for a time, but in the national interest control should be compulsorily exercised over all borings, which should be inspected during their progress by Government geologists and the facts carefully registered as the work progresses. Thus intending prospectors could at any rate obtain information as to whether the work proposed had already been done in that particular district, and unnecessary expenditure thus prevented. One of the most important functions of applied geology is to prevent people wasting their money on fruitless enterprises.

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The Department of Mines of the Dominion of Canada has shown commendable promptitude in the issue of its "Preliminary Report of the Mineral Production of Canada during the Calendar Year 1918", which bears date February 27, 1919. One can only say *O si sic omnes!* The total value of the minerals produced during the year shows an increase of 10·8 per cent over that of 1917, while since 1913, the last complete year before the War, the increase is no less than 44·3 per cent. More than half of the increment of value since 1917 is due to the higher price of coal, while silver, cobalt, and asbestos reached considerably higher prices, the actual production of the two latter being also higher. Copper, lead, and molybdenite show a considerably greater output, but the price of the last has fallen off sadly, owing to the lessened demand for munition purposes. For the first time for some years a small output of tungsten is recorded from the Yukon, Manitoba, Nova Scotia, and New Brunswick. The nickel industry of the Sudbury district fully maintained its position, and many of the minor products and non-metallic minerals showed substantial increases, especially petroleum, magnesite, and gypsum. Altogether the mineral industry of the Dominion appears to have been in a flourishing condition in 1918.

ORIGINAL ARTICLES.

I.—Foliation and Metamorphism in Rocks.

By Professor T. G. Bonney, Sc.D., LL.D., F.R.S.

(*Concluded from p. 203.*)

IN pressure-modified gneisses and schists certain minerals are often distinctly secondary in formation; actinolitic hornblende replaces ordinary hornblende in a gneiss, as on the southern side of the St. Gotthard Pass (**31**), or in a dark mica-schist, as in the Binnenthal (**32**), or a tremolite appears in marble near the Campolungo Pass (**33**). A mixture of crushed hornblende and felspar gives rise to a biotite, small flakes of which may be built, like bricks, into a newly-formed large crystal of hornblende, especially towards its exterior (**34**). Glaucophane in hornblendic rocks, such as diorites and eclogites, is often a secondary mineral (**35**), some constituents derived from a crushed soda-felspar having combined with those of the original hornblende. Rather large biotites have formed in a dark mica-schist in the Binnenthal, and here also some of them have been developed at right angles to the main pressure, but others in the direction of it (**36**). Scales of chloritoid, sometimes a third of an inch in diameter, are secondary formations in some gneisses and chloritic schists, and kyanites in some micaceous schists suggest a possible reconstruction of an original mineral. Chlorite itself is a mineral of secondary origin, and such rocks as smaragdite-euphotide (**37**), saussuritic gabbro, and possibly even ordinary gabbro[1] are all more or less altered from their original condition, and in some at least of these cases pressure may have been a factor in the change. Besides this, new felspars may be formed in rather basic igneous rocks which have been much crushed, such as the *grüner Schiefer* of the Alpine and other regions.[2] In most of these cases pressure has been essential as a preliminary factor (i.e. the rock must have been more or less crushed), but how far it has operated in the "rebuilding" process is less easily determined. Water has probably aided, and there may have been some, though not a great, elevation of temperature.

We can also find instances of intermediate or partial metamorphism, i.e. rocks in which an original fragmental structure has not been wholly obliterated. Of this the noted section at Obermittweida affords a striking example (**39**). Here a mass of gneiss, very probably of igneous origin but subsequently affected by pressure, is overlain by conglomerates and other sedimentary rocks. The matrix of the one and the materials of the other are sufficiently metamorphosed to

[1] Diallage may be always a mineral of secondary origin; at any rate, we can detect under the microscope grains of augite partly converted into it, and discover that the hornblende in not a few diorites was once an augite; but on the history of hornblendic gabbros it is needless to dwell (**38**).

[2] These, as it has been proved, are plagioclase, but with a higher percentage of silica and soda than the original mineral: albite or oligoclase, with a slightly porphyritic habit, forming in a rock of which labradorite was a constituent. These, it may be added, often fail to exhibit the characteristic oscillatory twinning.

convert what was once ordinary detritus into fine-grained mica (mostly biotite) and quartz, probably authigenous, but as that matrix becomes coarser, so the traces of a clastic origin grow more distinct, till that becomes conspicuous in the breccias or conglomerates. I recognize in their fragments under the microscope the following—granitoid rock (3 varieties), mica-schist (1), quartz-schist (4), quartzite (2), ? hälleflinta (2); still, even in these, mineral changes appear to have occurred, some of which at least may be later in date than the formation of the fragment.

The cuttings on the Canadian Pacific Railway on both sides of Sudbury Station exhibit similar cases of incomplete metamorphism.[1] Here we find two groups of rocks, one of which is more highly metamorphosed than the other, and is in much the same condition as that at Obermittweida. The matrix is an aggregate of biotite and quartz with some felspar. The first is mainly, the second to some extent, at least, authigenous, the third probably clastic, though it may have undergone subsequent augmentation. The larger fragments also exhibit some changes, secondary quartz and white mica being produced locally in the felspar, and the larger grains of quartz are replaced by a mosaic of this mineral. Biotite occurs more sparingly, in little flakelets, both clustered and isolated, which also suggests a breaking up of original constituents of that mineral. Another group, probably rather higher in position, occurs to the west of Sudbury, which contains fragments of volcanic rocks and shows less signs of metamorphism. There is also a group, traversed, as I was informed, by the railway from Sudbury Station to Algoma Mills and Saulte St. Marie, which seems to have been as much metamorphosed as the Upper schists of the Alps.[2] The important fact, however, in the two groups mentioned above is that, while retaining indubitable traces of clastic origin, they indicate very considerable mineral changes, which, however, differ from those directly resulting from either water, or pressure, or heat, when operating separately, though probably demanding a rather considerable and prolonged action of the last agent.

We pass now to rocks, the origin of which is indubitable and the metamorphism only micro-mineralogical. One instance will suffice, because this exhibits the most marked departure from its original condition, the group of the phyllites, a name often employed (as is almost inevitable) rather vaguely, but which may be conveniently restricted to argillaceous cleaved rocks, in which a minute secondary mica has been developed in such large quantities as to constitute the greatest part. These flakelets mostly lie in the same direction, i.e. perpendicular to the direction of maximum pressure; in fact, a phyllite is the first marked step in the passage from a slate to a schist. Phyllites occur in greatly folded districts, such as parts of the Alps, Brittany, Scandinavia, Scotland, and Wales; indeed, are frequent in mountain regions, past or present.

[1] Locally these are broken into by moderately coarse syenites, sometimes almost hornblende granites, and by basic rocks.

[2] A few specimens were shown to me at Sudbury.

One or two silicates, larger in size than the other constituents, are sometimes formed in this stage of metamorphism, but as they may become very impure by including material from the ground-mass, precise identification is often difficult, but they probably represent dipyr, couseranite, and a colourless chloritoid. In rare instances small idiomorphic garnets are found in rocks, the matrix of which shows little signs of change. These have a peculiar structure which distinguishes them from the ordinary garnet of true schists and igneous rocks, and are sometimes associated with "bunches" of small actinolitic hornblende, almost colourless. The evidence as to the origin of these minerals is not decisive, though it suggests the action of heated vapours (**42**).

The *knoten* and *prismen*, associated with crinoid and other organic relics of Liassic age, in the mountains above the Lukmanier Pass, on the eastern slope of the Nufenen Pass, and on or near the Nufenen Stock, are remarkable instances (**41**).

I have passed over one mineral, tourmaline, which is generally, if not always, a result of metamorphic action, because its mode of occurrence links it more closely with contact metamorphism. It is apparently the result of pneumatolytic action on the aluminous minerals in a rock, the felspars and the biotites in those of igneous origin (usually the granites) and the clayey constituents of the sedimentary. It also occurs in veins traversing these rocks, and especially granite masses, in association with quartz, fluor-spar, lithia-micas, chlorites, cassiterite, and one or two other minerals of less frequency, and the main difference from the ordinary results of contact metamorphism, which I have not discussed because they form so distinct a category, is that, as the tourmaline appears in the intrusive rock, which has produced that metamorphism, this mineral must be later in date than it.[1] Of this mode of occurrence the rock called luxulyanite is the most striking example (**43**).

The conversion of the felspar in a mass of granite into the material called china clay, so strikingly illustrated in the Devon–Cornwall region, and often closely associated with the tourmalinizing agencies, is strictly speaking a metamorphic process, and a still more striking change is occasionally found in the replacement of the quartz in a granite by fluor-spar (**44**).

Other igneous rocks have undergone conspicuous metamorphism since they first solidified. Of these the replacement of augite by hornblende, and felspar by saussuritic minerals, has already been mentioned, but some diabases exhibit still greater changes. These, however, so far as I have seen, occur only in small masses, and generally in regions where pressure appears to have co-operated with water. The result has been the removal of much SiO_2 and MgO, and the formation of a peculiar chlorite with a much higher percentage of alumina than in those ordinarily described (**45**).

But serpentine is the most conspicuous instance of an igneous

[1] It may also appear in the associated sedimentary rock, which shows the ordinary effects of contact metamorphism, but suggests by its mode of occurrence that it is due to some subsequent action.

rock subsequently metamorphosed. Originally a peridotite,[1] and frequently occurring in large masses, as at the Lizard and in the Alps, it has been converted by gradual change into a mass of flaky serpentine, as was described in my first paper on the Lizard, to which I have already referred,[2] and this rock also, by further action of water, may be altered with a talc-schist (**46**). An exceptional kind of chlorite-schist which occurs, apparently intrusive, in talcose-serpentine on the Gorner Grat and in Anglesey, has once been, as already mentioned, a diabase, and dykes of the latter can be seen at the Lizard occasionally to pass into varieties of "potstone", while the so-called white-trap is another modification of a basaltic rock too well known to need more than mention.

The metamorphic rocks still present difficulties—points in their history which require further elucidation—but during the last half-century, as I know from my own experience, and as any one can ascertain by consulting the books and papers, which at the beginning of that period were regarded as authorities, the mists which then obscured knowledge have been largely dispersed, and many misleading and erroneous notions have been banished.

The passage of sedimentary into igneous rocks, once so confidently asserted, has proved to be no better than a figment of the imagination. It is possible, of course, that a sedimentary rock may be melted down, especially if small fragments of it are caught up in large masses of molten material, but even these appear, as a rule, to be so refractory that little evidence can be found in its favour.[3] The gneiss and schists, the rocks commonly called metamorphic, prove, as a rule, to be more ancient than any strata to which a date can be assigned, and belong, apparently, to an era in the earth's history anterior to the appearance of life, when the temperature of its crust rose more rapidly in a downward direction than at the present day. This statement, fifty years ago, would have been scouted as heretical by most geologists; I think, however, that the bulk of those who have studied petrology, not only in the field, but also with the microscope, would now consider it to be the more probable hypothesis.

Bibliographical References.

I have omitted my own name where, as in the majority of cases, the papers are written by myself. Q.J. denotes Quarterly Journal of the Geological Society, G.M. Geological Magazine, M.M. Mineralogical Magazine.

1. Q.J. xlvii, p. 476; lii, pp. 22, 27–30; "Crystalline Schists of the Lizard," pp. 21–33.

2. Q.J. xxxiii, p. 888; xxxix, pp. 11, 16.

[1] I believe it is generally a deep-seated rock which occurs more often in bosses than in dykes, and never, so far as I have been able to ascertain, as a flow.

[2] Perhaps the minutely flaky form of serpentine named antigorite may be due to subsequent pressure during or subsequent to the action of water (**47**).

[3] The dark patches in igneous rocks have been discussed in an excellent paper by Mr. J. A. Phillips (Q.J. xxxvi, pp. 1–22), but I regard them, more often than he has done, as remnants of fragments of much older rocks, or pieces of a more basic igneous rock that have been broken off and carried along by the moving magma.

3. (With E. Hill) Q.J. xlviii, p. 122.
4. Q.J. xlvii, pp. 475, 480 (with General Macmahon); xlviii, p. 135 (with E. Hill); lxviii, p. 32.
5. G.M. 1894, pp. 118, 119.
6. (With E. Hill) Q.J. lxviii, pp, 41–3.
7. Q.J. xlii, Proc., p. 68.
8. G.M. 1894, pp. 115, 116.
9. Proc. Geol. Assoc. xv, p. 6.
10. Q.J. xlii, Proc. pp. 70, 71.
11. G.M. 1894, p. 116.
12. C. Lapworth, "Secret of the Highlands": G.M. 1883, pp. 120, 193, 337.
13. *Geological Structure of North-West Highlands* (Mem. Geol. Surv.), pp. 472–3.
14. J. Lehmann, *Entstehung der Altkrystallinischen Schiefergesteine*, etc., 1884; more especially chapters xvi–viii.
15. Q.J. xlix, pp. 94–103, 105–112; l, pp. 279–284.
16. Q.J. xlv, pp. 93–7; liv, pp. 358–67.
17. J. B. Jukes, *Students' Manual of Geology*, 1872, (ed. A. Geikie), p. 144.
18. J. B. Jukes, *ut supra*, pp. 246, 366. Also A. H. Green, *Geology*, 1876, pp. 271, 292–5. By 1878 I had convinced myself from personal examination that the important cases mentioned at the latter reference were quite wrong.
19. *Crystalline Rocks of the Lizard*, 1914, pp. 9, 21–33.
20. Q.J. xlvi, pp. 199–204, 208–13, 217–21; l, 297–90.
21. Q.J. xlv, pp. 91, 92.
22. G.M. 1893, p. 204.
23. G.M. 1895, p. 400.
24. Q.J. xlvi, pp. 200–2.
25. Q.J. xlvi, p. 217.
26. Q.J. xlix, p. 89.
27. G.M. 1901, p. 166.
28. Q.J. 1894, pp. 297–300.
29. Q.J. 1899, pp. 91, 92.
30. Q.J. xl, pp. 3–5.
31. Q.J. liv, pp. 361–3.
32. Q.J. xlix, pp. 108–9.
33. Q.J. i, p. 299.
34. Q.J. liv, pp. 366–7.
35. M.M. vii, pp. 1, 151, 191; Q.J. xliii, p. 303.
36. Q.J. xlix, p. 106.
37. Phil. Mag. 1892, pp. 237–48.
38. Q.J. lxviii, p. 51.
39. Q.J. xliv, p. 25. See also T. M'K. Hughes, id., p. 20.
40. Q.J. xliv, pp. 33–9.
41. Q.J. xlii, Proc., 73–5; xlvi, 214–21, 299–301.
42. G.M. 1901, pp. 163–6. C. A. Raisin, Q.J. lvii, pp. 63–71.
43. M.M. i, pp. 215–21.
44. Trans. Geol. Soc. Cornwall, x, pp. 180–6. See also M.M. vi, p. 48.
45. G.M. 1890, pp. 538–41.
46. G.M. 1890, pp. 532–42; 1897, pp. 110–13.
47. (With C. A. Raisin) Q.J. lxi, pp. 699–714.

II.—Non-German Sources of Potash.

By Arthur Holmes, D.Sc., A.R.C.S., F.G.S.

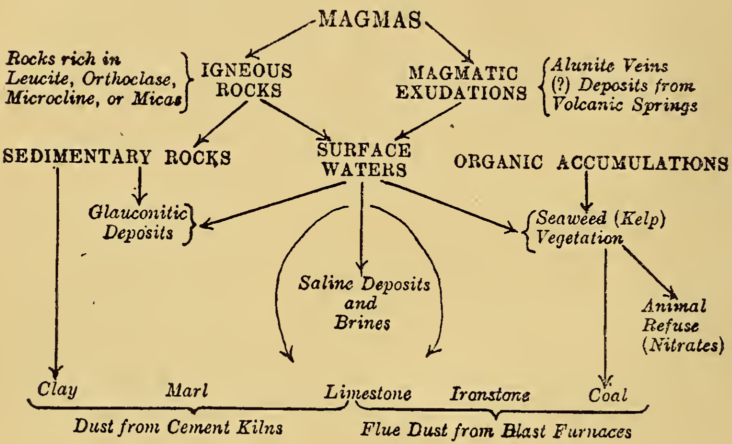
Introduction—Natural History of Potash—Saline Deposits—Alsatian Deposits—Spanish Deposits—Abyssinian Deposits—Natural Brines—Searles Lake—Nebraska and Utah—Tunis—Saltpetre—Kelp—Other Organic Sources—Insoluble Potash Minerals—Felspars—Leucite—Glauconite—Alunite—Dust from Cement Kilns—Blast Furnace Flue-dust.

It is scarcely necessary in this Magazine to insist upon the vital importance of potash, or upon the reasons which led to the former economic dependence of our own and many other countries on German resources. The shortage of potash, which arose as a direct consequence of the outbreak of war, became more and more accentuated until the latter part of 1917, when production from various revived and newly discovered sources began appreciably to relieve the then seriously acute position. In 1913, the last complete year of the older conditions, over £900,000 worth of potassium salts were imported from Germany by Great Britain, against imports of only half that value—much of which was cream-of-tartar, a by-product of the wine industry—from all other countries. It is now safe to say that the German monopoly is completely broken, partly because of the return of Alsace to France, and partly because of the discovery of new deposits, and the successful development, under the stimulus of war conditions, of new methods of potash recovery from sources formerly unremunerative or unsuspected. The purpose of this article is to pass briefly in review the chief sources from which potash is, or may be, profitably extracted, other than those of the famous German deposits, which already have a voluminous and familiar, or at least readily accessible, literature.

The natural history of potash is very different from that of soda. In average igneous rock the percentages of these two constituents are practically equal, while in average sedimentary (exogenetic) rocks potash is two and a half times as abundant as soda. Complementary to this selective retention, the potash of river waters amounts to no more than a quarter of the soda, and in sea water the proportion is still further reduced to a thirtieth. The following figures, based on denudational statistics, bring out clearly the difference of behaviour between the two elements.

	Potassium.	Sodium.
	(Figures represent millions of millions of tons.)	
In ocean water	450	12,600
In sedimentary rocks	18,300	7,400
	18,750	20,000
In parent igneous rocks from which the sediments were derived . . .	19,700	20,000
Unaccounted for	950	—

In round figures the circulation of sodium is completely accounted for, whereas a large balance of potassium, twice the quantity dissolved in the oceans, remains over. This amount, or something of the same order, must be mainly present in organisms. It is well known that potassium salts are preferentially adsorbed by colloidal and physically analogous substances from solutions that percolate through soils, and from the latter they are taken by plants, and thence by animals. Of the potash that reaches the sea a high proportion is similarly abstracted by seaweeds, while another considerable fraction is adsorbed by ferruginous and siliceous matter to form glauconite. Without going into further detail, the circulation of potash from its original magmatic sources is summarily set forth in the following scheme, with a view to indicating the deposits from which extraction is economically practicable, or likely to become so if need arose:—



Saline Deposits.

In addition to the extensive German salt-fields,[1] generally referred to as the Stassfurt deposits, there are at least half a dozen areas where beds of potassium salts are associated in workable quantities with saline formations. Three of these, in Alsace, Spain, and Abyssinia, are of outstanding importance. In Galicia, Lower Miocene beds of kainite and sylvite are mined at Kalusz, but as the output is insufficient to supply the local demand, these deposits are, for us, of minor interest.[2] Numerous potash-bearing seams have been discovered in the mines of the Salt Range of India.[3] Their commercial development, however, has been restricted by the irregularity of the potash and the abundance of sulphates, and at present their exploitation has scarcely passed the prospecting stage. In Chile there are extensive salt deposits lying to the east of the nitrate fields, and one of these, the Pintados Salar, which is skirted

[1] J. W. Gregory, Trans. Geol. Soc. Glasgow, vol. xvi, p. 12, 1916.
[2] Zeit. für das Landwirtschaftliche Versuchswesen, vol. xviii, p. 892, 1914.
[3] W. A. K. Christie, Rec. Geol. Surv. India, vol. xliv, p. 243, 1914.

by the railway from Iquique, has been found by chemical prospecting to be potash-bearing over an area of 20 square miles.[1] The potash is confined to a hard superficial crust averaging a foot in thickness, which overlies a loose granular deposit of glauberite and gypsum. The composition of the crustal salts is approximately 70 per cent NaCl with 30 per cent of sulphates, among which glaserite, $(K, Na)_2 SO_4$, is the chief. As in the Indian deposits, the effective extraction of potash presents a difficult problem to chemical engineering. Deposits that hitherto have not been worked, and of which very little is known, are said to occur in Holland, Sicily, Russia, Morocco, and Peru.

Alsatian Deposits.—The Alsatian deposits were discovered near Mulhouse in 1904 during a survey of the district for coal and oil by borings. They have since been thoroughly investigated, and are known to underlie an irregular oval-shaped area of about 80 square miles,[2] bounded by the Jura on the south, the Vosges on the west, and the Rhine on the east. A continuation of the same formations has also been recognized across the Rhine, but as yet the occurrence of potash in Baden remains hypothetical. The general succession of the Alsace deposits is stated in the accompanying table in comparison with those of other areas. Potassium salts occur in two well-marked beds separated by 50 to 80 feet of dolomitic marl. The lower bed is both thicker and more extensive than the upper, and is encountered at depths varying from 2,000 to 3,300 feet in different parts of the field. The beds are continuous, and as they are only very gently folded, unlike the Spanish deposits described below, they can be worked without difficulty. Moreover, they are superior in character to the German deposits because of the absence of carnallite. Each bed consists of practically pure sylvinite, in bands alternately red and grey, the average percentages of KCl being 35 and 30 for the upper and lower beds respectively. The field, as a whole, is estimated to contain over 400 million tons of KCl, a reserve ample, were it necessary, to supply the combined requirements of France, Great Britain, and the United States for several centuries.

The Alsace deposits differ most conspicuously from those of other regions by the deficiency of sulphates, salts containing $MgSO_4$ being absent, while even anhydrite and gypsum are less abundant than is usual. On the other hand, the succession of deposits begins with dolomite, and dolomitic beds occur at various horizons throughout, indicating that calcium and magnesium were present in normal quantities, and that they were precipitated as carbonates rather than as sulphates. The absence of sulphate is not improbably due to the bituminous character of the deposits, and conforming to the implied suggestion of reduction the bituminous beds are found to be unusually rich in sulphides.

[1] H. S. Gale, Eng. & Min. Journ., vol. cv, p. 674, 1918; R. C. Wells, ibid., p. 678.

[2] For a map of the area and a general discussion of its commercial value and political significance, see Paul Kestner, Journ. Soc. Chem. Ind., vol. xxxvii, p. T 291, 1918.

Wittelsbach District, Alsace.	*Suria and Cardona District, Spain.*	*Southern Harz District, Germany.*
Oligocene marls . .	*Oligocene* marls, sandstones, and limestones. Marls with rock-salt, anhydrite, and gypsum.	*Triassic* / *Upper Permian* { Sands, sandstones, clays, and shales.
Rock-salt and clay . .	Upper rock-salt . .	Younger rock-salt.
	Anhydrite	Anhydrite.
Dolomitic salt-marl .	Salt-clay	Salt-clay.
Zones of potash salts in dolomitic marl . .	Zones of potash salts .	Zones of potash salts.
Rock-salt with bituminous clays . . .	Lower rock-salt with partings of anhydrite.	Older rock-salt with partings of anhydrite (year rings).
Anhydrite	Anhydrite and gypsum.	Anhydrite and gypsum.
Dolomite.		
Green-grey marls . .	*Eocene* limestone . .	*Lower Permian* limestone.

Spanish Deposits.—Just before the war a zone of potash salts was discovered in Catalonia, near Cardona, a locality already well known for its rock-salt mines. The general succession has been revealed by a large number of bore holes and by a series of shafts which mark the beginning of the productive exploitation of the deposits. As shown in the detailed sequence set forth above, there is a marked likeness to the Southern Harz type of the German deposits. The saline beds were evidently precipitated in a gradually subsiding lagoon which covered parts of Barcelona and Lerida in Lower Tertiary times.

The structure of the deposits makes their commercial development rather troublesome. At Suria[1] the beds turn steeply over in a monocline, the dip of which is about 70°. They are then again brought near the surface by a fault, from which the beds continue to dip in the same direction but at a much reduced inclination. At Cardona the deposits are worked in the axis of a steep anticline, where the continuity of the beds has been repeatedly broken by faulting. Here the chief potassium salt is sylvite, which occurs in nearly pure seams. At Suria, however, the salts are more varied. Certain bands consist dominantly of carnallite, but generally there is intimate admixture with rock-salt, and occasionally layers of sylvinite appear. Numerous potash zones, alternating with rock-salt, and of variable thickness and value, have been proved, the aggregate thickness being equivalent to 60 feet of carnallite and 13 feet of sylvite. The complete extent of the Spanish potash field has not yet been determined, but it has already been explored over a belt more than 6 miles long, and consequently very substantial reserves may be anticipated. The first large shaft sunk by the Franco-Belgian Syndicate, which has a concession at Suria, has now been completed, and it is expected shortly to raise 1,000 tons of raw salts per day. That production was not commenced during at least the last year of the war was due mainly to German intrigues and political troubles, the details of which need not here be discussed.

[1] E. M. Heriot, *Mining Journal*, vol. cxix, p. 753, December 15, 1917.

(*To be continued.*)

III.—Notes on Yunnan Cystidea. III. *Sinocystis* compared with similar Genera.

By F. A. Bather, D.Sc., F.R.S.

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(With Figures 22–30 on PLATE VI.)

B.—Comparison with *Megacystis* (*continued*).

4. *The Thecal Openings.*

It is these which afford the justification for any comparison between *Sinocystis* and *Megacystis*. Those of *Sinocystis* are, it will be remembered (*antea*, December, 1918, p. 534), a transversely elongate peristome, a hydropore-slit approximately parallel to the peristome, a gonopore to the left of the anal plane, and a hexagonal or pentagonal periproct. These openings, though differing in details, are in number and position essentially similar to those of *Aristocystis*. Hitherto there has been much uncertainty as to the positions, and even the presence, of the hydropore and gonopore in *Megacystis*. It will here be shown that both are present, and that all four openings have much the same relations as in *Aristocystis* and *Sinocystis*, especially the latter.

(*a*) The Peristome and surrounding plates.

The shape of the peristome and the number and arrangement of the adoral plates are necessarily correlated with the number of brachiole-facets. Information on these points is forthcoming in regard to only 27 of the 48 named species; and even for these 27, intelligible drawings of the adoral region exist in the case of 15 at most. "Intelligible" is perhaps too favourable an epithet for some of these, but fortunately the British Museum specimens help in their interpretation.

The number of brachiole-facets varies from 3 to 5; being three in 2 species, four in 17 species, and five in 8 species, some of which are doubtful. It is clear from this, and still more from the numbers in actual specimens recorded, that four is the normal number of facets. The structure of specimens with that number will therefore be taken first.

Four brachiole-facets with a definite arrangement of adoral plates occur in the following British Museum specimens: E 7630–7637, E 7640, E 7642, E 7644, E 7645, E 7674, E 7677, E 16168, and E 16171, and probably also in E 7638, E 7643, and E 7676. There is a slight variation in E 7639, and a distinct difference in E 7673 (a pustulate form), which is the only other specimen that shows the structures in question.

In none of the British Museum specimens and apparently in none of those studied by other authors, with the doubtful exception of *H. gyrinus* Miller & Gurley (1894), have the cover-plates been preserved. Consequently the peristomial opening is clearly seen in most of the specimens (figs. 22, 24). In the normal form with four facets it appears quadrangular and somewhat extended transversely to the anal plane. Removal of the infilling matrix shows that the quadrangular outline is furnished by a slight ridge which bounds the peristome and joins up the four brachiole-facets that lie one at each angle. The ridge on each side is frequently a little curved, with an adoral convexity, and it does not meet adjacent ridges, but merges into the margin of each brachiole-facet. Within this rim the surface slopes downwards to an elliptical margin, and thence passes vertically downwards as a tube of uncertain depth.

Just within the quadrangular rim the slope is generally indented by a slight rebate, and along this the inner side of the ridge is marked by a row of notches, irregular in shape and size, but generally appearing as vertical indentations with a rounded upper end. These no doubt bore a series of small plates that covered the peristome and subvective grooves, as in *Sinocystis*. The alternative suggestion that there were large tegminals, each attached by a toothed hinge, is opposed to the fact that no such plates have ever been found.

From the elliptical margin a narrow groove leads to each brachiole-facet, whence no doubt it continued on to the brachiole itself, as a subvective groove. No remains of brachioles have yet been recognized.

The thecal plates forming the margin of the peristome are six in number; of these there are two on the anterior margin, two on the posterior, and one at each side. The four subvective grooves lie on the sutures between these last and the adjacent plates. All these form Adoral circlet I, and may be called Adorals I (Ad. I).

Outside them comes Adoral circlet II, composed of eight plates (Adorals II, or Ad. II), namely, one supporting each brachiole-facet, and therefore corresponding with the sutures at the angles of the peristome, and four lying between these. The former four might be designated 'radials', and the latter four 'interradials'. Of the interradials, the two on each side butt on the right and left adorals of circlet I; the two that are anterior and posterior alternate with the paired anterior and posterior Adorals I, i.e. correspond with the anterior and posterior sutures.

This arrangement is shown in only two of Miller's figures, namely those of "*Holocystites*" *commodus* (our fig. 23) and *H. gorbyi*, which are probably synonymous. The figures of *H. parvus* and *H. scitulus* show the eight Adorals II, but in Adorals I the two posterior plates are not distinguished, and in the anterior interradius only one plate is drawn. Probably the structure was quite normal, though the two anterior Adorals I may conceivably have fused.

The peristome of *H. ornatus* was described by Miller (1878) as "surrounded by seven plates, and four (possibly five) arm bases". The figure, when interpreted by our present knowledge, shows that the Adorals I have been either not preserved or not distinguished, except in the case of the two posterior. Assuming the facets to be, as usual, on Adorals II, then there are, as usual, eight plates in that circlet. The specimen therefore is probably of the normal (Ad. I, 6; Ad. II, 8) type; no reason is given for supposing that it had more than four facets.

There are four other alleged species with four facets: *H. ornatissimus* (fig. 25), *H. papulosus*, *H. subovatus*, and *H. asper*. These are all pustulate forms, and the first three differ only in the number of thecal plates; there are 6 rows with intercalated plates in *H. subovatus*, 7 rows of unequally-sized plates in *H. ornatissimus*, and about 8 rows in *H. papulosus*. These differences, as we learn from *Sinocystis*, are only those of growth. The names are therefore synonymous and, since all were published at the same time (1891), the name *ornatissimus*, which comes first in the book, may be selected for the species. *H. asper* seems to have more tumid plates, and the periproct is elongate transversely, not diagonally as in the other forms. It may perhaps be a distinct species. The four drawings of the adoral surface agree so closely that they must be regarded as correct, at least in so far as what they show (fig. 25). The peristome has a thick rounded margin, and this probably represents Adorals I, though the component plates are not distinguished in the figures and indeed may have been fused. The outlines of Adorals II are distinctly drawn and show only six plates, namely four with facets on the right and left, one anterior, and one posterior. These two interradial Ad. II are elongate, especially the posterior, which is drawn as stretching from the elliptical periproct right up to the peristomial rim. In this feature *H. ornatissimus* and *H. asper* differ from the normal plan represented by *H. gorbyi* (fig. 23), but a more essential difference lies in the absence of the right and left interradials from Adorals II. The specimen which R. R. Rowley (1903, Greene's *Contrib. Indiana Palæont.*, i, p. 166, pl. xlviii, figs. 16–18) has referred doubtfully to *H. papulosus* probably does not belong to this species, since it has adorals on the normal *H. gorbyi* plan. It might be *H. ornatus*. There is in the British Museum no specimen on the *H. ornatissimus* plan.

We may pause here to compare the arrangement of the adorals in specimens with four facets with that in the earlier form *Sinocystis*, which also has four facets (*antea*, fig. 9, 1918, p. 535). The four facet-bearing plates in that genus are presumably homologous with the facet-bearing Adorals II of *Megacystis*. They appear, however, to form part of Adoral circlet I, and those on the right and left join each other as in the *ornatissimus* plan. On the other hand, there are two anterior and two posterior Adorals I, as in the normal *gorbyi* plan. It is possible that the right and left Adorals I are present but hidden by the cover-plates. In that case there would, as in *Megacystis*, be six Adorals I, forming a peristomial ring. The facet-bearing plates of *Sinocystis* would thus fall into place as part of Adoral circlet II, and the right and left Adorals II would be represented by the plates that alternate with them; but the remaining plates of circlet II are more irregular in size and position than in most (perhaps all) specimens of *Megacystis*.

The occurrence of five facets in *Megacystis* is clearly shown in S. A. Miller's figures of five species, but the arrangement of the adorals is not so clear. Applying to the figures the knowledge gained from the specimens previously discussed, we note that Adorals I (though doubtless present) are not represented for any of these species except *H. splendens* Miller & Gurley (1894). In that species there are said to be 7 Adorals I, but the drawing shows 10. In the drawing (our fig. 28) the suture that should probably separate the two posterior adorals is not shown. If the figure be taken as roughly correct, then each pair of Adorals I enters into the proximal half of a facet; that is to say, the plates are larger than usual and so reach the actual facet. A similar arrangement is visible in specimen E. 7673 (fig. 29). In *H. splendens* the distal half of each facet is borne by an Adoral II alternating with the paired Adorals I. Between the five facet-bearing Adorals II are three interradial Adorals II, namely one posterior, one right postero-lateral, and one left postero-lateral. Thus this circlet, as drawn, has the normal number eight, and its difference from the four-facet plan is simply that the anterior Adoral II, instead of being an interradial, bears a facet. Circlet I, as drawn, owes the difference in the number of its plates (10 instead of 6) to the presence of interradial sutures in all interradii and not only in the posterior interradius. If those sutures were absent, the number and arrangement of the plates would be precisely as in the normal plan. Since Miller & Gurley say that the peristome is "surrounded with seven plates", it is possible that their drawing is wrong in this respect.

Miller's figure of *H. plenus* (1878) looks very different, but from his description it is obvious that the Adorals I enter into the facets in the same way as in *H. splendens*. The figure of *H. pustulosus* (1878) is so similar to that of *H. plenus* that the same interpretation of it seems legitimate. As to the number in each circlet, the evidence of these two species is unsatisfactory.

The drawing of *H. sphæroidalis* Miller & Gurley (1895) shows eight Adorals II, arranged as in *H. splendens*; but the drawing (our fig. 27) is so clear that it does not seem possible to suppose that Adorals I entered into the facets; they probably formed an inner, rather obscure rim. The original of *H. wykoffi* is crushed and in parts overgrown or missing; but it is easily interpreted on the lines of *H. sphæroidalis*.

Light is thrown on these specimens by the British Museum specimen E 7641 (fig. 26). This has been crushed along lines of weakness starting from the periproct and wandering towards the right anterior corner; thus some of the sutures in the adoral circlets are obscured. The specimen has been bored, during life, by some organism (possibly a bivalve mollusc) that has made round holes and caused a thickening of the test with obliteration of sutures. In addition the theca has been overgrown by bryozoans and one small pelmatozoan stem, probably after death, and the adoral region is much worn. One can, however, distinguish five facets, and a circlet of Adorals II arranged as in *M. sphæroidalis* (fig. 27). Indeed, a comparison of the two figures will show resemblances in such details as the irregular shape of the right posterior Adoral II, and the precise position of the facets on their respective plates—the anterior being approximately median, while those of the lateral pairs are shifted towards the adjacent interradials, so that the intervals between the facets are equalized. The importance of our specimen, however, lies rather in the traces of Adorals I, which, as was surmised, form a narrow ring round the peristome. The sutures between them cannot be made out, but the number of plates cannot have been less than six or more than eight; six is the more probable.

Five facets are also said to occur in *H. baculus* Miller (1879), but the statement is not well substantiated by the figure, and is somewhat opposed by the description of the peristome as subquadrangular; Adorals I "are not clearly determinable"; if five facets were present the arrangement was probably as in *H. sphæroidalis.* The figure of *H. elegans* Miller (1878) is like those of *H. plenus* and *H. pustulosus*, but the holotype has been attacked by a boring-organism, so that its plates are anchylosed. In *H. perlongus* Miller (1878) the five facets are not clear in the figure, and there is a lack of detail.

The general conclusion to be drawn from the figures and descriptions of specimens with five facets is that they differ from those with four facets mainly in the presence of a facet on the anterior Adoral II and of a food-groove leading to it between the two anterior Adorals I.

Finally we come to the two species said to have only three arm-facets.

In "*Holocystites*" *amplus*, Miller (1892) mentions three facets on large bosses, and seems to imply that this is all by describing the peristome as in the centre of the triangle formed by them; but in the absence of a figure and of other details it is impossible to consider the case. Miller compares the species with *H. ventricosus* (1879), which is equally ill-defined, and may well be a synonym of *H. dyeri* (1879). *H. amplus* may therefore provisionally be regarded as based on either an imperfect specimen or an individual variation of *H. dyeri.*

The number three is also found in *H. gyrinus* Miller & Gurley (1894). The drawing of the adoral face (our fig. 30) shows apparently three facets corresponding to the left anterior, left posterior, and the united right-hand pair of the normal plan. The food-grooves leading from the two left-hand facets meet at what would in a normal form be regarded as the left end of the peristome. From this point a straight groove connects them with the right-hand facet. Thus the groove-system is roughly in the form of a ≻-. These grooves are drawn of approximately equal width throughout, and, for the most part, with a structure that can only be interpreted as cover-plates. For these two reasons it is not possible to judge of the precise position or extent of the peristome, but the arrangement of the adoral plates suggests that it occupies about two-thirds of the stem of the Y measured from the fork. The length of this tract is about 9 mm., and the length of each food-groove is then also about 9 mm. The left posterior groove, however, is a little longer, perhaps as much as 11 mm., and it widens at its distal end as though it were forking. The left anterior groove has a slight curve, with the convexity on the left; and the stem of the Y is also slightly curved, with posterior convexity. The right-hand facet is obscure, perhaps over-grown, for it may be mentioned that there are several cystid roots adherent to the specimen, as in *Sinocystis mansuyi.* The facets are, as usual, on Adorals II. Adorals I consist of the usual 2 posterior, 2 anterior, and 1 left; but on the right side, instead of the single adoral between two facets, there appear to be two adorals with the food-groove passing between them; thus there is the unusual number of seven Adorals I. Adorals II seem from the drawing to form a very irregular circlet of 10 or 11 unequal plates; the irregularity is greater on the right side.

Miller & Gurley's description does not altogether correspond with the preceding account based on their figure. This is due probably to the peculiar morphological views of S. A. Miller. They write (1894, p. 6): "On each side near the bottom of the ambulacral furrow there is a row of pores, but a free plate of the same character from the same or a similar species, when examined from below, does not show these pores in lines, nor can they be distinguished from the other pores that penetrate the plate from all sides. The ambulacral furrow, therefore, is not homologous with the ambulacral furrows of either crinoids or blastoids. There is no reason to suppose that it was a food-groove, was covered with minute plates, or was furnished with pinnules. It appears as a triangular furrow cut only half-way through the plates, and where following the suture lines of plates, the plates are more firmly joined than elsewhere by the denticulated edges, but when it enters upon a plate that bears an arm the furrow runs up to the base of the arm where it does not cut one-fourth of the thickness of the plate, and where the pores upon the sides appear to differ from the other pores that penetrate the plate only by being arranged externally in two lines." Of course the "furrow" is homologous with the food-grooves of all other Pelmatozoa, and there is every reason to suppose that it had cover-plates. Whether the cover-plates are preserved in this specimen or no is a different question. It is most natural to suppose that they have here been exceptionally preserved, just as they are preserved as a rule in the specimens of *Sinocystis*; further, as in some of the latter, there is a slight furrow between the cover-plates in some parts, as shown in text-fig. 10 and discussed on p. 535 (*antea*, 1918). The pores mentioned by Miller & Gurley are, no doubt, the diplopores, which are occasionally ranged alongside the food-grooves.

In specimen E 7673 (fig. 29) only three facets can be distinguished, but the arrangement differs from that of either of the two specimens just considered. The specimen is strongly pustulate and is crushed in the left-anterior – right-posterior plane; on the posterior half of the adoral face the intervals between the pustules were filled with a matrix not easily distinguishable from the stereom and removed only with difficulty; on the anterior half of the adoral face the plates are weathered and worn down. The facets preserved are the two on the left and the right posterior. Adorals I are 9 or 10, probably the latter. Two of these border each food-groove, and enter into the adoral half of the facet. That accounts for six plates. One Adoral I is in the posterior interradius, and three rather large plates are on the anterior border of the peristome. The adoral third of the surface in the three anterior plates is marked with depressions at right angles to the peristomial border; they may be due to weathering, but even so the differential effect has to be accounted for. The middle one of these anterior plates has a further depression stretching along about three-quarters of the median line, or a little to the right of it. Since this depression starts from the fourth angle of the peristome, it may represent a much-worn facet. I am inclined to regard that as a correct interpretation, and, in that case, to consider the three anterior plates as compounds of Adorals II and I, the latter being represented by the depressed adoral tracts. This view makes the arrangement much more symmetrical and, but for the number of facets, very close to that in Miller & Gurley's figure of *H. splendens* (fig. 28), the general accuracy of which it thus confirms.

To summarize the facts concerning the adoral plates of *Megacystis*: In all species there are two circlets of adorals, Ad. I forming the peristomial rim and Ad. II bearing the brachiole-facets, normally four, sometimes five, and rarely (perhaps abnormally) three.

In the species with four facets two plans are distinguished. Of these the more common, exemplified by *M. gorbyi* and *M. commoda* (figs. 22, 23, 24), has Ad. I 6 and Ad. II 8. The four facet-bearing Ad. II are separated by four interradial Ad. II. The Ad. I are all interradial, two being posterior, two anterior, and one on each side. In the other plan, exemplified by *M. ornatissimus* (fig. 25), Ad. I are reduced in size, but probably remain six in number; Ad. II are only six, the two lateral interradials being eliminated.

In the species with five facets, Ad. II are eight as before, the difference being that the fifth facet is borne by the anterior Ad. II. In respect to Ad. I, these species show two plans of structure. In *M. sphæroidalis* (figs. 26, 27) Ad. I form a narrow rim, probably of six plates, as in *M. ornatissimus*. In the plan exemplified by *M. splendens* (fig. 28) Ad. I are enlarged so as to share in the facets, and seem to be 10 (or perhaps 11) in number, there being a suture in each interradius so that there are five pairs of adradial plates, with perhaps an additional posterior interradial. Specimen E 7673 (fig. 29) is, broadly speaking, built on this plan, but seems to have at most four facets; in other respects it resembles *M. splendens*. This suggests that the presence of a fifth facet may not be a truly specific character.

Of species with three facets, *M. gyrinus* (fig. 30) is the only one about which there is adequate information. The arrangement of the adorals round the single facet on the right is so irregular that one can hardly regard the form as normal. It does, however, differ from all the other species in the apparent cover-plates and the length of the tegminal food-grooves. The present comparative study at any rate shows that the three rays of *M. gyrinus* are not the primitive anterior, left, and right. In this connection it will also be remarked that the additional fifth anterior facet in some species of *Megacystis* does not correspond with the ray which the examination of *Sinocystis* led us to regard as possibly the primitive anterior, since that was the ray here called the left anterior. This fact does not necessarily upset the hypothesis of a primitive tri-radiate form, but it suggests further research.

EXPLANATION OF PLATE VI.

Adoral Surfaces of Megacystis.

The drawings with numbers underneath are from specimens in the British Museum, and are of the natural size. Those provided with names are copied from Miller's original figures, and are presumed to be of the natural size. In all the drawings the details of ornament have been omitted, so as to emphasize the suture-lines and thecal openings.

Fig. 22.—E 7630. Hydropore distinct. Gonopore apparently with two openings near left post. facet.

,, 23.—*M. commodus*, after S. A. Miller, 1891, Advance Sheets 17 Rep. Geol. Surv. Indiana, pl. iii, fig. 2. The suture between the posterior Ad. I, here dotted in, is not shown in the original figure.

,, 24.—E 7631. Hydropore indicated by a faint dotted line. Gonopore on post. Ad. II.

,, 25.—*M. ornatissimus*, after S. A. Miller, 1891, op. cit., pl. v, fig. 2.

,, 26.—E 7641. Gonopore on post. Ad. II. Periproct crushed. Holes due to boring organism seen in N.W. quarter and a small pelmatozoan root on left interradial Ad. II.

,, 27.—*M. sphæroidalis*, after Miller & Gurley, 1895, Bull. Illinois State Mus., vii, pl. v, fig. 3. Ad. I not shown in the figure.

,, 28.—*M. splendens*, after Miller & Gurley, 1894, op. cit., v, pl. i, fig. 9. Suture between post. Ad. II not shown.

,, 29.—E 7673. The sutures between the posterior adorals are obscure.

,, 30.—*M. gyrinus*, after Miller & Gurley, 1894, tom. cit., pl. i, fig. 3. Hydropore low down on suture between post. Ad. I. Gonopore near base of left post. facet.

IV.—Drake's Island, Plymouth.

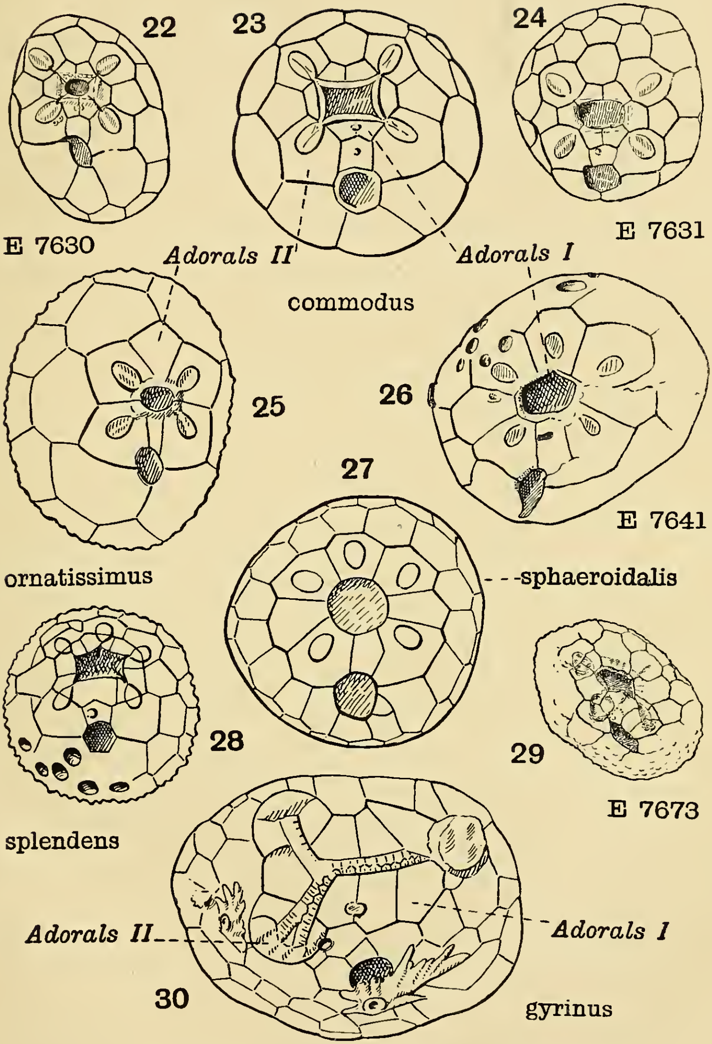
By E. B. Bailey, M.C., B.A., F.G.S.

THE main feature of the geology of Drake's Island is the association of volcanic rocks with marine limestone of Mid-Devonian age. The Geological Survey memoir[1] by Mr. W. A. E. Ussher attributes the discovery of the volcanic rocks to Mr. R. N. Worth. Mr. Ussher leaves their precise nature, "whether lavas or tuffs," somewhat in doubt, but states that they are "most certainly contemporaneous". As a matter of fact both lava and tuff occur, and are definitely distinguishable.

The limestones A and C of the sketch-map are attributed by Mr. Ussher to the Plymouth horizon, and the double outcrop is interpreted as a repetition due to plication. It is certainly possible that there is only one limestone—reduplicated by faulting—but I think it more probable that the limestone C is distinct from A, and is interstratified between the tuffs B and the lava D. At any rate the tuffs B are not very like the tuffs E, for they are much less distinctly bedded, and they much more commonly contain fragments of limestone.

On broadly based grounds of succession and structure, Mr. Ussher regards the Plymouth Limestone as older than the Drake's Island

[1] *The Geology of the Country around Plymouth and Liskeard*, 1907.

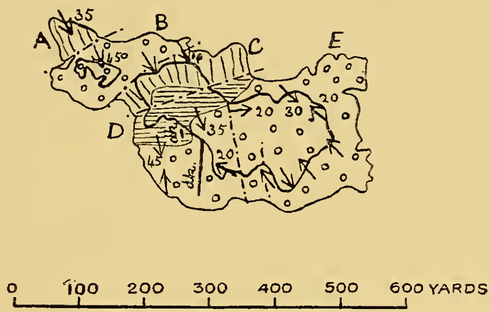


F. A. B. del.

ADORAL SURFACES OF *MEGACYSTIS*.

Volcanic Rocks. I have not found any evidence in Drake's Island bearing upon this point, and have therefore contented myself with a description of the rocks as they lie. If Mr. Ussher is correct, then the superpositions referred to presently are merely the result of inversion. All the rocks of the district, except the massive limestones, show a strong cleavage, so that there is no difficulty in admitting that such an inversion may exist.

My notes on Drake's Island were written down in the hope that they might be of value to those who make a study of the geology of the neighbouring mainland. During the winter 1915–16 I had several opportunities of going round the shores at low-water, so that it has been easy to clear up certain points, which have hitherto remained in doubt.



Map of Drake's Island, Plymouth.

Publication of a map of Drake's Island was forbidden so long as hostilities continued, and the resultant delay makes it possible to refer here to an important paper which has appeared in the interval. Mr. R. H. Worth,[1] a son of the late R. N. Worth, has given an account of the igneous rocks of Plymouth. It is true that our districts scarcely come in contact, since, while the War put one of us temporarily on to Drake's Island, it kept the other off; at the same time our subjects do seem to overlap, and it is only fair to state that Mr. Worth is of opinion that the so-called lavas of Plymouth are all intrusive, and that their associated fragmental rocks are intrusion-breccias. Experience of Drake's Island and a study of Mr. Worth's descriptions and figures do not tend to confirm this intrusion hypothesis. At the same time one cannot but welcome the additional data supplied in many particulars; and certain of his results will be made use of in their appropriate connection in the sequel.

A representative suite of specimens collected from Drake's Island is now in the possession of the Geological Survey (E 11402–11414). The lava D of the sketch-map is uniformly fine-grained,

[1] "The Dunstones of Plymouth and the Compton-Efford Grit": Report and Transactions of the Devonshire Association for the Advancement of Science, Literature, and Art, vol. xlviii, p. 217, 1916.

and its igneous structure cannot be made out with a pocket lens, though quite clear under the microscope. On the other hand, many of the fragments in the ashes B and E, especially E, when examined with a lens, show small felspars, set in a compact, sometimes almost flinty, base. These fragments have not uncommonly a well-marked fluxion structure, and under the microscope they look distinctly more acid than the lava D. All the igneous products of Drake's Island are very decomposed, with a plentiful development of albite, calcite, etc. In the tuffs, amygdales filled with albite, anorthoclase, and orthoclase, more particularly the first-named, occur in profusion. This feature is probably correlated with the comparatively acid nature of many of the enclosed fragments; the lava D was not closely examined for felspar-amygdales, but the similar rocks of the mainland[1] are seldom well endowed in this respect. The amygdales of the tuffs are interesting since they have in large measure resisted the Post-Carboniferous movement. At the same time it does not appear likely that the amygdales antedate the formation of the tuff, since the latter is itself cut by veinlets of alkali felspar. It is possible, however, that they formed before the tuff cooled.

Much the most peculiar rock on the island is an amygdaloidal limestone, closely mimicking a lava in appearance. A suggestion as to its origin is offered below (under C), where the various divisions distinguished by letters on the map are described *seriatim*.

Groups A–E.

A. Seventy feet of bedded grey limestone with some chert. The limestone does not appear very fossiliferous, but is so covered with barnacles that detailed examination is difficult.

Junction A B.—Fault.

B. One hundred and fifty feet of rather indistinctly bedded tuffs. These contain somewhat frequent lumps of limestone, and occasional separate corals, apparently blown into their present position.

Junction B C.—Probably a fault.

C. Fifty feet of limestone. The lower part has a little chert, and is well bedded and fossiliferous, consisting in some exposures of *Stromatopora*, with encrinites, etc. The upper part is practically unbedded, and is often very vesicular like a lava. The vesicles are filled, either partially or completely, with quartz and calcite, the former in finely crystalline aggregates. The appearance strongly suggests that this portion of the limestone was ejected as a hot bubbling calcareous ooze—a mud lava in fact.

Junction C D.—Very clear upward passage from limestone to pillow-lava exposed on south-west coast just north-west of a well-marked fault. The top of the limestone for a couple of feet serves as a matrix more or less completely isolating highly vesicular pillows of lava. The dip is very gentle.

D. Two hundred feet of lava. The lava (or lavas, if there is more than one flow) becomes compact a little above the vesicular pillowy base just described. The compact zone is of considerable thickness,

[1] R. H. Worth, op. cit., p. 225, pl. iii, fig. 13.

and is followed upwards by a mass of thoroughly vesicular lava disposed in rudely shaped pillows which are more or less separated from one another by chert rich in carbonate. The pillows only occasionally show a concentric arrangement of their vesicles.

The carbonate of the chert-carbonate rock just mentioned occurs as lenticular aggregates, sometimes showing, under the microscope, a dark centre, and also zones of growth marked by layers of dirt. It looks as if the carbonate had been precipitated first, followed by the chert. From analogy one may consider it possible that micro-organisms have played a part in the production of the deposit, though this is by no means certain. What I think is clear, is that the rock is in no sense a vein-stone. Mr. Ussher and Dr. Flett (op. cit., p. 83) have described a very similar chert from a quarry near Devonport Workhouse on the mainland. The Drake's Island chert weathers very readily to a soft rusty sponge through the removal of its carbonate crystals.[1]

Junction D E.—Upward passage from lava to tuff very well seen (though partially built over) in the cliff face of the south-west shore. The dip here is about 35°. Many local faults cross the junction; in fact, the whole of Drake's Island is cut up by small faults.

E. Two hundred feet of well-bedded tuffs.

Dykes cutting B, D, *and* E.—Four narrow dykes with rather conspicuous felspar phenocrysts have been traced for short distances through the volcanic rocks of Drake's Island and Little Drake's, though only two are shown on the sketch-map. They are for the most part two feet thick, and they share in the cleavage of the tuffs and lava through which they cut.

V.—The Mineral Composition of the Lower Greensand Strata of Eastern England.

By R. H. Rastall, M.A., F.G.S.

(Concluded from p. 220.)

6. Sandy.

THE well-known section alongside the Great Northern Railway just north of Sandy Station shows a total thickness of about 50 feet of ferruginous sands with occasional concretionary ironstone bands, resting on the Oxford Clay. This is therefore the lowest portion of the Lower Greensand. Numerous specimens from different levels in the exposure have been collected and examined, but they were all found to be very similar, and as a matter of fact not very interesting, so that a short description will suffice.

[1] Mr. Worth describes and illustrates additional occurrences of chert-carbonate rock from Plymouth; he regards the type as a product of the contact alteration of slate (op. cit., pp. 234–6, pl. iv, figs. 20–2). Professor T. J. Jehu and Dr. R. Campbell have found chert-carbonate rock among the fragments of a volcanic breccia on the border of the Scottish Highlands; "The Highland Border Rocks of the Aberfoyle District," Trans. Roy. Soc. Edinburgh, vol. lii, p. 183, 1917.

The only minerals occurring in abundance are zircon, kyanite, tourmaline, and staurolite, with small quantities of rutile and epidote and a few crystals of colourless amphibole and pyroxene. The zircons are quite normal and require no special remarks. Tourmaline is abundant and of many colours, including blue, green, olive-green, yellowish-brown, and brown varieties; the crystals vary a good deal in size and in degree of rounding, some being rather angular, while others are much rolled. Kyanite occurs in large blade-like crystals, often with very sharp edges, as well as in smaller and more rounded grains. Staurolite is unusually abundant in both large and small fragments, the smaller ones being as usual notably sharp and angular. Rutile and epidote are both rare, but of quite ordinary types, the former occurring only in small deep-red prisms. Several crystals of colourless pyroxene were easily identified by their high refractive index, strong birefringence, and extinction angles up to 40°. Some rather similar crystals with extinctions up to only 10° appear to be tremolite or some other amphibole.

As before stated, all samples contained a similar assemblage of heavy minerals, but it was noted that in some cases they were distinctly of larger size than in others. This is probably a process of natural sorting, correlated with varying strength of currents, rather than with any actual difference in the sources of the material itself. In such a notoriously current-bedded formation as the Lower Greensand this would naturally be expected to occur, and is evidently not of much significance.

7. Parish Sand Pit, Aspley Guise.

This pit, which is situated some 200 yards west of the church, is excavated in the lowest beds of the Greensand, as indicated by an examination of the neighbourhood and by the published 1 inch map of the Geological Survey (Sheet 46, N.W.). It shows about 30 feet of yellowish and greyish-white sand, very free from iron, and scarcely at all consolidated; near the top is a band of fullers' earth about 6 inches thick.

The process of separation was particularly easy owing to the small amount of iron present. When cleaned in the usual manner a sample of the unseparated sand shows fairly large grains of quartz of remarkably angular forms, together with a good deal of turbid felspar and a little glauconite. The shapes of some of the quartz grains are very curious, as may be seen from Fig. 5. These are, of course, specially selected examples and therefore not truly representative of the whole, but they are by no means the only peculiar forms present. Rounded and subangular grains of the type usually found in water-borne sands are quite uncommon.

The heavy minerals that sink in bromoform, though very abundant, are nearly always in quite small grains of very uniform size, averaging about 0·2 mm. in diameter, and very rarely exceeding 0·3 mm. The non-magnetic portion shows an unusually large number of mineral species. The most important are zircon, tourmaline, staurolite, kyanite, rutile, sphene, pyroxene, and ilmenite. The most noteworthy and unusual feature is the presence of numerous crystals of sphene.

Sphene is quite abundant in crystals which are as a rule much rounded and chipped, but still show the characteristic lozenge shape. They are easily distinguished by their pale-yellow colour, very high index of refraction, which gives a broad black border, and very strong birefringence: crystals of the usual size generally give colours of the fourth order. Owing to the high refractive indices and strong dispersion the crystals when in the position of extinction between crossed nicols often show curious prismatic colours, which afford a useful indication of the mineral. Inclusions are very abundant, both circular bubbles of gas (or glass) and minute needle-like crystals. Fig. 6 shows a sketch of an unusually well-formed crystal of sphene, with both kinds of inclusions.

Fig. 5.—Quartz grains, Parish Sand Pit, Aspley Guise. × 50.

Rutile is also common in the usual red grains, generally much rounded and corroded. In a few crystals the colour is quite unusually deep. There are also orange or yellow crystals still sufficiently undamaged to show crystal-faces. Kyanite is abundant in large angular flakes and blades of quite normal character. Staurolite is very common in good-sized angular fragments of an orange-yellow colour. These need no special description. Tourmaline is fairly abundant, both the common brown variety in drop-like grains and in good crystals, together with a few more angular grains of an extraordinarily deep blue colour. Muscovite is very common in small flakes and a few broken crystals of pyroxene were also seen. The opaque iron ore is ilmenite. One very fine tabular plate with an etched surface shows the rhombohedral symmetry of the etched figures on the crystal faces.

Other samples taken from different parts of the same pit differ from the one described above chiefly in the much lower proportion of sphene, together with a greater abundance of colourless pyroxene (diopside), which shows the characteristic jagged appearance of this mineral, due to the imperfection of the cleavage. Its maximum extinction angle is about 30°, and some care is needed to discriminate it with certainty from kyanite, which has about the same extinction angle. The well-marked transverse cleavage or parting of kyanite, parallel to c 001, will generally serve to distinguish them.

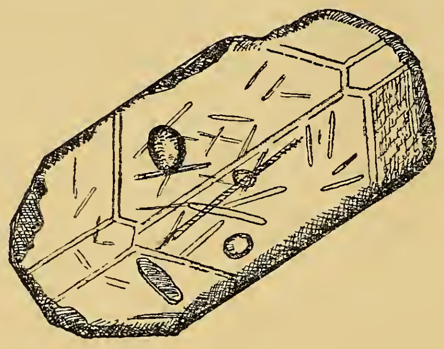


FIG. 6.—Sphene. Aspley Guise. × 300.

The most abundant heavy mineral is zircon; the crystals are often so sharp and well developed that the crystallographic characters can be determined and some of the angles measured approximately. The most common forms are 100, 110, 111, 001, 311 in various combinations, the usual ones being 110, 111, 311, and 100, 110, 111. The basal plane 001 is often well developed, apparently a somewhat unusual circumstance. The simple combination of a prism and pyramid 110 and 111 was also observed, though not frequently. According to Krushtchov the bipyramid 311 is specially characteristic of zircons in gneissose rocks, but rare or absent in those found in true granites. Both types are here almost equally plentiful. One small zircon was observed enclosing a minute but perfect crystal of sphene. Quite abundant also are well-rounded pink crystals with the optical properties of zircon and showing a well-developed zonary structure as figured by Krushtchov. It is still an open question whether these are zircon or xenotime, a mineral which is probably isomorphous with zircon and may even form mixed crystals with it. It is noticeable that in the pink crystals the tabular and rounded inclusions are less conspicuous than in the undoubted zircons and of a different type. The birefringence also seems to be slightly weaker; this is said to be characteristic of xenotime. There is also a pink mineral with slight pleochroism and birefringence higher than that of zircon. This commonly occurs as rounded grains with a curiously pitted surface. Those crystals which show prismatic forms are optically positive. Inclusions of any kind are rare. This is probably merely a variety of zircon.

8. A Small Exposure in a Cottage Garden by the Roadside, about half a mile west of Woburn.

This sample consisted of a dirty brown sand, containing much fine muddy material, and very ferruginous. The larger constituents showed no noteworthy features, and the heavy residue was quite small in amount. All the usual minerals were observed, namely kyanite, staurolite, rutile, tourmaline, and zircon, together with a good deal of magnetite and brownish opaque grains. None of these minerals showed any characters worthy of special description. It may be mentioned that the crystals of kyanite show the worn and rounded outlines usual in this district, while the staurolites also are more rounded than ordinary.

9. Leighton Hollow Wood, Woburn.

These specimens were collected from a long section by the side of the road from Woburn to Aspley Guise, and consisted of rather dirty ferruginous sands, which when cleaned, panned, and separated yielded some good specimens of heavy materials. As usual the chief species present were zircon, kyanite, staurolite, tourmaline, and rutile.

Zircon is very abundant as small, well-rolled grains, mostly as the clear colourless variety without zones, but showing characteristic inclusions.

Tourmaline is very common, chiefly as well rounded drop-like grains of an olive-green or brown colour, but other grains are distinctly blue. One in particular showed a peculiarly intense and brilliant blue shade, while in others the same tint is less marked. Kyanite shows many good examples of the most characteristic forms, some fairly sharp, while others are a good deal rounded.

Staurolite is found in grains showing a wide range of forms: while some are very angular indeed, others are unusually well rounded, and many transitional types are seen. The orange-red variety of rutile is the more common, sometimes in fairly large and irregular pieces, but there are also a few large crystals of a deep blood-red colour. Epidote is a rather rare constituent, generally in rounded green grains, but occasionally in large angular pieces. Although this locality is so near Aspley Guise no sphene was found, a rather remarkable circumstance.

10. Small Pit by Side of Road between Woburn and Little Brickhill.

This is a small excavation about 5 feet deep, in fine incoherent yellow sand, with a few brownish streaks and patches. The sand is of uniform grain, nearly all passing through a sieve of about 1 mm., and there is very little fine mud on washing, hence the grains must be naturally well-graded.

A small sample, strongly heated in a crucible for some time, turned to a bright brick-red colour, presumably from dehydration. Another sample boiled for some time with acid and well washed showed a large amount of bright-green glauconite, and also some grains, similar in size and shape, but of a pale-brown colour. As this seemed a favourable opportunity to investigate the nature of these grains, they were separated as well as possible by washing in a flat dish and mounted in Canada balsam in the usual way for microscopic examination. The grains vary much in colour, showing many shades of green, also pale brown and nearly colourless. Those with the smoothest surface and least appearance of corrosion show the brightest green colours, while the brown and white grains are obviously altered grains originally green ; all intermediate stages can be seen. Some grains are yellowish brown by transmitted and green by reflected light. It was not possible to determine whether the white or the brown grains represent the greater degree of alteration. When small, the brown, and more particularly the white, grains show a peculiar mottled depolarization effect. Some of them show a curious resemblance to grains of turbid felspar, and the discrimination is not always easy. However, the felspars generally show a definite extinction, which the others do not. The most interesting feature of these grains, however, is their form. Many of them have peculiar curved, nodular, or botryoidal outlines, and often a distinctly globular centre. A careful examination of a large number under high magnification, up to 100 diameters, goes far to confirm the idea that many grains of glauconite are in fact casts of the chambers of Foraminifera, while the brown grains so common in the Lower Greensand in surface exposures and shallow pits are undoubtedly formed by oxidation of the green grains of glauconite. This process of change so greatly increases the density of the grains, by the elimination of their lighter constituents, that many of them sink in bromoform until the outer weathered skin has been dissolved away by acid.

The quartz grains in this specimen show some remarkable features; they are specially notable for their angularity and very irregular shape. A few are subangular, while really rounded grains are rare. The average size of the quartz grains is about 0·3 mm. One or two grains contain a few small needles of rutile, the so-called sagenitic quartz, but after prolonged search the presence of tourmaline needles could not be established. Felspar is very abundant, in white or pale pinkish grains; most of them are orthoclase, but microcline was also seen, and a few grains of plagioclase, with extinction angles up to 30°. It was estimated that quartz is the most abundant mineral, making up perhaps half of the total, and that felspar and glauconite are in about equal amounts, while other minerals of any considerable size are scarce: a slide mounted from material without previous separation showed only one crystal of rutile and one or two flakes of muscovite.

The heavy minerals from this locality are of special interest, since they are abundant and in great variety. The most important minerals quantitatively are kyanite, staurolite, rutile, tourmaline, zircon, and iron ores, but, as will be noted in due course, several rarities are found. It is, however, less confusing and better to treat these separately, together with any notable peculiarities of the commoner minerals.

Kyanite is abundant in large thick tabular and blade-like crystals, most of them being distinctly rounded and rolled (Fig. 7). Nearly all of them lie on the cleavage parallel to 100, and therefore show a constant extinction angle of about 30° and the emergence of a negative bisectrix. Staurolite is unusually abundant, in crystals of all sizes, some being as much as 0·3 mm. in diameter: the crystals are nearly always angular and shapeless, very few showing any traces of crystal forms. The colour is always orange-yellow and the pleochroism distinct (pale yellow to orange). Rutile is extraordinarily abundant, both in good crystals and in shapeless grains of all sizes. The colour also varies remarkably, from quite pale yellow to the deepest crimson red with submetallic lustre. The presence of brookite was suspected, but has not been confirmed. Tourmaline is in crystals of various sizes and shapes, but not very abundant. The majority are of a brown colour and much rounded, more angular blue grains being rare. Zircon is numerically the most abundant of all the heavy minerals, and some

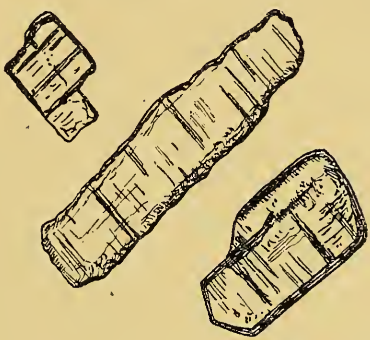


FIG. 7.—Kyanite crystals, near Woburn. × 100.

crystals are unusually large, up to 0·2 mm. in length and 0·1 mm. in breadth; the majority are much smaller than this. The number of different varieties observed is great, and the variation very wide. Black and brown iron-ores are plentiful, but in no way remarkable. Muscovite is abundant in minute flakes.

The slides made from this material present several features of considerable mineralogical interest: apart from the great abundance and variety of the zircons as before mentioned, there are also several good examples of twin-crystals of rutile of various types, especially "elbow twins". In a curious flat tabular twin of this kind, the angle between the two portions is about 120°. As the crystal does not lie quite flat the angle cannot be determined with great accuracy, but the twin clearly belongs to the e (101) type, the commonest law in this mineral. As shown by reflection in incident light the large faces of both individuals are exactly co-planar. The flat tabular form is not common in this mineral, and suggests that the crystal developed between the foliation-planes of a schistose rock. Another elbow twin is remarkable in that one individual shows in addition lamellar twinning, apparently on the same law. This crystal is pale yellow in colour. A small and very irregular fragment also shows an immense number of closely set twin-lamellæ: the law in this case is indeterminable.

Among the rare minerals may be mentioned a single subangular grain of garnet, with unusually rounded contours and smooth surface. This must have undergone an immense amount of attrition during a prolonged period and has doubtless been derived ready-made from some older rock, since such a degree of smoothness is very unusual in this mineral. Two good-sized grains of a brown mineral are of much interest, since they are probably cassiterite. The most notable characters are the pleochroism, red to greyish brown, and the very numerous twin-lamellæ, so characteristic of the cassiterite in Devono-Cornish granites. Sphene was not found, though a prolonged search was made for it during several hours.

Summary and Conclusions.

Although it is obvious that much more detailed work would be required before any positive deductions could be drawn from the facts here set forth, nevertheless certain interesting features present themselves and may be briefly summarized here. In the first place, although the general mineral assemblage shows great similarity throughout the whole stretch of country yet examined, being characterized everywhere by zircon, kyanite, staurolite, tourmaline, and rutile, there are certain distinct local differences. In Norfolk we find in fair abundance garnet and blue soda-amphibole, and these appear to extend as far as Ely. Further west than this the amphibole is non-existent and garnet is exceedingly rare, having been observed at two localities only in the minutest quantity. Green mica was also observed only in the Sandringham Sands. Again in Norfolk most of the heavy minerals are distinctly larger than further to the west and some of them more angular. These facts taken together, and especially the presence of blue amphibole, suggest derivation from the north-east, possibly from Scandinavia.

Further to the west a different assemblage of accessory minerals appears to set in, such as colourless pyroxene and green epidote, with curious pinkish zoned crystals usually attributed to zircon. Here also deep-blue tourmaline seems to be more common, though it is not confined to this neighbourhood. But perhaps the most noteworthy mineral of the western area is sphene; this is local in its distribution: although it was observed at Great Gransden, it is really common only at Aspley Guise. It is also of some interest to note that some grains believed to be cassiterite were seen only in the extreme west, near Brickhill. If the presence of this mineral in any quantity could be established with certainty a south-western origin for the material could be regarded as established. This point needs further investigation.

Thanks are due to Professor Bonney for the kindly interest that he has shown during the progress of the work and for opportunities of examining specimens in his collection for purposes of comparison; also to Mr. W. H. Wilcockson for help in the field and laboratory in 1914.

VI.—On a Scandinavian Erratic from the Orkneys.

By Instructor-Lieutenant W. I. Saxton, B.A., R.N., and
Lieutenant A. T. Hopwood, R.A.F.

THE general behaviour of the Scandinavian ice-sheet which spread over the North Sea at the climax of the Glacial period is fairly well known. Numerous erratics show that it reached the coast of Yorkshire and the eastern counties of England. Farther north no erratics have been found, but Dr. Jamieson[1] and others have shown that it approached the coast of Aberdeen. Dr. Croll[2] and Drs. Peach and Horne[3] have shown that it forced the Scotch ice flowing eastward from the Moray Firth to turn in a northerly and north-westerly direction across the northern part of Caithness and over the Orkneys. They concluded that ice from the Christiania district must have passed a few miles to the north of the Orkneys. This is well shown in the chart attached to their paper and also in Professor James Geikie's[4] map. The occurrence of a few Scandinavian erratics in the Orkneys would confirm these deductions. The only erratic recorded from Orkney which may be of Scandinavian origin is the Saville boulder described by Professor Heddle,[5] Drs. Peach and Horne, and Dr. J. S. Flett.[6]

The rock which it is the object of this paper to place on record was found between Quoy Ness and Stanger Head on the eastern shore of Flotta—a small island at the southern entrance to Scapa Flow. Several boulders were found, one of which was nearly a foot in diameter. Specimens were examined by Dr. Flett, who describes the rock as follows: "It is of grey colour with black spots of ferruginous minerals, and the felspar which is its principal component has the simple twinning, elongated form, and blueish shimmer that characterize the holocrystalline rocks of the laurvikite series.

"In microscopic section it proves to be a 'laurdalite',[7] as shown by the following characters: The felspars are natron-microcline (soda-orthoclase or anorthoclase), with the types of inclusions known in laurdalite. Nepheline is fairly abundant, often in pegmatitic intergrowth with felspar. The principal ferromagnesian mineral is a violet or greenish-violet augite, in which diallage structure and schiller inclusions may frequently be noted. A bright green pyroxene (ægirine or ægirine-augite) is also not uncommon. Black mica (lepidomelane) is frequent. Hornblende (barkevikite) in

[1] Thomas F. Jamieson, "The Glacial Period in Aberdeenshire and the Southern Border of the Moray Firth": Quart. Journ. Geol. Soc., vol. lxii, p. 13, 1906.

[2] Croll, "The Boulder-clay of Caithness a Product of Land Ice": Geol. Mag., Vol. VII, pp. 209, 271, 1876.

[3] B. N. Peach & John Horne, "The Glaciation of the Orkney Islands": Quart. Journ. Geol. Soc., vol. xxxvi, p. 648, 1880.

[4] James Geikie, *The Great Ice Age*, 3rd ed., 1894.

[5] Heddle & Forster, *Min. Mag.*, vol. ii, p. 174.

[6] J. S. Flett, "On Scottish Rocks containing Orthite": Geol. Mag., 1898, p. 388.

[7] W. C. Brögger, *Die Eruptivgesteine des Kristianagebietes.* III. Das Ganggefolge des Laurdalits. Kristiania, 1898.

small amount; comparatively large prisms of apatite are numerous. The rock is very fresh; it shows in places a well-marked protoclastic structure, and there is a tendency to the formation of reaction rims around clusters of pyroxene. The minerals and the structures of this rock accordingly enable us to identify it beyond question with the laurdalite of the Christiania district."

Foreign erratics are not uncommon on the shores around Flotta. They are the typical erratics of the Orkney boulder-clays, and have mostly been derived—as shown by Drs. Peach and Horne—from the Moray Firth area. The association of the laurdalite with these rocks is evidence that it is of the same glacial origin. The alternatives to transport by glacial ice are transport by floating ice or transport by a ship as ballast. The first is rendered improbable by the fact that floating objects in the Kattegatt drift to the north along the Norwegian coast.

Although a close connexion formerly existed between the Orkneys and Scandinavia, there is but little likelihood of a ship coming to Flotta, for it is a very unimportant island. If a ship came there she would use the harbour of Pan Hope near by, and not the open shore, and would probably take in rather than discharge ballast. The warships of the Norsemen frequented Scapa Flow, but the same remarks are true of them, for they went to the northern side of the Flow. There is, then, no reasonable doubt that it is a true glacial erratic, and as such it confirms the accuracy of the track of the ice as shown in the glacial maps, and is of interest as being the first undoubted Scandinavian erratic found in Scotland or in the Orkneys and Shetlands.

In conclusion, we wish to express our thanks to Dr. Flett for more than encouragement in preparing this paper.

REVIEWS.

I.—The Geological Aspects of the Coral-reef Problem. By W. M. Davis, Ph.D., Sc.D. *Science Progress*, vol. xiii, pp. 420–44, 1919.

For some years past Professor W. M. Davis has been engaged in a detailed study of the old problem of the origin of coral reefs, in the light of the new material accumulated by many observers, both European and American. As he very justly points out in this paper, the problem is mainly geological, whereas the majority of writers have regarded it chiefly from the biological standpoint, without a proper appreciation of the geological significance of the facts observed by them, and what is perhaps of still greater importance, the meaning of certain facts that they failed to observe. According to him the most significant of these facts are the embayment of the shore-lines of islands encircled by barrier reefs and the existence of unconformable contacts of reef and lagoon limestones with their foundations. In the past attention has largely been directed to atolls, where it is obvious that neither of these features can be observed, but they undoubtedly have a considerable bearing on the origin of these, as well as of reefs with central islands and of raised reefs of all kinds. Professor Davis concludes definitely that both these features are inconsistent with the formation of reefs during still-stand conditions or elevation, and that all the evidence is strongly confirmatory of Darwin's original view of reef-building during subsidence or submergence.

Furthermore, a distinction must be drawn between the two effects just mentioned: the drowning of an island, with embayment of the coast, may be brought about by a relative rise of the sea-level brought about by elevation of the sea-floor elsewhere, or by the setting free of water from an ice-sheet, as elaborated by Daly in the theory commonly known as "glacial control". Professor Davis does not consider, however, that either of these processes have played a large part in the production of coral-reefs; he believes that actual subsidence, in many cases of a local nature, is the dominant factor, while the raised reefs must obviously owe their present position to uplift, which also is frequently limited to comparatively small areas, and is sometimes referable to tilting of island groups.

One of the most significant structural features of coral reefs is the usually well-marked "unconformable" contact of reef and limestones with their foundations, the word "unconformable" being here used to mean inclined, while "conformable" means that the base is horizontal. This feature has been neglected by the great majority of writers, many of whom were not geologists. A careful examination of many such contacts, where visible in raised reefs, has shown in nearly all cases pronounced erosion of the underlying, usually volcanic rock, amounting in some cases to 600 or 800 feet. This sloping contact with the eroded surface below is inconsistent with formation of reefs on wave-worn submarine platforms, according to the Rein-Murray theory. Even the reefs around the granitic islands on the Seychelles bank may be assumed to possess unconformable contacts, since they clearly rest on sloping granitic spurs, indicating deep erosion and embayed coastlines. It follows, therefore, that here also there must have been submergence.

The general conclusion reached by Professor Davis is that in the great majority of cases the features exhibited by fringing and barrier reefs can best be explained on the hypothesis of their formation during subsidence. The downward movement is not necessarily continuous; in fact, it is clear in many cases that it was intermittent and occasionally reversed, and a wide field is thus allowed for local variations. The problem of atolls now at sea-level is on a somewhat different footing, since the facts are less accessible to observation, but by analogy the same line of reasoning can be applied. The recent work of Foye on the Fiji group is confirmatory of the general ideas here put forward, and this most important paper must be regarded as a step forward in the rehabilitation of Darwin's theory, which has of late years been more or less under a cloud, but is now apparently destined once more to hold the field as the orthodox solution of this difficult but most interesting geological problem.

II.—Subsidence of Reef-encircled Islands. By W. M. Davis. Bull. Geol. Soc. Amer., vol. xxix, pp. 489–574, 1918.

SINCE the preceding review was written, another and much longer paper of earlier date has come to hand, in which Professor Davis enunciates in greater detail, with more numerous figures, the views summarized above. He also pays more attention to the negative evidence, as shown by the absence of reefs on coasts of emergence or in areas where their growth is prevented by accumulation of detrital deposits on a large scale. The reefless coast of Madras, which has risen from the sea, is contrasted with the half-submerged cliffs of the north-east side of New Caledonia, now bordered by fringing reefs, with a barrier reef 5 to 10 miles off the shore. Stress is also laid on the unequal depths of lagoons and banks, which are inconsistent with the requirements of the glacial control theory, and several pages are devoted to a discussion of the origin of atolls. The conclusions to be drawn from the Funafuti and Bermuda borings are briefly summarized, and it is pointed out that information as to the depth of atoll-lagoons is still far from complete. Professor Davis believes that Darwin's theory of intermittent subsidence affords the most satisfactory explanation of atolls as well as for the other types of reef. He also considers that Molengraaf's theory of volcanic subsidence, while not proved to demonstration, is a contribution of much value to the solution of the reef problem. An extensive bibliography is appended to the paper.

III.—The Antiquity of Parasitic Disease.

On the Parasitism of Carboniferous Crinoids. By Roy L. Moodie. Journ. Parasitology, iv, pp. 174–6. June, 1918.

MR. MOODIE means "parasitism *on* crinoids" or what our scientist-stylists would call "the parasitization of crinoids". He has found in America (North or South; locality not given) in some Carboniferous rocks of age not stated (though Keokuk is alluded to), crinoid stems swollen in reaction to the attacks of a parasite, similar to those described by R. Etheridge fil. (1879, Proc. Nat. Hist. Soc. Glasgow, iv, pp. 19–36). Mr. Etheridge quoted descriptions by previous authors, but was the first to assign the phenomena to their true cause, and (*pace* Mr. Moodie) to determine the parasites in several instances. Von Graff (1885) compared these swellings, as well as others in Mesozoic crinoids, to those due in recent crinoids to the attacks of *Myzostoma*, but he did not prove this by any discovery "of the carbonized remains of" a myzostomid, as Mr. Moodie states. Mr. Moodie claims that the stems at his "disposal are the first to be recognized in America as in many ways suggesting parasitism". He should look at Wachsmuth & Springer's *Crinoidea Camerata of North America* (1897), p. 43, pl. i, fig. 2; also p. 502, pl. xxxix, fig. 7, which shows swellings on the arms of an *Agaricocrinus* much more like myzostomid cysts than anything figured by Von Graff.

Mr. Moodie's "interest in these objects is due to the fact that the [Carboniferous] swollen stems must be regarded as the first evidences of disease in geological history". This is not quite correct. A number of the thecas of *Holocystites* (=*Megacystis*) from Indiana, described by S. A. Miller, present circular depressions plainly due to the attacks of some boring organism, and as a result the component plates are usually anchylosed and swollen (see fig. 26 of my "Notes on Yunnan Cystidea" now appearing in this Magazine). Mr. Moodie will also find a description and figures of a stem of *Botryocrinus ramosissimus* with small pittings, apparently the work of parasites, accompanied by swellings and by a curious breaking-up of the columnals, in "Crinoidea of Gotland" (1893, Svensk. Vet.-Akad. Handl., Bd. xxv, No. 2, p. 120, pl. vi, figs. 174–8). Plate lxxiv of the Crinoid volume in Barrande's *Système Silurien de Bohême* (1897) represents several swollen stems from bed f. 2 of Konieprus. All these instances are of Upper Silurian age.

If nothing of the kind has hitherto been recorded from Ordovician or older rocks, this is due, at all events for our country, to the greater rarity of crinoid-stems and to their less frequent preservation as calcified fossils. It must not be inferred that the Ordovician or Cambrian were golden ages free from disease. Indeed, among stem-fragments from the Upper Ordovician Rhiwlas Limestone of Llwyn-y-Ci, north of Bala (Brit. Mus. E 21503) is one that is slightly swollen and shows traces of boring; a similar fragment less clearly preserved comes from the same or a slightly lower limestone at Glyn Ceiriog (E 21495). Anyone with time to search our museums would probably find further examples.

F. A. Bather.

IV.—Descriptions of some Queensland Palæozoic and Mesozoic Fossils. By R. Etheridge, Jun. (1) Queensland Lower Cretaceous Crustacea; (2) Additional evidence of the largest Australian Permo-Carboniferous Trilobite; (3) A Remarkable Univalve from the Devonian Limestone, Burdekin; (4) *Vetofistula*, a new form of Palæozoic Polyzoa, Reid's Gap. Geol. Survey of Queensland, Pub. No. 260, pp. 26, with 3 pls., 1917.

(1) The Brachyuran *Prosopon etheridgei*, H. Woodward, is redescribed from specimens showing portions of the chelipeds and ambulatory limbs as well as the abdominal somites and telson. *Hoploparia mesembria*, n.sp., is described from a portion of a carapace and six abdominal somites. *Glyphæa arborinsularis*, n.sp., is based on one fairly complete and one imperfect carapace, and a third specimen showing the abdominal somites and portions of appendages. An imperfect cheliped is referred with doubt to the genus *Callianassa*. The illustrations, reproduced from photographs, give an excellent idea of the general appearance of the specimens, but a few line drawings would have greatly assisted their comprehension.

(2) Portions of a trilobite, of which the total length when complete must have been about 60 mm., are referred to the species previously described by the author as *Phillipsia grandis*, the generic reference being only provisional.

(3) *Polyamma burdekinensis*, n.g. and n.sp., is compared with the Canadian Silurian *Helicotoma* (?) *spinosa*, Salter, and with Triassic and Silurian species referred to *Cœlocentrus*, Zittel, but as the single specimen does not display the characters of the aperture and base its systematic position is left undetermined. The figures are "a trifle larger than natural size", but the exact dimensions of the specimen are not given.

(4) *Vetofistula mirabilis*, n.g. and n.sp., from the Middle Devonian, is compared with *Rhabdomeson*, Young & Young, and *Chilatrypa*, Ulrich, and is provisionally referred to the family Rhabdomesontidæ, and still more hesitatingly to a sub-family for which the name Vetofistuliporidæ (*sic*) is proposed.

V.—Revision of some Phacopid Genera. By F. H. McLearn. *Ottawa Naturalist*, xxxii, pp. 31–6, 1918.

SEVERAL genera of the Phacopid Trilobites are re-defined and their phylogenetic relationships are discussed. *Dalmanitina*, Reed, is extended to include a series of generalized forms extending from the Ordovician through the Silurian. In the Devonian this line gives rise to species forming the genus *Phacopina*, J. M. Clarke, which, however, does not belong to the sub-family Phacopinæ but to the Dalmanitinæ. The Phacopinæ originated at the beginning of the Silurian as an offshoot from the primitive line, and gave rise to two stocks. One of these forms the genus *Phacops*, s.str., of wide distribution in the Silurian and extending into the Devonian; the other, *Phacopidella*, Reed, is confined to the later Silurian of Bohemia.

VI.—The Phylogeny of the Acorn Barnacles. By Rudolf Ruedemann. Proc. Nat. Acad. Sci. Washington, iv, pp. 382–4, 1918.

Possible Derivation of the Lepadid Barnacles from the Phyllopods. By John M. Clarke. T.c., pp. 384–6.

ONE of the most characteristic features of the Cirripedia is the possession of an armature of shelly plates developed by the calcification of separate areas in the "mantle", which represents the shell-fold or carapace of other Crustacea. It is characteristic of, but not peculiar to, the Phyllocarida that certain portions of the carapace are separated by suture-lines—a movable rostrum in the recent forms and an additional dorsal plate in certain fossil genera. With little more than these facts to go upon, Mr. Ruedemann endeavours to show that the Cirripedia, and in particular the sessile or operculate forms, have been derived from the Phyllocarida. He mentions an undescribed genus, *Eobalanus* (no specific name is given), from the Upper Ordovician, in which the form of the five pairs of lateral compartments suggests a bivalved carapace, and he ingeniously compares this with the carapace of certain Devonian Phyllocarida. As in many fossil Cirripedia, the opercular valves, scuta and terga, have been lost, and these valves, the most persistent of all throughout the group, are neglected in Mr. Ruedemann's morphological speculations. Apart from this, however, there are many difficulties in accepting the derivation of the Cirripedia here suggested. The recent Phyllocarida are, beyond a doubt, members of the sub-class Malacostraca, and it can only lead to confusion if they are grouped under the Phyllopoda. There is no hint of affinity with them in the structure of recent Cirripedia. They differ widely in the regions of the body, the structure and grouping of the appendages, and the position of the genital apertures. The resemblances which Mr. Ruedemann has to set against these differences are trivial and far-fetched. It is possible that the Cirripedes have been derived from Phyllocarida, but Mr. Ruedemann does not convince us that it is probable.

Mr. J. M. Clarke, accepting Mr. Ruedemann's hypothesis with regard to the sessile barnacles, tries to show that the pedunculated forms were independently evolved from the Phyllocarida by way of the obscure genera *Lepidocoleus*, *Turrilepas*, and *Strobilepas*. If these genera are Cirripedes at all, which, according to Withers, is more than doubtful, their connexion with the normal Pedunculata has still to be elucidated. If the latter have been evolved independently of the Operculata from ancestors that were not Cirripedia, the resemblances between the two groups go far beyond any case of convergence hitherto recognized.

Phylogenetic speculations are of value in proportion to the extent and importance of the facts on which they are based. In these two papers the foundation appears altogether inadequate to sustain the superstructure.

W. T. C.

VII.—A CENTURY OF SCIENCE IN AMERICA, WITH SPECIAL REFERENCE TO THE *AMERICAN JOURNAL OF SCIENCE*, 1818–1918. Edited by E. S. DANA. pp. 458, with 22 portraits. Yale University Press, 1918. $4.

THIS handsome volume is published in commemoration of the centenary of the founding of the *American Journal of Science* by Benjamin Silliman in July, 1818. Some of the chapters were based on a series of seven Silliman Memorial Lectures, and the whole cost of publication has been defrayed from the income of the Silliman Memorial Fund. As might naturally be expected, therefore, the subject-matter is very largely geological and mineralogical, but some 150 pages are occupied by chapters on the progress of chemistry, physics, zoology, and botany, each contributed by a specialist in his own subject. The first chapter, by the editor, details at some length the history of the *American Journal of Science* and the gradual evolution which it has undergone, from its earliest beginnings as a magazine of science, agriculture, and the arts, to its present rather specialized form, in which geology and mineralogy are dominant. It is shown that its foundation marks the beginnings of active scientific research on modern lines in the United States, and its progress is coeval with the extraordinary development of science in that country. The other chapters are written by men of light and leading in their respective spheres, and give admirable summaries of the history of the various branches of geology and mineralogy in the last hundred years, mainly from the American standpoint, but still with complete acknowledgment of the value of work done in other countries. Of special interest, because somewhat novel, is the chapter entitled "A Century of Government Geological Surveys" by Director George Otis Smith, giving a detailed account of the beginnings and subsequent progress of that vast organization known as the United States Geological Survey, which has accomplished such wonders in the exploration and development of the resources of the country. This book leaves on the mind of the reader a feeling of admiration at the many-sidedness, activity, and originality of geology and the allied sciences in America at the present time.

VIII.—Ore-deposits of the Boulder Batholith of Montana: a Genetic Description. By P. Billingsley and J. A. Grimes. Trans. Amer. Inst. Min. Eng., vol. lviii, pp. 284–361, 1918.

At the present time the State of Montana is the most important producer of copper in the world, and the geological relations of its deposits are naturally of the utmost interest. In this paper the authors show in the clearest possible manner the intimate relation that exists between orogenic movements, igneous activity and mineralization. The main folding of the Rocky Mountains, in the Middle Cretaceous, was followed by andesite eruptions in the Upper Cretaceous; and this again by extensive thrust-faulting. The intrusion of the main batholith probably took place in the Eocene, while normal faulting, accompanied by rhyolite flows, extended from the Oligocene to the Pliocene. The intrusion of the batholith, here called the granite stage, is divided into four phases: (1) basic diorite and pyroxenite, (2) quartz-monzonite (the main mass), (3) aplites and pegmatites with tourmaline and other pneumatolytic minerals, (4) quartz porphyry with metalliferous quartz-veins. The mineralization belonging to the monzonite phase is mainly associated with outlying bosses or cupolas rather than with the main intrusion: it includes auriferous pyrrhotite, pyrite and magnetite, as disseminations and contact deposits, the latter also bearing copper and bismuth: the fissure veins also contain copper, zinc and lead: in many localities secondary enrichment is important. The veins of the aplite and pegmatite phase carry galena, blende, chalcopyrite, pyrite, arsenopyrite and rhodochrosite. The final quartz-porphyry phase gave rise to very rich copper deposits with enargite, tennantite, tetrahedrite, bornite, covellite and chalcocite; these are mostly rather deep within the batholith.

The earlier andesite stage gave rise to deposits of native copper, magnetite and galena with gold and silver, while the later rhyolite flows are accompanied by gold veins with little sulphide. It is shown that the greater part of the mineralization, perhaps as much as 99 per cent, belongs to intrusions and especially to their later phases: it is therefore magmatic and the richness of the later small phases indicates differentiation and concentration in the magma-basins. There is a definite time-sequence, as follows: (1) contact and border deposits, (2) internal segregations, (3) fissure and fault veins from deep-seated sources: furthermore, a definite primary zoning exists in the fissure-veins, and the horizon of ore-precipitation migrates regularly downwards in the successive stages of mineralization. All the facts here put forward are clearly consistent with the view that the mineralizing solutions are direct products of magmatic differentiation, when allowance is made for modifications introduced by the ordinary processes of chemical change and secondary enrichment that go on to a greater or less extent in all mineralized areas. This admirable study may be strongly recommended to the attention of all geologists interested not only in ore-deposits, but also in the theoretical side of petrogenesis.

R. H. R.

IX.—Report on the Inclusions of the Volcanic Rocks of the Ross Archipelago. By J. Allan Thomson. British Antarctic Expedition, Geology, vol. ii, pp. 131–51, with 3 plates and 3 text-figures. London, n.d.

NUMEROUS specimens of nodules and inclusions in the igneous rocks were examined by the author, who concludes that the olivine, pyroxene, and gabbroid nodules in the basalts and limburgites of Hut Point were formed by normal differentiation from the magma itself. In the trachytes and kenytes are found nodules of sanidine and plagioclase: it is not quite clear whether these are magmatic segregations or included xenoliths. Hornblendic inclusions in the trachytes, such as those at Observation Hill, are believed to be inclusions, but those at Cape Bird seem to be xenoliths of camptonite. The plagioclase-pyroxene inclusions in the trachyte of Mount Cis appear to be metamorphosed fragments of dolerite, possibly torn off from sills in the Beacon Sandstone. The quartz-bearing masses in the trachytes and kenytes are certainly altered fragments of impure sandstone: they contain a lot of glass and are very vesicular. There are, therefore, two distinct categories: (1) segregations, (2) xenoliths. It follows that parts of the Ross Sea are underlain by sandstones, probably faulted-down Beacon Sandstone and the presence of the lumps of dolerite confirm this idea, since in this formation dolerite sills are abundant and characteristic.

X.—Kongsbergfeltets Geologi. By C. Bugge. Norges. Geol. Undersök, No. 82, with English Summary. pp. 272, with 12 plates. Kristiania, 1917.

ALL the rocks of the famous Kongsberg mining district are of pre-Cambrian age, except certain diabase dykes, which are supposed to be post-Silurian. The older Knute formation consists mainly of volcanic rocks converted into amphibolites and gneisses, with some schistose sediments. Into these are intruded laccoliths of granite, quartz-mica-diorite, and gabbro-diorite, as well as hypabyssal representatives of these magmas; petrographical descriptions are given of these rocks and the properties of their constituent minerals are described.

The silver-ores of Kongsberg naturally come in for a good deal of attention; they are associated with fahlbands; that is, bands impregnated with sulphides, which originate from the Vinor diabase dykes. The silver-bearing veins contain chiefly native silver, with argentite, pyrargyrite, blende, galena, chalcopyrite, and pyrrhotite. These veins cut across the schists and are locally enriched in the fahlbands, most of the silver being concentrated at the intersections. The veins are of two generations, the sulphidic brecciated quartz veins being the older, while the well-known calcite-silver veins all belong to the second generation, and are apparently associated with the post-Silurian Kongsberg diabase dykes. The genesis of the ores is discussed in considerable detail.

XI.—Nogen Bemerkninger i Anledning av Seterne i Österdalen. By Dr. Hans Reusch. Norges Geol. Undersök, Aarbok for 1917, pp. 37, with English Summary. Kristiania, 1917.

The distribution of erratics in the Österdal, the valley of the Glommen, in the eastern part of Southern Norway, indicates that during some part of the Glacial period the ice-shed lay to the south of the present watershed; hence it was argued that there should have been in the Österdal great ice-dammed lakes, like those that existed in Sweden and in Glen Roy. Dr. Reusch was, however, unable to find any signs of the existence of this ice barrier in the Storsjö region, where according to theory it ought to have been. He examined the "seterne" or inland raised beaches of this region, and has come to the conclusion that they were formed by summer-ponds lying on the surface of valley-glaciers during the melting stages; they are closely related to various eskers and side-moraines of the district, and a detailed study of these relations has confirmed his view. One of the figures, which are not numbered, gives a remarkably fine view of an esker near Röros. This paper may be recommended to the attention of students of glacier-lakes in this country.

XII.—Notes sur l'Érosion en Portugal. II. Les Lapiés des Calcaires au Nord du Tage. By E. Fleury. Comunic. da Commiss. do Serv. Geol. de Portugal, tom. xii, pp. 127–274, with 10 plates. Lisbon, 1917.

In this immensely long paper, in French, the author discusses the character and origin of the peculiar denudational forms of limestone regions comprised under the various designations of lapiés, chaos, roches ruiniformes, rock-pillars, Karrenfelder, Dolinen, grikes, swallowholes, crevasses, and endless other names, comparing those seen in Portugal with the corresponding types of the Karst, the Jura, the Pyrenees, and many other regions. Since the paper runs to no less than 147 pages the reviewer freely confesses that he has not read it, but a cursory examination shows that it is an important contribution to an interesting subject. The precise meaning of the terminology employed by different authors is discussed in detail, and a kind of glossary with definitions is drawn up, which should be very useful. Many of the plates recall in a remarkable degree the structures seen in the Mountain Limestone of the North of England.

XIII.—The Charters Towers Goldfield. By J. H. Reid. Geological Survey of Queensland, Publication No. 256. pp. 236, with 37 plates, 10 figures, and 25 plans. Brisbane, 1917.

AT one time Charters Towers had the greatest output of any Australian goldfield, the production in 1899 being 319,572 oz. of fine gold, but in 1916 this had decreased to 42,000 oz., and the writer of this memoir takes a gloomy view of the future. The geological relations of the gold ores are simple and of some interest from the theoretical point of view. The oldest rocks of the region are pre-Devonian schists, quartzites, and metamorphic limestones, penetrated by a batholith of granodiorite, and this again by dykes of aplite, quartz-porphyry, diorite, and porphyrite, the eroded surface of the whole being covered in places by patches of sandstone, possibly Tertiary. Two series of faults later than the dykes determine the position of the lodes, which strike N.–S. and E.–W. respectively. They may be described as simple and composite fissure lodes, up to 5 or 6 feet wide, with occasional "bulges" up to 50 feet in width. The vein-stuff is quartz, rarely calcite, carrying pyrites, galena, and blende, with occasional tellurides. Most of the gold was obtained from highly mineralized pay-shoots of irregular form, diminishing in value in depth. The vein-fillings are clearly of magmatic origin, belonging to Lindgren's type of siliceous gold ores of the middle depths, deposited by ascending solutions derived from the granodiorite magma. No gold values of any importance are found outside of the igneous rocks, and the association of the lodes with the porphyritic dykes is very definite.

XIV.—The Geology of the Country around Gatooma. By A. E. V. Zealley and B. Lightfoot. Southern Rhodesia Geological Survey, Bulletin No. 5. pp. 68 and 7 plates. Salisbury, 1918.

THIS memoir, written by the late Mr. A. E. V. Zealley and Major Lightfoot, records the results of a geological examination of about 600 square miles of territory some 200 miles north of Buluwayo, in the years 1912–14; about half of it is devoted to the geology, and the other half to the economic development of the region, with descriptions of the mines. The rocks in the area are almost entirely igneous, the dominant feature being a portion of a large granite batholith in the south-east corner, with other granite masses of smaller size on the west. Other rocks include porphyry, felsite, and greenstone, the two last names being wisely used in a very broad sense. One of the most interesting results of the field-work is the discovery that nearly all the "banded ironstones" exposed in the district are ferruginized and silicified felsite and quartz-porphyry. This obviously has an important bearing on the origin of the quartz-magnetite schists of other regions, both in South Africa and elsewhere, and especially the much-vexed question of the origin of the ironstones of the Lake Superior region. The chief mineral product of the district is gold, which occurs both in quartz lodes and in replacement deposits of auriferous sulphides in fissured dissemination-zones. Antimonite lodes are known to exist, and scheelite has also lately been produced from quartz veins in felsite on the Scheelite King claim, and as a by-product from several gold-mines.

R. H. R.

XV.—Microscopic Secondary Sulphide Enrichment in the "Kuromono" Ore from the Kosaka Mine in the Province of Rikuchû, Japan. By Takeo Katô. Journ. Geol. Soc. Tôkyô, vol. xxv, pp. 7, with plate, 1918.

THIS is a study of the details of secondary enrichment seen on microscopic examination of a mixed pyrite-chalcopyrite-galena-blende ore. The secondary copper minerals observed are bornite, chalcocite, and covellite: these occur enclosed in chalcopyrite and are formed by metasomatic alteration of pyrite and chalcopyrite by descending solutions from the zone of oxidation above. The careful drawings reproduced in the plate are of considerable interest as showing clearly the order of formation of the different minerals and especially the development of bornite from chalcocite, a reversal of the usual order. Pyrite enclosed in blende has also been altered successively to bornite and covellite.

XVI.—The Ring-ore from the Akenobe Mine, Province of Tajima, Japan. By Takeo Katô. Journ. Geol. Soc. Tôkyô, vol. xxiv, pp. 35–41, with plate and 2 text-figures, 1918.

THE author describes concentric growths of ore and gangue minerals round fragments of silicified country rock in veins. The successive layers consist of (*a*) quartz with cassiterite, (*b*) chalcedony, (*c*) quartz. The interspaces contain fluorspar, scheelite, and siderite, and the whole is cut by numerous veinlets of chalcopyrite, forming a tin-copper ore. It is supposed that the second layer was deposited as gelatinous silica and afterwards recrystallized as fibrous chalcedony; this suggests that the veins were formed hydrothermally at a temperature below the critical temperature of water.

XVII.—Pre-History in Essex, as recorded in the Journal of the Essex Field Club. By S. Hazzledine Warren, F.G.S. pp. 44. Stratford and London, 1918.

MR. HAZZLEDINE WARREN has performed a useful service by bringing together in this publication a bibliography, with brief abstracts in most cases, of the papers dealing with prehistoric archæology in the widest sense, to be found in the Journal of the Essex Field Club. It covers a very wide range of subjects from the problem of pre-palæolithic man and the relation of palæolithic and glacial deposits to salt-making, wild-fowl decoys, and folklore, and cannot fail to be of great value to workers in this field of research.

XVIII.—Another Fossil Tze-Tze Fly.

FROM that extraordinarily rich deposit of Insecta at Florrisant, comes another Tze-Tze fly, found in 1916, by Mr. George Wilson. Mr. Cockerell, who describes it as *Glossina veterna* in the Manchester Museum Publication No. 80, remarks that it is a "truly marvellous specimen, showing not only the proboscis, wings, and body, but even the characteristic hairs". The wings, which are quite clear, measure 10·9 mm. As there are now four species of Tze-Tze fly known from Florrisant, Mr. Cockerell reminds us of Professor Osborn's suggestion that a fly carrying disease-producing organisms may have been a possible cause of the disappearance of the Tertiary herds which formerly occupied America.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *April* 9, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communication was read—

"The Section at Worms Heath (Surrey), with Remarks on Tertiary Pebble Beds and Clay-with-Flints." By William Whitaker, B.A., F.R.S., F.G.S. (With "Petrological Notes on the Beds at Worms Heath", by George MacDonald Davies, M.Sc., F.G.S.)

The chief pit now shows a fine set of more or less vertical pipes in the Chalk, filled with pebbles and sands of the Blackheath Beds, separated from the Chalk by Clay-with-Flints.

The pebble beds here, like those elsewhere, consist of well-rolled black flint pebbles, amongst which pebbles of a brownish quartzite are occasionally found. It is concluded that the water in which these flint pebbles were formed touched no other firm rock than Chalk; but, as there are no subangular flints, the deposition of the beds cannot have taken place close along a Chalk coast.

The great mass of these pebbles is confined to the western part of Kent and the adjoining part of Surrey, and they go but little way underground beneath the London Clay northwards. A few patches of pebbles at the same horizon have been mapped in the Hampshire Basin, but heretofore have not been classed as Blackheath Beds.

From a consideration of older Tertiary pebble beds, it seems that these are not big enough to have afforded the material for the Blackheath Beds. On the other hand, the Blackheath Beds may have yielded the pebbles of the Bagshot Series in Essex, though not in Hampshire.

An examination of the various Tertiary pebble beds (up to the Barton Series) points to overlaps of considerable extent; so much so that the probable thinning of beds below the Barton Sand, in the London Basin, and its former southward extension is comparable with the underground thinning of the Wealden and Lower Cretaceous in that area, though smaller and in a contrary direction.

As to the Clay-with-Flints, it is inferred that it is not a deposit of definite age, but a residual product, representing a condition of things that may have held through long geologic ages, from the start of the Blackheath Beds to the present time.

Mr. G. M. Davies gives a petrological description of the Chalk, of the Clay-with-Flints (both grey and red), of the Eocene sands, sandstones, and pebble beds. He also describes the presumed allophane originating from the base of the Eocene deposits, and discusses the probable sequence of events which resulted in the formation and infilling of the pipes and the deposition of the strata overlying the Chalk.

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2. *May* 7, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The President said: Major R. W. Brock, formerly Director of the Geological Survey of Canada, was called upon last year to undertake, on behalf of the War Office, an arduous journey in Palestine, during which he had to devote particular attention to the Dead Sea region. At the request of the officers of the Society, Major Brock has kindly undertaken to tell us something of his observations in the country. It is needless to say that the region is of surpassing interest to geologists, and I am sure that the Fellows will appreciate the opportunity of hearing how its remarkable features have impressed so acute and experienced a field-geologist.

Major Reginald W. Brock, M.A., F.G.S., then proceeded to deliver his lecture on the Geology of Palestine, his observations being summarized as follows:—

The following formations are recognized:—

QUATERNARY.	Alluvium.	Dunes; Valley and Plains Clay and Silt; Desert Crust.		Heavy volcanic flows, basalts, ashes, tuffs, etc.
	Diluvium.	Terrestrial. Lisan Formation (Jordan Lake Beds).		
		Marine. Upper Calcareous Sandstone and Limestone.		
		Lower Calcareous Sandstone.		
TERTIARY.	Pliocene.	Lacustrine.		
	Eocene	Nummulitic Limestone.		
MESOZOIC.	Cretaceous.	Upper	Senonian: Danian, Campanian, Santonian	volcanics, basalts.
			Turonian	
			Cenomanian.	
		Lower	Nubian Sandstone.	
			Jebel-Usdum Formation (?).	
	Jurassic.	On Lebanon and Hermon only.		
PALÆOZOIC.	Carboniferous.	Possibly south-east of the Dead Sea.		
	Cambrian.	Dolomite and Sandstone.		
PRE-CAMBRIAN.	Volcanics and arkose.			
	Red granites and porphyries.			
	Grey granites, gneiss, and crystalline schists.			

The structure was shown to be that of a tableland bisected by a great rift-valley (Graben), and flanked by a coastal plain. A section was exhibited illustrating East Jordanland acting as a horst; the boundary faults of the Jordan Trench; the unequal sinking of the contained blocks; the western section of the tableland sunken with relation to the eastern, and thrown into an asymmetric anticline, the limbs of which rise in steps through monoclinal flexures or faults.

Lantern-slides were used to illustrate the character of the country and outstanding features iu its geology, more particularly the following: the dependence of the topography upon geological structure, slopes depending on the attitude of the rocks and elevation upon the raising or depressing of fault-blocks or on lava-flows; basins and sunken areas in the tableland; the scarps bounding the Jordan Trench, especially the western fault and fault-blocks in the Trench or against its walls that hava not sunk equally with others; the upturned block of Jebel-Usdum which, with the Dead Sea bottom and the block north of Jericho, indicates a median fault between the boundary-faults; the interbanding of the Jebel-Usdum salt with sandstone and shales that resemble Nubian Sandstone; the unconformity of the Jebel-Usdum formation with the Jordan lake-beds (Lisan formation) which, with the chemical composition of the salt (lack of bromine, etc.), shows that it is not a Jordan lake-deposit; high lake-terraces in the centre of the Trench, with corresponding ones north of Tiberias and south in the Araba Valley, showing that the Jordan lake stood 1,400 feet above the present Dead Sea, and that there has been no marked warping since their formation; old gravel-filled cañons of the Arnon and Terka Main which prove that the level of the Dead Sea before Jordan-lake days stood at about its present level, and that climatic conditions must have been about the same, also that it did not long precede the Jordan lake; the Lisan formation of the Jordan lake-beds, thin layers of mechanical and chemical sediments veneered along the Jordan river with fluviatile clays; bad-land topography near the wadis and in the Lisan formation; narrow box cañons of the wadis in the Jordan Trench and the more open valleys above producing a sort of "hanging valley".

In the main, Blanckenhorn's recent work was confirmed, in particular the fault forming the western border of the Trench and disturbances and sinking in the tableland; but new points were mentioned, such as the evidence of a median fault within the Trench; the sea-cliffs of Lisan and Jebel-Usdum; the wave-cut shelf and the salt of Jebel-Usdum; the tilting of the Jebel-Usdum block and its independence from and unconformity with the old lacustrine beds; lack of disturbance and of warping since their deposition; the age and former level of the Old Dead Sea and the recent rise in the present sea, the latter indicating an increase in moisture and not drier conditions as generally supposed.

A vote of thanks was unanimously accorded to Major Brock for his lecture.

II.—Palæontographical Society.

Annual General Meeting.

April 25, 1919.—Dr. Henry Woodward, F.R.S, President, in the Chair.

The Council presented its seventy-second annual report and announced the completion of the seventy-first volume of monographs, comprising instalments of Wealden and Purbeck Fishes, Pliocene Mollusca, Cambrian Trilobites, and Palæozoic Asterozoa. It referred to the increased cost of publication, and the consequent reduction in the size of the annual volume. It also appealed to members to help in making the work of the Society more widely known so that the number of subscribers might be increased. The officers were re-elected, and Messrs. H. Dewey, F. L. Kitchin, W. P. D. Stebbing, and H. Woods were elected new members of Council.

OBITUARY.

CAPTAIN T. E. G. BAILEY, B.A., F.G.S.

Captain T. E. G. Bailey, B.A., F.G.S., was killed in action on April 2, 1919, while serving in North Russia. Bailey will long be remembered for his share in "The Geology of Nyassaland" published in the Quarterly Journal of the Geological Society, 1910. The paper in question was written in conjunction with Mr. A. R. Andrew, and gives the geological results of a mineral survey carried out for the Imperial Institute during the years 1906–8. Since then Bailey did much good work as an oil-geologist in Burma and Borneo until the outbreak of war. He came home from Borneo to take a temporary commission in the Yorkshire Regiment, and with them he served in France during the years 1915–18. He was promoted for his services during the Battle of the Somme, 1916, and was severely wounded in the Battle of Arras, 1917. In November, 1918, he was sent to Russia.

FERNAND PRIEM.

Born November 10, 1857. Died April 4, 1919.

Professor Fernand Priem was one of the most successful students of fossil fishes and made many important contributions to our knowledge. He was born at Bergues, near Dunkerque, and after graduating in the University of Paris he studied palæontology under the late Professor Albert Gaudry. He became honorary Professor of Geology in the Lyceum of Henry IV and correspondent of the National Museum of Natural History, Paris. For many years most of his energies were devoted to research, and his numerous writings on fossil fishes are as valuable for their bearing on stratigraphical geology as on ichthyology. Besides papers published by the Geological Society of France, he wrote a memoir on the fossil fishes of the Paris Basin for the *Annales de Paléontologie* (1908) and a report on the Cretaceous fishes collected by the De Morgan Mission in Persia.

A. S. W.

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EDITED BY

HENRY WOODWARD, LL.D., F.R.S.

AND

R. H. RASTALL, M.A.

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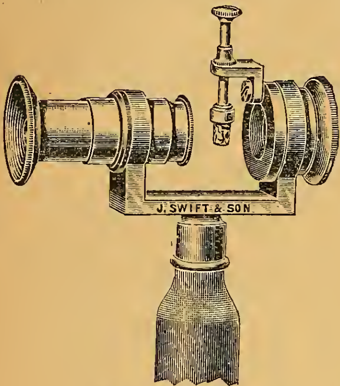

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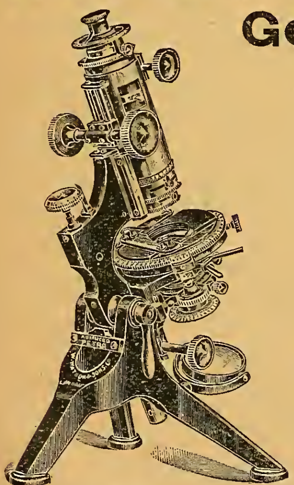

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JAN 16 1920
National Museum

EDITORIAL NOTES.

IN view of the interest aroused among geologists by the active political and press propaganda now in progress concerning the oil-borings in Derbyshire, it seemed advisable to publish forthwith the paper by Mr. V. C. Illing alluded to in our editorial last month. To do this necessitated the postponement of the second half of the paper on Potash by Dr. Holmes, begun in our June number, but Dr. Holmes has kindly consented to give precedence to his colleague in view of the urgency of the matter. Even by this arrangement the traditional balance of the Magazine has been somewhat upset, but the case is exceptional, and we do not intend to apologize for it. Our only concession is to cut down the editorial pages to a considerable extent, in order to prevent too much encroachment on the space allotted to reviews.

* * * * *

WE are glad to note the election of Professor O. T. Jones, M.A., D.Sc., to the Professorship of Geology in the University of Manchester. Professor Jones graduated at Cambridge in 1902 and was subsequently awarded the Harkness Scholarship and the Sedgwick Prize; in 1903 he joined the Geological Survey of England, on which he served with distinction until 1910, when he was elected to the Professorship of Geology at University College, Aberystwyth. During his tenure of that chair he has discharged his duties with marked success and has published important papers on the Lower Palæozoic rocks of Wales. We wish him a prosperous career in his new position, where he will have increased opportunity to carry out geological work of various kinds.

* * * * *

NOTWITHSTANDING the demands made by the War on the United States National Museum, the report for the year ending June 30, 1918, gives a record of much progress. Apart from the activities connected directly with the War, such as the selection of suitable vesicular rocks for use in the construction of concrete ships, the provision of technical information to Intelligence Bureaux, and the satisfying of demands from such State Departments as the Bureau of Standards and the Department of Agriculture, much has been accomplished for the Museum itself. In connexion with the collection of minerals of importance for war materials, an exhibit worthy of note is that of the largest mass of tungsten ore yet mined—a mass of scheelite weighing 2,614 pounds. Another notable addition is a collection of nearly ten thousand specimens obtained by Dr. C. D. Walcott from the Middle Cambrian of Burgess Pass, British Columbia. From this locality also, a ton and a half of material was sent to the Museum as the result of last field-season's work. The quarry that yielded the best of the famous Middle Cambrian fossils is now practically exhausted. Details given of other results of the Museum's official "Explorations" show quite clearly the advantages that would accrue if corresponding features were organized in the big institutions of this country.

* * * * *

So much unpublished information was accumulated by the Geological Survey of Western Australia, that the preparation of reports occupied a proportionately greater amount of the Staff's time than actual field-work (Annual Progress Report of the Geological Survey of Western Australia for 1917). This circumstance, combined with the fact that the activities of the Survey are becoming more and more of an economic nature, tend to show that some augmentation, in personnel at least, could be made with advantage. In addition to duties in the field and in the office, the Survey is conducting experiments on clays, potash minerals, etc., from which results of value to industry are expected. The Laboratory Report shows that highly satisfactory results are being attained; and in the year under review 1671 samples were registered, an increase of 20 per cent over the previous year. Among the results of the field-work recorded in the above-mentioned report, we read that wolfram, occurring as "floaters", has been found at a locality about 3 miles north of Grass Valley Township, on the Great Eastern Railway, east of Northam. The rocks in this neighbourhood are granitic, with a network of dolerite dykes; the surface is covered by a varying thickness of débris, which has prevented detailed mapping up to the present. It is thought that when the true matrix is discovered it will be a pegmatite.

* * * * *

The election of Dr. Arthur Smith Woodward to the Presidency of the Linnean Society of London will be of great interest to geologists. Dr. Woodward filled the office of President of the Geological Society from 1914 to 1916, and has served a term as Vice-President of the Zoological Society.

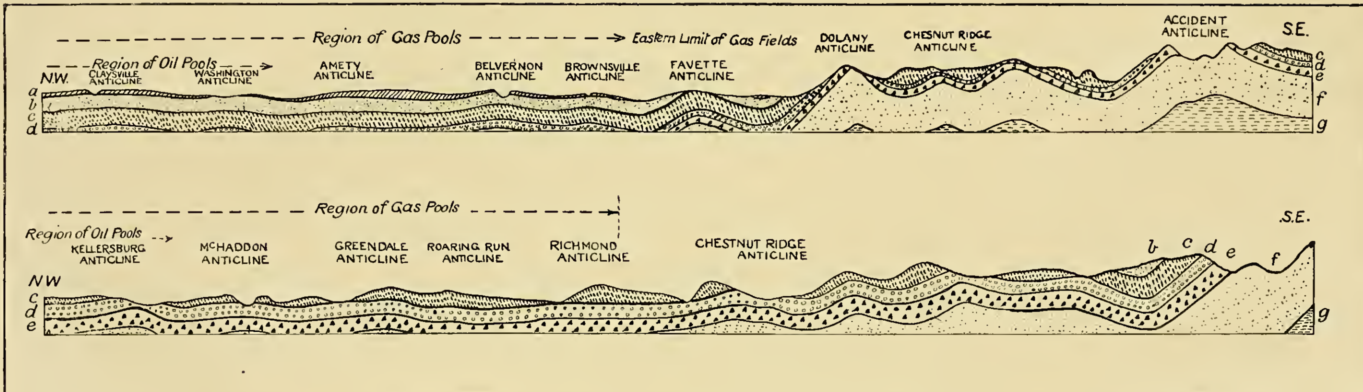
ORIGINAL ARTICLES.

I.—The Search for Subterranean "Oil-pools" in the British Isles.

By V. C. Illing, M.A., F.G.S.

(PLATE VII.)

It is curious how readily the public misconceives even the most simple of scientific problems. A plausible theory, no matter how fallacious, will gain an immediate currency which it is difficult to undermine until it has run its course. Such theories do harm to the public, to industry, and to science, and they should be



V. C. Illing del.

Sections across the Northern and Southern Oil- and Gas-fields of Pennsylvania.

The vertical scale is exaggerated ten times. *a*, Permian; *b*, Pennsylvanian above Pittsburg Coal; *c*, *d*, Pennsylvanian below Pittsburg Coal; *e*, Mississippian (oil and gas); *f*, Upper Devonian (oil and gas); *g*, Middle Devonian. The sections illustrate the complete loss of oil and gas when the strata approach the eastern zone of folding.

combated rather than avoided, so that the mischief may be curtailed, if not entirely eliminated.

It is but a few years since the geologist and botanist were popularly regarded as mere dilettantes, dabblers in fossils and plants, harmless individuals with a craze for the useless. The recent problems of agriculture, timber, mineral resources, and water-supply have shown how essential are these sciences in the national economy, and the geologist and botanist have gained an assured place in industry beside the chemist and the physicist. This position implies responsibility of the collective body as well as of the individual, and it is becoming increasingly necessary that the opinion of organized science should be less inarticulate when matters in which it is interested become the subject of public discussion.

This is especially true of geology, the science directly concerned with the mineral wealth of the country, and no better example of this need can be found than the question recently raised of the possible occurrence of underground oil-pools in Great Britain. The subject is essentially a geological one, and the British School of Geologists holds no uncertain views about the project, yet these views have been completely overshadowed by the insistent utterances of a few individuals.

Geology is not an exact science. The personal factor looms so large in many of its problems that he must needs be hardy who dares to be positive, and inexperienced who considers his verdict a final solution. The paths of progress in geological thought are strewn with discarded theories, the working hypotheses of the individual in his search for truth. To confuse theory with fact, to pivot an immense industrial undertaking on the transitory opinions of a few individuals, when there is ample opportunity for a wider appeal, is poor policy. The appointment of a representative committee of scientists to discuss and report on the possibilities of finding commercial quantities of crude petroleum in the British Isles should have been a necessary preliminary to the whole undertaking.

In the maze of involved economic and political interests it is difficult and profitless to follow the drilling scheme from its inception to its adoption. Primarily it was essentially a war measure, a forlorn attempt caused by a desperate need, and to view it in any other light is to rob it of its main excuse for existence. To the geologist, however, the fact which matters is the problem itself, and the ultimate possibilities are sufficiently interesting to need no excuse for being intruded on the notice of the reader. It is obvious that the discovery of large pools of oil and gas in this country would be of great national importance. The mere possibility of success would be ample warrant for the public expenditure, but at the same time the problem should be examined with a calm discussion and judgment of facts to give pause to the wild hopes raised by the utterances of misguided optimism.

It is not difficult to surmise the main guiding principles which are being adopted in the present search for oil in Britain. The chief reliance is being placed on the lower portion of the Carboniferous system, particularly the porous horizons of the Millstone Grit series and the Carboniferous Limestone. On the other hand, the Coal-Measures and Yoredale Shales, which respectively overlie these porous rocks, will be relied on to form impervious cover-rocks to prevent the oil and gas from escaping during the normal processes of denudation. The next stage in the undertaking is the examination of the tectonics of these Carboniferous rocks and the choosing of areas for drilling operations where the structures are suitable for oil and gas accumulation. Such areas are mainly anticlinal in form with an adequate thickness of undenuded impervious rocks on the crest of the fold. This almost necessarily implies drilling in the Coal-Measure basins on subsidiary anticlines in the main synclines. This restriction in the choice of sites for wells, which is due to the extreme dissection of the Carboniferous rocks in Britain, is in itself a very unfavourable factor. It limits the possible areas for drilling to a small percentage of the whole area, and localizes the wells on structures which, although themselves favourable, are merely subsidiary portions of larger structures that are distinctly unfavourable. The wells which are being put down in the Chesterfield area are situated on the axis of a sinuous anticline in the main Yorkshire basin; this anticline runs through Brimington in a northerly direction and then curves westward. Drilling operations are also in progress both in North Staffordshire and Midlothian.

The evidence which has been brought forward in favour of the possible occurrence of oil-pools in Great Britain may be considered under three heads:—

1. The indications of petroleum.
2. The supposed association of oil and carbonaceous strata.
3. The analogy with the American oilfields.

The writer proposes to describe and discuss this evidence in an endeavour to estimate the chances of success which await the present drilling operations.

1. Indications of Petroleum.

It is natural that prominence should be given to the evidence of asphalt, oil, and gas within the strata of these Islands by those who favour the present project. The occurrences are not uncommon, especially in the Carboniferous system, and apart from the pre-Cambrian and older Palæozoics, examples appear to have been noted almost throughout the geological column. The rare and local occurrences of bitumen in the pre-Carboniferous rocks of Britain, mainly in the Old Red Sandstone, are of no economic significance, and he would need be more than an optimist who drilled his wells within these formations. Throughout the Carboniferous system the evidence of hydrocarbons is more common. Instances of local oil impregnation in the strata of the Calciferous Sandstone series of the Lothians are probably due to destructive distillation of contiguous "oil-shale" by pyrometamorphism. This reaction is essentially similar to the present process of retorting the shale, and a corresponding effect is often noticed in the Coal-Measures where igneous dykes and sills approach the carbonaceous material. The Carboniferous Limestone often contains dark bituminous impregnations and small patches of hard black asphalt, but the elaterite of the Castleton area is of doubtful significance. A boring at Norton, near Stockton-on-Tees, yielded a small show of oil from shales above the Carboniferous Limestone, and paraffin wax was noted from the same formation at Ladysmith Colliery, Whitehaven. The oil obtained from the Kelham boring near Newark appears to have come from the Millstone Grit series.

Among the Coal-Measures methane is, of course, a well-known material associated with coal-seams, but it is significant rather of a phase of vegetable decomposition than of any necessary association with petroleum. Sometimes this gas escapes at the surface, the old gas spring at Wigan described by Thomas Shirley in 1667 being an interesting example. Liquid petroleum has sometimes been recorded in mines, either as an oily impregnation of the shales or as a slight drip from the roof of a coal-seam. Such instances occur in most of the coalfields, but the quantities of oil are small. Occasionally larger yields have been obtained. At Meirhay Colliery, Longton, North Staffordshire, five tons of oil were produced and refined per week for several years, while the still better-known example at Southgate Colliery, Clowne, yielded about 300 gallons per week. This oil was refined by James Young in 1848, and when the supply ceased attempts were made to distil coal. These led to the retorting of torbanite and eventually to the foundation of the Scotch oil-shale industry. Occasionally oil escapes to the surface of the Coal-Measures, examples being found at Coalport and Pitchford in Shropshire. Still more rarely it impregnates an outcropping porous rock; the best example occurs at Coalbrookdale.

Both the Permian and the Trias have afforded a few examples of bitumen; oil from the Magnesian Limestone and gas from wells in the Trias. The Jurassic clays frequently contain a small amount of bituminous matter. The Calvert boring yielded gas from the Lias clays, while the gas from Heathfield, probably from the Upper Jurassic clays, was used for lighting the local railway station. Among the Cretaceous and Tertiary strata in Britain, evidences of bitumen are exceedingly rare.

Having briefly enumerated the main indications of bitumen in the British Isles, it will be necessary to discuss their significance. They may be generally summarized as small, even insignificant, and in the rare cases of a somewhat larger yield the supply was quite ephemeral. Now it is not generally realized that bitumen in small quantities is almost universally distributed in nature; even igneous rocks are not free from the material, and among the marine sediments it is quite common. Hence the mere enumeration of a long list of interesting but minute occurrences of asphalt, oil, and gas in a country like Great Britain, where geological exploration, quarrying, mining, and drilling have accumulated large stores of knowledge of the strata, can hardly be a matter of surprise. The significance of an oil show is not in the seepage itself, but in what it indicates. It may mean nothing or it may mean everything. It is only of economic value when it is indicative of an underlying porous reservoir rock impregnated with petroleum.

A series of small shows of gas, oil, and asphalt, distributed haphazard in a thick mass of marine or deltaic sediments, with no consistency of geological horizons, and not associated with fault planes, can hardly be significant of an underground oil reservoir. The formation of hydrocarbons in small quantities is quite common in nature; it is the large accumulations which are more rare. If these small oil and gas shows were the result of gradual upward migration from a lower formation, it would be natural to expect that the movement would largely take place along the easiest planes of egress, i.e. faults, and porous strata. The extensive mining of the Coal-Measures would have given ample opportunity to illustrate this feature. Admittedly faults in softer strata tend to become sealed by a plastering effect, but even so they form easier avenues of passage than the undisturbed strata. The absence of any evidence of this upward migration along fracture planes, and the promiscuous distribution of the insignificant oil and gas shows, justify the assumption that they are in the main of local origin. In view of the fractured nature of the Carboniferous rocks, it is incredible that large supplies of oil could be held in the lower portions of these strata without giving abundant evidence of migration. The known tendency of these materials to take advantage of every shatter-plane, which is exemplified in all disturbed oilfields, is so characteristic that it may be taken as a general law.

But the question of the indications of oil is by no means exhausted. It has been previously noted that in the present search for oil, reliance is being placed largely on the possibility of oil occurring in the porous Millstone Grits or Carboniferous Limestone, where these are capped by impervious shales. If this assumption is true, it ought to be found that wherever there exist anticlines composed of these porous strata, wherein denudation is at present just stripping off the overlying impervious beds and revealing the crest of the underlying reservoir rock, the exposures of the latter ought to yield unmistakable evidence of an oil impregnation, even though most of the lighter oil may have been volatilized. Two excellent examples of such partially denuded domes occur at Ashover, and a few miles north-east of Leek. Both of these have been examined by the writer; neither of them yields evidence of oil impregnation beyond the insignificant amount usual to the Carboniferous elsewhere.

Thus it is seen that when the porous horizons of the Lower Carboniferous rocks are exposed in the cores of domes, there is no adequate oil impregnation or remains of such. Also, when these porous horizons are covered by impervious shales, there is no indication of oil migration such as would inevitably occur where the numerous fault-planes in the Coal-measures crossed the position of the underlying oil-pools. These two factors indicate that little or no value can be attached to the so-called indications of petroleum in Britain. These are merely insignificant examples of the universality of bitumen in minute quantities.

2. The supposed Association of Coal and Oil.

In Pennsylvania, Trinidad, Burma, Borneo, and elsewhere, it has been stated that the oil is found associated with coal or lignite. Those organic-origin theorists who believe that oil has been produced from terrestrial vegetation lay stress on this association of coal and oil, and infer that similar vegetable material entombed within the clays in the lower and more deeply buried strata have undergone a process of destructive distillation resulting in the production of liquid and gaseous hydrocarbons. It would be out of place to discuss the merits or demerits of this purely theoretical question. Suffice it to say that in the majority of the world's oilfields no such association of oil and coal exists, and in the cases noted above the line of demarcation between the oil and the coal-bearing strata is so well defined that the observer is impressed with the distinction between the two formations, rather than with their association. As far as the British Carboniferous strata are concerned, it is difficult to understand of what significance this supposed association can be in favouring the occurrence of underground oil-pools.

It has been stated by Mr. E. H. C. Craig that the oil-shale group of the Lower Carboniferous of the Lothians represents an old oilfield below the Carboniferous Limestone series with its contained coal-seams. The exact original form of the organic material which constitutes the oil-yielding portion of "oil-shale" is not at present known, but neither the chemical, microscopic, nor geological evidence can be brought into agreement with Mr. Craig's hypothesis. As far as the Lower Carboniferous rocks of Britain are concerned, to postulate that the coal-bearing measures will be succeeded at depth by oil-bearing strata on the grounds of a purely theoretical idea of oil formation, is to beg the whole question. The strata below the British Coal-Measures are a distinct and separate formation. The question whether they do or do not contain oil is a matter which must be settled by an examination of their own lithology and contents. The overlying Coal-Measures are only significant as a possible impervious cover rock to prevent the underlying oils from escaping.

3. The Analogy with the American Oilfields.

The two previous sections have really not touched the heart of the whole problem. Oil and gas fields have been discovered without any surface indications whatsoever by the mere process of trial and error, the lucky well of a "wild-cat" venture followed by the inevitable rush of oil prospectors, all eager to share in the gain. Indeed, it may be said that most of the American Palæozoic oilfields have been discovered in this way. Is it not therefore legitimate to assume that what is true of America may also prove true in this country? That, if deep wells are drilled so that the lower strata are thoroughly tested, and if in addition the sites of these wells are carefully chosen, it ought to be possible, or even probable, that similar supplies of oil and gas will be found. It is urged that England has not been thoroughly tested by deep wells, and until this is done no one can consider the matter as finally settled. In this section the writer will endeavour to compare the geological conditions in Britain with those of the American oilfields, with a view to discovering whether these conditions are sufficiently similar to warrant the assumptions which have just been stated.

Before proceeding with the comparison it will be necessary to make a few preliminary statements on the general geological occurrence of petroleum in the world. In the first place, the oilfields may be divided into two main groups—those of Upper Cretaceous and Tertiary age, and those of Palæozoic age. This somewhat sweeping assertion overlooks a few small fields in Europe and America, but is in the main correct. The Upper Cretaceous and Tertiary fields form a belt encircling the world: Galicia, Rumania, Caucasus, Persia, Burma, Sumatra, Java, Borneo, Japan, California, the West Indies, and Peru. In all these fields the strata are in the main strongly folded, often faulted, and sometimes thrust. Usually surface indications of asphalt, oil, and gas are numerous, and productive wells are largely located on the anticlinal folds.

The Cretaceous–Tertiary fields of Mexico, the Gulf States, and Alberta are exceptions to this general assertion; the structures are not folded to the same extent and usually the surface indications are not so numerous. The Palæozoic oilfields on the other hand are at present completely confined to North America, and particularly to the United States. The more important oilfields range in age from the Upper Ordovician to the Pennsylvanian, most of the oil being found in the Devonian, Mississippian, and Pennsylvanian. As contrasted with the Tertiary oilfields, the older fields do not occur on belts of mountain-building movement. They are not even affected by well-defined folds, but occur on broad open undulations with such gentle dips that the structures would not be apparent on sections drawn to scale. The oil-pools are situated on terraces, minor flexures, and gently dipping sand-lenses. To speak of these minor flexures as anticlines and synclines tends to give a wholly exaggerated idea of their importance, for the dips rarely exceed 2°, and are usually only from 20 to 50 feet in the mile. As a general rule surface indications of petroleum are rare in these fields. Asphaltic sandstones are found in Oklahoma and Texas, and oil and gas seepages to a small extent in Western Pennsylvania and New York State, but such occurrences are infinitesimally small compared with the immense supplies of oil and gas which are found underground.

Now there is no peculiar significance in geological age which would lead us to infer that all new oilfields will necessarily conform in their stratigraphical position to those at present known. Yet there are distinct lithological portions of the crust where it would be futile to search for petroleum, i.e. the pre-Cambrian and the British Trias. The strongly folded and deeply dissected Lower Palæozoics, the Old Red Sandstone, the Mesozoics, and the Tertiaries of Britain are all for varying reasons ruled out as possible strata containing oil-pools. There remains the Carboniferous system, the strata of which have yielded the most abundant signs of bitumen, and which have been more extensively mined than any others in the geological column.

If it is expected that the British Carboniferous strata will contain underground oil-pools, it will be legitimate to assert that the same general laws which are found essential for the occurrence of oil-pools in the American Palæozoic fields, ought to be applicable with the same force to the Carboniferous strata in Britain. It will then be advisable to examine the general tectonics of the American Palæozoic fields in order to discover the structural laws governing the occurrence of the oil, and afterwards to apply these laws to our own Upper Palæozoics in Britain.

The Pennsylvanian oil and gas fields will be taken as a typical area which has been thoroughly tested with the drill, and which, moreover, can be readily studied by means of the excellent maps and reports published by the United States Geological Survey. The structure of these fields is in the main a broad flat geosyncline of Devonian and Carboniferous rocks bordering the western edge of the Pennsylvanian Mountains. The beds are entirely devoid of true folding, but are warped into an alternating series of structural terraces or curved into a succession of extremely gentle undulations. These sinuous undulations are termed anticlines and synclines, but it must be remembered that their dips are usually only from 20 to 50 feet in the mile and seldom approach 2°.

The structures throughout the oil and gas field belt are all of this gently undulating, almost horizontal type. It is significant that where the productive zone approaches the real zone of folding on the east, where the sinuous broad undulations are replaced by definite anticlines and synclines with dips of 5° and upwards, the oil and gas suddenly disappear, though the same strata still persist in this outer belt of folded rocks. Thus in S.W. Pennsylvania the gas anticline of Belle Vernon is succeeded on the east by the Brownsville anticline with a small oil and gas field at its southern extremity. Both these structures are merely gentle undulations with dips below 1°. The succeeding anticline on the east, the Fayette anticline, is a definite fold structure with dips of 3° to 4°. Here the prolific oil and gas zone has almost completely disappeared, and only a few gas wells of small yield lie on this otherwise completely barren anticline. Still further east no oil or gas has been discovered.

This sudden impoverishment of the strata takes place within a distance of 5 to 10 miles, and it can be traced longitudinally along the border of the folded zone for over 100 miles. The position which marks the eastern limit of the main oil and gas fields is found in every case to coincide with the first anticline where the dips approach or exceed 3° to 4°.

It may be objected that these statements are a direct negation of the well-established theory of the anticlinal occurrence of oil, a theory which has proved its value all the world over. In spite of the recent tendency in oil technology to overestimate the importance of this idea, there is no doubt that it constitutes one of the fundamental principles of oil concentration. It is not suggested by the writer that the oil in Tertiary fields cannot and does not occur in strongly developed anticlinal folds, but it is asserted that the productive fold structures of the American

Palæozoic fields are of an entirely different type. They are mere broad undulations of the strata associated with epeirogenic movements, and differ essentially from the folds immediately associated with orogenesis. Pennsylvania has been chosen merely as a good example of structures which are typical of all the American Palæozoic oil-fields, with perhaps the single exception of Southern Oklahoma and North Texas, which will be alluded to later.

The characteristic association of oil with relatively undisturbed strata in the American Palæozoic oilfields has been emphasized by David White in a general law which he has formulated that "In regions where the progressive devolatilisation of the organic deposits in any formation has passed a certain point, marked in most Provinces by 65 to 70 per cent of fixed carbon (pure coal basis) in the associated or overlying coals, commercial oil-pools are not present in that formation nor in any other formation normally underlying it, though commercial gas-pools may occur in a border zone of higher carbonization".[1]

The exact relationship of the composition of coals to earth stresses is a disputed point, but it is certain that if White's law holds good, and it is the result of wide experience in American fields, it effectively eliminates the possibility of oil being found below most of the British Coal-Measures.

The fundamental truth which is contained in this generalization appears to the writer to be largely concerned with the last of the three necessary conditions for the formation of a commercial oil-pool:—

1. The formation of the oil.
2. Its migration to suitable porous reservoir rocks.
3. Its preservation from seepage and denudation by a thick cover of impervious strata.

The formation of the oil entails the entombment of organic matter under marine anærobic conditions, and probably includes certain biochemical changes resulting in the production of hydrocarbons.

The migration of the oil probably results from the compacting of the sediment, the pressing out of the oil and salt water from the compressible argillaceous sediments into and through the sandy and dolomitic horizons whose spore space is not materially reduced by pressure.

With regard to the third essential, the rapid seepage of oil and gas in the folded Tertiary oilfields teaches us how quickly such material can be lost from the strata, and it is obvious that the most important factor in the preservation of oil over long geological periods is the effectiveness with which it is sealed by the overlying impervious rocks. This essential implies the absence of strong folding, important fracturing, and deep dissection of the strata. Where this is not the case, the resultant migration during long geological periods has been sufficient to allow complete loss of the volatile gas and fluid from the oil reservoirs below. The same tendency is of course true of the Tertiary oilfields; the process of

[1] Journ. Wash. Acad. Sci., vol. v, p. 212, 1915.

loss by evaporation and seepage is going on in them at the present time, but the geological time has been insufficient for complete leakage, being relatively short compared with the long geological periods of post-Carboniferous history.

An interesting and instructive example of the great importance of migration in disturbed strata is afforded by the Palæozoic oilfields of Southern Oklahoma and Northern Texas. The oil is found mainly in strata of Permian age, the so-called "red beds". These rocks are tilted at angles somewhat greater than is usual in Pennsylvania, and they are underlain unconformably by strongly disturbed Carboniferous strata. There are two interesting features about the oil occurrence in these fields to which attention is here directed. Firstly, the common occurrence of asphaltic sandstones in surface outcrops indicating the petroliferous nature of the underlying strata. Secondly, the almost certain conclusion that the oil is not indigenous in the Permian formation, but has migrated upwards from the disturbed Carboniferous strata. During this migration some of the oil has evidently escaped to the surface, hence the asphaltic sandstones, but the great thickness of the Permian cover-rock, probably helped by overlying Cretaceous and Tertiary beds now removed, retained large portions of the oil in the strata.

These features serve to illustrate the two main facts on which stress is laid in the present communication:—

1. That disturbed strata, especially when strongly faulted, do not easily retain oil over long geological periods owing to the leakage of this somewhat elusive material to the surface.

2. That when such migration has taken place, or is taking place, the indications of bitumen in the overlying rocks or at the surface are sufficiently obvious to leave no doubt in the mind of the investigator as to the petroleum content of the underlying strata.

The writer must apologize for a long digression into the occurrence of petroleum in the American Palæozoic rocks, but such a comparison is necessary seeing that it is among the British Palæozoics that the search for oil is at present being carried out. The same laws which are necessary for the preservation of oil in the one country should hold good in the other, and the folding, fracturing, and subsequent denudation of the British Carboniferous strata should be compared with that of the same strata in the American oilfields. This comparison will indicate whether it is possible or likely that large quantities of oil still remain in the Carboniferous strata of these Islands.

It will be noticed that the writer is assuming that the first two essentials, the formation of the oil and its migration to suitable porous reservoirs, have been fulfilled in the case of the British rocks. Such an assumption may in itself be illegitimate, for oil formation on a large scale requires special geological conditions. Whether these conditions were fulfilled during the deposition of any of the sedimentary formations in the British Isles must be largely a matter of opinion, but it is quite probable that such has been the case. Apart from the Carboniferous rocks in the South of England, Wales, and Ireland, these strata elsewhere escaped the main thrust of the American mountain-building movements. In spite of this they have been folded, tilted, and fractured to an extent which can be readily gauged by the inspection of any of the Coal-Measure maps. In addition, the subsequent denudation has been so extensive that the lower rocks are exposed in the anticlinal areas and the Coal-Measures are largely confined to the structural basins. It is largely in the subsidiary upwarps of these synclinal areas that the borings for oil are situated. The tilting and faulting of the Coal-Measures, small as it may be when compared with the structures in the main mountain zones, is much more intense than in any of the American Palæozoic oilfields. In view of this difference in tectonics, and still further the extreme erosion to which Palæozoic rocks have been subjected in these Islands, the chances of finding commercial supplies of petroleum are extremely small. To be sure there is hardly any doubt that small quantities of oil and gas lie locked up within the impervious strata of Britain; such patches have been found before and no doubt will be found again, but they will give little satisfaction to those who believe the country is yet to be covered with flourishing oilfields.

The comparison of Britain and America is an unfortunate one. The broad area of American Palæozoic rocks, between the Pennsylvanian Mountains on the east and the Rocky Mountains on the west, lies on the great Pre-Cambrian shield of North America, and, though bordered by mountains, it has never been affected by orogenic movements. On the other hand, the structure of Britain may be said to be based on mountain-building movements. Pre-Cambrian, Caledonian, and Armorican movements have successively striven to impose their structures on the ground-plan of these Islands. The folded, crumpled, and rifted nature of our Palæozoic structures testify to the success of their efforts. Even the Alpine folds invaded our southern shores. To search for petroleum in such structures, deeply dissected by extensive periods of denudation, cannot be justified by comparison with any analogous examples of successful oilfields in the equivalent formations of the rest of the world.

Conclusions.

It appears to the writer, after a review of the oil indications and comparison of the geological conditions both in Britain and America, that the following conclusions may be drawn :—

1. The asphalt, oil, and gas occurrences in Britain are no more than would be expected in any thick mass of deltaic and marine sediments. Their haphazard distribution indicates their local origin and does not imply any association with commercial oil-pools.

2. There is a significant absence of definite oil and asphalt indications in localities where the geological conditions would lead one to expect such occurrences, on the assumption that the Lower Carboniferous rocks contain large supplies of oil.

3. No parallel can be drawn between the structures of the British Carboniferous rocks and the equivalent formations of the American oilfields. The structures in the British formations are much more highly warped and fractured than are those in America.

Furthermore, their denudation is so extensive that the possibility of preservation of large oil-pools in such fractured rocks which have suffered such deep dissection is unlikely in the extreme.

4. Small quantities of oil and gas locally preserved among the impervious strata are both possible and probable. Such occurrences, however, are too small to be of commercial importance.

On May 27 an oil-show was struck at the Government boring at Hardstoft, near Chesterfield, at a depth of about 3,075 feet. The oil is stated to have risen slowly in the well and finally overflowed, yielding about 400 gallons a day. It appears to have come from the compact limestones and shales at the base of the Yoredale Series, and the absence of porosity in these strata limits the hope of a large commercial supply of petroleum. The character of the seepage in the well tends to confirm the impression of a slow outflow from relatively compact rocks. It was presumed, somewhat hastily, that the Hardstoft oil-show was indicative of a large oil supply which would be tapped when the cover-rock had been completely pierced, but the resumed drilling operations have so far negatived this assumption. Similar oil seepages are quite likely to occur in some of the other bores at the same geological horizon, but the statements which have been assiduously circulated that the discovery at Hardstoft proves the existence of large quantities of crude petroleum in these Islands, betray a complete inability to estimate such occurrences in their true proportion.

In the discussion of a problem where political, economic, public, and scientific interests are deeply involved, it is difficult to avoid the clash of warring elements. The writer wishes to emphasize the fact that the present discussion is entirely concerned with the possibilities of success. Whether the present oil development operations were justifiable in view of the urgency of the war needs, is a question rather of political responsibility and is entirely beyond the scope of the present paper.

That a large sum of money could be well spent on boring in this country is undoubtedly true—the survey of our natural wealth is inadequate without it—but why confine the search to oil, one of the most improbable materials, if scientific evidence stands for aught? The data afforded by the percussion method of drilling are very unsatisfactory, especially when the sampling is left in the hands of the driller. Core drills are more slow, but the scientific evidence obtained is incomparably greater. It is true that small oil-shows would possibly be overlooked in core drilling, but this difficulty is not insuperable, and in addition the type of oil-well which will alone repay the cost of such deep wells as are anticipated would leave no doubt of its occurrence. In the Chesterfield area, where operations are now in progress, little additional knowledge could be obtained of the beds in association with the Black Shale coal, but a series of cores in the underlying strata would yield useful and possibly valuable data. It is to be deplored that by a system of haste where no haste is now necessary, and where the possibilities of success are extremely doubtful, an opportunity should be thrown away of getting valuable evidence which would possible repay the public expenditure.

II.—On the Stafford Earthquakes of January 14–15, 1916, and on the Relations between the Twin-Earthquakes of the Midland Counties.

By Charles Davison, Sc.D., F.G.S.

THE strong shock of January 14, 1919, originated in a region from which earthquakes have been absent for many years, perhaps for several centuries, and its interest is therefore increased by the fact that it was a twin-earthquake, that is, one produced by a single generative effort in two detached foci.

There is no certain evidence of any fore-shock, and, so far as I know, there was only one after-shock.

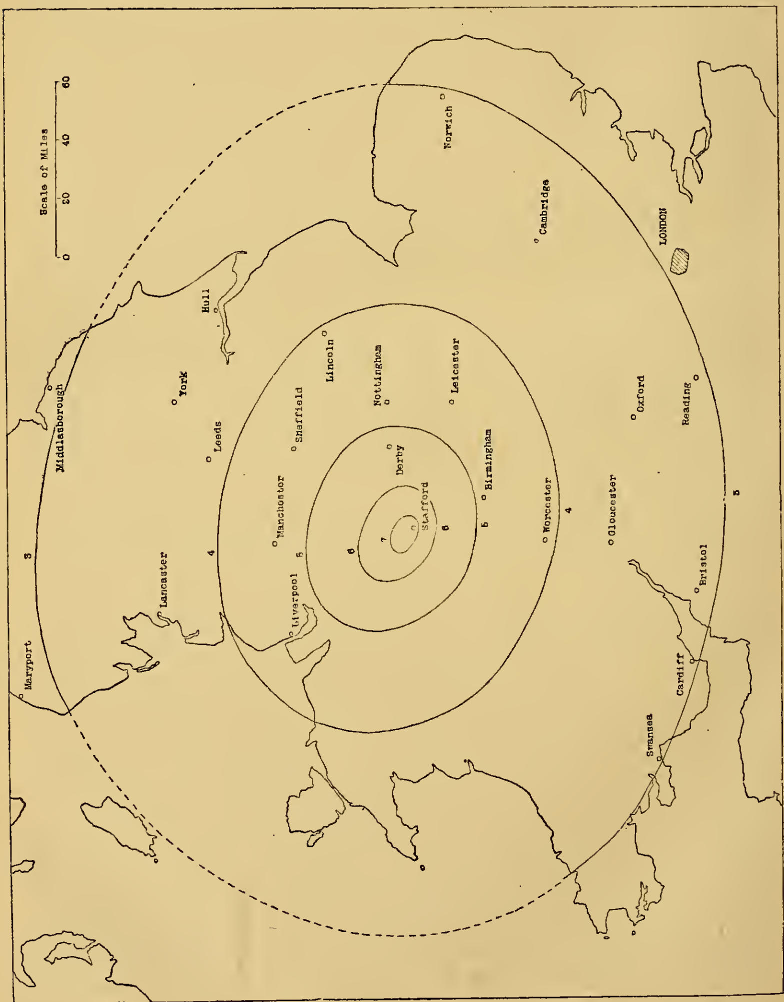


Fig. 1.

Principal Earthquake of January 14, 1916.

Time of occurrence, 7.29 p.m.; intensity, 7; centre of isoseismal 7 in lat. 52° 52′ N., long 2° 9′ W.; number of records, 1241, from 580 places.

Time of Occurrence.

The time of occurrence is determined with unusual precision. The first tremors were recorded at West Bromwich, as Mr. J. J. Shaw kindly informs me, at 7 h. 29 m. 6 s. p.m. At Birmingham I felt the shock at 7 h. 29¼ m. The average of seventy-four estimates of the time, which, according to their observers, are accurate to the nearest minute, is 7 h. 29 m. As these observers were all within the isoseismal 4, it is probable that the time at the epicentre must have been 7.29 p.m., or possibly a few seconds earlier.

Isoseismal Lines and Disturbed Area.

On the map of the earthquake (Fig. 1) are shown five isoseismal lines corresponding to intensities 7–3 of the Rossi-Forel scale, or rather of that form of the scale which I have employed in studying British earthquakes,[1] the two inner isoseismals being represented on a larger scale in Fig. 2. With regard to all the isoseismal lines, except the innermost, it should be mentioned that the comparative scarcity of observations in the western district does not admit of great accuracy in tracing the lines there. The true course of each line may vary by a mile or more, and in the outermost line by several miles, from that laid down on the map. The inaccuracy, if it exists, is not, however, of much consequence.

The dimensions of the isoseismal lines are given in the following table:—

Isos.	Length, miles.	Width, miles.	Area, sq. miles.	Direction of longer axis.
7	12½	9	88	E. 22° S.
6	32½	25	637	E. 28° S.
5	68	55	2,908	...
4	144	112	12,500	...
3	281	225	50,200	...

The centre of the isoseismal 7 is in lat. 52° 52′ N., long 2° 9′ W., or 2 miles S.S.W. of Stone. The distances between the isoseismals 7 and 6, 6 and 5, 5 and 4, are respectively 9½, 18, and 32 miles on the north side, and 5, 12½, and 12 miles on the south side.

Outside the isoseismal 3, the shock was probably felt at Maryport, 14 miles from the line. Excluding this exceptional observation, the area disturbed by the earthquake is about 50,200 square miles.

If we measure the relative strength of British earthquakes by the area enclosed within the isoseismal 4—for the isoseismal 3 cannot always be drawn—the Stafford earthquake occupies the seventh

[1] *Geogr. Journ.*, vol. xlvi, pp. 360–1, 1915.

place among the earthquakes of the last thirty years, the areas for the ten strongest earthquakes being given in the following table:—

Earthquake.	Area of Isos. 4, in sq. miles.
Hereford, 1896	98,000
Pembroke, 1892	44,800
Swansea, 1906	37,800
Pembroke, 1893	35,900
Inverness, 1901	33,000
Carnarvon, 1903	19,500 (about)
Stafford, 1916	12,500
Derby, 1903	12,000
Doncaster, 1905	10,700
Derby, 1904	10,120

Fig. 2.

It is remarkable that all these earthquakes, with two exceptions (the Inverness and Carnarvon earthquakes) belong to the class of twin-earthquakes.

Nature of the Shock.

The following accounts may be regarded as typical of the nature of the shock in different parts of the disturbed area (see Fig. 2) :—

(1) Chebsey: the shock consisted of one series of vibrations accompanied by sound which increased in strength to a maximum and then died away.

(2) Coton Hill (near Stone): the shock consisted of one continuous series of vibrations, lasting about six seconds, increasing in strength from the beginning and dying away towards the end; in the middle, there were two maxima separated by about half a second.

(3) Brereton: the shock was in two distinct parts, the first being the stronger, and the interval between the two series being two or three seconds.

(4) Kinnersley: the shock was again in two distinct parts, separated by an interval of two seconds, the second part being the stronger.

Over the greater part of the disturbed area, and in some directions even as far as the isoseismal 3, the shock consisted of two distinct parts. Thus, the wide distribution of the places at which the double shock was felt precludes the supposition that the earthquake was caused by a single impulse, the resulting waves of which were duplicated by reflection or refraction. Nor can the two parts of the shock represent direct and transverse vibrations resulting from a single impulse; for, as will be seen later, the duration of the interval between the two parts does not increase with the distance from the origin. Nor, lastly, could the two parts be caused by successive impulses in the same focus; for, if this were the case, there could be no part of the disturbed area in which the two series of vibrations coalesce. We are thus led to conclude that the two parts of the shock were derived from distinct impulses originating in different foci.

When the places are mapped at which the double and single shocks were felt, we find that the former are absent from a band which crosses the isoseismal 7 at right angles to its longer axis at a short distance to the west of the centre. The band is very slightly curved, the concavity facing the west. Within this band (as at Chebsey), the shock was either single or consisted of one series of vibrations with two maxima. Close to the band (as at Coton Hill, one mile to the east), and on either side of it, the shock was single with two maxima. At many places the observers differed, some regarding the shock as single, others as double. For instance, at Hanley and Stoke-on-Trent, which lie one mile to the west of the band, fifteen observers regarded the shock as single and five as double. At places farther from the band, such as Brereton (13 miles) and Kinnersley (4 miles), the two parts were entirely distinct.

It is clear, from the above account, that the two series of vibrations were felt practically in all parts of the disturbed area, but that in the curvilinear band, the two series were felt simultaneously and so appeared as a single shock either with one maximum or two maxima close together. On this account, the band is known as the synkinetic band.

The existence of this band is evidence that the impulses in the two foci occurred so closely together that the second focus was in action before the vibrations from the first focus had time to reach it. When the two impulses are simultaneous, the synkinetic band is straight and crosses the axis of the central isoseismal at right angles through its middle point. This was the case in the Derby earthquake of 1903. If one impulse were to occur a second or so before the other, then the waves from the focus first in action would travel farther than the waves from the other focus before the two series of vibrations coalesced. That is to say, the synkinetic band would be slightly curved, it would pass nearer to the focus last in action than to the other, and its convexity would be turned towards the focus at which the first impulse occurred. From the form of the synkinetic band, as shown by the broken lines in the map, we conclude that the two impulses which formed the Stafford earthquake occurred almost simultaneously, but that the eastern focus was in action very slightly—perhaps a second or two—before the western focus.

That the two impulses were very nearly equal in strength is clear from the wide observation of the double shock. If they had differed greatly in intensity, only the stronger part would have been felt near the boundary of the disturbed area. This approximate equality is also indicated by the observations on the relative intensity of the two parts of the shock. For instance, in Staffordshire and the adjoining counties of Shropshire and Derbyshire, on the east side of the synkinetic band, 25 persons regarded the first part, and 20 persons the second part, as the stronger; on the west side of the band, 21 persons regarded the first part, and 27 the second part, as the stronger. Thus, it seems probable that, though the two impulses were nearly equal, that of the eastern focus was slightly stronger than that of the other.

The synkinetic band has only been traced for four earthquakes. In the Derby earthquake of 1903, the impulses were simultaneous and practically equal in strength. In the Hereford earthquake of 1896, the Derby earthquake of 1904, and the Stafford earthquake of 1916, the foci were in action not quite simultaneously, and the impulses were unequal in strength.

The duration of the shock was estimated with care by 198 observers, and that of the interval between the two parts by 107 observers. The average of the former estimates is 3·1 seconds, and of the latter 2·2 seconds. The figures in the following table (p. 307) show how these averages vary with the distance from the origin.

It should be mentioned that, in determining the average duration of the shock, estimates when one part only was observed are included.

District.	Average Duration.	
	Shock, secs.	Interval, secs.
Within isoseismal 7	4·0	2·0
Between ,, 7 and 6	4·0	2·1
,, ,, 6 ,, 5	3·2	2·4
,, ,, 5 ,, 4	2·4	2·4
,, ,, 4 ,, 3	2·5	1·1

Sound-Phenomena.

Sound-Area.—The boundary of the sound-area is represented on the map of the earthquake by the dotted line. This lies between the isoseismals 4 and 3, and includes an area 177 miles long, 157 miles wide, and containing about 21,000 square miles.

Within the whole area, the sound was heard by 77 per cent of the observers. The decline in audibility, as the sound-waves progressed outwards, follows the same law as in other strong earthquakes, being 98 per cent within the isoseismal 7, 96 per cent between the isoseismals 7 and 6, 83 per cent between the isoseismals 6 and 5, 57 per cent between the isoseismals 5 and 4, and 31 per cent outside the last isoseismal. For the Derby earthquake of 1904, which closely resembles the Stafford earthquake, the corresponding percentages are 94, 93, 79, 56, and 38.

Nature of the Sound.—The sound is described by 663 observers, In 53 per cent of their records the sound is compared to passing traction-engines, motor-cars, etc., in 7 per cent to thunder, in 9 to wind, in 8 to loads of stones falling, in 9 to the fall of a heavy body, in 12 to explosions, and in 2 per cent to miscellaneous sounds.

The variation in the nature of the sound with the distance from the epicentre is shown in the following table, in which the figures are percentages of comparison to the different types for each of the districts mentioned :—

District.	Passing vehicles.	Thunder.	Wind.	Loads of stones falling.	Fall of heavy body.	Explosions.	Miscellaneous.
Within isoseismal 7	35	10	2	11	17	23	2
Between ,, 7 and 6	46	7	9	9	13	14	2
,, ,, 6 ,, 5	61	5	9	8	6	9	2
,, ,, 5 ,, 4	47	14	10	5	8	13	3
Outside ,, 4	46	15	15	8	0	15	0

Omitting the references to miscellaneous sounds, the types of passing vehicles, thunder and wind are of long, and the others of short, duration. The percentages of reference to types of long duration for the above districts are respectively 47, 64, 77, 73, and 77; showing that as the distance increases from the origin, the sound becomes smoother and more monotonous. This is especially noticeable in the case of references to the third type, that of wind.

Time-Relations of the Sound and Shock.—In the following table the figures under the letters p, c, and f indicate the number of records per cent in which the beginning or end of the sound preceded, coincided with, or followed, the corresponding epoch of the shock; and those under the letters g, e, and l show the number of records per cent in which the duration of the sound was greater than, equal to, or less than, that of the shock:—

District.	Beginning.			End.			Relative Duration.		
	p	c	f	p	c	f	g	e	l
Within isoseismal 7	56	26	18	8	71	21	58	42	0
Between ,, 7 and 6	63	29	8	33	35	32	58	42	0
,, ,, 6 ,, 5	58	38	4	21	60	19	56	35	9
,, ,, 5 ,, 4	63	12	25	...	...	...	...	...	...
Whole sound-area	60	32	8	25	51	24	57	38	5

It will be seen that the percentages for the beginning and end lend no support to the view, sometimes expressed on insufficient observations, that the sound travels more rapidly than the waves which form the shock. Had this been the case, the figures for the precedence of the sound would have shown a very rapid increase with the distance from the origin.

After-Shock: January 15.

Time of occurrence, 10.45 a.m.; intensity, 4; number of records, 7, from 7 places.

A slight shock was felt at Alsager, Cheadle, Coton Hill (near Stone), Croxden (near Uttoxeter), Horseley (near Eccleshall), Huntley (near Cheadle), and Stone. With one exception, these places lie within the isoseismal 6 of the principal earthquake (Fig. 2). Alsager lies one mile to the north. From the distribution of these places, it seems probable that the epicentre is not far from the centre of the isoseismal referred to, and therefore lies between the two epicentres of the principal earthquake. The shock was a slight one, and consisted of a single series of vibrations.

Origin of the Earthquakes.

From the forms and relative positions of the isoseismal lines, we obtain the following elements of the originating fault: (1) its mean direction lies between E. 22° S. and E. 28° S., or about E. 25° S.; (2) its hade is to the north; and (3) the fault-line must pass within a short distance (about a mile or two) on the south side of the centre of the isoseismal 7. This position for the fault-line is, however, given on the supposition that the fault-surface is a plane. If the surface were curved and increasing in inclination to the horizon as it approached the surface of the earth, the position above given would be the line in which a tangent-plane at the depth of the focus to the fault-surface meets the surface of the earth, and this ought to lie some distance to the south of the actual fault-line.

This apparent displacement of the presumed fault-line is specially characteristic of deep-seated earthquakes. In British earthquakes, the only test that we possess of the greater or less depth of the seismic foci is the less or greater rate of decline in the intensity of the shock at the surface. A rough test of this rate of decline is the area enclosed within the isoseismal 4 for shocks of different intensity at the epicentre. For earthquakes of intensity 7, this average is 22,000 square miles in England and Wales, and less than 1,000 square miles in Scotland; for those of intensity 5, the corresponding figures are 780 and 450. Thus, the rate of decline of intensity outwards from the epicentre is much more rapid in Scotland than in England; and this implies that the average depth of focus is much less in Scotland than in England and Wales. Now, Scottish earthquakes which cannot be correlated with known faults are very rare. In English and Welsh earthquakes it is quite an exception to be able to associate an earthquake with a known fault; and, in the few cases in which this is possible, the area within the isoseismal 4 is always small. It is therefore not surprising if we cannot point to any definite fault in the case of the Stafford earthquake.[1] Should we not rather look on the results of the earthquake investigation as adding to our knowledge of the structure of the crust at a depth which is far beyond the range of the field-geologist's methods?

Returning to the Stafford earthquake, the positions of the two epicentres cannot be determined with accuracy, but, from the form of the isoseismal 7 and the course of the synkinetic band (which must pass between the epicentres), it follows that the eastern epicentre must lie about two miles north-east of Stafford and the western epicentre about twelve miles north-west of Eccleshall. The distance between the epicentres would thus be about 8 or 9 miles, which differs little from the average (10 or 11 miles) for British twin-earthquakes.

For very many years, possibly for centuries, there has been no perceptible movement along the earthquake fault. Then, suddenly, two earthquakes occurred so closely together that the later could not possibly be a consequence of the earlier, for it took place before the earth-waves had time to traverse the interfocal region. The only movement that could produce such practically simultaneous displacements is one of rotation. We may conceive the earthquake-fault as cutting transversely a crust-fold (Fig. 3) the crest C and trough T of which are separated by a distance of about nine miles. If a small step took place in the growth of the fold, that is, if the

[1] Close to Eccleshall there is a small post-Triassic fault (Geol. Surv. map, sheet 22, S.W.), which is parallel to the longer axis of the isoseismal 7, and hades to the north. If this fault were continued to the east it would occupy the position assigned to the fault-line by the seismic evidence.

crest and trough were to become more pronounced, simultaneous movements of the fold—the crest C to C′ and the trough T to T′—would occur, and these movements would be accompanied by a rotation of the median limb, the central portion M of which would undergo no displacement. Thus, we should have two foci, CC′ and TT′, entirely separated by the interfocal region about M. Moreover, the forces which give rise to an earthquake of this kind must act at right angles to the direction of the fold, that is, parallel to the direction of the fault.

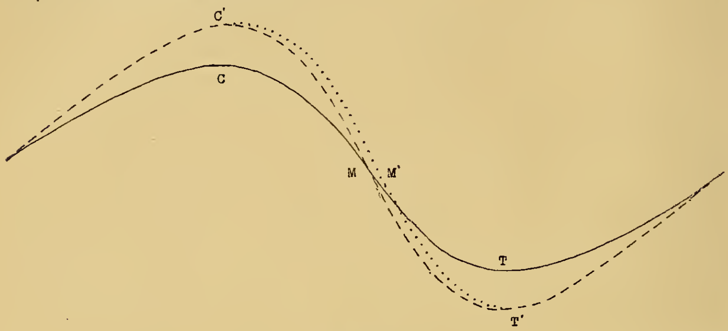


Fig. 3.

It is evident that movements of this kind would suddenly increase the stress within the median limb, and the effect of this increase would be a sudden movement of translation of the median limb into some such position as that indicated by the line C′M′T′, thus giving rise to a simple shock with its epicentre in the interfocal region of the twin-earthquake. The interval between the twin-earthquake and its first after-shock varies from a few hours to several weeks. In the Stafford earthquake, the observations of the after-shock are insufficient to determine its epicentre with precision; but it was probably due to a translation of the median limb of the fold about fifteen hours after the occurrence of the twin-earthquake.

On the Relations between the Stafford Earthquake of 1916, the Derby Earthquakes of 1903, 1904, and 1906, and the Leicester Earthquakes of 1893 and 1904.

On March 24, 1903, a strong twin-earthquake occurred in Derbyshire,[1] one focus being near Ashbourne and the other about 3 miles west of Wirksworth. The distance between the foci is thus about 8 or 9 miles, and the direction of the longer axis of the isoseismal 7 is N. 33° E. This earthquake was followed on May 3 by an interfocal after-shock, the direction of the longer axis of the isoseismal 5 being N. 25° E. On July 3, 1904,[2] another strong twin-earthquake occurred, in which the same foci were in action, the southern focus being 1½ miles east of Ashbourne, and the northern probably in the same position as in 1903. The

[1] Quart. Journ. Geol. Soc., vol. lx, pp. 215–32, 1904.
[2] Quart. Journ. Geol. Soc., vol. lxi, pp. 8–17, 1905.

distance between the foci is 6 or 7 miles, and the direction of the longer axis of. the isoseismal 6 is N. 31° E. Eight hours later, on the same day, the earthquake was followed by an interfocal after-shock, the direction of the longer axis of the isoseismal 4 being N. 27° E. Lastly, on August 27, 1906,[1] a much slighter twin-earthquake occurred in the same foci as the earthquake of 1904, the direction of the longer axis of the isoseismal 5 being N. 25° E. The mean direction of the earthquake fault is thus about N. 28° E., which is nearly, but not quite, at right angles to that of the Stafford earthquake fault.

Again, on August 4, 1893,[2] a twin-earthquake of intensity 5 occurred in Leicestershire. The principal epicentre lies 2 miles S.S.W. of Loughborough, and the direction of the longer axis of the isoseismal 5 (which surrounds this epicentre only) is E. 30° S. The second epicentre lies close to the village of Tugby, and is 17 miles E. 34° S. of the other. There can be little doubt that both impulses originated along a single fault, the direction of which at the north-west end is E. 30° S., and at the south-east end about E. 40° S. A later earthquake, which occurred on June 21, 1904, in the south-eastern focus only, shows that the direction of the fault there is E. 42° S.

Now, if the fault-lines of the Stafford and Derby earthquakes be produced to meet, their point of intersection is 9 miles from the eastern focus of the Stafford earthquake and 18 miles from the southern focus of the Derby earthquakes. In both earthquakes, the distance between the foci is 8 or 9 miles, which is therefore the distance between the crest and trough of a crust-fold. Thus, the point of intersection of the two fault-lines is at a distance of half a crust-fold-length from the nearer focus of the Stafford earthquake, and of a whole crust-fold-length from the nearer focus of the Derby earthquakes. Also, if the fault-lines of the Derby earthquakes and of the Leicester earthquake of 1893 be produced to meet, their point of intersection is about 10 miles from the other point of intersection, about 8 miles from the southern focus of the Derby earthquakes (that is, about half a crust-fold-length from either), and about 26 miles from the north-western focus of the Leicester earthquake and 43 miles from its south-eastern focus (that is, about three and five half crust-fold-lengths from the two foci).[3]

If we may assume that the earthquake-faults are at right angles to the folds, to the growth of which the earthquakes are due, it would seem that the crust at a depth of a few miles below the counties of Stafford, Derby, and Leicester, is corrugated in two systems of folds approximately at right angles, and that the axes of the north-and-south folds exhibit a fan-shaped arrangement or

[1] Geol. Mag., Vol. V, pp. 301-3, 1908.

[2] Quart. Journ. Geol. Soc., vol. lxi, pp. 1-7, 1905.

[3] It will be noticed that the distance between the foci of the Leicester earthquake is about double that between the foci of the Derby and Stafford earthquakes. Possibly, the foci of the Leicester earthquake occupy the crests of successive folds ; but there are difficulties in the way of such an explanation.

continued easterly twist in successive lines, the direction being about N. 25° E. through the Stafford foci, N. 28° E. through the Derby foci, and N. 30° E. and N. 42° E. through the Leicester foci.

The existence of this deep-seated double system of corrugations may perhaps explain another peculiarity of British earthquakes. Dividing them into three classes of strong, moderate, and slight earthquakes, according as the areas embraced by the isoseismal 4 are greater than 5,000, between 5,000 and 1,000 or less than 1,000, square miles, it appears that the average length of focus for strong earthquakes is 12¼ miles, and for moderate, earthquakes 13 miles. Slight earthquakes are divisible into two groups, in one of which the focus is 9 miles or more in length, and in the other 6 miles or less in length. The average length of focus for the former is 12 miles, and for the latter (omitting a large number of very slight shocks) 4¼ miles. If we leave out of account the second division of slight shocks, which are of the nature of local creeps, it follows that the average length of focus in all three classes of earthquakes is very nearly the same, about 12½ miles.[1]

III.—The Late Glacial Gravels of the Vale of Edeyrnion, Corwen, North Wales.

By Bernard Smith, M.A., F.G.S.

(WITH A MAP.)

The Corwen gravels were described by D. Mackintosh, forty-three years ago, in a paper "On the mode of Occurrence and Distribution of Beds of Drifted Coal near Corwen, North Wales".[2] He attributed the gravels to an interglacial marine submergence and claimed that the coal found in them was derived from the outcrop of Coal-measures near Ruabon, twelve miles due east of Corwen.

In the present communication a correlation is made between the Corwen gravels and certain gravels of Late Glacial age formed during the melting stages of the North Welsh valley glaciers. A brief description of these gravels, as a preface to our correlation, seems advisable in view of the fact that no general account of them has been published.

Reasons are given for assuming that the drifted coal, found at Corwen, was derived from a local concealed outcrop.

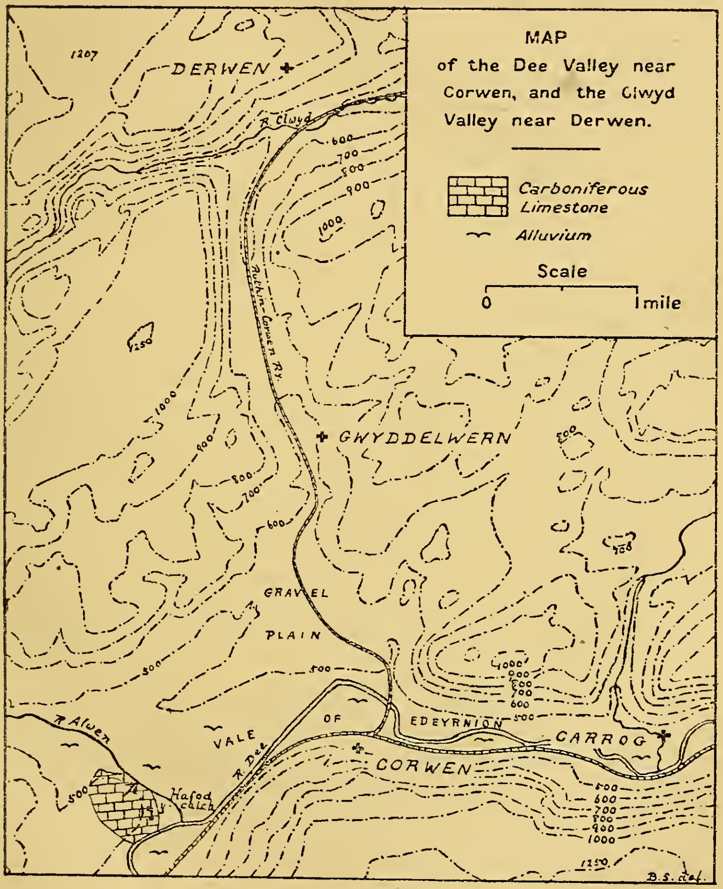
Late-Glacial Gravels.—In many of the valleys of North Wales, such as the Dee, Ceriog, Tanat, Vyrnwy, and Severn, especially in the more mature parts of their courses through the mountains, the recent alluvium is flanked at intervals by terraces of gravel,[3] derived chiefly from the boulder-clay which previously clung to the valley slopes, and still floors the valleys over long stretches. These terraces have usually been regarded as post-glacial, and mapped as ordinary

[1] "Characteristics of British Earthquakes": Geol. Mag., Vol. VII, pp. 410–19, 1910.

[2] Quart. Journ. Geol. Soc., vol. xxxii, pp. 451–3, 1876.

[3] *Summary of Progress* for 1914 (Mem. Geol. Surv.), 1915, p. 17; and for 1915 (Mem. Geol. Surv.), 1916, pp. 11, 12.

alluvium. But just as the highest terraces of the Trent valley between Newark and Nottingham[1] have been shown to be late-Glacial, so also the highest terraces of these mountain valleys are now recognized as having been formed during the retreat of the ice. They are the equivalents of the present day sheets of gravel formed alongside, and at the snouts of, the retreating valley-glaciers of the Yakutat Bay region of Alaska.



Map showing site of Gravel Plain near Corwen.

In broad open valleys, like that of the Trent, the late-glacial terraces are of fairly regular height and level surface; but in mountain valleys, such as those of the Tanat and Vyrnwy, they appear at various heights above the recent alluvium—here 20 feet, there 40 feet—even when the remnants of a dissected terrace are

[1] *Geology of the Country between Newark and Nottingham* (Mem. Geol. Surv.), 1908, pp. 73-6.

fairly close together. At some points, where a valley was winding, narrow and constricted, the escaping glacial waters distributed the débris irregularly, the resulting terrace being of varying height and uneven surface and occasionally pitted with kettle-holes.[1] Where the valleys debouched on the plain, for example where the Vyrnwy leaves the mountains at Llanymynech, the gravel is spread out as a huge apron or fan several miles across,[2] the grade of material becoming finer and finer, and the fan progressively thinner, towards its margins.

Near the mountainous headwaters of the rivers these gravels are usually thin and patchy, and their surfaces are not far above the present alluvial level, whilst the floor (boulder-clay or "solid") upon which they rest is also sometimes above this level. As we fellow them down stream towards their lower mountain course the terraces rise higher and higher above the alluvium. Where the rivers debouch on the plain the terraces descend quickly to stream-level. Thus the gradient of the late-glacial streams was flatter than that of the present stream. The gravels themselves also are actually thicker in the middle or lower part of the mountain course than near the headwaters or in the fan. This result was undoubtedly due to the aggrading power of the streams, which were choked with more débris than they could conveniently carry. The dissected terraces that now rise prominently in bold bluffs above the present rivers are not primarily due to any uplift of the land, but to the sinking of the thalwegs of the present streams to a curve consonant with their present volume and rate of flow. During this process the late-glacial gravels have been attacked and redistributed as post-glacial terraces at one or more lower levels.

The gravels are varied in grade and character, in places being fairly clean boulder beds with good-sized erratics, which gradate through finer gravel and silts or clayey gravel into a more clayey deposit that cannot be distinguished easily from the parent boulder-clay. Usually the gravels are roughly stratified, the constituent beds often dipping at steep angles; but in some places they appear to be tossed together in disorder.

The Corwen Gravels (*General*).—At Corwen there lies an open plain, surrounded by an amphitheatre of mountains, near and north of the confluence of the River Alwen, which flows from west to east, with the River Dee, which flows from south-south-west to east-north-east and then turns due east past Corwen and traverses the famous Vale of Edeyrnion.

The plain is made up of two physiographical units. On the south it consists of the recent flood-plain of the above-mentioned rivers, north of which is a gently undulating plain of gravel extending 1½ miles in the direction of Gwyddelwern and averaging about 550 feet above sea-level, or 100 feet above the alluvial plain of the Dee at Corwen. The two features are separated by a steep bluff.

The gravel plain is about 1½ miles wide near the rivers, but

[1] *Summary of Progress* for 1915 (Mem. Geol. Surv.), 1916, pp. 11, 12.
[2] Op. cit., p. 12.

narrows northward in the direction of Gwyddelwern. It also occurs on both flanks of the flood-plain in the valley east of Corwen. This plain is probably floored by boulder-clay, because its surface is diversified by low patches of undrained marshy ground where the gravels are thin or absent, not through denudation, but apparently because they have never been deposited there. From our own observations this boulder-clay, on the hill-slopes near Corwen and in the Dee valley farther east, comes out from beneath the gravels and river deposits and ascends to higher levels.

Corwen Gravels (*Details*).—We may take it that Mackintosh's description of the succession of the deposits is, as usual, correct. The sands and gravels and the occasional irregular kind of brick-clay over-lie boulder-clay with beds of coarse gravel. The cuttings along the railway north of Corwen, examined by Mackintosh, are now, unfortunately, grassed over to a great extent; but it is still clear that an irregular deposit of layers and lenticles of unevenly-bedded gravels and false-bedded sands and silts on silty loam (? brick-clay) is over-lying boulder-clay which appears here and there at about rail level. The beds dip almost due east. A section on the left bank of the Nant Fawr, south of the line, contained masses of gravelly clay, loam, and clayey gravel like boulder-clay with intercalated sands.

About half a mile N.N.E. of Corwen, at the junction of the Carrog road, north of the river, with the by-road to Tan-y-gaer at the east end of the bridge over the railway, 2 feet of soil with boulders rests on 2 feet or more of partly stratified loam with stones, on 3 feet of pebbly gravel. The loam is generally grey or grey-brown, but contained small patches of *brick-red* sand, rusty or yellowish-red sand, and streaks of bluish clay. The stones were partly rounded, partly subangular. Many were of igneous rocks, but none were of types that might have come from the Irish Sea area. There were also occasional cherts and sandstones.

Similar deposits extend as far north as the railway cutting south of Gwyddelwern, where, at about 580 feet O.D., they die out above the boulder-clay.[1]

Turning again to the Dee valley we note that in a pit in the gravel terrace near Groes-faen, about 530 yards west of Carrog Church, the beds were unlike ordinary river gravels. The dip is in all directions, and the deposit is silty, sandy, and gravelly in streaks and patches, often inclined at high angles. Some patches are clayey, others of fine loam with a feel like French Chalk or Fuller's Earth.

The following section was exposed at one point in the south side of the pit:—

		ft.	in.
Coarse gravel and pebbles . . .	about	2	0
Grey silt and sand	,,		6
Pale fine gravel	,,		6
Light-brown finely laminated clay .	,,	1	0

[1] In a north-easterly direction towards Bryn Eglwys the boulder-clay is associated with very little sand or gravel, but makes good drumlin scenery. The exceptions are some morainic sands and gravels in the valley at Bryn Eglwys and near the southward bend of the Afon Morwynion, north of the Carrog Gap.

Amongst the boulders were some of subangular pink crinoidal limestone up to 1 foot in length, fossiliferous rocks from the Bala Beds, subangular cherts, and fragments of local Silurian rocks.

About 300 yards west of Carrog Church there is a large natural hollow or kettle-hole; whilst on the south side of the river, west of Nant Llechlog, the gravels are distinctly moundy and sandy, and possess nothing like the nearly flat surface we should expect if they were normal river deposits. The sand is greyish and the boulders are usually of local rocks, with some of carboniferous limestone, and a few of cherty rock.

Corwen Gravels (*Probable Origin*).—The deposits described above, in their general mode of occurrence, their arrangement and composition, resemble fluvio-glacial accumulations rather than those of an ordinary river. They appear to have been formed during the retreating stages of the Dee valley glacier as marginal and terminal gravels that choked the valley, through which the glacial waters swung from side to side in many interosculating channels.

The general direction of glaciation at the height of the Ice Age, as shown by striæ in the neighbourhood, was from W.S.W. to E.N.E. or S.W. to N.E., with local variations in direction due to the topography of the lower ground. The Corwen amphitheatre, formed by the confluence of the Dee valley with several tributary valleys, was filled at a later stage in the glaciation with a mass of ice from which tongues were thrust out eastwards down the Dee valley, north-eastward up the Morwynion (Bala Fault) valley in the direction of Bryn Eglwys, and northward past Gwyddelwern over a low col into the Clwyd valley near Derwen. A prolonged halt or very slow melting and retreat of the ice in the Corwen amphitheatre favoured the accumulation of a broad outwash fan covering an area of over two square miles, the drainage escaping by the Dee valley.

The Gwyddelwern Valley.—The deep trench-like valley, two miles in length, crossing the watershed between the Dee and the Clwyd north of Gwyddelwern, and now traversed by the Corwen-Ruthin railway, is at first sight suggestive of a gorge cut by overflow waters from a glacial lake impounded in the amphitheatre to the south. However, no water carrying much gravel seems to have entered the Clwyd valley; and since the valley bottom now forms a water-parting covered by boulder-clay, and the western side is a natural escarpment capped by Wenlock Grit, it is more probable that the valley is a natural pre-glacial feature[1] accentuated by the scour of the lower layers of ice moving into the Clwyd valley, and at the time we are considering it was filled by a stagnant melting mass of ice cut off from its base on the south. Had it been used as a channel for overflow water, the boulder-clay at least would have been cleared out and there should have been a steady descent of the floor from Gwyddelwern to the Clwyd valley. The floor, on the contrary, rises north of Gwyddelwern to a mile-long stretch at above 600 feet O.D. before it descends to about 550 feet in the Clwyd valley.

[1] In pre-Glacial days a south-flowing tributary of the Dee must have risen in this valley and have made a near approach to capturing the head-waters of the Clwyd.

Source of Coal in the Gravels.—The occurrence of coal débris in the gravel varying in size from large lumps to fine dust, is a point of great interest. Mackintosh records it (i) in a roadside section immediately east of the Carboniferous Limestone Quarry (Hafod-y-calch) about a mile and a half west of Corwen; (ii) in a railway-cutting some distance east of Corwen and not far from Carrog Station; (iii) north of Corwen, near to where the Ruthin railway crosses the River Dee—this was the principal locality. He was also assured that coal could be found at many other places around Corwen.

After diligent search the author failed to find any coal, probably because of the overgrown state of the cuttings, but residents in the neighbourhood stated that coal had been found in the gravels.

Mackintosh rejected the hypothesis that there might be a concealed outcrop of coal-bearing beds in the neighbourhood, and suggested that the coal was drifted some twenty miles up the winding Dee valley from the neighbourhood of Cefn or Ruabon, during an interglacial submergence. This idea of submergence cannot be maintained.

The coal might have been derived from three possible sources: (1) from the Vale of Clwyd; (2) from the Ruabon district; (3) from a local outcrop.

1. This direction of transport may be dismissed forthwith. South of St. Asaph the movement of ice was from S.W. to N.E., and all waters due to melting ice flowed northward.

2. Any movement of coal from Ruabon must have been against the general direction of glaciation, and must have been caused by ice-bergs or water moving up the Dee valley, and escaping in a south-westerly direction, owing to a huge ice-dam (Irish Sea Ice) across the Dee valley below Llangollen. There is no evidence for this as far as I am aware, nor has it been suggested by my late colleague, Mr. L. J. Wills. The boulders in the Corwen gravels include no rocks from the Irish Sea basin.

3. Thus we are thrown back upon the theory rejected by Mackintosh, namely, that the "very-little-waterworn" fragments of coal could only have come from some now-buried or completely destroyed outcrop in the vicinity.

If we imagine that the Carboniferous Limestone at Hafod-y-calch near Corwen was formerly succeeded by "Millstone Grit" (Cefn-y-fedw Sandstone) and a considerable thickness of normal Coal-measures, it may be difficult to believe that there is a local outlier of the latter that has escaped detection north of the Bala Fault; but when we remember that in the Vale of Clwyd the so-called Millstone Grit is wanting and the Coal-measures are represented by thin purple shales and sandstones[2] with occasional thin coal-seams (one of which had shafts sunk along it) resting upon the highest beds of the Carboniferous Limestone, belief in the occurrence of Coal-measures near Corwen, which is only slightly farther west, is strengthened. In the quarries at Hafod-y-calch

[1] *The Geology of the Neighbourhood of Flint, Mold, and Ruthin* (Mem. Geol. Surv.), 1890, pp. 10–16.

the higher beds of Limestone dip north-eastward at 45° beneath the alluvium of the River Alwen. We may, therefore, be justified in assuming on stratigraphical grounds, and on the evidence of the gravels themselves, that the coal in the latter may have been derived from some portion of an outcrop that was demolished by glacial action. The erosion may have removed the stratum entirely if it were quite a small wedge between the limestone and a branch of the main Bala Fault concealed by the alluvium on the northern side of the outcrop. Our experience shows that such little wedges of rock, clipped in at the junction of important faults like that which traverses the Dee valley from Corwen to Llangollen and the Bala Fault, are the rule rather than the exception.

The shales and sandstones in such an outlier might have yielded some of the material of the finer silts and loams and sandy patches in the late-glacial beds. Whether the sandstones were purple might depend upon whether they were overlain by any Triassic Sand like that which succeeds the purple sandstone in the Vale of Clwyd. No boulders of purple sandstone have been found (it is very friable material), yet the patches of brick-red Triassic-like sand, mentioned above as being found in the drift, are distinctly suggestive.

How far the Trias overspread the Carboniferous rocks in this area is not known, but it is fairly certain on other evidence that the Bala and other large structural faults were in action both before and after the deposition of the Trias.

IV.—Notes on Yunnan Cystidea. III. *Sinocystis* compared with similar Genera.

By F. A. Bather, D.Sc., F.R.S.

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B.—Comparison with *Megacystis* (*continued*).

4. *The Thecal Openings.*

b. The Periproct.

In *Megacystis* the periproct—which S. A. Miller always called the mouth—lies between adoral circlets II and III, being bounded by the two posterior facet-bearing plates and the posterior interradial, i.e. 3 of Adorals II, also by 2 or 3 of Adorals III, making 5 or 6 plates in all. The number 5 is the more usual; it occurs in *M. aspera*, *faberi*, *gorbyi*, *indianensis*, *ornatissima*, *ornata*, *parvula*, *parva*, *perlonga*, *plena*, *scitulus*, and *spangleri*, also in British Museum specimens E 7631, —33, —35, —37, —38, ?—39, —40, —42, —44, —45, —74, —76, —77, E 16167, and E 16168 (see our figs. 24, 25, *antea*). The number 6, due to an additional Adoral III, is found in *M. baculus*, *commoda*, *splendens*, and perhaps *gyrinus*, also in E 7630, —34, —36, ?—75, and E 16171 (see our figs. 22, 23, 28, 30, *antea*). This does not seem to be a difference of such constancy as to be relied on for the discrimination of species. It is the sole character distinguishing Miller's *M. commoda* from his *M. gorbyi*, not to mention *M. scitulus* and *M. parva*, which may be younger stages of the latter species. Similarly such specimens as E 7631, E 7635, E 7638, and E 7644, each with 5 plates, cannot otherwise be distinguished from E 7636 with 6 plates; while E 7630 and E 7634 with 6 plates are otherwise the same as E 7633, E 7640, E 7642, E 7677, and E 16168, each with 5 plates.

There are a few exceptions to the preceding general statements. S. A. Miller (1879) regarded the additional plate in *M. baculus* as an Adoral IV rather than III, but, since his figure lends no particular support to this view, the species has been included in the above list. In *M. gyrinus* (fig. 30) it does seem probable that an Adoral IV enters into the periproctal frame, but it is obscured. In *M. sphæroidalis* (fig 27) there are at least two additional plates in the Ad. III series; indeed the drawing shows three, but the small triangular plate is possibly a corner separated by a crack. Thus the periproct is surrounded by 7 or 8 plates; but this extra number is correlated with the spheroidal shape of the theca rather than with any structural peculiarity in the periproct.

There may also be a reduction in the number of plates. The specimen figured by R. R. Rowley (1903) as "*Holocystites papulosus*?" shows the posterior Adoral II descending on each side of the periproct so as to meet the two Adorals III and to exclude the facetted plates from the periproct, which therefore is surrounded by only three plates. By a similar downgrowth in *M. subovata* the right posterior facetted plate is excluded from the periproctal frame, which here consists of four plates. This is an exaggeration of a tendency which this species shares with *M. ornatissima* (fig. 25) and *M. papulosa*, and which results in an obliquely elliptical periproct with its long axis passing from the left facetted plate to the right of the two Adorals III. In the otherwise similar *M. aspera* this tendency is not manifest, so that the long axis of the periproct is horizontal.

The numerical reduction discussed in the preceding paragraph is due to elimination of a plate or plates from the periproctal frame. Specimen E 7632 presents a reduction to four plates owing to the presence of only one Ad. III in the frame; and this one, being a large plate, may be taken to represent the usual two, whether there has been fusion or no. In other respects this specimen resembles E 7631 and E 7635, and the reduction can only be regarded as a meristic individual variation.

Other exceptions to the general statement are caused by modifications in the posterior interradius of circlet Ad. II. Thus, in E 7639 the left facetted plate is excluded from the periproctal frame by the intercalation of a plate between it and the posterior Ad. II, so that there are 9 Ad. II instead of 8; correlated with this is an extra plate in circlet Ad. I, apparently cut off from the left posterior Ad. I. This intercalation of plates is, oddly enough, not accompanied by an additional Ad. III, so that the number of plates surrounding the periproct is still 5. In E 7675, a somewhat similar intercalation of an Ad. I and an Ad. II only just eliminates the left posterior facetted plate from the periproctal frame, and is accompanied by an additional Ad. III, so that there are 6 plates in the frame and only just escape being 7; in this specimen, however, the three posterior Ad. III are relatively much narrower than in the more swollen or spheroidal E 7639. In these cases the additional Ad. II seems to be due to nothing more than the development of a suture separating the prolongation of the left posterior facetted plate from the body of the plate, for the sake of greater flexibility; in harmony with this the adjacent Ad. I also becomes longitudinally divided, but its suture in both specimens is a very close one and not easy to see.

In no specimen of *Megacystis* recorded or known to me are the anal valves (or periproctals) preserved. The usually rectilinear outline of the opening, with its slightly rebated sides, denotes that the periproctals were, as in *Sinocystis*, triangular plates. Their number may be inferred from the number of sides possessed by the periproct. This is not necessarily or invariably the same as the number of bounding plates. Occasionally the sides of the periproct, and consequently the periproctals, do approximately correspond with the margins of the bounding plates in both position and number, e.g. E 7634, and Miller's figures of *M. parva* and *M. scitulus*, his fig. 6 of *M. commoda* (*not* the figure copied *antea* fig. 23), and less closely his figure of *M. gorbyi*. Frequently the sides correspond with the plates in number but not in position, and in this case the angle at which two sides meet lies not at the suture between two bounding plates but at some distance from it, so that the free margin of the dlate is notched. This notching may affect one or more or even all plates; thus E 7640 and E 16168 have each 5 sides and 5 bounding plates, and all the latter are notched. Usually, however, the correspondence is fairly exact with Adorals II; it is the Adorals III that tend to be notched. When the numbers correspond the notching may be confined to the left-hand Ad. III (e.g. E 7642, E 7645, E 7677); when there are 6 sides and 5 plates, the notching extends usually to the right-hand Ad. III (e.g. E 7638, E 16167) or it may instead affect the left Ad. II (as in E 7637). In the cases (probably rare) when 6 plates surround a 5-sided opening, the median Ad. III has a conspicuous median notch (e.g. E 7636). Sometimes it is impossible to identify any precise number of sides, since all angles seem rounded off so as to produce a circular or elliptical opening. This is particularly noticeable in the *M. ornatissma* series (see p. 257) and in *M. sphæroidalis*. Possibly in such forms the triangular periproctals were separated from the periproct margin by a flexible finely-plated membrane. In *M. aspera* and in the specimen described by Rowley as "*Holocystites papulosus*?" (see p. 257) the periproct has a quadrangular outline and may have been closed by four valves.

The preceding facts show that, though there were certain tendencies in the several groups of species, still there was no fixity. Neither the number of the periproctals nor that of the sides of the periproct can be regarded as a specific character. Possibly the sides of the periproct may originally have corresponded with the margins of the bounding plates, and this correspondence is usually retained in the adoral half of the periproct; but the variability in the third adoral circlet may have conflicted with the persistent conditions in the second circlet, and so induced shiftings or numerical changes in the opening between them. In *Sinocystis* the number of the periproctals was more fixed, being six in *S. loczyi* and *S. yunnanensis*, five in *S. mansuyi* (*antea*, 1918, p. 511). A rough correspondence with the bounding plates is shown in Reed's pl. i, fig. 3, but the available evidence is not enough to warrant any general statement. The greater irregularity and variability of the thecal plates in *Sinocystis*, as well as the absence of any connexion between the periproct and the relatively fixed Adorals II, suggest that the constitution of the theca had here little influence on the periproctals. The preservation of the periproctals in the fossils of *Sinocystis* indicates that they were more solid, or more firmly united to the frame than in *Megacystis*. Therefore, in *Sinocystis* the number of the periproctals dominates the bounding plates, whereas in *Megacystis* it is more affected by them. To some extent the periproctals and the bounding plates form two systems, each subject to its own hereditary and environmental influences, and therefore liable to be brought into conflict.

c. The Hydropore and Gonopore.

When the various openings in *Megacystis* were discussed by P. H. Carpenter in 1891 (J. Linn. Soc., Zool., xxiv, pp. 48–50), on the basis of Miller's figures, he recognized all four openings in *M. commoda*, though in general he regarded the openings as confined to peristome, periproct, and "nephridial opening" [=hydropore], and in some cases (e.g. *M. elegans*) to the two former alone. His view was that the periproct served as an osculum, embracing the gonopore as a rule and in some cases the hydropore as well.

Jaekel (1899) did not specifically mention or figure the hydropore and gonopore in his *Trematocystis*, but, since he regarded the presence of both those openings as characteristic of the Aristocystidæ, he must at any rate have assumed their presence in *Trematocystis*.

Miller's figures and descriptions are rather insecure evidence, and there are reasons for believing that the opening observed in a number of species cited by Carpenter, and regarded by him as "excretory" or "nephridial" and "equivalent to the fourth opening of *Aristocystis* and *Glyptosphæra*", i.e. what we now take as the hydropore, is really the gonopore, and that the hydropore, though present, was not observed. The reasons for this belief are first a morphological argument, secondly comparison with other genera, thirdly actual observation of the British Museum material.

The morphological argument depends on a structural feature to which attention has not, it seems, previously been directed. This is the tendency in so many of these primitive echinoderms for the hydropore to be a slit crossing the suture between two plates. So it is in *Edrioaster* (Bather, Studies in Edrioasteroidea, Geol. Mag. 1914, p. 168, pl. xi, fig. 2), *Aristocystis* (Barrande, 1887, Syst. Silur., vol. vii, pl. ix, figs. 2, 3, 6, 13; Bather, 1906, Palæont. Indica, II, 3, p. 9.), *Sinocystis* (*antea*, 1918, p. 535), *Pleurocystis* (Jaekel, 1899, Stammesges. d. Pelmatozoen, pp. 101, 138), *Schizocystis*

(Bather, 1900, Treatise, p. 61, fig. xxv), *Cryptocrinus* (*op. cit.*, p. 70, fig. xxvii, 2, after Jaekel), and other genera.

The gonopore, on the other hand, is a simple hole, as often as not through the middle of a plate. It further differs from the hydropore in being frequently (perhaps normally) closed by valves, and these, as in the case of the periproct, give it a rectilinear—often pentagonal—outline. It is so small itself, and its valves are so minute, that the structure often cannot be made out, even if the pore itself be not obscured by the processes of petrifaction.

It seems probable that both hydropore and gonopore originally emerged between thecal plates, and that they were subsequently surrounded by the plate-stereom in the same way as the podia of echinoids have become surrounded by the ambulacral plates between which they originally passed. The gonopore of the Cystidea, being the outlet of a single gland, has remained a simple pore and has been wholly occluded by a single plate. It is not so easy to see why the hydropore should affect two plates. The curious bilateral folding of the stone-canal in Asteroidea and the alleged occasional paired hydropore of the embryo might suggest that here was a relic of the bilaterally symmetrical Dipleurula. On the other hand, the obliquity of the hydropore-passage in *Edrioaster* and elsewhere shows how two plates may be involved without any suggestion of duplicity. The essential difference between hydropore and gonopore seems to be the conversion of the former into a filter through the formation of numerous minute pores connected by a ciliated channel on the exterior. This channel extended from the original opening in both directions. For the present this must be taken as a fact, but we have still to explain the direction followed and its frequent regular curvature. In later forms these primitive features were obscured by the excessive folding that produced the characteristic madreporite.

If the preceding statements be accepted, we are provided with a touchstone enabling us in most cases to decide which of two visible openings is the hydropore, which the gonopore, or, in the case of only one visible opening, to say which of the two it is. For example, in *Cheirocrinus constrictus* Bather (1913, Trans. R. Soc. Edin., XLIX, ii, p. 445, fig. 51), the "extended pore" that crosses "the curved suture" is probably the hydropore, and the "poriferous elevation at the other end of the plate" is probably the gonopore; the converse interpretation was tentatively suggested in the memoir. In the "Treatise on Zoology" some openings are perhaps lettered wrongly: in *Echinosphaera*, p. 53, fig. xiv, and *Sphaeronis*, p. 72, fig. xxxviii, the tri-valved opening marked M, and in *Protocrinus*, p. 75, fig. xlv, 1, the pore through the plate marked M, should all be the gonopore. The test will be applied to *Megacystis* later.

In comparing *Megacystis* with other genera, Carpenter went on the belief that there was no hydropore or gonopore at all in *Agelacrinus*, the Caryocrinidae, and *Malocystis*, and no separate gonopore in seven other genera that he mentions. Therefore he was ready to admit similar conditions in *Megacystis*. Since then we have learned that there is a hydropore in the Edrioasteroidea (S. R.

Williams has just claimed to have detected it in *Agelacrinus* itself), the Caryocrinidae, and *Malocystis*; also that there is a gonopore, probably or certainly with a hydropore also, in *Caryocystis*, *Cryptocrinus*, *Cheirocrinus*, *Orocystis*, *Sphaeronis*, and *Sphaerocystis* (here Schuchert, 1904, calls it the hydropore, although he acknowledges another opening as "madreporite"). In a word, it is no longer safe to ascribe the apparent absence of these openings from any cystid to anything but our ignorance and the extreme difficulty of dispelling it. Thus the argument from other genera, so far from supporting the views of Carpenter, points to the presence of both gonopore and hydropore in all species of *Megacystis*.

Lastly we come to the evidence of the British Museum specimens. These, even when they are closely similar in all other respects, do, it is true, present some interesting variations in the shape and distribution of these openings, but both openings can nearly always be detected.

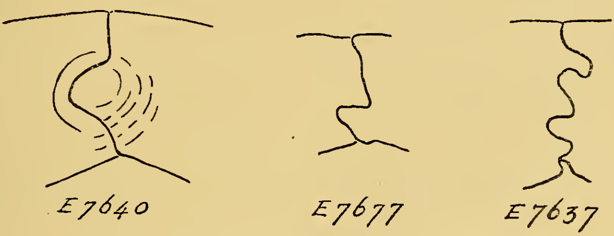

FIG. 31.—Hydropore-sutures in *Megacystis*.

These all occur in specimens of *M. gorbyi* character, and show the replacement of the hydropore-slit by a sinuous suture between the posterior Adorals I. × 10 diam.

The Hydropore is plainly seen in ten specimens, and faintly suggested in about six more. In the remainder it has been obscured by crushing or by encrusting organisms, or the plates are absent. Normally it appears as a narrow groove or a dark line, indicating a slit, crossing the suture beween the two posterior Adorals I at right angles, just outside the peristome rim. In E 16168, identified as *H. scitulus* by S. A. Miller, the length of the slit is 1·2 mm., and this seems to be above the average. In E 7638 the slit seems to be continued on the right into a sinuous suture, which reaches the right posterior facetted plate and so bisects the right posterior Ad I. Sometimes the slit is on an eminence, as in E 7633, ? E 7635, E 7642. All these specimens are, like *M. scitulus*, of *M. gorbyi* character. In E 7673, a strongly pustulate form, the position of the hydropore seems indicated by a rather irregular rim (*antea*, fig. 29).

In a few of the specimens where the hydropore is less plain, the existence of some such structure is suggested by a remarkable sinuosity of the suture (fig. 31). In E 7636, a dark spot indicates the actual pore, and the suture just here makes a slight bend. In E 7644 the suture is sharply bent where it crosses the hydropore-slit. In E 7640 no opening can be detected, but in the middle of its course the suture takes a sharp semicircular curve to the left, and all this tract forms a gentle eminence. In E 7677, there is a similar sharp, but less regular, curve to the left at the aboral end of the suture, and the rest of the suture is waved; there is no obvious eminence. In E 7637 there are three sharp curves to the left and three to the right, beginning with a small one at the aboral end on the left and increasing in swing towards the oral end; although there is no trace of a pore or of an eminence, it cannot be doubted that this exaggerated sinuosity does in some way represent the foldings of the hydropore.

The variations here described bear little or no relation to differences that might be taken as specific. They show how easily one may overlook the indication of a hydropore, especially when it is merely a passage between two plates; and they warrant the conclusion that a hydropore is present in all species of *Megacystis*, though previously recorded only in *M. commoda*, *M. gyrinus*, and *M. hammelli*.

The Gonopore appears in one of two distinct places. In eleven specimens out of the eighteen in which it is visible it pierces the posterior Ad. II (*antea*, figs. 24, 26). It may be near the centre or in either the adoral or aboral half of the plate, but always lies to the left of the median line (E 7631,—32,—35,—36,—38,—41, —44,—73,—74,—75). In E 7639, where there are abnormally two posterior Ad. II, the gonopore is on the left-hand one. In the remaining seven specimens the gonopore is on the right slope of the left posterior facet-boss, sometimes very close to the brachial facet itself, e.g. ·7 mm. distant in E 7634, E 7640, ·6 mm. in E 16168, ·5 mm. in E 7630, ·4 mm. in E 7677, and ·3 mm. in E 7633 (*antea*, fig. 22). This position is more than a mere crossing over the suture between the facet-bearing plate and the interradial. Only in E 7642 is the opening as near to that suture as it is to the facet, the respective distances being each 1·3 mm.; in this particular case the left posterior facet is curiously widened in the direction of the gonopore, as though stretching out to meet it. Remembering that in the Crinoidea the genital strand passes into the arms, some may see here the beginning of a similar relation. The brachia of a crinoid, however, are outgrowths of the theca and contain extensions of the body-cavity; in this they differ fundamentally from the brachioles of a cystid, which are purely epithecal structures, and contain, so far as one can see, no such extensions. Carpenter (1891, p. 49) drew attention to a somewhat similar variation in two of Barrande's examples of *Aristocystis bohemica*: "In one of them the distal opening, which I regard as genital, is on the very edge of the anal aperture, while in the other it is nearly halfway up towards the peristome"; it remains, however, on a plate distinct from that connected with the brachiole.

From Miller's descriptions or figures it is inferred that the gonopore is on the posterior Adoral II in nine species, viz., *M. baculus*, *commoda*, *faberi*, *hammelli*, *ornata*, *parvula*, *rotunda*, *scitulus*, and *splendens* (*antea*, figs. 23, 28); near the left posterior facet in four species, viz., *M. gyrinus* (fig. 30), *plena*, *pustulosa*, and *subglobosa*. It has not been recognized in any other of the described species. These numbers, as well as those drawn from the British Museum specimens, suggest that the position on post. Ad. II was the more usual. Since either position is found in specimens otherwise identical, the character cannot well be taken as diagnostic of species. Neither does there seem any convincing reason for regarding it as a secondary sexual character.

When clearly seen, the gonopore has a pentagonal outline, indicating that it was closed by five valves. In E 7632 it has a slightly raised rim which appears toothed, perhaps owing to the preservation of portions of the valves. In E 7636, the opening is hexagonal. When the pore pierces post. Ad. II, it is generally flush or on a very slight eminence; the latter feature is seen in E 7631 (*antea*, fig. 24). When the pore is near the facet, it is always on a rounded eminence, which in E 7630 and E 7634 is so pronounced as to simulate the root of a young pelmatozoön.

In two of the specimens the gonopore seems to be double. In E 7630 (fig. 22), where it is on an eminence near the facet, there is close beside it another smaller eminence with a pore. In E 7635, where it is on the left side of post. Ad. II, the appearance is rather obscure, but there certainly seems to be a smaller opening to the right of the main pore, and barely separated from it.

As compared with *Sinocystis*, the position of the gonopore is here slightly more definite, and in all cases is well above the periproct (not on a level with it) and nearer to the subvective system.

(*To be continued.*)

REVIEWS.

I.—Military Geology and Topography. Prepared and issued under the auspices of the National Research Council, Division of Geology and Geography. Edited by Herbert E. Gregory, Ph.D. pp. xv + 280. New York: Yale University Press. London: Oxford University Press. Price 5*s*. 6*d*. net.

THIS book was specially prepared in response to many requests for guidance in the presentation of courses, required by the Committee on Education and Special Training of the War Department, for the training of officers for the new American Army.

The list of collaborators in its preparation is a long and distinguished one, including thirteen University professors and lecturers and several well-known officers of the Geological Survey of the United States.

A modest statement appears in the preface: "The book is the result of a preliminary effort, and its authors hope that it will be a nucleus about which will gather material for a more complete volume."

The fact that the American War Department recommended that officers should be taught geology and geography is worthy of attention. When the entry of America into the War was decided upon, American officers visited the Western Front to study conditions and methods in order to profit by the knowledge gained for the training of their new Army. They were at once struck by the great increase, as compared with former wars, in the numbers and varieties of maps and also by the far greater employment of mining. At one period the Western Front was to all intents and purposes in the hands of the mining engineers of both sides, mine and countermine determining the success of costly local operations. It was therefore natural to assume that the study of mining would form a greater part of the education of the military engineer of the future than it had done in the past. The study of mining is closely linked with that of geology. Again, it was found that geological experts were attached to the headquarters of the Armies, the most highly organized branch being found in the German Army. There were also special branches of the engineering staff dealing exclusively with water supply. The authors had, therefore, a wide field to cover, and by the nature of the case were compelled to be very concise. They have acquitted themselves very well, for the book contains just as much geology and topography as the military engineer—that jack of all trades—need know, clearly and attractively presented.

The subject first studied is that of rocks and other earth materials. The scheme adopted is to describe the rock and give an account of its occurrence, then to note its practical utility, as for example in the preparation of concrete. Rock weathering is then shortly described as its direct bearing on military work is only slight. Next streams, lakes, and swamps are considered, and examples, from the War and history, of their influence on military campaigns are frequently inserted.

The study of water supply is gone into pretty thoroughly, occupying fifty-two pages. This attention is indeed merited, good and plentiful water being most important to the health and comfort of troops in any campaign. Theory and practice are skilfully intermingled.

The chapter on land forms, in which field of study American geologists lead the way, enables the reader to appreciate the forms characteristic of the different kinds of rocks.

The portion of the book devoted to map-reading and interpretation is not quite so good as our own Army handbook on the subject, except that the interpretation is treated from the geological point of view. It is also interesting to note that the authors make no attempt to explain geological map-reading; probably they consider this should be left to the expert.

The last chapter deals with the economic relations and military uses of minerals.

Throughout the text numerous references to more advanced works by American authors are given. The book is clearly printed, profusely illustrated with excellent photographs and diagrams, and is reasonable in price.

In spite of the fact that the book was written for the special purpose of training officers for the War just concluded it would be of great value to officers, particularly to those of the Royal Engineers, as the essentials of their requirements of geology and topography are collected together under one cover. B. Lightfoot.

II.—The Origin of Serpentine: a Historical and Comparative Study. By W. N. Benson. Amer. Journ. Sci., vol. xlvi, pp. 693–731, 1918.

FOR some years past Professor Benson has made a comprehensive study of serpentine rocks, arising from his work on the Great Serpentine Belt of New South Wales. He has had the advantage of working at Cambridge, with the advice and assistance of Professor Bonney, and has also visited many European localities and consulted some of the leading Continental authorities and examined their material. The results of his investigations are brought together in this valuable paper, which begins with a short but clear account of the historical development of the views of the leading petrologists on the genesis of serpentine. Starting from the now universally accepted view that serpentine rocks are altered deep-seated peridotites, consisting mainly of olivine and pyroxene, the author shows that in many cases, at any rate, the process of serpentinization is essentially of a pneumatolytic nature, analogous to a certain extent to the formation of greisen, water and carbon dioxide being the chief agents concerned; coarse-textured veins of serpentine and olivine occasionally found in such rocks show some resemblance to granitic pegmatites. Serpentine with mesh-structure (chrysotile) is usually found in undisturbed regions, while antigorite is specially characteristic of high pressure; the latter is sometimes formed by dynamic metamorphism of the former. It appears that although serpentinization is usually due to the pneumatolytic action of the residues of the same magma that gave rise to the original peridotite intrusion, nevertheless there have often been several intervening intrusions of differentiates from this magma, ranging even to acidic composition, hence the process of serpentinization may appear to be due to a granitic intrusion; however, geologically speaking, the interval is short and the alteration is completed before the end of the same orogenic and eruptive phase. It is also considered possible that in certain cases a peridotite which has escaped hydration by its own magmatic waters may subsequently be changed to serpentine by the action of deeply circulating epigene waters. At any rate, it is clear from the facts stated by Professor Benson that it is no longer permissible, as has been done by many writers, including the present reviewer, to consider serpentinization as an effect of weathering now in general operation near the earth's surface; it must for the future be relegated to the category of deep-seated late-magmatic phenomena, which for want of a better name are generally classified under that blessed word "pneumatolytic".

R. H. R.

III.—Bidrag til Finmarkens Geologi. By O. Holtedahl. Norges Geol. Undersök, No. 84, with English Summary, pp. 314, with 21 plates and 2 coloured maps. Kristiania, 1918.

AS the result of careful field-work extending over nearly six months in the years 1914–17, the author shows that Dahll's classification of the rock-systems of the extreme north of Norway cannot be maintained; his Gaisa system in particular includes a large number of rocks of different ages.

The oldest rocks in the south of the district are of pre-Cambrian age, comprising hornblende schists, quartzites, and crystalline magnesian limestones; towards the west, in Jori, is a region of less advanced metamorphism with slates, dolomites, and volcanic rocks resembling those of the Kiruna district in Sweden, while east of the River Tana the country is mainly composed of gneisses and granites; both of these types are probably younger than the schists of the south.

The oldest Palæozoic zone in Finmarken resting on a peneplain of erosion is a shale with *Platysolenites antiquissimus*, a fossil found in many places in the Lower Cambrian of Scandinavia and the Baltic region; this is supposed to be part of a Cystidean. This zone is clearly a continuation of the *Hyolithus* zones of Sweden and Norway. Above this comes the very thick Porsanger Sandstone with shales and dolomite, the latter enclosing laminated structures called by the author stromatolites and referred by him to chemical precipitation possibly brought about by algæ. These structures and the silicified layers in the dolomite strongly recall the characters of the Durness Limestone, and the series is assigned to an Ozarkian–Canadian age. Unconformably above the Porsanger Sandstone comes a younger series with conglomerates and tillites, formerly included in the Gaisa Series; the tillites of the Varanger Fjord were well described by Sir A. Strahan in the Quarterly Journal for 1897. The author concludes on what appears to be good evidence that these deposits are of Ordovician or possibly Silurian age.

All these rocks are again overlain in the Alten division of the district by the mylonitic rocks of the Caledonian thrust zone. It was formerly believed that these overthrust rocks were of pre-Cambrian age, but there is no evidence to support this view, and it is concluded that they are simply highly metamorphosed representatives of the unaltered Palæozoic rocks below the thrust. The resemblance to the general succession as seen in the North-West Highlands is obvious, and this memoir is of great interest on account of its bearing on the problems of British stratigraphy.

IV.—Falklandia. By J. M. Clarke. Proc. National Academy of Science of U.S.A., vol. v, No. iv, pp. 102–3, April, 1919.

IN the valuable monograph published in 1913 by the Geological Survey of Brazil (Fosseis Devonianos do Paraná), Dr. J. M. Clarke included a discussion on the palæogeography of the austral lands in Devonian times. He pointed out that the extent of the Southern Devonian shore faunas indicated the union of Gondwana-land and Antarctis during Devonian times. The Devonian of these latitudes is a unit both in life and sedimentation. In the present short paper Dr. Clarke proposes the name "Falklandia" for the "continental land which, during the Devonian period in the occidental parts of the Southern Hemisphere, preceded Gondwana-land and Antarctis". It is considered that other names, such as Frech's "South Atlantic Island", which have been suggested for the Pre-Gondwana austral lands, have been founded on insufficient evidence.

V.—The Tin Field of North Dundas (Tasmania). By H. Conder. Geol. Surv. Bull. No. 26. 96 pp. and 4 maps. Hobart, 1918.

THIS area consists of a region of slates, sandstones, grits, and conglomerates, with volcanic tuffs, their early Palæozoic age being proved by the discovery of some badly preserved graptolites. The mineralization appears to be due to the intrusion of a granite magma of Devonian age, which gave rise first to porphyroids, then to the main acid mass with a basic marginal facies: certain masses of diabase may be of much later date. The metalliferous deposits belong to several different types, as follows: quartz-tourmaline lodes, quartz lodes, pyritic and pyrrhotitic lodes, and dolomitic lodes, with other less well-defined types. The chief minerals are ores of tin, lead, zinc, and silver, together with pyrite and pyrrhotite.

VI.—Fossil Cockroaches.

AMONG Mr. Bolton's energetic efforts to seek out all the Carboniferous Cockroaches, we note the Manchester Museum publication, No. 80, describes those specimens obtained by Mark Stirrup from Charles Brongniart. These came from Commentry and are now in the Manchester Museum. Among them is a fine dragon-fly, *Megagnatha odonatiformis*. To these forms have lately been added a series from the Pennsylvanian of the United States, described and figured by Cockerell in the Proc. U.S. Nat. Mus., liv, 1918. Eight in number, they comprise two new genera, *Cobaloblatta* and *Ptilomylacris*.

VII.—Annual Report of the Director of the Geophysical Laboratory, Washington, for the year 1918.

THE publication under review is the last of a series of Annual Reports which we owe to Arthur L. Day as Director of the Geophysical Laboratory of the Carnegie Institution. It must be a source of great gratification to Day to realize the high position which the Geophysical Laboratory has won for itself in scientific regard in the course of a comparatively few years.

The present Annual Report leaves untold the story of the year's progress achieved in the laboratory, for nothing but war work has been attempted. It gives, however, a most valuable résumé of papers written by members of the staff and published in various American scientific journals. These papers, it is explained, are for the most part records of researches in progress at the time of the entry of the United States into the War.

The summary thus afforded exactly meets the requirements of geologists the world over. It is an easy matter to turn from it to the journal containing the particular paper to which more detailed reference seems desirable. It is to be hoped on this account that the Annual Reports have a wide circulation.

Thirty-three papers in all are considered. Several are concerned with laboratory technique. A few, again, relate to matters of predominantly physical or chemical interest, as, for instance, the Planck radiation law, the place of manganese in the Periodic Table judged by the colour of its chemical compounds and the high-temperature specific heats of platinum, silica, and the alkali felspars.

Three papers deal with glass. One of them, by N. L. Bowen, is entitled "The significance of Glass-making to the Petrologist". The summary given is as follows:—

Contrary to certain claims that have been made, glass-making processes offer no support to the belief in liquid immiscibility among silicates, nor to the belief in a significant density stratification in a mass wholly liquid. They do, however, suggest the importance of gravity acting on a mass partly solid and partly liquid, and emphasize two stages: (1) that at which there is much liquid and little solid, and (2) that at which there is little liquid and much solid. In magmas these two stages are probably those during which the most significant results in the way of differentiation are accomplished.

Bowen's paper is a valuable contribution to a difficult subject. Field experience, especially in Mull, has led the present reviewer to favour the opinion that gabbro and granophyre are sometimes immiscible for a short range of temperature before crystallization sets in in earnest. Evidence pointing in this direction is often wanting even in the field, and under certain experimental conditions it might well be absent, owing, for instance, to such complications as metastable miscibility.

Various other papers treat the side of petrological inquiry that receives its inspiration from the writings of Willard Gibbs. Thus, G. A. Rankin and H. E. Merwin illustrate the temperature-concentration relations of the various crystalline phases in equilibrium with liquid in the ternary system $MgO - Al_2O_3 - SiO_2$. Arising from this we find a reinvestigation of the melting points and stability relations of cristobalite and tridymite, carried out by John B. Ferguson and H. E. Merwin. Cristobalite is confirmed in its claim to be the high-temperature form of silica.

Ferguson also gives an account of the equilibrium relations of the volcanic gases CO_2, CO, SO_2, and S_2.

Henry S. Washington has quite a number of papers to his credit. Three refer to Italy, and include a consideration of the leucitic lavas as a potential source of potash. Of his other works may be mentioned a compilation and discussion of chemical analyses of igneous rocks, 1884 to 1913, and a new edition of his *Manual of the Chemical Analysis of Rocks*. He also gives an account of a method of calculating from chemical analyses of clays the mineral composition "generally quartz, felspar, and kaolin". No novel principle is involved, but the procedure is recommended as "of great simplicity and accuracy".

E. B. Bailey.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

May 21, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Silurian Rocks of May Hill." By Charles Irving Gardiner, M.A., F.G.S. With an appendix by Frederick Richard Cowper Reed, Sc.D., F.G.S.

The district of May Hill comprises a small area of ashy grits, which Dr. Callaway in 1900 considered to be of Pre-Cambrian age. The evidence now available does not seem to warrant any definite opinion as regards the age of these beds. Llandovery sandstones are extensively developed, and are of Upper Llandovery age. They consist of a lower division of coarse sandstones and conglomerates, and an upper one of fine sandstones. No beds of Tarannon age occur.

The Woolhope Limestone is never thick, and fossils in it are very few. The Wenlock Shales and Limestone show a normal development. The latter is very fossiliferous, and shows coral-masses in the position of growth.

The Ludlow Beds are, in the main, of a brown sandy nature. No Aymestry Limestone is present, and the Ludlow Beds cannot be separated into an upper and a lower division. A bone-bed is seen at the top of the Ludlow Beds by the side of the road near Blaisdon. This was described by H. E. Strickland in 1863, who saw it in the railway-cutting close by.

Downton Sandstone occurs in the north of the district, where it is about 300 feet thick; but it is only some 11 feet thick near Blaisdon on the south. It is conformably overlain by Old Red Sandstone.

The Silurian rocks are arranged in an anticline in the part of the district where May Hill is, but elsewhere show no such arrangement. On the north they are much broken by faults. Near Flaxley, in the extreme south, rocks from the Wenlock Shale to the Old Red Sandstone inclusive are overfolded.

Dr. F. R. C. Reed describes a new species of *Lichas* from the Wenlock Limestone and a new variety of *Calymene papillata*.

2. "The Petrography of the Millstone Grit Series of Yorkshire." By Albert Gilligan, D.Sc., B.Sc., F.G.S.

Since the pioneer work of Sorby on this subject, published in 1859, the clastic deposits of the Carboniferous System have been unaccountably neglected by petrologists. The author has followed the usual methods of investigation, and has collected a large number of pebbles and specimens from widely separated areas which have been examined microscopically. Numerous separations of the heavy minerals have also been made from all types of rock, varying from coarse conglomerates to shales, which occur in the series.

Quartz-pebbles are dominant, and vary much, both in size and in colour. The largest are found in the coarse-grained beds at the bottom and top of the series. They often show double-sphenoid forms suggestive of derivation from mechanically deformed rocks, which inference is shown to be correct by the undulose extinction, the crenulate and mylonized structure seen when sections of them are examined in polarized light.

Blue and opalescent quartz is very common, containing inclusions often of indeterminable character arranged in streams or rows; others contain liquid with movable bubbles, while needles and hair-like inclusions are also usually present. The quartz of the finer material is similar in character, and the inclusions in the grains suggest that it has been originally derived for the greater part from such rocks as gneisses and schists.

Felspar pebbles are abundant in all the coarse beds. They are dominantly microcline or microcline-microperthite, and when broken are found to be perfectly fresh, the lustre of the cleavage-faces being most remarkable. Blebs of quartz are frequently present in these felspars. In many of the rock-sections, grains of microcline and oligoclase, quite fresh and unaltered, are common. Fragments showing the intergrowth of blue or opalescent quartz and microcline are fairly abundant.

Chert pebbles are plentiful in the coarse beds at the base of the series; they are also sporadically distributed throughout the upper beds, and in some of these oolitic structure has been observed. One pebble of silicified oolite shows a microscopic structure strongly resembling a structure found in the Torridon Sandstone. A few fragments containing microscopic organisms have also been obtained.

Mica is not plentiful in the coarser beds, but increases in amount with decrease in grade of the material.

From the Middle Grits of Airedale a remarkable assemblage of pebbles has been obtained, including the following types: gneisses, granites, schists, quartz- and felspar-porphyries, quartzites, grits, sandstones, and mudstones. One of these pebbles has been recognized as the black schist associated with the Blair Athol-a-Nain Limestone of Scotland. Another pebble is doubtfully referred to the rhomb-porphyry of the Christiania region.

The results of the investigations into the heavy mineral contents may be summarized as follows, dividing for this purpose the Millstone Grit Series into three more or less well-defined groups:—

(*a*) Lower Division—Base of the Ingleborough Grit to the base of the Leathley Sandstone.
(*b*) Middle Division—Leathley Sandstone to the base of the Flags below the Rough Rock.
(*c*) Upper Division—Flags and Rough Rock.

The minerals are in decreasing order of relative abundance:—

(*a*) Coarse beds contain garnet, ilmenite and leucoxene, zircon, tourmaline, rutile, monazite and magnetite.
Fine beds contain zircon, rutile, garnet, and tourmaline.
(*b*) Coarse beds contain zircon, rutile, garnet, tourmaline, ilmenite and leucoxene, magnetite and monazite.
Fine beds contain zircon, rutile, tourmaline, and garnet. Some of the separations from the shales of Otley Chevin were almost entirely zircons, only a few grains of other minerals being present.
(*c*) Coarse beds contain garnet, ilmenite and leucoxene, zircon, rutile, tourmaline, monazite and magnetite.
The Flags at the base of the Rough Rock contain zircon, rutile, garnets, and tourmaline.

The monazite has been determined by spectroscopical and chemical tests.

In view of the similar work which is being done among the younger sedimentary rocks, it is important to record that, although the author has not yet discovered staurolite in the Millstone Grit, he has found it to be common in some of the sandstones near the top of the Coal-measures in Yorkshire, namely, Ackworth Rock, Pontefract Rock, and the Red Rock of Rotherham, and also in basement Permian at Conisborough.

In Yorkshire alone, to which area for the greater part the researches have been limited, the Millstone Grit forms the surface of 840 square miles; while, if that which lies beneath the newer rocks and that represented by outliers on the Pennine Fells were taken into account, it must have extended over at least 2,000 square miles. If 1,000 feet be taken as its average thickness, the Yorkshire Millstone Grit would represent a volume of 400 cubic miles, the equivalent of a range of mountains 800 miles long, 1 mile high, and 1 mile wide at the base.

The beds attenuate southwards, and the only possible conclusion from their stratigraphy, reached by Sorby, and later confirmed by Edward Hull and A. H. Green, is that the material was derived from a northern source. The evidence which the author has obtained corroborates this view.

The ancient land-mass of the Midlands must be excluded as a possible source for more than a small fraction of the material, both on account of the inadequacy of the area and on account of its lithological constitution.

The Lake District was probably submerged in Viséan times, and for that reason could not have supplied material to the Millstone Grit. Further, the abundance of monazite in these beds and its absence from the granites of the Lake District, as shown by R. H. Rastall and W. H. Wilcockson, definitely exclude that area. Southern Scotland may have contributed to the homotaxial deposits farther north than Yorkshire, but inadequacy of area is again pointed out.

Thus, by elimination of other areas for one reason or another, the author shows that the most probable source of the material lay still farther north in a land-mass of continental extent, of which Scandinavia and the North of Scotland represent the remaining fragments. In these areas alone can the mineralogical demands of the Millstone Grit be satisfied, and the author institutes a comparison between the Torridon Sandstone and the Millstone Grit, which shows that their similarity of constitution is altogether too great to be merely fortuitous. He infers that, despite their disparity in age, they had a common source in that northern continent.

That continent had probably been base-levelled in pre-Millstone Grit times, and the advent of this period was brought about by renewed uplift rejuvenating the rivers, which removed the old rotted soil-mantle and exposed fresh unleached rock. The extension of the land-mass across the North Atlantic would produce a monsoon type of climate, and the rock-débris broken up under semi-arid conditions, as seems clear from the extreme freshness of the felspars in the grits, would be swept along rapidly by floods to the deltas of the large rivers.

The author concludes by postulating one such large trunk river flowing southwards from the northern continent, and receiving tributaries from what are now Northern Scotland and Scandinavia, debouching somewhere off the north-east coast of England, the deltaic material of which (now consolidated) forms the Millstone Grit.

II.—Geologists' Association.

June 6, 1919.—Mr. J. F. N. Green, B.A., F.G.S., President, in the Chair.

The following paper was read: "Old Age and Extinction in Fossils." By W. D. Lang, Sc.D., F.G.S.

I. A Biological view-point.

The phenomena of old age and extinction must affect our general biological views; and these, in turn, are reflected in our attitude towards these phenomena. Vitalistic (or automatic) and mechanistic (or environmental) views are contrasted, and emphasis laid on the former. An organism has tendencies, or potentialities, towards developing in definite and not in haphazard directions; and these tendencies become actualized during evolution. They are kept in check by inhibiting factors, and on the removal of an inhibition there is an outburst of evolutionary activity; thus evolution is seen to be periodic. Potentialities tend to become exhausted on actualization; but, before this happens, may lead to the exaggeration of a character which, in turn, may cause the extinction of a lineage. Homœomorphy is the expression of common tendencies or potentialities becoming actual along many divergent lineages.

II. This view reflected on to the phenomena of old age and extinction in (*a*) Cretaceous cribrimorph Polyzoa; (*b*) Ammonites; and (*c*) Rugose Corals.

III. The consequences of this view.

A view which ignores, or at least slights, environmental influences is likely to overlook the truth in one direction as far as (so the author believes) a purely environmental or mechanistic view, such as orthodox Darwinism, overlooks it on the other side. As an organism is a synthesis of structure and function, so its structure is a synthesis of expression and impression — expression of potentialities and impression of the environment. A synthesis is not an aggregate, for it transcends the sum of its components. A transcendental theory of evolution would link the field of philosophical biology to the realm of general philosophy.

CORRESPONDENCE.

RECENT PAPERS ON THE DURHAM COALFIELD.

Sir,—In the Geological Magazine of April last (p. 163) I observed a paper by Dr. D. Woolacott relating to the above Coalfield, where he writes of "the little-known Ganister Series" of that district, and I wondered what might be the precise meaning he wished to convey by those words. Three or four coal-seams belonging to that Series (i.e. below the Brockwell Seam) have been vigorously worked for the past thirty years or more. The measures have been sunk through and bored, perhaps in a hundred places, whilst scores of mining engineers, inspectors, colliery managers (whose success depends largely on their detailed knowledge of the strata of their mines) are and have been engaged in the exploitation of these seams, and we may presume that the sequence must be fairly well known lithologically. And so far as one can gather from his paper, it is solely upon lithological evidence Dr. Woolacott bases his conclusion that the boreholes he describes were in the Ganister Series. The generic names of the fossil plants he gives are quite useless in Coal-measure stratigraphy, and his quaint note that "no trace of any *characteristic fossil* [italics are mine] such as *Aviculopecten papyraceus* was found" leads one to infer that he has not followed recent palæontological work in the Coal-measures, or he would not place so much reliance for zoning purposes on the discovery of *Pterinopecten papyraceus*. It is to be hoped that Dr. Woolacott is in possession of other evidence of higher diagnostic value to warrant his opinion of the horizon reached by the boreholes. A perusal of this paper has suggested a fair reason for the disinclination of some mining people to seek the assistance of the geologists.

In the May issue of the Geological Magazine (pp. 203–211) Drs. Trechmann and Woolacott were constrained "to put definitely on record" the fact of the occurrence of the zone of *Anthracomya phillipsi* in the Coal-measures of Durham. They omitted to mention that this had already been done in the following papers, viz. Geol. Mag., 1905, pp. 536–7, and Trans. Inst. Min. Engineers, vol. xxx, pp. 453–4, 1906, where the stratigraphical significance of the discovery was clearly stated.

J. T. Stobbs.

Stoke-on-Trent.
May 21, 1919.

PRODUCTUS HUMEROSUS IN DOVE DALE.

Sir,—I had the good fortune recently to meet with two specimens of *Productus humerosus* (*P. sublævis*) in Dove Dale (Derbyshire). This discovery seems worthy of record in point of view of the fact that hitherto the species has only been recorded for the Midland area from Caldon Low (Staffs). The Dove Dale examples occurred in a loose limestone block on the screes immediately below Reynard's Cave. In general form the specimens are strongly convex, narrow, and smooth, resembling the narrow form from Caldon Low described in this Magazine for February, 1919, p. 64. The matrix, however, is quite unlike that of the Caldon examples.

J. Wilfrid Jackson.

Manchester Museum.
May 22, 1919.

MOUSTERIAN FLAKE-IMPLEMENTS.

Sir,—I notice that in my letter published in the Geological Magazine for May, p. 240, I am made to speak of "the earlier Palæolithic 'cave' implements", and of "a normal Chellean or

Acheulean cave-implement". In both cases the word "cave" should be "core". The mistake has no doubt arisen owing to a printer's error.

J. Reid Moir.

Ipswich.
May 27, 1919.

OBITUARY.

ALEXANDER McHENRY, M.R.I.A.

Born October 24, 1843. Died April 19, 1919.

Mr. A. McHenry was born on October 24, 1843, and died at his residence in Dublin, after a very short illness, on April 19, 1919, in his 76th year. His connexion with the Geological Survey of Ireland dates back to his appointment as a fossil collector under J. B. Jukes in 1861, and he had consequently completed forty-seven years of public service on his retirement under the age-rule in 1908. His last work in the field took him back to his native county of Antrim, where he reported on the interbasaltic iron-ores and bauxites for a memoir published in 1912. He was appointed Assistant Geologist in 1877 and Geologist in 1890.

McHenry will be always remembered as a strong and zealous worker, ready to accept new views, and to test them in the elucidation of Irish geological problems. His unfailing consideration for others and his equable temper in discussion inspired the affection of his colleagues, and his contentions, which were never contentious, demonstrated the necessity for new research, even where they could not be sustained in their entirety. In 1878 McHenry was charged with the mapping of wild and difficult districts in Mayo, including Achill Island, and then, years later, he was facing similar problems in still more complicated ground among the Caledonian ridges of Donegal. He was associated with other geologists in the memoirs on the Giant's Causeway area and on north-west and central Donegal, and in the production of a series of maps and memoirs on districts round the larger cities of Ireland, issued under Mr. G. W. Lamplugh's guidance from 1903 onwards. In this series the detailed mapping of the superficial deposits was undertaken, and McHenry showed as much adaptability in this new work as he had shown in the revision of the Silurian strata of Ireland, or of the igneous rocks bordering on the Leinster Chain.

The discovery that graptolitic zones proved the presence of beds of Llandovery or later age in many areas mapped as Lower Silurian (Ordovician) led McHenry, with characteristic enthusiasm, to the conclusion that very little Ordovician rock occurred in Ireland. Had he been able, in his later years, to undertake independent field-research, he would have critically examined some of the work that he had helped to publish, and would have usefully reopened the discussion of the succession of beds in the Dingle promontory, on which he has left valuable notes.

G. A. J. C.

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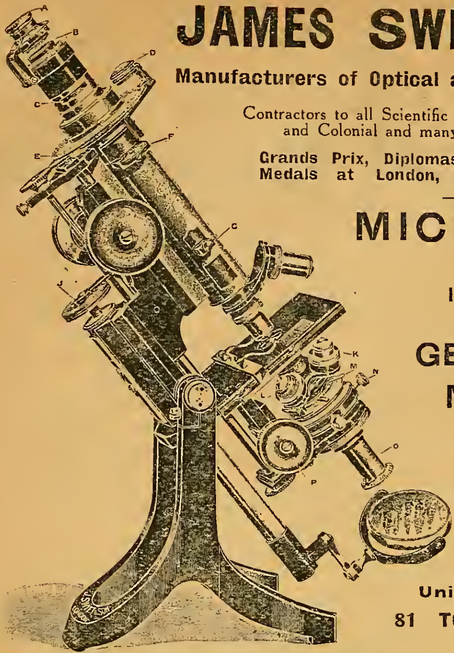

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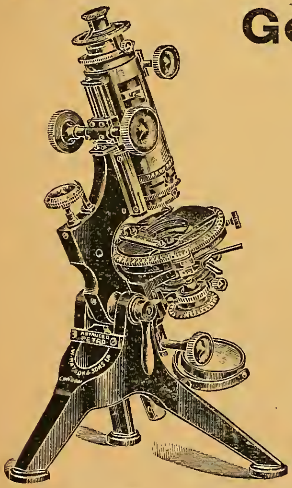

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NOTICE OF CHANGE OF ADDRESS.

All communications for the Editor of the "Geological Magazine" should be addressed to R. H. Rastall, Esq., M.A., F.G.S., Christ's College, Cambridge. Letters for Dr. Henry Woodward, F.R.S., to be sent to Tudor Cottage, Clay Hill, Bushey, Herts. Books and parcels, especially from abroad, may be directed to the care of the Publishers, Messrs. Dulau & Co., 34–36 Margaret Street, Cavendish Square, W.1.

EDITORIAL NOTES.

OWING to the release of many geologists and Government workers and the demobilization of old contributors, besides the addition of numerous new ones, we have received, during the past few months, a very large number of important and interesting articles, many of them on subjects of immediate topical interest, and therefore necessitating early publication, and several also needing plates and text-figures for their illustration. Some of our friends have kindly come forward and contributed towards the cost of these necessary but expensive additions to their articles, but owing to the present high prices it is not possible to meet all the requirements of authors in this respect and cover the cost of production with our present circulation. The GEOLOGICAL MAGAZINE is not *primarily* a money-making proposition, nevertheless it is necessary to its continuance that it should at least cover its expenses, and obviously the more copies sold the better value can be given in return. Therefore it behoves our friends, the readers and well-wishers, to use every effort in their power to secure among their associates new subscribers and increase its circulation, which is as essential to the life of a periodical as to that of a living organism.

* * * * *

A VACANCY having arisen in the body of the Trustees of "The Percy Sladen Memorial Fund" by the retirement, after five years of office, of Sir John Rose Bradford, F.R.S., the Trustees requested the President and Council of the Linnean Society to nominate a successor to the Trust; and they have, in compliance, chosen Dr. Arthur Smith Woodward, F.R.S., President of the Linnean Society, to fill the vacancy for the term of five years.

* * * * *

The late Dr. S. P. Woodward recorded in his notebook, 1864: "The collection of the late Dr. John Woodward, the founder of the Chair of Geology in Cambridge, originally was kept locked, and a bond for several thousand pounds was given by the Professor for the security of the specimens. Two auditors were appointed yearly by the University to go over the whole collection and compare it with the official catalogue to ascertain the safety of the specimens, and to report to the Vice-Chancellor, who entertained them and the Professor at dinner. The dinner was paid for out of the Woodwardian fund, and the guests were required by the will to drink *burgundy*. The collection consists of about 10,000 specimens, chiefly British fossils. By Woodward's will the Professor must be a *bachelor* and a graduate of the University. The salary was £100, with a further sum for the audit and dinner. The University has lately raised the Professor's salary to £300." It is hardly necessary to add that this salary is now calculated on a more modern and generous basis.

*   *   *   *   *

A highly successful dinner, in honour of those members of the Geological Survey and Museum Staff who have served with His Majesty's Forces, was held at Anderton's Hotel, Fleet Street, on the night of April 30, with Sir Aubrey Strahan in the chair. Forty-eight present and past members attended; of this number twenty have seen active service in one capacity or another. It is to be regretted that distance or other circumstances prevented any of the nine service members of the Edinburgh staff from being fêted also by their colleagues.

*   *   *   *   *

Mr. Harold Cox's pamphlet, *The Coal Industry: Dangers of Nationalisation* (Longmans, Green & Co., 1919, price 6*d*.), should be read by everyone, since there is not a single individual in this country unaffected by the present enormous increase in the price of coal. This rise in price is to a very large extent due to the spread among the miners of ideas based upon unsound premises. Mr. Harold Cox exposes very clearly the fallacies underlying the arguments put forward by the Fabian Society and various miners' organizations deriving their ideas from that source, in favour of nationalization and bureaucratic control, and abolition of royalties. These arguments are shown to be in their way triumphs of irrelevancy and middle-class theorizing founded on out-of-date statistics and applied to problems affecting mainly the relations of capital and labour. It is impossible here to quote these points in detail, but the author's comparison with the Post Office and his remarks on Government departments in general are well worth reading. It is categorically stated in a Fabian pamphlet on nationalization that the State would be able to supply coal at £1 per ton delivered to the cellar. In view of recent developments, largely due to State interference, this makes somewhat ironical reading. With regard to royalties, it is shown that with the present scale of taxation, the State already gets back more than half the total, and that confiscation of royalties would be not only a breach of faith with those who have acquired a legal right in them, but also an economic blunder, as in countries where minerals are in theory national property the State does not appear to get as much as it does in Great Britain; and after all the total amount of royalties is but small in comparison with the actual value of the mineral output of this country.

* * * * *

At a Special General Meeting, held on June 25 last, the Geological Society of London decided to raise the annual contribution of Fellows elected after November 1, 1919, to three guineas per annum. This step was rendered inevitable by the enormous increase in expenses of all kinds, and especially by the greatly enhanced cost of publication of the Quarterly Journal and other literature issued by the Society. This is undoubtedly one of the most important functions of the Society, and some sacrifice is necessary on the part of geologists if its usefulness in this respect is not to be impaired. The cost of publication must in any case necessarily be very heavy in the immediate future, as a good deal of leeway still has to be made up in the Quarterly Journal and the index of current literature, and it remains to be seen whether the step already taken is sufficiently drastic. At the same meeting it was decided to adhere to the present hour for meetings, 5.30 p.m. This decision will rejoice the hearts of all those Fellows who live within a couple of hours or so of London. At the present time, it is no small undertaking to spend a night in town, owing to shortage of hotel accommodation. Residents within 70 or 80 miles of London can usually return home after an afternoon meeting, whereas an evening meeting makes this impossible. Those coming from further afield must in any case stay in town, hence the present arrangement possesses many advantages and does no harm to any one. It has the additional good feature of making a shorter day for the permanent officials, whose hours on meeting-days, under the old arrangement, were unreasonably long.

* * * * *

A fine collection of minerals of economic value was lately exhibited in London, on behalf of the Government of one of the Dominions. Even more interesting than the specimens themselves was the knowledge of mineralogy displayed by the officials responsible for the preparation of the explanatory labels. The following are some specially illuminating examples culled from this source:—*Apatite Sugar:* Mineral sugar is a poisonous salt. *Manganite:* A mineral occurring in crystals. *Molybdenite:* A soft mineral containing a great deal of sulphur, often known as "amber mica". *Galena:* A lead ore, formed by the action of sulphur on a non-metallic element. *Pyrrholite:* Name means "fire-light stone", another variety of serpentine. *Ilmenite:* Taken from Ilmen Hills. Composed of tartaric acids and oxides of iron. *Sphalerite:* Name comes from word meaning treacherous. Better known as "blende", which comes from a word meaning to dazzle—a sulphide of arsenic.

ORIGINAL ARTICLES.

I.—Non-German Sources of Potash.

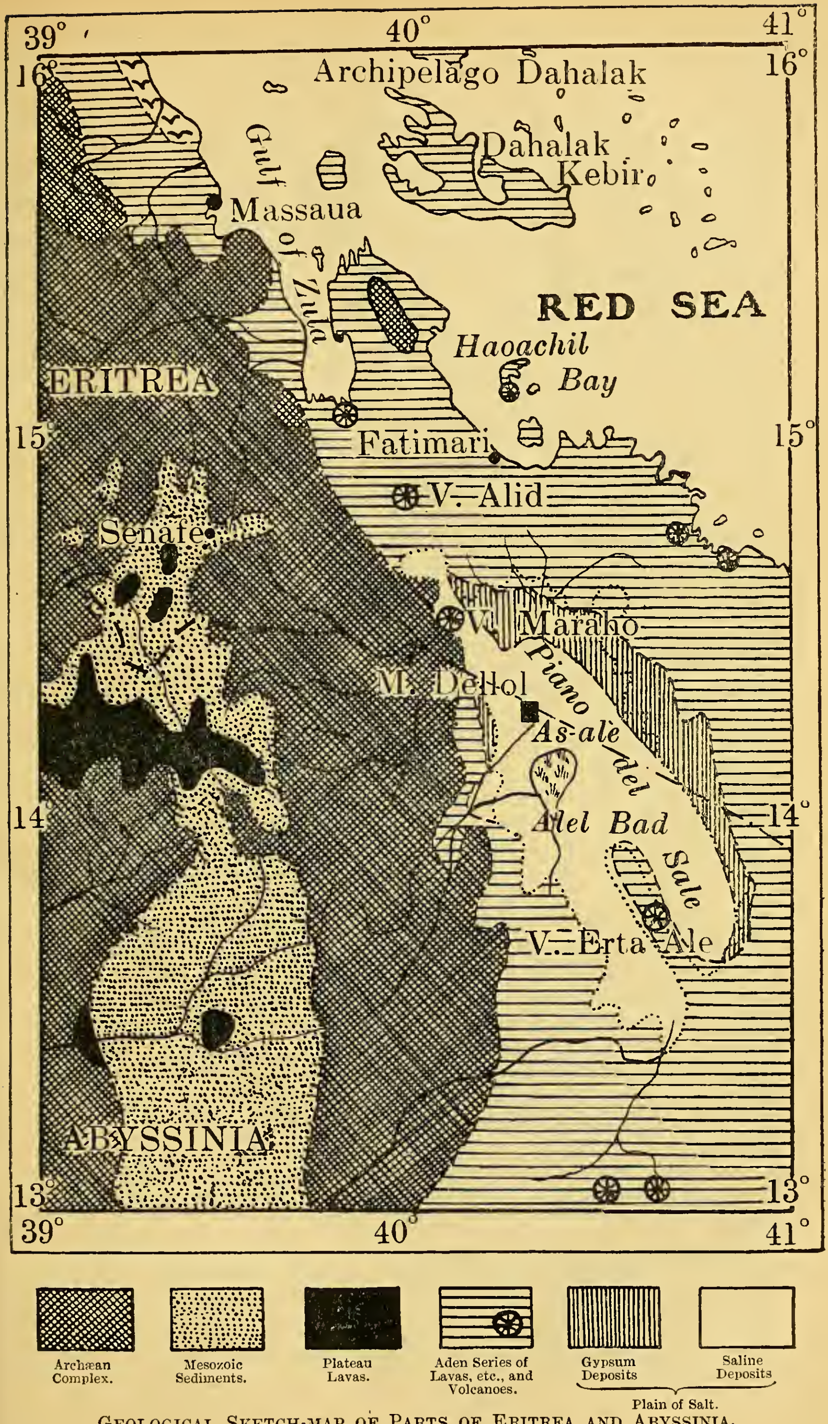
By Arthur Holmes, D.Sc., A.R.C.S., F.G.S.

Abyssinian Deposits.—During 1911 an Italian resident in Eritrea discovered a remarkable occurrence of potash salts in the *Piano del Sale*, near the provisional boundary between the Italian colony and Abyssinia. On account of its equivocal situation, development was somewhat handicapped during the early stages by Abyssinian hostility. Fortunately these preliminary difficulties were successfully overcome, and the deposit proved to be of great assistance to the Allied Powers during the war. The rate of production has gradually increased, and the estimated output for 1918 is stated to be equivalent to 50,000 tons of KCl.

The situation of the deposit is indicated on the accompanying geological sketch-map by a black rectangle (due south of the Bay of Haoachil, and just touching the recently determined boundary) which marks the position of Mt. Dellol. The *Piano del Sale*, or "Plain of Salt", is a depressed region almost entirely below sea-level. It is, in fact, as indicated on the map by a dotted line,[1] approximately bounded by the contour of sea-level. The depression is separated from the Red Sea, of which it is structurally a part, by the lavas and sediments of the Aden Series. On the west the edge of the Abyssinian plateau, carved in an ancient complex of metamorphic and igneous rocks, constitutes the real western boundary of the Red Sea Rift, and forms one side of the funnel-shaped sunkland into which the East African Rift Valley opens out near Ankober. The *Piano del Sale* is itself the exposed basin-like surface of a gigantic saline deposit, in which the older beds are disposed around the periphery, while the younger beds outcrop at successively lower levels towards the interior. Beds consisting mainly of gypsum, and representing the earliest phase of deposition, outcrop conspicuously around the northern and eastern sides, and similar beds also appear on the western edge, opposite Mt. Dellol. Within the gypsum zone, and at a lower level, though resting upon it, is a wide expanse of rock-salt over 20 miles across, and generally free from alluvium. The level gradually drops until it reaches about 390 feet below sea-level around Mt. Dellol. This so-called "mount" is a rectangular mass consisting mainly of rock-salt, the summit of which is within a foot or two of sea-level. It has been weathered into curious castellated forms, so that when seen from a distance in the slanting rays of the sun it resembles a vast mediæval fortress.

At the south-eastern corner of this curious edifice, in the heart of the depression, red and yellow masses of sylvite are exposed at the

[1] For a map showing the relation of this area to the Red Sea and to the Rift Valley of East Africa, see G. Dainelli & O. Marinelli in *Atlante d'Africa*, by A. Ghisleri, 1909, p. 139, fig. 6. The information from which the geological sketch-map was compiled was mainly obtained from this publication (see pls. xxxi, xxxii, and pp. 133–9).



GEOLOGICAL SKETCH-MAP OF PARTS OF ERITREA AND ABYSSINIA.
Scale, 1 inch = 34 miles.

surface. Over an area of 200,000 square yards sylvite has been proved to a depth varying from 2 to 5 feet. The average content of KCl in this part of the deposit amounts to 80 per cent, while locally the purer material exceeds 98 per cent of KCl. Small quantities of NaCl are present, and also traces of $MgCl_2$, bromine, and iron oxides. Surrounding the sylvite and extending over an area ten times as great, carnallite is found to a depth of 150 feet. This is the greatest depth reached by the boreholes, and even near the junction of the carnallite with the surrounding rock-salt the lower surface of the former had not, in 1918, been reached, suggesting a plug- or funnel-like mode of occurrence. The carnallite beds average from 25 to 15 per cent of KCl according to the depth, but it is possible, without difficulty or special plant, to prepare for export much richer material. The carnallite is exposed to the sun as it is dug, and at the relatively high temperature normal to the district it becomes unstable, and liquefies in its own water of crystallization. From the solution so produced most of the KCl is directly deposited, leaving a mother-liquor which is concentrated with respect to carnallite, but which is still unsaturated with respect to $MgCl_2$. By allowing this liquor to flow away, a high proportion of the $MgCl_2$ is removed. The first effect of the evaporation of the liquor is the redeposition of carnallite, and although it is stable in the presence of $MgCl_2$ solution, it breaks down as before when the $MgCl_2$ flows away. The process is allowed to continue on these lines until finally a residue containing over 80 per cent of KCl remains to be packed for transport to the coast.

The saline deposit as a whole displays an unusually complete sequence, and is clearly the result of evaporation in an arm of the Red Sea cut off permanently or intermittently by the volcanic hills of the present coast. Associated phenomena, however, indicate that volcanic agencies have also contributed to the development of the deposit. A series of springs rises through the carnallite zone, varying in temperature from 50° C. to 90° C. These consist essentially of saturated solutions of $MgCl_2$, with appreciable quantities of bromine and small amounts of sodium, potassium, and iron.[1] At the north-eastern corner of Dellol a deposit of "brimstone" has been found, surrounded by a deep bed of "flowers of sulphur". The latter mode of occurrence points indubitably to condensation of the sulphur, either directly from the gaseous state or from the interaction of gaseous sulphur compounds. The hot springs, the sulphur deposit, and the abundance of volcanic activity in the neighbourhood add extraordinary interest to the area, and it is to be hoped that an authoritative description and interpretation may soon be forthcoming.

The southern part of the *Piano del Sale* has not yet been thoroughly explored, and as it contains various focal points of depression there is a reasonable possibility that other areas of potash salts still await discovery. Political considerations are likely, however, to prevent development in this direction, at least for the present, since the

[1] The springs are described in an Italian paper by M. Giua, of which an English summary is published in the Journ. Soc. Chem. Ind., vol. xxxvii, p. R 460, 1918.

Abyssinians are very jealous of the economic invasion of their territory.

The Dellol deposit itself is now definitely known to be within Abyssinia, though it is worked by an Italian Syndicate under concession from the Abyssinian Government. Conditions of labour are far from pleasant, as the region is one of extreme aridity, while the average temperature in the shade is over 120° F. Nevertheless, in spite of climatic difficulties, there were at one time nearly 8,000 men employed in mining the potash, making a road to the coast, and building a port at Fatimari, a tiny settlement on the Bay of Haoachil, 46 miles to the north of Dellol.[1] Early in 1917 arrangements were made for constructing a light railway to Fatimari, and by now this should have taken the place of camel transport, for at the end of last year the track was rapidly approaching completion.

For many of the details made use of in the above description I am indebted to Captain Cockerell, the Controller of the Department of Mineral Resources Development of the Ministry of Munitions, and to Mr. Henry C. D. Blattner, who spent some months in examining the deposit during the early stages of its commercial development.

Natural Brines.

Since potassium salts are among the most soluble of the saline materials contained in natural waters, they become gradually concentrated as evaporation proceeds, and are finally deposited from the brines that lie over the crystalline body already deposited, or from the mother-liquors that occupy its pores. In various arid regions there are more or less desiccated lakes from which potash-rich brines are extracted; notably in the United States and Tunis. Here also the salt-marsh of Salin-de-Giraud in the delta of the Rhône may be mentioned, though the output of KCl derived from the evaporation of its waters is comparatively small.

Searle's Lake.—The deposit to which this name is applied occurs in a depressed and elongated basin-like region in the north-eastern corner of San Bernadina County, California.[2] During the Glacial epoch the basin, which is nearly surrounded by abruptly rising hills, was occupied by a lake whose surface stood 640 feet above the level of the present floor. A firm but very porous sheet of white salts now lies exposed over an area of 12 square miles, and laterally the deposit extends still further beneath the surrounding mud-flats. Down to a considerable depth rock-salt is the chief mineral found, but below 12 to 20 feet from the surface irregular layers are found rich in trona or thenardite, and rarely in sylvinite. The deposits have provided a rich suite of minerals, the genetic study of which, as yet scarcely begun, will rival in interest that of the Stassfurt salts.

Except quite near the surface, the interstices of the crystal aggregates—amounting to 40 per cent by volume—are occupied by a highly concentrated brine, and from this the American Trona Corporation extracts a number of salts, including KCl. The brine, which has the composition set forth in the table below, is known to

[1] *African World*, August 18, 1917.
[2] A. de Ropp, Journ. Ind. & Eng. Chem., vol. x, p. 839, 1918.

amount to over 110,000 million gallons, averaging about 4 per cent of KCl, and, therefore, containing 24 million tons of that salt.

Composition of American Potash Brines.

Saline Constituents.	*Searle's Lake, California.*	*Jesse Lake, Nebraska.*	*Salduro Salt Marsh, Utah.*	*Great Salt Lake, Utah.*
KCl	13·5	10·0	7·03	3·16
K_2SO_4	—	31·5	—	—
K_2CO_3	—	13·0	—	—
NaCl	46·3	—	81·04	75·91
Na_2SO_4	19·2	—	1·98	9·52
Na_2CO_3	13·0	45·5	—	—
$Na_2B_4O_7 . 10H_2O$	8·0	—	—	—
$CaSO_4$	—	—	0·88	0·34
$CaCO_3$	—	—	—	0·15
$MgCl_2$	—	—	9·07	10·92
	100·0	100·0	100·0	100·0
Percentage of salts in solution	35·8	19·3	27·1	20·0

During the evaporation processes, sodium carbonate and sulphate, and borax are produced, and finally crude potassium chloride (75 to 80 per cent KCl) is recovered. At the present rate of working, from 50,000 to 60,000 tons of the crude salt are produced annually, together with one quarter that amount of borax.

Other American Brines.—In Nebraska an area of some 8,000 square miles is occupied by sand-dunes, interspersed with flat-bottomed lakes or salt marshes. These represent every stage of evaporation, from nearly fresh water to residual brines. The "lakes" are generally underlain by green muds and beds of sand, the latter containing the whole of the brine when superficial water no longer remains. The potash-content varies from 9 to 35 per cent of the dry salts, and when commercial operations on the richer brines were undertaken in 1915, they met with such success that the following year's results gave Nebraska first place in the United States as a producer of potash.[1] Jesse Lake [2] is the most important of the basins from which brine is pumped, and a statement of its composition is listed above. The sands of the dune area are rich in orthoclase and microcline, but in a semi-arid climate it is unlikely that much potash can have been derived directly from such a source. The richness of the brine in carbonates suggests that its dissolved contents represent an accumulation of wind-blown ashes from years of prairie fires, concentrated by intermittent surface drainage.

In Utah potash was recovered from the brine of Great Salt Lake during 1916 and in later years, but, as the analysis shows, it is unlikely that the production can continue to compete with that from more favoured sources. In the Salduro Salt Marsh,[3] however, Utah

[1] Eng. & Min. Journ., vol. civ, p. 827, 1917.
[2] E. E. Thun, Met. & Chem. Eng., vol. xvii, p. 693, 1917.
[3] Eng. & Min. Journ., loc. cit.

possesses a more valuable deposit which somewhat resembles Searle's Lake; but here the salt crust is only 3 to 5 feet in thickness, and the brine is not only less concentrated than in Searle's Lake but contains less potash relatively to the other constituents.

Tunis.—South of Gabes (long. 10° E.), in the lowland of the Tunisian Shotts, a salt lake is worked for both bromine and potash. A product known as "sebkainite", which contains about 34 per cent of potassium, is obtained by solar evaporation of the brine. Commercial exploitation began in 1915, and the present rate of extraction is equivalent to over 1,000 tons of KCl per month. The plant now being installed will gradually increase the production to four times the present output, and will make possible the export of the pure chloride, refined on the spot from crude salt such as is now obtained.

Saltpetre.

Deposits of potassium nitrate are generally of organic origin, but in Chile a small proportion is associatod with the sodium nitrate deposits, and in Brazil a deposit has recently been discovered containing 89 per cent of KNO_3. In the Eocene marls and limestones of Fergana in Central Siberia saltpetre has been found to the extent of between 2 and 5 per cent over a very considerable area, and as fuel (coal and petroleum) is abundant in the same district the conditions appear to be favourable for its extraction. India, however, is the only large-scale exporter of saltpetre, Behar being the chief district from which it is obtained. The conditions of its formation are well described in the *Review of the Mineral Production of India, 1909–13*, from which the following paragraphs are extracted [1]:—

"For the formation of saltpetre in a soil the necessary conditions are:
(1) Supplies of nitrogenous organic matter;
(2) climatic conditions favourable to the growth and action of Winogradski's so-called nitroso and nitro bacteria, converting urea and ammonia successively into nitrous and nitric acids;
(3) the presence of potash; and
(4) meteorological conditions suitable for the efflorescence of the potassium nitrate at the surface.

An ideal combination of these necessary circumstances has made the Behar section of the Gangetic plain famous for its production of saltpetre.

"In this part of India we have a population of over 500 per square mile, mainly agricultural in occupation, and thus accompanied by a high proportion of domestic animals, supplying an abundance of organic nitrogen. . . .

"With a population largely using wood and cow-dung for fuel, the soil around villages naturally would be well stocked with potash, and, finally, with a period of continuous surface desiccation, following a small rainfall, the subsoil water, brought to the surface by capillary action in the soil, leaves an efflorescence of salts, in which, not surprisingly, potassium nitrate is conspicuous. Under these conditions Behar has for many years yielded some 20,000 tons of saltpetre a year."

Kelp.

Since the beginning of the eighteenth century seaweed has been utilized along various parts of the Scottish and Irish coasts as a source of potash and iodine, but owing to foreign competition the

[1] Sir T. H. Holland & L. L. Fermor, Rec. Geol. Surv. India, vol. xlvi, pp. 210–15, 1915.

industry had long before the war fallen to very small dimensions, and even since 1914 it has not been appreciably revived. The home contribution of potash during the war from kelp[1] was, indeed, barely sufficient to supply the $KClO_3$ required for the manufacture of matches.

Along the Pacific coast the kelp industry has developed on an enormous scale under the impetus of the demand for acetone and potash that arose early in the war. Giant seaweeds are harvested directly from the sea by floating mechanical reapers. After the weed is dried and burnt, the resulting ash contains salts equivalent to about 15 per cent of K_2O. As a method leading to potash recovery alone—that is, without the collateral separation of by-products—this process was found to be wasteful, and even when the ash was sold directly as a fertilizer it was not found possible to compete with other sources of supply. Consequently more economical methods of treatment have been devised, the most successful being that in which acetone is prepared as the main product, with potash as a by-product. At San Diego the seaweed is fermented in large bins, and the resulting solutions (containing crude acetic acid with KCl and iodine compounds) are collected. Calcium acetate is formed by neutralizing the acid with limestone, and by its ignition acetone is formed. Meanwhile potassium chloride and iodine are concentrated in the residual liquors, and are ultimately separated in a crude state. The three products taken together have provided satisfactory profits under war conditions, but the future stability of the industry is less certain, especially as, in common with Searle's Lake, the site of production is far removed from the principal centres of demand.[2]

Other Organic Sources.—The fact that 90 per cent of the potash used in Great Britain is devoted to fertilizing purposes, is clearly an indication that the plants which absorb potash from the soil may themselves be utilized for its subsequent replenishment. Among important crops, flax and potatoes in particular require large quantities of potash for continued growth. It is, however, not possible to produce potash economically from waste vegetation except as a by-product in already established industries. Even in the lumber camps of Canada the wood-ash from saw-mills waste contains insufficient potash to justify its collection and treatment, and its only value is as a local fertilizer applied to the land directly.[3] In Belgium and Italy potassium salts (K_2CO_3, KCl, and K_2SO_4) are recovered from the residual liquors left after the treatment of molasses in beet-sugar factories. In the Caucasus district there was formerly a considerable local potash industry dependent on the

[1] The ash or slaggy matter that remains when seaweed is burnt in a kiln for six or eight hours is called *kelp*; but in the United States the weed is *kelp*, and the product *kelp-ash*. The ash, as obtained on the west coast of Scotland, contains about 18 per cent of KCl and 13 per cent of K_2SO_4.

[2] Since writing this paragraph I have been informed (April 24, 1919) by the Controller of Potash Production that most of the American kelp recovery plants have been shut down since the effective termination of the war. See also Journ. Soc. Chem. Ind. (June 15, 1919) for a recent statement of the potash position in the United States.

[3] *The World's Supply of Potash*, Imperial Institute, 1915, p. 25.

collection of sun-flower stalks from the Russian peasants, and no doubt under settled conditions this source will again become productive. Cream-of-tartar is a by-product of the wine industry, and is exported in large quantities from France, Italy, and other wine-producing countries.

Reference to the chief animal source of potash has already been made in connexion with saltpetre; wool, grease, and dried sweat (suint) remain for brief consideration, for this material, the waste product from processes of wool-scouring, contains the potash salts of various fatty acids. In France and Belgium K_2CO_3 has been recovered from suint liquors for several years, and under war conditions its extraction was commenced in Britain. Incidentally the treatment of suint is to be advocated, if only to avoid the fouling of rivers which attends the usual method of its disposal.

Insoluble Potash Minerals.

The chief silicate minerals rich in potash are felspars (orthoclase and microcline), leucite, micas, and glauconite, while a mineral which may conveniently be considered with these is alunite, a basic sulphate of potassium and aluminium.

Felspars.—Although numerous attempts have been made to devise a commercially successful method of separating potash from felspar, none has yet satisfactorily emerged from the experimental stage, except possibly where the separation is introduced into, and made part of, the process of manufacturing Portland cement (see below, p. 348). In Britain [1] our potash-felspars are not well situated, and the cost of quarrying and carriage forbids their utilization as a source of potash, and is likely to do so unless the very bulky residue can itself be employed in a profitable capacity.

Leucite.—Leucite contains about 19·5 per cent of potash, and as it is readily decomposed by acids, giving a solution of potassium and aluminium salts, it certainly provides a more favourable material for treatment than felspar. The leucitic lavas of the Italian volcanoes contain between 8 per cent (leucite-tephrite) and 10 per cent of K_2O (leucite-phonolite), and those of the Leucite Hills in Wyoming [2] average 10 per cent; consequently these rocks might be treated directly, and they are undoubtedly a valuable potential asset to the countries in which they occur. H. S. Washington [3] has recently drawn attention to this comparatively neglected source of potash in an elaborate review of the Italian lavas, in the course of which he estimates the reserves of potash in the seven leucitic volcanoes, extending from Vesuvius to Bolsena, at a minimum of 10,000 million tons. The corresponding American resources are but a fiftieth of this amount, and are, moreover, less favourably situated with respect to industrial centres. Already, in both areas, the rocks have been used directly as fertilizers, and the American Potash Company has

[1] Mem. Geol. Surv., Spec. Reps. on Mineral Resources, vol. v (Potash-Felspar, etc.), 1916; P. G. H. Boswell, Trans. Soc. Glass Technology, vol. ii, p. 35, 1918.

[2] R. C. Wells, U.S.G.S., Prof. Pap. 98 D, p. 37, 1916.

[3] Met. & Chem. Eng., vol. xviii, p. 65, 1918.

been formed to extract potash from the Leucite Hills,[1] but little progress has as yet been reported, while in Italy the problem is still a subject of active research.

Glauconite. — British "greensands" rarely contain more than 4 per cent of potash, and consequently they fail to provide a practicable source. In the United States, however, potash has already been successfully recovered from glauconitic sands and marls. A narrow belt of Upper Cretaceous greensand extends from Sandy Hook to Virginia, and in many parts of New Jersey glauconite is so abundant that the air-dried sediment contains from 6 to 7 per cent of K_2O, three-quarters of which can be liberated by the process adopted. Glauconite has the advantage over felspar of being practically free from alumina and soda. To remove the latter impurity from potash concentrates is somewhat troublesome, and the alumina, if extracted by digestion, requires so high a proportion of water that the expense becomes prohibitive. In the case of glauconite a similar method of treatment can be applied at a comparatively low cost. The process involves digesting with high-pressure steam a mixture of the finely-ground raw material with lime. The resulting filtrate contains potash with little impurity (80 per cent KOH on evaporation), while the residue contains cementitious constituents, and is utilized in the manufacture of bricks and tiles.

Alunite.—This mineral, the composition of which may be represented by the formula $K[Al(OH)_2]_3(SO_4)_2$, is readily decomposed by calcination; sulphuric acid is driven off, together with all the water, leaving a residue of soluble K_2SO_4 and insoluble alumina. Although alunite has been generally used as a source of alum, in recent years high-grade potassium sulphate has been prepared from it, the first successfully operated plant having been established in Utah. Alunite occurs in veins, and disseminated through the adjacent rocks, in certain volcanic regions, where it is produced in association with propylitization, by the action of hydrothermal emanations containing sulphuric acid or its constituents. The chief localities where it is actively mined are Marysvale, Utah; Goldfield, Nevada; Bullah Delah, New South Wales; La Tolfa, Italy; and Almeira, Spain.

Recovery of Potash from the Dust of Cement Kilns.

Several years ago the fruit-growers in the vicinity of the Riverside Portland Cement Company, California, complained that the dust from the kilns caused serious damage to their crops. In consequence the Company took steps to abate the nuisance, and installed an electrical precipitation plant to settle the dust. Hoping that the dust might be of some economic value, and so might contribute towards the cost of its collection, analyses were made, and it was found that it contained 10 per cent of potash. Expectation was thus amply fulfilled and the recovery of potash was at once developed as a profitable by-product.[2]

[1] A. H. Rogers, Met. & Chem. Eng., vol. xv, p. 387, 1915.
[2] L. Bradley, Journ. Ind. & Eng. Chem., vol. x, p. 804, 1918.

During the last two years experimental plants have been run by certain British firms for the same purpose, and although the raw materials generally contain only a very small proportion of potash, the quantities of cement manufactured are so great that a considerable output of potash is potentially available from this source. Unfortunately, no authoritative statement has yet been issued of the results of the processes so far tested. As a further development, the scope of the experiments has recently been extended to test the suggestion that potash-felspar might advantageously be substituted in part for the clay used as a raw material. When one part of orthoclase is intimately mixed with three parts of calcium carbonate, and the mixture heated to 1,300°–1,400° C. for about an hour, potash is volatilized, and the residual clinker corresponds in composition with that of Portland cement as normally prepared. Similarly, when the mixture is digested with steam at a pressure of from ten to fifteen atmospheres, a solution is obtained containing as hydroxide 90 per cent of the potash originally present in the charge, and the residue is again a Portland cement clinker.[1]

There can be little doubt that the cement industry could, if necessary, supply very substantial quantities of potash by developing along these lines; but on the other hand the incentive of urgent national need having now passed, and the attraction of high prices being but temporary, it is unlikely that the extraction of potash from felspar by this means will become a peace industry.

Blast Furnace Flue-dust.

Among the various methods exploited in Britain with a view to developing our home resources, the recovery of volatilized potash from blast-furnace flue-dust and gases has emerged as the most fruitful. Potash is present in small quantities in all the materials charged into the furnaces, iron-ore being regarded as the principal source. Iron-ores vary greatly in their potash content, the figures ranging from 0·2 to 2·5 per cent. The ash from coal contains from 0·2 to 0·7 per cent, but it is possible that these figures do not adequately express the potash content of the original coal, as they do not include potash that may have been volatilized during combustion. That coal may possibly supply more potash than is usually recognized, is indicated by the fact that in certain experimental runs the potash balance-sheet actually revealed a greater recovery of potash than the amount estimated to be present in the raw materials fed into the furnace. Generally, however, the balance-sheet shows a more or less marked deficit.[2]

Since the early part of 1915 a series of valuable experiments have been carried out by Mr. Kenneth M. Chance[3] of the British Cyanides Co., Ltd., and Mr. Lennox Leigh, of the North Lincolnshire Iron Co., Ltd. It was found that the volatilization of potassium as chloride could be greatly increased by adding to the charge a small

[1] W. H. Ross, Journ. Ind. & Eng. Chem., vol. ix, p. 469, 1917.

[2] R. A. Berry & D. N. McArthur, Journ. Soc. Chem. Ind., vol. xxxvii, p. T 1, 1918.

[3] Journ. Soc. Chem. Ind., vol. xxxvii, p. T 222, 1918.

percentage of common salt. The conditions for successful working on a large scale have been carefully investigated, with a view to controlling the introduction of salt so that the products of volatilization should not be deleterious to the quality of the iron or to the furnace linings. The success of the experiments led to the formation of the British Potash Co., Ltd., for the commercial recovery of potash from flue-dust supplied by the blast-furnaces of Lincolnshire. It is estimated that the blast-furnaces of the country should be able without difficulty to contribute at least 50,000 tons of potassium chloride per annum, an amount approximately one-half of our pre-war imports of potassium salts. Thus the fear that Britain will ever again experience a shortage of potash as acute as was suffered in 1916–17 is completely dispelled. At the same time it appears to be certain that the country can never be completely self-supporting, unless, perhaps, the dormant exploration[1] of British saline deposits for potash is continued with success.

II.—The Igneous Rocks of the Ashprington Area.

By Miss I. H. Lowe, B.Sc., Demonstrator in Geology, Bedford College, University of London.

1. Introduction.

In South Devon the outcrops of Middle Devonian igneous rocks form a series of roughly parallel bands, which broaden out and occupy a continuous area about twelve square miles in extent in the neighbourhood of Ashprington village. No detailed account of the petrological characters of these rocks has been given, although similar types have been described fully in the Plymouth Survey Memoir. For this reason, and also in the hope that further study might explain more completely the cause of the broadened outcrop, I investigated many exposures in the Ashprington area.

A large number of specimens were collected from this district, a general survey of which showed that the determination of the relations of the rocks to each other over any but limited areas was difficult. This was due to the isolated character of the outcrops, the comparatively rapid change in the rocks exposed, the difficulty of tracing bedding planes owing to the development of a marked cleavage, and the absence of sections showing junctions. In consequence a more detailed study was made of a small area east of Harbertonford village, covering about two square miles (Fig. 1) This was chosen because there were numerous exposures in a limited space, and the structure is typical of that throughout the district.

The rocks examined are all basic in composition and strikingly uniform in character, and are either diabases or fragmental basic rocks. Many of the specimens collected cannot be definitely classified owing to the amount of alteration they have undergone. The absence of acid igneous rocks is very noticeable; a rotten felsitic rock from a recess in the road from Gerston Cross to Totnes was the only specimen obtained.

[1] Journ. Soc. Chem. Ind., vol. xxxvii, p. R 313, 1918.

The field work necessitated a series of visits on which Dr. Raisin accompanied me, and I should like to express my gratitude to her for the unfailing help she has given me in this work, and to Dr. H. H. Thomas, who kindly made some valuable suggestions. The work was carried on in the Geological Department of Bedford College.

2. The Field Relations of the Igneous Rocks.

A general account of the field relations of the volcanic rocks to the sedimentary in the Ashprington area is given by W. A. E. Ussher in the Geological Survey Memoir of Torquay (pp. 77 et seq.).

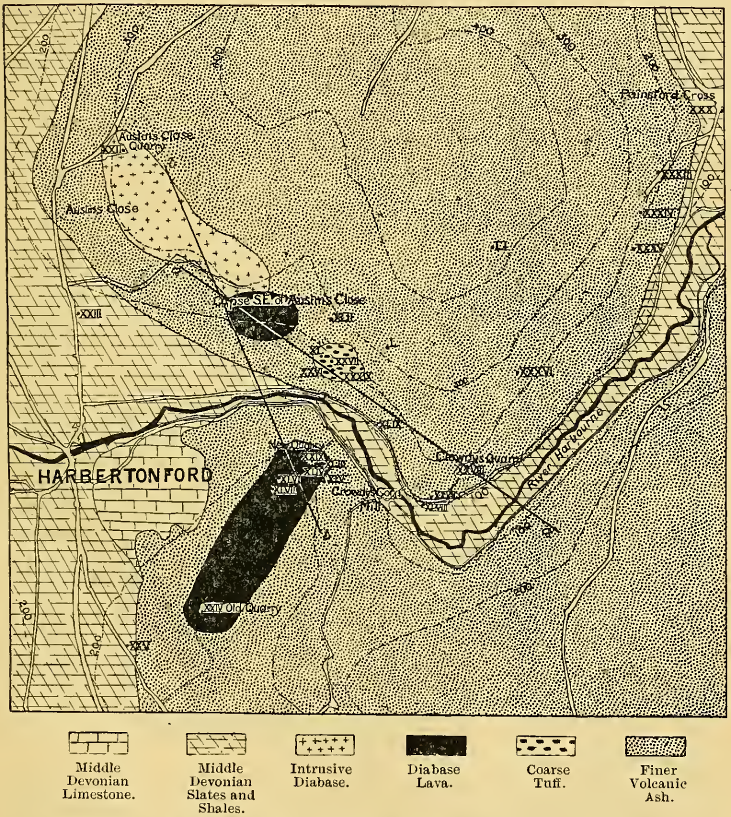


Fig. 1.—Map showing the outcrops in the Harbertonford area. Scale, 4 inches = 1 mile (approx.).

The exposures[1] of igneous rock in the area east of Harbertonford are shown in five quarries, and form crags on the slopes of the hills

[1] The exposures to which reference is made are marked on the accompanying map by Roman numerals.

facing the Harbourne River. The contour of the ground did not seem to be dependent on the nature of the rocks, and could not be relied upon in tracing the extent of any one type.

North of the River Harbourne diabase alone is exposed in Austin's Close quarry (XXII) and in several crags in a copse to the south-east (XLI). Eastward of this, in Crowdy's quarry (XXVIII), there is a more varied section, at the base of which fine greenish-grey banded ash is shown, followed by a layer of calcareous ash containing fragments of crinoid stems and casts of brachiopods and corals, and passing up into an impure fossiliferous limestone. Above this is an amygdaloidal lava, succeeded by ashy and concretionary calcareous bands. The beds in this quarry are gently undulating, the axes of the folds running east and west. Similar sections in which ashy and calcareous bands alternate are exposed on the banks of the River Dart; from these, recognizable fossils have been obtained and are described in the Torquay Survey Memoir (p. 81). To the south of the River Harbourne, in a recently opened quarry, which will be referred to as "New quarry" (XXIX), the rock is worked from a platform about 50 feet above the level of the entrance. The section exposes at the base much cleaved fine ashy material, forming the walls of the approach to a slide down which the quarried material is shot. Above this a coarser green ash with whitish patches and silvery cleavage surfaces forms the platform, and is succeeded by a dark-green amygdaloidal diabase, which also crops out as crags on the hill above. The dip of these rocks is practically horizontal. To the south, in the same hill, is a quarry (XXIV) largely overgrown, where the rock exposed is diabase, red in colour from long-continued weathering.

To the south-east of Austin's Close, forming crags in a hedge (XL, XXVII, XXVI), a rock occurs containing large fragments (9 by 4 inches and 10 by 3 inches). The fragments are splintery, subangular, and greyish-white in colour, embedded in a tough green rock. The matrix showed irregular hollows on the weathered surfaces; these hollows have a distinct linear arrangement, and may represent cavities from which other fragments have been worn. The cleavage planes cross these lines and dip to the south-east at 45°; a dip which is very constant throughout the area (Fig. 2). Rocks collected from higher up on the hill (XLII, L, LI) and on the south-east slope of the hill (XXXIII–XXXVI) were not easy to distinguish as either diabase or ash.

3. Petrological Characters of the Igneous Rocks.

(1) *Diabases.*

Throughout the Ashprington district diabase, when freshly exposed, is dark green, tough, compact, and frequently amygdaloidal. The amygdales often have a linear arrangement, are not more than an inch in length, and are filled with a fine aggregate of chlorite, sometimes associated with epidote. A few of the diabases are slate-grey in colour; the one from Down's Hill quarry, a quarter of a mile south of Totnes, is an example of this type. It contains exceptionally large banded amygdales several inches in diameter, filled with quartz, chalcedony, calcite, and hæmatite. The red and brown colour of the rocks in the area is especially characteristic of those exposed in road cuttings and old disused quarries. The specific gravity of the fresher specimens varies from 2·87 to 2·98.

The rocks are cleaved and generally show curved irregular joint planes; but typical "pillow structure", such as that developed in the spilite in Chipley quarry and described in the Newton Abbot Memoir (p. 54), is only shown in one exposure in a small road cutting just outside Cornworthy village. A large pillow is exposed, showing numerous small vesicles arranged in concentric bands; the material of which it is formed is dark brown, but is too rotten to allow of microscopic examination.

Narrow veins are abundant in all rocks, frequently intersecting and crumpled or faulted. The minerals filling the veins are quartz, epidote, chlorite, actinolite, asbestos, and calcite.

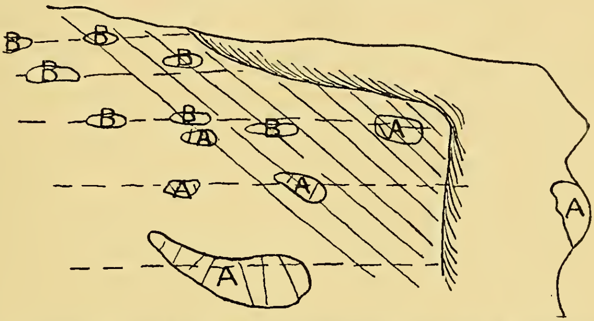


FIG. 2.—Diagram illustrating the arrangements of the coarse fragments in the crag at exposure XXVII. A = imbedded fragments, B = the cavities resulting from the weathering out of the fragments. Continuous lines represent the direction of the cleavage planes. Broken lines represent the bands along which the fragments are arranged.

One of the least decomposed of the diabases is that exposed in a quarry at Stancombe Linhay, two miles south of Totnes. When examined under the microscope the rock was seen to be sub-ophitic and to contain fairly large, fresh, pale puce-coloured crystals of augite, which are irregular in shape, slightly pleochroic, and are abundantly penetrated by very small lath-shaped felspars. In most of the diabases the augite is only recognizable under a ¼ in. objective. They are all noticeably rich in felspar, which must have been originally the most abundant constituent of the rock. Most rocks show two generations of felspar; those of the earlier are well-formed phenocrysts, the sections of which are elongated and rectangular or rhombic in shape. Some of the felspars show evidence of corrosion, having rounded angles, and in the rock from Down's Hill quarry containing devitrified glass inclusions. The crystals vary in size, from microscopic to large macroscopic, one in a specimen from Austin's Close quarry measuring 85 sq. mm. The felspars of the second generation are small and lath-shaped; in the ophitic diabases they penetrate the augite, and in the non-ophitic types usually have a parallel arrangement due to flow. All the felspars are much decomposed, a few still show signs of repeated twinning, the angles of symmetrical extinction of these indicate oligoclase or albite-oligoclase. The refractive index, when compared with that of the Canada balsam, is, as far as can be determined, in agreement with this identification. Skeleton crystals of ilmenite occur in the rock from Stancombe Linhay, and are also irregularly developed in other diabases. Apatite is rare, and is only present in the diabase from Down's Hill quarry; even in this rock it is slight in amount.

All the rocks are very much decomposed; the resulting products include chlorite, epidote, granular sphene, actinolite, white mica, and a mosaic of a clear colourless mineral, probably quartz. The chlorite occurs very abundantly in decomposed felspars, both in veins traversing the crystals and in the felspar itself; it also forms elongated irregular patches in all the rocks. Epidote is abundant in flocculent aggregates of fine granules both in the felspars and throughout the slides, and also as distinct crystals. Actinolite is present in some specimens in the form of scattered needles, in others forming a fringe from the edge of augite crystals. In one specimen the development can be seen to have taken place to such an extent that practically the whole section consists of patches of actinolite, the needles in each patch being parallel and extinguishing simultaneously. Brown hornblende is very rare, but a few small, ill-defined flakes occur in a slice of the rock collected from the old quarry south of Harbertonford. Granular sphene is associated with leucoxene as the result of the decomposition of ilmenite. Secondary iron oxide in the form of minute irregular patches can be observed in all the sections; in much decomposed specimens earthy limonite frequently occurs as the material filling the vesicles which have been exposed to surface weathering. White mica in small flakes and a fine mosaic of a colourless mineral occur in the decomposed felspar. Kaolin as a decomposition product of felspar is especially well developed in the rock of Down's Hill quarry. The section in this exposure showed at the east end a compact, grey, amygdaloidal rock with phenocrysts of felspar, becoming more vesicular towards the west. The rock is cut by almost vertical faults, along one of which a development of kaolin occurred, forming a highly cleaved white flaky mass a few inches in thickness and stained in parts with iron. It seemed to be a final stage of decomposition of the rock, which is very rich in felspar.

Calcite is conspicuously absent in these rocks, except in the cases where they overlie limestone bands, as at the old quarry near Tuckenhay. Its absence as a decomposition product of felspar gives further support to the view that the felspar is not of a very basic species.

Summary of the Decomposition of the Diabases.

All the diabases of the Ashprington area are intensely altered; the modifications which the rocks have undergone have resulted in three types of change.

(1) Mineralogical alteration by which the original constituents of the rock have been replaced by secondary minerals.

(2) Mechanical modification which caused the breaking and deformation of the minerals and the development of cleavage planes in the rocks.

(3) The disintegration of the rocks by weathering agencies. As a result of the mineralogical alteration the felspar was replaced by chlorite, epidote, muscovite, quartz, some kaolin, and possibly in some cases by calcite. These alteration products often show evidence of being developed before the rocks were modified by pressure to which this area was subjected, and probably at an early stage in their history.

As a result of pressure the rocks became folded, faulted, and cleaved. The veins were crumpled, strain shadows were developed in the quartz in the veins, amygdales were elongated and flattened, and felspar and augite crystals broken. The chlorite patches also were elongated and lost any definite outline they may originally have possessed. Very little mineral development seems to have taken place at this stage of alteration.

A further effect of mechanical deformation is shown in the scoriaceous basalt from Eaglewood quarry, which is dark purple in colour and much cleaved; it passes into a purplish-red slate, with greenish and whitish patches on the cleavage surfaces. Rocks of this character are common throughout the district, and, no doubt, many of them have originated in this way, although no other exposure than the one quoted showed proof of this.

The last stage of decomposition is that caused by weathering agencies which split up decomposed rocks along the cleavage planes and oxidize the irony material to minute grains of limonite and hæmatite, giving the characteristic red and brown colour to the soil and much decomposed rocks.

(2) *Fragmental Rocks.*

A certain number of undoubted fragmental rocks can be identified in this area, although many of the much altered rocks cannot be definitely determined as clastic or igneous. The undoubted fragmental rocks differ in coarseness, but the recognizable fragments in all cases are mainly of felspar. In addition, some of the tuffs contain rock fragments and remains of basic lapilli.

The felspars are often broken and always decomposed. In the case of the tuff collected from the quarry behind Crowdy's corn mill (XXIX), the felspars could be identified as oligoclase. Aggregates of crystalline calcite are often abundant in the tuffs, and as a rule no organic structure is traceable; but in the ash from this quarry one of the calcite patches showed distinctly the typical structure of a fragment of an echinoderm.

Lapilli do not occur in the specimens collected from the main Ashprington area, but are shown in a section from a loose specimen found on a hill near Eight Acre Pens, Linhay. This is the locality referred to in the Torquay Memoir (p. 73) as occupied by a coarse volcanic tuff surrounding a probable volcanic neck. The outlines of the lapilli, which are roughly elliptical, have become very indistinct. In them the groundmass is a colourless devitrified glass, and contains numerous small amygdales filled with chlorite. Similar tuffs containing lapilli have been collected on the western borders of the area from an old quarry south of Harberton, and also from quarries east of North Huish church and south of Diptford.

Rock fragments are abundant in the rock exposed in the hedge near Austin's Close (see Fig. 2, p. 353). When examined microscopically they show structure characteristic of basalts, and in some, fine ophitic structure is recognizable in the groundmass. Small decomposed phenocrysts of felspar, rectangular, lath - shaped or rhombic in section are abundant, and often show a roughly parallel orientation indicative of flow. Amygdales are common, small, irregular in outline, and mostly filled with a fine quartz mosaic. Calcite patches occur, which sometimes fill the amygdales, and are sometimes associated with the decomposed felspar. One of the fragments contained two xenocrysts of felspar; their angles are rounded, and two concentric zones of mineral development occur at the margin; an outer of felspar and actinolite and an inner rich in chlorite and iron oxide granules. The felspar is decomposed and contains chlorite and a few actinolite needles. A similar large felspar is found in one of the sections cut from the rock from the copse south-east of Austin's Close. Numerous fine veins of quartz cross the rock, and patches of quartz mosaic associated with chlorite show rectangular and rhombic shape and evidently replace some of the felspar phenocrysts. The silica percentage of one of the fragments was determined as 59·6, and the specific gravity as 2·68.

From these facts it is clear that, although the structure of the rock fragments is that characteristic of basalts, the silica percentage and the specific gravity are typical of less basic rocks. It seems, therefore, from the consideration of chemical composition and petrological characters, that the fragments are of basalts which have undergone subsequent silicification. In structure the fragments closely resemble the unsilicified rock from the copse to the south-east of Austin's Close, from which they are possibly derived. The matrix of the tuff in which the fragments are imbedded consists mainly of broken felspar and chloritic material and an abundance of fine granular epidote.

4. Summary.

The foregoing description makes it clear that the rocks of the Ashprington area closely resemble the spilites and schalsteins of Upper Devonian age in the Plymouth district, described in the Plymouth and Liskeard Memoir (p. 94 et seq.), but the diabases of the former differ from the spilites of the latter in having fine-grained ophitic structure and in the prevalence of felspar phenocrysts.

No example of coarser intrusive ophitic rock or proterobase such as is described by Dr. Flett in the Survey memoir mentioned above is met with in the Ashprington area. The sub-ophitic rock exposed at Stancombe Linhay and Eaglewood quarries approaches most closely to the ophitic type. North Huish and Diptford to the west of the area (Ivybridge and Modbury Memoir, p. 78) are the nearest localities at which coarse ophitic rock is exposed.

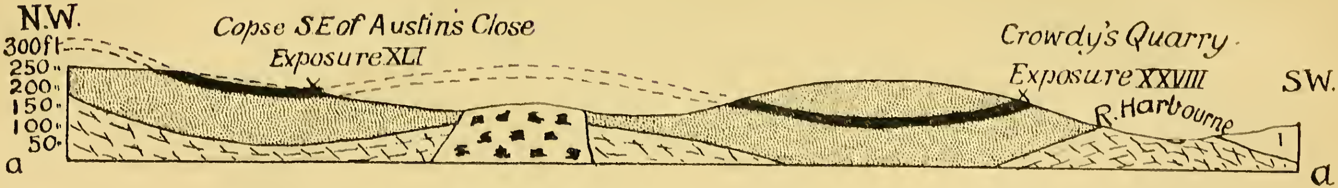


FIG. 3.—SECTION ALONG THE LINE *a—a* IN MAP 1. Scale 10·5 inches = 1 mile (approx.).

[1] This blank place should be stippled as "finer volcanic ash".

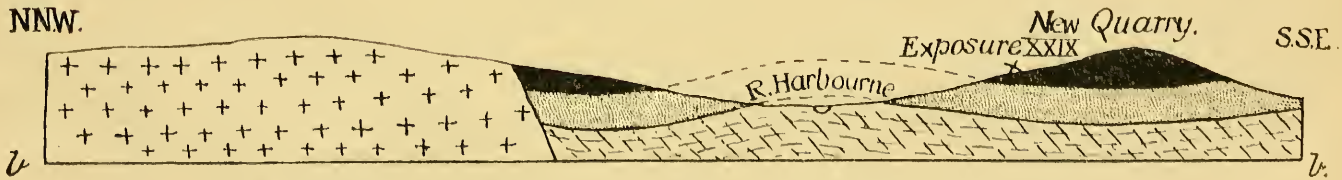


FIG. 4.—SECTION ALONG THE LINE *b—b* IN MAP 1. Scale 10·5 inches = 1 mile (approx.).

The key to the symbols for Figs. 3 and 4 is the same as for Fig. 1.

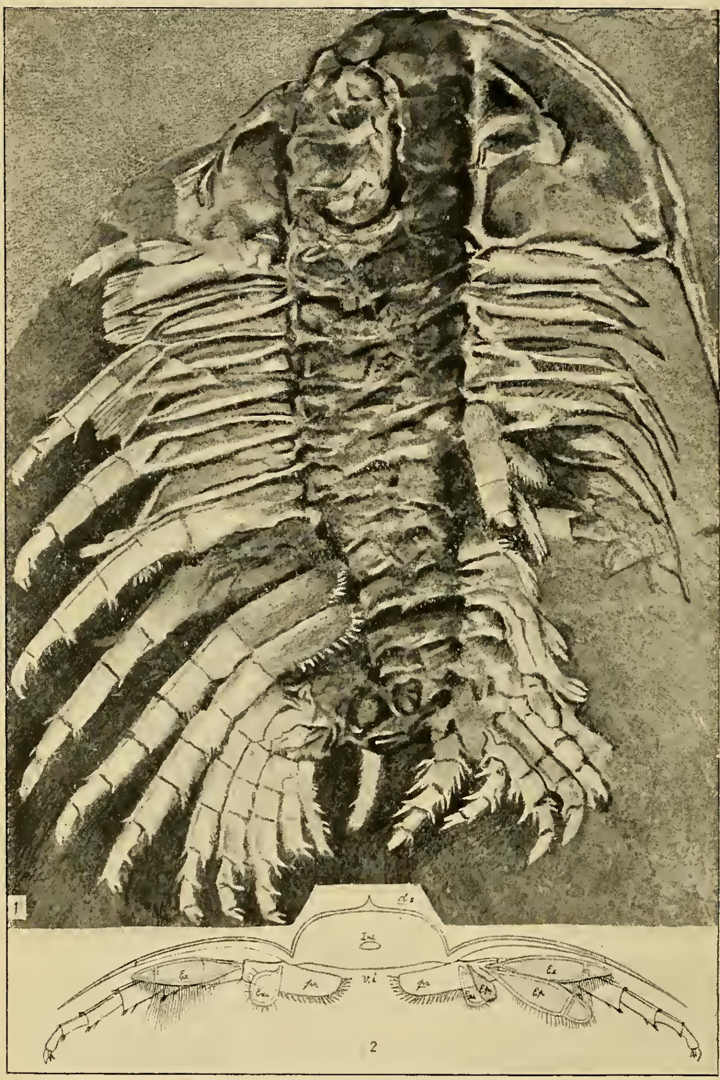
The petrological characters of all the specimens of diabase collected from the exposures in the area east of Harbertonford, with the exception of that from Austin's Close, are similar. They are fine-grained and porphyritic, showing only such variations as might be found in different parts of the same lava. Thus the rocks show more marked flow structure in some parts than in others, variation in the coarseness of the ophitic structure, and slightly different degrees of decomposition. In the exposures at "New quarry" and Crowdy's quarry the diabase is evidently a lava flow interbedded with ashes, and from the resemblance of the petrological characters of these rocks to those of the old quarry and of the copse south-east of Austin's Close, it can be inferred that the last two exposures are of the same lava-flow. The dip of the beds is gentle and all the outcrops of diabase occur either just above or just below the 200 feet level.

The diabase of Austin's Close differs from the other specimens. It shows no trace of original ophitic structure, and the phenocrysts of felspar are large and well-shaped, although much decomposed and with rounded angles; they have no definite arrangement. The rock seems to have been more resistant to the pressure which affected the district; cleavage is not so marked, and the felspars, though often deformed and cracked, are not so distorted and drawn out as those in more cleaved diabases. These facts suggest that this rock was not part of the same lava-flow but originated as a small intrusion shown at N.N.W. in Fig. 4. No junctions with the neighbouring rocks could be found, so that direct evidence was not available.

The limited extent of the coarse fragmental rock, the size of the included fragments and their silicification, which is doubtless due to the action of vapours connected with volcanic action, leads to the conclusion that this rock occupies the position of a small parasitic vent (see Fig. 3). Similar vents were probably numerous in the Ashprington area, and if so, this would account for the extensive development of the volcanic rocks in this district.

We have, therefore, near Harbertonford, evidence of a lava-flow, a great preponderance of ash, a small vent and a small intrusive mass. This is probably typical of the occurrence and origin of the spilitic volcanic rocks in the larger Ashprington area, whose development was initiated early in the Devonian period in a district that was undergoing gentle subsidence. Thus these rocks give an additional illustration of the view expressed by H. Dewey and Dr. Flett,[1] and more recently by Dr. A. Harker,[2] as to the connection between the petrological characters of the spilites and the conditions under which they were formed.

[1] Geol. Mag., 1911, p. 246.
[2] Quart. Journn. Geol. Soc., vol. lxxiii, p. lxxxviii, 1917.



C. D. Walcott.

NEOLENUS SERRATUS (Rominger). Burgess Shale (Middle Cambrian). British Columbia. (From Walcott.)

III.—Dr. C. D. Walcott's Researches on the Appendages of Trilobites.

By Dr. W. T. Calman, D.Sc., F.Z.S.,
of the British Museum (Natural History).

[Dr. C. D. Walcott. Cambrian Geology and Paleontology, IV, No. 4: Appendages of Trilobites. Smithsonian Miscellaneous Collections, vol. lxvii, No. 4, Washington, December, 1918, pp. 115–216 + Index, pls. xiv–xlii, text-figs. 1–3.]

(PLATE VIII AND TEXT-FIG. 1.[1])

It is nearly forty years since Walcott published the well-known memoir which first gave palæontologists definite information regarding the appendages of Trilobites. This work was based on a laborious investigation of *Calymene senaria* and some other species by means of thin sections. Since then much knowledge has been gained, and, in particular, Beecher's researches on *Triarthrus* have provided us with a new conception of the Trilobite limb which, in some respects, is not readily to be reconciled with Walcott's earlier results. Now, at length, in this finely illustrated monograph, the veteran student of the Trilobita brings together the results of his own work and that of other investigators and reviews the whole in the light of his unrivalled experience.

In all, eleven species are dealt with, and restorations are given of *Calymene senaria*, *Triarthrus becki*, and *Neolenus serratus*, the three species of which the structure is most fully known. The last-named species is represented by finely preserved specimens in the Burgess shale (Middle Cambrian) of British Columbia, from which Dr. Walcott has described so many novel forms of animal life in recent years.

By the kindness of Dr. Walcott we are able to reproduce two of his figures illustrating *Neolenus* (see Plate VIII and Text-fig. 1). It will be seen from the restorations that the limbs are of some complexity. The jointed and spinous leg (endopodite) has a strong basal segment, produced inwards as a toothed gnathobase, to which are attached as many as four lobular appendages. One of these, distinguished by the marginal fringe of long setæ, is identified as the exopodite, and two others, one large and one smaller, are lettered as epipodites. Another small lobe is called an "exite", but as it is stated to be "probably attached to the inner side of the protopodite" the name is hardly well chosen. The most remarkable feature of the species, however, is the presence of a pair of long multiarticulate caudal filaments resembling those of *Apus*. Nothing like these has hitherto been seen in any Trilobite (Text-fig. 1, *c.r.*, p. 360).

In the case of *Triarthrus* the modifications which Dr. Walcott finds it necessary to make on Beecher's well-known restoration are mostly of a minor kind. The chief is the addition of a series of small leaf-like epipodites attached to the bases of the limbs. The fringes of the exopodites were described by Beecher as made up of "narrow, oblique, lamellar elements", and he suggested that they may have served as gills. The photographs now given

[1] The original illustrations have been kindly lent by Professor C. D. Walcott.

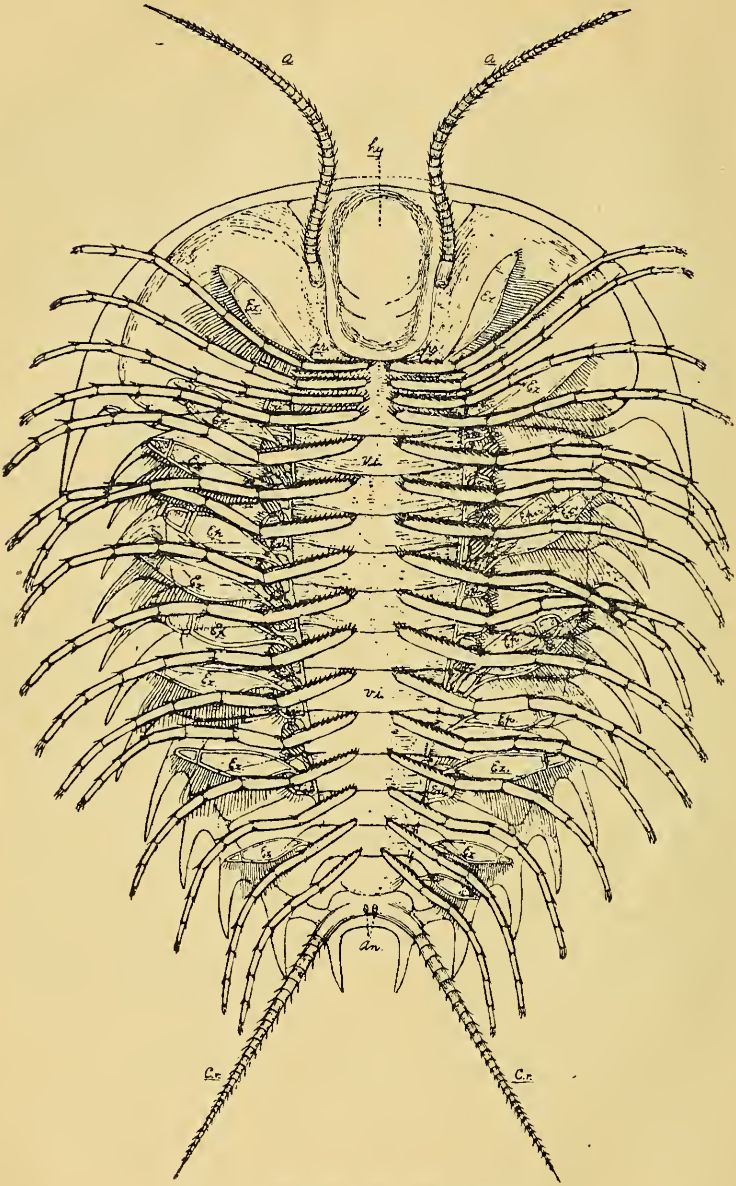


FIG. 1.—*Neolenus serratus* (Rominger).
Restoration of the ventral aspect with appendages. Burgess Shale (Middle Cambrian), British Columbia. (From Walcott.) *hy.* hypostome; *a.* antennules; *an.* anus; *c.r.* caudal rami; *ep.* epipodite; *ex.* exopodite; *pr.* gnathobasic process of protopodite; *v.i.* ventral integument.

show some resemblance to the pectines of scorpions, and at all events the form of the elements is very different from that usually indicated by the term "setæ" which is here applied to them. Dr. Walcott attaches considerable importance to his conclusion that the limbs of the pygidium had long and slender endopodites like those of the middle region of the body, and that the lobate, phyllopod-like elements described by Beecher should be referred to the exopodite. The photographs illustrating this point, however, are not sufficiently clear to be quite conclusive.

The revised restoration of *Calymene* now given differs in some important details from that published in 1881. Dr. Walcott has re-examined the material on which his earlier work was done, and reproduces some of his figures alongside of photographs of the sections from which they were drawn. As now interpreted, all the limbs are provided with large gnathobases like those of *Triarthrus* and *Neolenus*. In addition to the bifid spirally coiled appendage, now called the exopodite, all the limbs bear a curiously shaped epipodite with a terminal fringe of setæ. Dr. Walcott maintains his opinion that the two branches of the so-called exopodite were of the spirally coiled form which he originally described, rejecting the suggestion that the appearances seen in his sections resulted from the cutting across of fringes of obliquely-set lamellæ like those on the exopodites of *Triarthrus*. His conclusions are not to be lightly disputed by anyone who has not studied the actual specimens, but some doubt must remain so long as these spiral appendages have only been seen in the species examined by the method of section-cutting, and not in any of the forms in which the appendages are displayed in surface view. Evidence has now been obtained that this species had filiform antennules like those of *Triarthrus* and *Neolenus*, and they are included in the restoration.

On the much-discussed question of the affinities of the Trilobites, Dr. Walcott unhesitatingly decides for their association with the Crustacea, and against the view that they were related to the Xiphosura and Arachnida. He does not discuss the reasons for this conclusion in any great detail, and it may be suggested that in the comparisons brought forward he hardly makes sufficient allowance for the very wide range of structure in the Crustacea. Thus, for example, it is only with large reserves and qualifications that the resemblances of the Trilobite limb to the thoracic legs of *Anaspides* can be regarded as supporting the previous comparison with *Apus*, while it may be stated with some confidence that the sessile eyes of *Koonunga* have nothing whatever to do with the fact that the eyes of Trilobites are also sessile. Before such comparison can be profitably entered upon it is essential to have a clear conception of the classification and phylogenetic relations of the main divisions of the Crustacea, and on this point Dr. Walcott has not availed himself of the most recent information. He quotes, apparently with approval, Beecher's arrangement of the Trilobita "as a sub-class of the Crustacea, equivalent to the sub-class Entomostraca and to the third sub-class Malacostraca". Now it is true that many writers even at the present day adopt the classification of Crustacea into the two sub-classes Entomostraca and Malacostraca, but this is due merely to the inertia of tradition. The "Entomostraca" have no more claim to constitute a taxonomic unity than have the "Invertebrata". The groups included under the name, the Branchiopoda, Ostracoda, Copepoda, and Cirripedia, are no more closely related to one another than any one of them is to the Malacostraca, and they should be treated as equivalent sub-classes of the Crustacea. When they are arranged in this fashion it becomes clear that the Branchiopoda are the only sub-class that can be regarded as having any direct relationship with the Trilobites. Each of the other sub-classes has attained to a more or less strictly defined number of trunk-somites and appendages. Only the Branchiopoda, like the Trilobita, are, to use Lankester's term, *anomomeristic*. The Malacostraca, in addition, have the trunk appendages grouped in the two sharply defined "tagmata" belonging to the thorax and abdomen. The Ostracoda, Copepoda, and Cirripedia are, in different ways, highly specialized groups, and the only characters which can be usefully considered in comparing them with Trilobites are those that may be supposed to be inherited from the common stock of Crustacea. Thus, it is legitimate to supplement a comparison of the Trilobites with the Notostraca (*Apus*) by a reference to the more generalized mouth-parts (biramous mandible-palp, etc.) of certain Copepods.

One of the pieces of evidence that has influenced opinion most strongly in favour of the Crustacean affinities of the Trilobites is afforded by Beecher's determination of the number of cephalic appendages in *Triarthrus*. Behind the preoral antennules, he found four pairs of appendages, each biramous and provided with a gnathobase. Since the antennæ of Crustacea are still postoral and carry a masticatory process or gnathobase in the nauplius larva, the correspondence of the postoral cephalic appendages of *Triarthrus* with antennæ, mandibles, maxillulæ, and maxillæ seems to be complete. In view of the great importance of this correspondence it is much to be regretted that it has not been possible to confirm it in any of the other species of Trilobites. Dr. Walcott, indeed, repeatedly refers to four pairs of cephalic legs, but it is not clear that the precise number could be determined in any case without reference to the analogy of *Triarthrus*.

The biramous form of the limbs in *Triarthrus* has been regarded, with justice, as one of the main supports of Crustacean affinity. The objection that the protopodite, to which the two rami are attached, appears to be unsegmented, while in the Crustacea it is usually composed of two, sometimes of three segments, need not be regarded as insurmountable. Dr. Walcott definitely describes the protopodite of the Trilobites as "consisting of a fused coxopodite and basopodite", but this would appear to be rather a probable inference than an observed fact.

The discovery of a pair of multiarticulate caudal filaments in *Neolenus* is a new and weighty piece of evidence in favour of affinity with Crustacea. In one form or another a caudal furca is found in all the main divisions of the Crustacean stock, and the rami are filiform and multiarticulate not only in the Notostraca (*Apus*, etc.) but also in certain Cirripedes. Nothing of the kind is found in any of the Arachnidan groups.

While giving due weight to these and other evidences of Crustacean affinity, it is important not to lose sight of the characters, some of them of considerable weight, in which the Trilobita differ from what we must suppose the primitive Crustacean to have been like. One of the most important is the absence of a carapace. In the Crustacea the carapace is formed by a fold of the dorsal integument arising from the hind margin of the head-region, enveloping and sometimes coalescing with more or fewer of the body-somites. Only in the Anostracous Branchiopoda, in some Syncarida (*Bathynella*), and possibly in the Copepoda, is this shell-fold entirely absent, and it is a reasonable conclusion that it must have been present in the ancestral stock of the Crustacea. No Trilobite shows any trace of such a fold.

The sessile eyes of the Trilobites may perhaps be reckoned as another non-Crustacean character. Sessile eyes are indeed common enough among recent Crustacea, but there are good reasons for thinking that the condition is in all cases a secondary specialization and that the eyes were primitively pedunculate and movable. Even the sessile eyes of the Notostraca and Conchostraca, which are movable and covered by an invagination of the integument, are regarded, with considerable probability, as derived from stalked eyes. In the Trilobita we have no evidence that the eyes were ever movably pedunculate, although the suggestion has been made that the eye-bearing "free cheeks" may have been formed by the expansion of ocular peduncles.

Finally, it is to be noted that the exopodites of *Triarthrus* with their fringe of lamellar elements, possibly branchial in function, are something very different from the "setiferous exopodites" of many Crustacea with which they have been compared. It is possible that we have here a hint as to the origin of the "gill-books" of *Limulus*.

No Trilobite yet discovered is so generalized that it could be regarded as standing in the direct line of descent of either Crustacea or Arachnida, but the group as a whole seems to point the way towards some form that may have been the common ancestor of both. Dr. Walcott's wonderful discoveries in the Burgess shale give hope of further progress in tracing the phylogeny of the primitive Arthropods, and the fuller investigation which he promises of the remarkable *Marrella* will be awaited with much interest.

EXPLANATION OF PLATE VIII.

FIG. 1.—*Neolenus serratus* (Rominger). Burgess Shale (Middle Cambrian), British Columbia. (From Walcott.) Specimen displaying the ventral surface with the appendages *in situ*. At the posterior end of the body a portion of one of the caudal rami is visible. (From a retouched photograph, × 1½.)

,, 2.—Diagram of a transverse section of the body. *d.s.* dorsal shield; *ep.* epipodite; *ex.* exopodite; *exi.* exite; *int.* intestinal canal; *pr.* gnathobasic process of protopodite; *v.i.* ventral integument.

IV.—The Two Magmas of Strathbogie and Lower Banffshire.

By H. H. Read, H.M. Geological Survey, Scotland.

THE field-work upon which this communication is based was carried out in 1917 and 1918, in preparation for the Geological Survey map of Sheet 86 (Huntly).

In the Strathbogie district of Aberdeenshire and in Lower Banffshire [1] two series of igneous rocks have a wide distribution. The earlier of these series was intruded prior to the movements which caused the foliation and schistosity of the Dalradian sediments, the later after these movements had ceased. The object of this paper is to detail the diversity of original rock types constituting the Older Series, to delineate their magmatic sequence, and to compare them, both in order of intrusion and in petrographic characters, with the similarly diversified Younger Series.

1. The Older Series.

Igneous rocks of prefoliation age have a wide distribution in this district, as will be seen from the Sketch-map. These Older rocks are mostly altered to serpentine, tremolitic serpentine, epidiorite, amphibolite, hornblende-schist, and augen-gneiss, but it has been found possible to trace back the serpentines to pyroxene and olivine rocks, the epidiorite, amphibolite, and hornblende-schist to gabbro and enstatite gabbro, and the augen-gneiss to granite. The most important locality of the Older Series from this point of view is that of Portsoy, Banffshire. The rocks of this locality have been described many years ago by Jameson,[2] Cunningham,[3] and Heddle.[4]

The non-felspathic ultrabasic members of the Older Series are usually in the condition of serpentine, occasionally well foliated but more often massive. Throughout the district, however, rocks composed wholly of monoclinic pyroxene are strongly developed and can be found in all stages of transformation to serpentinous and tremolitic derivatives. Such anchi-monomineralic rocks form independent intrusions, and since they are cut by epidiorite may be considered as the earliest manifestation of the Older igneous activity. Type localities are at Portsoy, at Whitehill west of Rothiemay Station, and on both flanks of Evron Hill. The pyroxenite is a coarse massive greenish-grey non-foliated rock which in thin slice is seen to consist of large interlocking crystal plates of a pale-coloured augite. No felspar has been seen in the rock. Occasionally olivine in small grains is scattered sporadically throughout the rock and may have been locally predominant. Enstatite and hornblende, probably primary, also occur at certain localities. There is never any banding of the constituents, collection of olivine in layers or fluxional arrangements of the

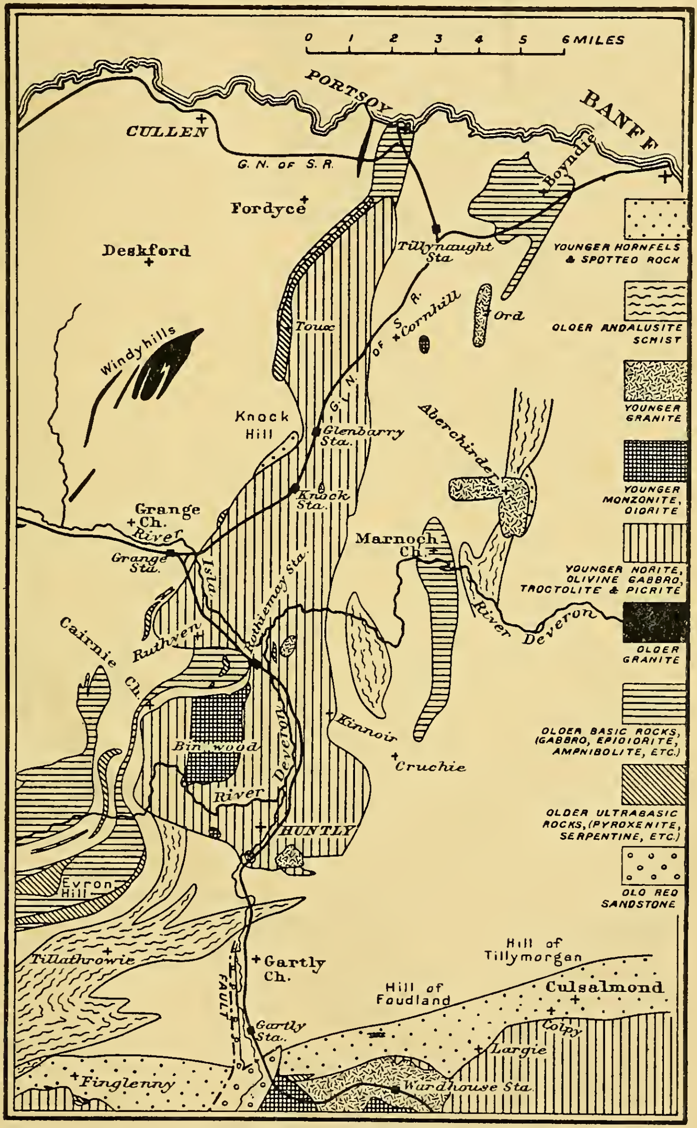
[1] Further notes on these districts will appear in the *Summary of Progress of the Geological Survey of Great Britain for 1918*.

[2] R. Jameson, *Mineralogy of the Scottish Isles, etc.*, 1800, vol. ii, p. 270 et seq.

[3] Hay Cunningham, "Geognostic Account of Banffshire": Trans. High. and Agric. Soc. Scot., ser. II, vol. viii, p. 447, 1842.

[4] M. F. Heddle, "Chapters on the Mineralogy of Scotland": Trans. Roy. Soc. Edin., vols. xxvii–xxix, 1876–80.

crystals. The position of such pyroxenite masses as are associated with epidiorites, etc., seems in no case due to gravitative differentiation. These pyroxenites by their alteration produce



Sketch-map, showing distribution of Older and Younger Igneous Rocks in Strathbogie and Lower Banffshire.

a mixture of tremolite and serpentine, and in the olivine-rich types homogeneous serpentine usually results. The tremolite of the pyroxene rocks has been developed under pressure from the solid augite, the large crystals of which are crushed and distorted, the amount of tremolite present being in intimate relation to the degree of crushing suffered by the rock.

At Portsoy a second independent intrusion of a monomineralic rock is furnished by a small mass of anorthosite. This coarse-grained greenish-grey rock is composed almost entirely of labradorite felspar in crushed augen between excessively fine-grained cataclastic granules of similar felspar. Scarce chlorite, rare epidote, and talc complete the rock. This anorthosite is undoubtedly an independent intrusive mass, and is against Dalradian limestone and schist on one side and a pyroxenite on the other.

The great majority of Older basic rocks is derived from a gabbro which is found well preserved at Portsoy. This parent rock of the epidiorites and amphibolites is a coarse gabbro composed of labradorite, augite, apatite, and iron oxides, with secondary hornblende and biotite. The rather elongated crystals of labradorite are saussuritized and slightly crushed. The ophitic augite is marginally altered to the fibrous or compact hornblende of the epidiorites.

Primary modifications of this gabbro are common, but form only local variations in the gabbro mass. By the dwindling of the felspar content and by the incoming of olivine, a rock is formed in which the original constituents were olivine, diallage, and scarce labradorite. The olivine, now entirely replaced by pilitic tremolite, quartz, chalcedony, and carbonates, formed rounded grains poikilitic in large diallage plates which are in process of alteration to hornblende and biotite. The felspar is a scarce rather fresh basic plagioclase. Compound reaction rims between the olivine and felspar are occasionally developed and are exactly similar to those found in certain types of the Younger Series. The rock is occasionally crushed.

In the Burn of Durn at Portsoy an enstatite gabbro is found in which a colourless enstatite is predominant over the monoclinic pyroxene. Both species of pyroxene are partially or completely altered to a pale-green hornblende, and cataclastic effects are common in the plagioclases.

Bands and streaks of a rock more acid than the predominant type are found in the gabbro of Portsoy. Such dioritic types are composed of a medium plagioclase, quartz, and biotite.

Primary banding is common in the Portsoy gabbro. This is of two types, the first being formed by alternations of two rocks, the second by alternations of two minerals. The first type consists of bands of a labradorite rock with a little hornblende secondary from pyroxene, alternating with bands of hornblendic (originally pyroxenic) rock with subordinate plagioclase. This complementary banding is undoubtedly original. Those rocks to which the name gabbro schist may be applied show a delicate banding of light coloured saussuritized labradorite and of dark secondary hornblende enclosing augen of diallage. This banding is due to movement during consolidation, and the effect of the subsequent cataclasis has been to emphasize the banded nature of the rock, which in structure then resembles the foliated gabbro described and figured by Teall.[1] All banding is parallel to the stress lines of the country.

The olivine-pyroxene-felspar rock, enstatite-gabbro, diorite, and banded gabbros do not form independent intrusions, but are small parts of a heterogeneous intrusion whose predominant member is ordinary gabbro. No differentiation in place can be demonstrated and it is considered that this heterogeneity is due to differentiation before intrusion. All the varieties of the gabbro pass into epidiorites by the complete replacement of their pyroxene by secondary hornblende. From the epidiorites are derived the widespread amphibolites by a still more abundant development of secondary hornblende and the concomitant recrystallization of the original labradorite into a mosaic of clear acid plagioclase. These two types, displaying no marked foliation, are predominant in the Older basic series as now found. By the development of cataclastic foliation the hornblende-schists are produced.

The acid members of the Older Series are exemplified by the augen-gneisses of Portsoy and Windyhills. In these rocks large lens-shaped patches of microcline and orthoclase, with subordinate oligoclase, are set in a cataclastic groundmass of granular quartz and felspar with shreds of primary biotite, and much secondary muscovite along shear planes. The original rock was a biotite microcline granite.

The magmatic sequence of the Older Series is, as usual, one of decreasing basicity or of increasing alkalinity. The main magma was largely gabbroic in nature and has been intruded as a heterogeneous magma due to differentiation in a lower basin, and now displays the varied types of predominant gabbro, scarce olivine-pyroxene-felspar rock, scarce enstatite-gabbro, scarce diorite, with banded felspathic and pyroxenic portions. The manner of differentiation cannot be stated, but no degree of differentiation in situ has taken place. The anchi-monomineralic rocks are earlier than the gabbro; one of these independent intrusions is composed of the femic constituents, the other of the felspathic constituent of the original gabbroic magma from which they have split. The acid differentiate is quite late and consists of an alkali-granite. The areal relations for this district of the three divisions are ultrabasic rocks 2·6 square miles, basic 15·6 square miles, and acid 1·55 square miles. The basic rocks are much cut out by the Younger Series, and the area formerly occupied by them may be approximately double that given above.

The Older Series must be considered with regard to Dr. N. L. Bowen's[2] recent work on differentiation by the sorting and collection of crystals in a crystallizing magma. At Portsoy among the Older

[1] J. J. H. Teall, Geol. Mag., 1886, Pl. XIII, p. 481; *British Petrography*, 1888, pls. xxvi, xliii.

[2] N. L. Bowen, "The Last Stages in the Evolution of the Igneous Rocks": *Journal of Geology*, vol. xxiii, supplement, pp. 1–91, 1915. "The Problem of the Anorthosites": ibid., vol. xxv, p. 209, 1917.

Series, and as will be seen later at Huntly among the Younger Series, it can be shown that differentiation has not taken place in situ. The absence of gravitative separation and of continuous variation and the presence of independent monomineralic intrusions point to the conclusion that differentiation took place in a lower magma basin. The main intrusion was undoubtedly one of a heterogeneous,[1] predominantly gabbroic, magma, and from this magma had already been separated off the two monomineralic types —pyroxenite and anorthosite. On Bowen's theory, such separation of monomineralic types would be by the collection of masses of crystals of pyroxene and of labradorite, and therefore, if such monomineralic rocks were intruded as independent masses, their origin would be demonstrated by cataclastic structures. Such structures are, of course, apparent in the monomineralic rocks of Portsoy, but these rocks were affected by the regional folding and, in common with all the igneous rocks of the Older Series, show evidences of crushing stresses. How, then, are these crush effects due to later folding to be distinguished from those due to intrusion as a mass of crystals? Orientation of crystal plates has never been seen in the massive pyroxenites of this series, there is no segregation of olivine into layers, and the crystals of pyroxene form interlocking junctions. The sporadic olivine is often interstitial to the pyroxene. In the author's opinion, the crushing seen in the pyroxenite is best explained as due to the effects of regional folding on a solid and cold rock. Similarly the crushing of the anorthosite is exactly like that of the augen-gneisses. Until further knowledge is obtainable concerning the immiscibility of silicate magmas,[2] especially under pressure, and also concerning the role of mineralizers, particularly of magmatic water, in ultrabasic rocks, the question of the origin of the monomineralic rocks of the Older Series must be left open. On the whole, however, the writer considers some kind of separation of a magma into liquid phases to be demanded by the field relations of the Older Series of this district. Such a separation of liquid phases would be afforded by the operation of liquid immiscibility, or by the refusion of a solidified magma basin already differentiated, perhaps by crystallization. Such a refusion was postulated by Martin Schweig[3] and has lately been favoured by Dr. Harker,[4] but the cause of the rise in the isogeotherms evoked by the latter is unexplained. Liquid immiscibility, therefore, until proved impossible, should be considered as a process probably effective in magmatic differentiation.

2. The Younger Series.

The Younger Series of the Strathbogie district forms an elongated mass with a north and south trend, a direction parallel to the

[1] Cf. Geikie & Teall, "On the Banded Nature of some Tertiary Gabbros in the Isle of Skye": Q.J.G.S., vol. l, p. 656, 1894.

[2] Cf. R. A. Daly, *Igneous Rocks and their Origin*, 1914, pp. 225, 226. "Genesis of Alkaline Rocks": *Journ. Geol.*, vol. xxvi, pp. 123, 124, 1918.

[3] M. Schweig, "Untersuchungen über Differentiation der Magmen": Neues Jahrbuch, Beil. Bd. xvii, p. 563, 1903.

[4] A. Harker, "Differentiation in Intercrustal Magma Basins": *Journ. Geol.*, vol. xxiv, p. 556, 1916.

foliation of the country. The younger igneous rocks of the Wardhouse district will not be considered here. That part of the Huntly Mass which occupies the district around Huntly has been described in detail by W. R. Watt,[1] but the whole of the area shown in the Sketch-map has been mapped by the present writer. The rocks of the Huntly Mass, with its isolated granite bosses of Aberchirder, Ord, and Longmanhill (4 miles E.S.E. of Banff), form a lengthy sequence, here appended in order of intrusion:—

1. Picrite-Norite Set (Picrite, Olivine-gabbro, Troctolite, Norite).
2. Diorite of Gibstone.
3. Monzonite and Diorite (Central Intrusion of W. R. Watt).
4. Granite.
5. Pegmatites with tourmaline.

The picrite-norite set are well seen around Huntly and extend thence northwards to within two miles of Portsoy. The picrite forms a narrow border on the western edge of the Huntly Mass in the Huntly district. It is a black rock with conspicuous lustre mottling and in thin slice is rather variable. Occasionally it approximates to a peridotite, but usually carries common ophitic pyroxene with relatively scarce basic plagioclase. Brown hornblende, biotite, and hypersthene occur in small amount. The olivines are slightly serpentinized. No trace of cataclastic structure is found. The olivine-gabbro occurs east of the picrite and forms a coarse very fresh rock with labradorite, olivine, and pyroxene, with subordinate brown hornblende and biotite. The troctolitic type occurs mainly east of the olivine gabbro and is a characteristic olivine-labradorite rock with beautiful fluxional arrangements of the felspars and with banding of more basic types of peridotite, etc. These fluxion structures are parallel to the margin of the mass, as is usual amongst fluxional gabbros.[2] Such structures are best explained for the Huntly Mass as due to movement during the intrusion of a somewhat pasty and not strictly homogeneous magma. Troctolite also occurs at the western edge of the Huntly Mass west of Knock Station. Beautiful reaction rims of anthophyllite and actinolite are developed between the olivine and felspar of the troctolitic and olivine gabbros.[3] The predominant body of the picrite-norite set is, however, the norite. This type forms nine-tenths of the Huntly Mass. It is usually a fine-grained bluish rock, consisting of labradorite-bytownite and hypersthene with widespread augite, hornblende, biotite, and olivine. Structures are variable, being ophitic, granular, or granitic. Occasionally the norite lacks its hypersthene and then forms a very coarse gabbro.

The members of the series—picrite, olivine-gabbro, troctolite, norite—follow in order from west to east, and at first glance this arrangement seems to point to a direct gravitative differentiation of a gabbro magma in the position in which it is now found. But no

[1] W. R. Watt, "Geology of District around Huntly (Aberdeenshire)": Q.J.G.S., vol. lxx, pp. 266–93, 1914.

[2] F. F. Grout, "Internal Structures of Igneous Rocks": *Journ. Geol.*, vol. xxvi, p. 439, 1918.

[3] W. R. Watt, loc. cit., pl. xxxviii, fig. 2.

gradual passage from one rock to another can be demonstrated and the individual rock types are well marked. Again, the west–east sequence in certain localities may be partly reversed. Moreover, there is no ultrabasic western border to the norite north of the Huntly district. It seems more probable that the differentiation of a gabbroic magma took place in a lower chamber and that the picrite was intruded as a small sill, followed by increasingly acid derivatives, each of which slid in roughly on the top of its fore-runner. But most of the picrite-norite set were fluid at the time of intrusion of the whole series and so no marked contacts are seen; schlieren and banded types occur and mixed edges may have been formed locally. Finally, the phase of the picrite-norite set was ended by the widened sphere of sill-like intrusion, together with great cross-cutting, of the norite magma, and by the time of intrusion of this norite the more basic members were sufficiently solid to be cut by dyke-like apophyses of gabbro and norite. The areal relations of this set are: picrite ·83 sq. mile, olivine-gabbro ·39 sq. mile, troctolite 3·32 sq. miles, and norite 37·4 sq. miles.

After the composite intrusion of the picrite-norite set had finished, there were intruded a few small bosses of diorite (quartz, biotite, augite, andesine). Of these bosses, that at Gibstone (1½ miles N.W. of Huntly) has a marked foliation which is, however, not of cataclastic origin. This Gibstone diorite is intermediate in composition between the earlier norite and the later monzonite, and probably owes its foliation to its soft and hot nature at the time of the movements which caused the monzonite to present a markedly intrusive character to the norite.

The picrite-norite set was solid at the time of intrusion of the large monzonite mass of the Bin Wood (Central Intrusion of Watt[1]). This rock is a coarse garnetiferous monzonite which has produced great contact effects on the earlier norite.[2] It consists of orthoclase, plagioclase, augite, biotite, quartz, and garnet.

The next member of the Younger Series is of granitic nature and forms small masses, sometimes in the basic members and sometimes as isolated bosses, as shown on the Sketch-map. The rock is a grey granite composed of quartz, predominant microcline, orthoclase, scarce plagioclase, biotite, and scarce muscovite. It often shows a very rude fluxional structure. All the granites associated with the Huntly Mass are biotite-microcline granites.

Tourmaline pegmatites are common as the final stage in the intrusion of the Younger Series of the Huntly Mass.

The areal distribution of the whole Younger Series of this area is: ultrabasic ·83 sq. mile, basic 41 sq. miles, intermediate 2·8 sq. miles, and acid rocks 3·2 sq. miles.

Continuous variation in place is not seen in the Huntly Mass, and there seems to be an individuality about the various closely related types which is not explained by a crystallization-differentiation hypothesis.

[1] W. R. Watt, loc. cit., p. 275.
[2] W. R. Watt, loc. cit., pp. 282 ff.

3. The Two Series.

On comparing the two series of igneous rocks outlined above, it will be seen that there is a well-marked similarity in sequence and characters, but this similarity does not extend to details. The Older Series forms two anchi-monomineralic differentiates, one a femic type consisting of predominant pyroxene with subordinate olivine, the other of a felspathic type provided by the small anorthosite of Portsoy. The Younger Series has only a locally developed monomineralic phase, and its ultrabasic member is provided by a predominant olivine type with subordinant pyroxene and plagioclase, intrusion occurring before the production of a non-felspathic femic magma had been possible. So, felspar is common in the picrite of this series, but is never found in the pyroxene-olivine rocks of the Older Series. The basic members of the two series again present the same general types of gabbro, enstatite or hypersthene-gabbro, and diorite, but are different in the relative development of such types, in the predominance of certain species of pyroxene, and in the widespread occurrence of olivine in the Younger Series. The acid members are perfectly similar, both being biotite-microcline granites. The areal relations of the Older Series and of the Younger Series of the Huntly Mass show the same order of magnitude for the different differentiates of each series.

The distinction between the two series may be based upon the degree of alteration of the rocks, the character of this alteration among the Older Series, the characters of the predominant mineral in the ultrabasic facies, and the character of the pyroxenes in the two orthorhombic pyroxene-gabbros. In the field, the general greenish appearance due to the alteration into hornblende of the augite of the Older Series and the occurrence sooner or later of cataclastic foliation in them are of great value. Finally, a most important criterion is supplied by their metamorphic effects on the country rocks. The contact rocks produced by the Older Series are foliated by the later regional folding, whereas the effect of the intrusion of the Younger Series is to obliterate this foliation.

It may be stated, therefore, that in this district there are two petrogenic cycles separated by an epoch of great earth movement. Between Huntly and Portsoy the rocks of these two cycles have risen along almost the same belt of country and present great similarities in their main characteristics.

In conclusion, the author wishes to express his indebtedness to Dr. John Horne, F.R.S., and to Dr. J. S. Flett, F.R.S., for many helpful suggestions.

V.—Brachiopod Nomenclature: *Spirifer* and *Syringothyris*.

By J. Allan Thomson, M.A., D.Sc., F.G.S., Director of the Dominion Museum, Wellington, New Zealand.

According to a strict interpretation of the international rules of zoological nomenclature the generic name *Spirifer* is wrongly used for the group including *Anomites striatus*, Martin, and should be restricted to the group including *Anomites cuspidatus*, Martin, i.e. it should replace *Syringothyris*, Winchell. My object in pointing this out is not to urge a strict interpretation of the international rules in this case, for it would serve no useful purpose to attempt to displace a name which through a century of usage has become the geological equivalent of a household word, but to show the need for geologists to combine with zoologists in demanding a list of *nomina conservanda* in zoology.

In 1814 or 1815 James Sowerby read a paper before the Linnean Society describing the presence of spiral coils in *Anomites striatus*, Martin, and proposing for it the genus *Spirifer*. He also stated that he suspected that *Anomites cuspidatus*, Martin, possessed similar coils. The substance of this paper became known not only in England but on the Continent, but the paper was not published until 1821.[1] In the meantime Sowerby published the genus in *Mineral Conchology*, vol. ii, 1818, pp. 41–43, Tab. 120, giving a diagnosis of the genus, followed by a description of *Spirifer cuspidatus*. Other species are mentioned, but none are named. King, Meek, and others have accepted *Anomites cuspidatus* as the type of *Spirifer*, but Davidson urged that Sowerby's intention that *Anomites striatus* should be the type must be accepted, and in this he has been followed by most subsequent authors, and *Anomites cuspidatus* has since been referred to the genus *Syringothyris*, Winchell, 1863. If *Anomites cuspidatus* is regarded as the type of *Spirifer*, *Syringothyris* becomes a synonym of *Spirifer*, while the group of *Anomites striatus* must take another name. Dall[2] sums up the position thus: If the work of restriction were to be done over again, it is probable that most authors would consider the rules of nomenclature better served by taking *cuspidatus* as the type, but the reverse process has been the rule among authors so long that it would be a serious detriment to science to attempt such a change at present.

Since the Fourth International Zoological Congress at Cambridge in 1898 there has been a Permanent International Commission on Zoological Nomenclature which studies questions of nomenclature and renders opinions upon cases submitted to it. Opinion 30[3] on Swainson's *Bird Genera* of 1827 almost exactly applies to the case of *Spirifer*. Swainson wrote and sent for publication to the *Zoological Journal* a paper containing diagnoses of several genera, with explicit designation of their types. This first written paper was unexpectedly long delayed in publication, greatly to the disappointment of the author, as he stated, who was powerless to prevent the inopportune delay. This paper was published in two

[1] *Fide* W. H. Dall, "Index to the Names which have been applied to the Subdivisions of the Class Brachiopoda": Bull. U.S. Mus., No. 8, 1877, p. 63. F. J. North ("On the Genus *Syringothyris*, Winchell": GEOL. MAG., Dec. V, Vol. X, pp. 393–401, 1913) gives the date of publication as 1818. I have not access to the publication in question, but all authors agree that it was published subsequently to *Min. Conch.*, vol. ii.

[2] Loc. cit.

[3] "Opinions rendered by the International Commission on Zoological Nomenclature." Opinions 30–7. SmithsonianIn stitution, Publication 2013, 1911, pp. 69–72.

parts appearing April–July, 1827, and August–November, 1827. In the meantime he described some new species of Mexican birds in a paper which appeared in the *Philosophical Magazine* in May and June, 1827, referring some of them to the new genera proposed in the earlier written but later published paper. The International Commission held that Swainson's bird genera in the *Philosophical Magazine* of 1827 are monotypic, and according to Article 30 (*c*) the species mentioned are types of their respective genera. Therefore, these types must take precedence over the designated types of Swainson which occurred later in the *Zoological Journal* of 1827. The argument on which this opinion was based was stated as follows:—

"In order to fully realize the bearing of the principle involved in the present case, let us ask ourselves the question: What was the type of these genera in the interim between the prior publication in the *Philosophical Magazine* and the type designation in the *Zoological Journal*? During these 'two or five months (as the case may be)' the genera rested solely on the generic name and the single species described in the *Philosophical Magazine*. No other species was known to belong to these genera during the two or five months. Surely during that period these generic names were monotypic, and could rightfully have no other type than the only species then described. But if a genus once has a rightful type there is no way under the international rules to substitute another later. If a genus has been monotypic for two or five months, or any other length of time, subsequent publication cannot alter its status however plausible may be the argument otherwise, and this status can be no more 'subject to change' than 'designation of the type' itself.

"Any interpretation other than the one here followed might give rise to serious complications. For instance, to admit that a later article can undo the types actually (though possibly unintentionally) published in an earlier article, as in this case, would make it possible for an author to publish a genus as monotypic and then, years later, to alter his type in some manuscript the publication of which had been purposely or unintentionally delayed for decades. Thus, unless an author definitely stated that a genus was monotypic, no genus originally published with mention of only one species could be looked upon as having the genotype definitely established until after the author's death, and after it was proved that he left no unpublished manuscript behind him."

The case of *Spirifer* is extremely similar but simpler. From 1818 to 1821 the genus was monotypic so far as Sowerby was concerned, and included only *Spirifer cuspidatus*, and this, therefore, cannot be displaced as the type of the genus if the international rules are to be adhered to.

Thanks to *Punch*, the name *Ichthyosaurus* has become a household word in a more complete sense than *Spirifer*, but it also can be used only in contravention of the international rules. It was proposed by Conybeare in 1821, but it is preoccupied by *Proteosaurus*, Home, 1819. Lydekker[1] stated the case thus: "There is no real

[1] R. Lydekker, *Cat. Foss. Rept. Brit. Mus.*, pt. ii, 1881, p. vii.

justification for superseding the earlier name *Proteosaurus* by the later *Ichthyosaurus*; but since the latter name has been universally adopted, the writer, after consultation with the Director of the (British) Museum, has come to the conclusion that this is one of the cases where an adherence to the rule of priority is not advisable."

An analogous case is furnished by the common mollusc, popularly known as *Octopus*. As a matter of fact *Octopus*, Lamark, 1798, is preceded by *Polypus*, Schneider, 1784, and in this case malacologists have applied the rule of priority and displaced *Octopus*,[1] but it may be doubted whether the interests of science are best served by such action.

These three cases, and doubtless many others which could be cited, show that a rigid application of the law of priority will displace names which by a century of usage have found their way into hundreds of textbooks, and even into popular literature. The best way to avoid so regrettable a step is for an International Zoological Congress to adopt a list of *nomina conservanda*. This paper is written to enlist the co-operation of geologists in creating a public opinion in this direction.

REVIEWS.

I.—Novitates Palæozoicæ.

Paleontologic Contributions from the New York State Museum. By Rudolf Ruedemann. N.Y. State Mus. Bulletin, No. 189. 226 pp., 36 pls. September, 1916.

THE belated appearance of this review must be excused by the War's delays, which hindered the receipt of the volume. It would, however, be a pity to pass over for that reason all the observations of interest that Dr. Ruedemann has here collected. Let us consider a few of them.

Plumalina plumaria, from sandy shales of the Portage group, described by J. Hall as a graptolite and referred by J. W. Dawson to the plant *Lycopodites*, is here said to possess no thecæ, but to have an inner solid carbonaceous (? chitinoid) axis and an outer granular (? calcareous) rind, comparable with the structure in the Gorgonidæ. The fossils are therefore referred provisionally to the Alcyonaria.

Another plant-like fossil, *Buthotrephis lesquereuxi*, from the Silurian Eurypterus beds, is found to consist of twisted thin tubes opening on the general surface in pores (about ·5 to 1 mm. linear), and is referred to *Inocaulis*, which Dr. Ruedemann regards as a graptolite allied to *Dictyonema*. Some species hitherto referred to *Dictyonema* (*D. furciferum* Rued., *D. cervicorne et alia* Wiman) are shown to have apertural processes with forked ends which attach themselves to the neighbouring branch, and so, while outwardly resembling the dissepiments of *Dictyonema*, differ from them in origin; they are placed in a new genus *Airograptus*, which should have been spelled

[1] e.g. H. Suter, *Manual of the New Zealand Mollusca*, Wellington, 1913, p. 1062.

Haerograptus. Dr. Ruedemann has previously described colonial stocks of various genera, but not of *Climacograptus*; he now figures a fine example of one in *C. parvus.*

The strangest fossil of the Portage beds was described in 1900 by Dr. J. M. Clarke under the name *Cryptophya* and referred by him to the echinoderms. Th. Fuchs (1905) suggested that it was the float of a siphonophore, and this view is strengthened by the recent discovery of specimens in which presumed air-chambers have been injected with sediment. A curious imprint from the same beds, on which a new genus *Plectodiscus* is here based, is probably a related form.

From the Glens Falls Limestone at the base of the Trenton, Dr. Ruedemann has obtained a *Pleurocystis*, the first found in New York State, and figures it as "*Pleurocystites squamosus* (Billings) mut. *matutina* nov." Why should Billings be in brackets, by the way? In the absence of a detailed description and measurements, one cannot say more than this: the fossils are certainly specifically distinct from *P. squamosa*, but closely resemble the Kentucky fossil *P. mercerensis* Miller & Gurley (not mentioned by Dr. Ruedemann) in all the characters that I have regarded as "specific" for this genus, as well as in the radiate sculpturing of the plates, a somewhat unusual feature. (See Trans. R. Soc. Edinburgh, 1913.)

The many valuable notes on Devonian Asteroidea, with their beautiful illustrations, may be left for Dr. W. K. Spencer to deal with. Here let us only state that they propose the new genera *Clarkeaster*, *Lepidasterina*, and *Klasmura*. There are also two new starfishes from the Silurian Conularia Limestones of Argentina, one an *Encrinaster*, the other serving as basis for a new genus, *Argentinaster*.

A curved, flattened, segmented body from the Marcellus shale, with overlapping scales on the concave margin, is certainly, as Dr. Ruedemann says, reminiscent of certain palæozoic fossils usually referred to the Cirripedia. He prefers, however, to regard it as a new species of *Protonympha* J. M. Clarke, which may be a polychætous annelid. Several annelid tubes from palæozoic rocks, apparently congeneric with *Serpulites longissimus* Murchison, are shown to spring from the adhesion discs which J. Hall described as *Sphenothallus* under the impression that they were plants. These fossils also present close resemblance to *Torellella* Holm, and a further link with the Conularida is thought to appear in *Conularia gracilis* Hall. Dr. Ruedemann therefore suggests that the Conularida may be derived from the Annelida.

The description of some new species of *Spathiocaris* revives the discussion about the Discinocarina. H. Woodward has considered them to be crustacean carapaces. Roemer and others took them for aptychi of goniatites. J. M. Clarke hesitates between a brachiopod, crustacean, and cephalopod connexion. Dr. Ruedemann now brings further arguments in support of their aptychus nature, though without fully satisfying even himself.

In some specimens of Lower Silurian age, Dr. Ruedemann recognizes the first American representatives of the doubtful fossils which Barrande called *Anatifopsis*, and their study leads him to conclude that the genus should be placed in the Lepidocoleidæ. His description and figures are, however, far from convincing. For one thing, the ornament of his fossils differs in several respects from the growth-lines of both *Anatifopsis* and *Lepidocoleus*.

The description of some new Eurypterid remains leads Dr. Ruedemann to traverse the view of A. W. Grabau and Miss M. O'Connell that the Eurypterids always lived in rivers, and this he does to good effect.

The existence of eyes in the limuloid arachnid *Pseudoniscus*, of Silurian age, has long been debated. Specimens of two species here described show small but distinct eyes on the facial suture further forward than they had been alleged to occur in the known species from Oesel. Somewhat similar reduced eyes in the trilobites have occasionally been called "ocelli", but no eyes truly homologous with the ocelli or median eyes of Merostomata and of various Crustacea have hitherto been demonstrated. Both Beecher and Cowper Reed, however, have suggested that the distinct and isolated tubercle on the median line of the glabella in *Trinucleus* may be such a median eye. Dr. Ruedemann now maintains the correctness of that suggestion, and extends it to most, if not all, trilobites, for the following reasons. Such a tubercle is found in many species belonging to over thirty genera, and its frequent association with a smooth glabella proves that it had some use. In *T. tesselatus*, of which he gives good figures, and in other species, he has found evidence of a lens, not crystalline, but probably a sack filled with fluid. The test is thinner over the tubercle. The tubercle is more prominent in early growth-stages, as are true ocelli, and is well developed when the lateral eyes are aborted. It is always on the highest point of the glabella, generally between the lateral eyes, and often at the hinder end of a short crest which may indicate the course of the nerve. An ocellar tubercle or mound is commonest in Ordovician and Silurian trilobites. In Cambrian genera there is some evidence of transparent spots. In Devonian genera the strong development of the lateral eyes may have led to the loss of the median eye. The occurrence of a median eye in many primitive arthropods renders it *a priori* probable that such an organ was also possessed by the trilobites.

The discovery of a median eye in *Trinucleus* showed that the vestigial eyes of that genus were not ocelli but lateral eyes, and suggested search for the sutures on which they should occur. The detection of these here and elsewhere corroborates the views of Jaekel, Richter, and Swinnerton (Geol. Mag., 1915, p. 490) and upsets the Order Hypoparia. The search also led to the discovery of a new suture, which starts from a minute tubercle at the front end of the short crest mentioned above, and diverges to enclose the middle region of the front end of the glabella. Dr. Ruedemann suggests that this is "the rostral piece or epistoma . . . drawn up into the glabella by the exceptional swelling of the frontal lobe of the glabella and the development of the broad brim".

Enough has now been said to show how the palæontologists of

New York State are still making us their debtors, and to warrant our once more exclaiming with Miranda:

O wonder!
How many goodly creatures are there here!
O brave New World, that has such people in't!

F. A. Bather.

II.—Mesozoic Insects of Queensland. By R. J. Tillyard. (1) Planipennia, Trichoptera, and the new Order Protomecoptera; (2) The Fossil Dragon Fly *Æschnidiopsis flindersiensis* (Woodward) from the Rolling Downs (Cretaceous) Series; (3) Odonata and Protodonata; (4) Hemiptera Heteroptera; the Family Dunstaniidæ. Proc. Linn. Soc. N.S. Wales, xlii, pp. 175–200 (1917), 676–92 (1918); xliii, pp. 417–36, 568–92 (1918).

THE first, third, and fourth of these papers deal with the insects of the Ipswich Beds (Upper Trias) of Ipswich, Queensland. It is stated to be a definitely Mesozoic fauna, not unlike that of the Lias of England, but including a number of older forms apparently relics of the Coal-measure fauna; it is especially interesting because it fills up a gap in the succession of insect faunas owing to the hiatus in the Trias of the Northern Hemisphere. *Protopsychopsis* is a new genus of the Order Neuroptera Planipennia; *Mesopsyche* and *Triassopsyche* are new genera of the Trichoptera. The new Order Protomecoptera, including *Archipanorpa*, n.gen., forms a connecting link between the Palæozoic Palæodictyoptera and the recent Mecoptera. New genera of Odonata are *Triassolestes* and *Perissophlebia*. *Aëroplana*, n.gen., of which the venation does not show any close relationship to that of any other insect, either fossil or recent, is referred to a new sub-order (Aeroplanoptera) of the Protodonata. The affinities of *Dunstania* are discussed at considerable length; it was formerly regarded by the author as belonging to the Lepidoptera, but is now referred to the Hemiptera Heteroptera. Two new genera (*Dunstaniopsis* and *Paradunstania*), allied to *Dunstania*, are described.

The second paper deals with a dragon-fly from the Rolling Downs Series (Cretaceous) of Flinders River, North Queensland. This was originally described by Dr. H. Woodward (1884), who recognized its relationship to *Æschnidium* from the Purbeck Beds of Dorset. This specimen is described in detail by Dr. Tillyard, who regards it as the type of a new genus, *Æschnidiopsis*.

III.—Permian and Triassic Insects from New South Wales, in the Collection of Mr. John Mitchell. By R. J. Tillyard. Proc. Linn. Soc. N.S. Wales, vol. xlii, pp. 720–56, 1918.

THE Permian insects described in this paper come from the upper part of the Newcastle Coal-measures, which are generally classed as Permo-Carboniferous on account of the affinities of the marine fauna. The insects are associated with a *Glossopteris* flora, and have nothing in common with any known Carboniferous fauna, but show distinct affinities with Triassic forms. New genera of the Hemiptera Homoptera are *Permoscarta* and *Permofulgor*, the latter believed to have close affinity with the ancestors of the recent Fulgoridæ. The

Mecoptera are represented by *Permochorista*, n.gen., from which it appears that the Mecoptera are probably the most ancient of all Holometabolous insects.

The Triassic insects come from the Wianamatta Shale Beds at horizons from 300 to 700 feet above the Hawkesbury Sandstone, and are regarded as of Upper Triassic (probably Keuper) age. *Notoblattites* was originally placed in the Blattoidea, but is now referred to the Protorthoptera, and it is suggested that the cockroaches do not really belong to a separate Order, but are a specialization from a very ancient Protorthopterous type. *Mesopanorpa*, n.gen., is referred to the Mecoptera. The Coleoptera are represented by *Ademosyne*, *Elateridium*, *Adelidium*, n.gen., and *Metrorhynchites*; the Hemiptera Homoptera by *Triassopsylla*, n.gen.

IV.—Iron Ores of Scandinavia.

Jernmalm og Jernverk. By J. H. L. Vogt. Norges Geol. Undersök, No. 85, pp. 181, with 4 figs. Kristiania, 1918.

THIS important memoir of the Norwegian Geological Survey consists of two parts; the first part includes a review of the iron-ore production of Norway in recent years and especially since the publication of the author's earlier work, *Norges Jernmalmforekomster* (1910), together with statistics of export, import, and consumption of iron, import of coal and coke, and prices of ore and of pig-iron. It is interesting to find that in 1915 Sydvaranger produced, by magnetic concentration, 600,000 tons of 65 per cent ore, of which nearly half was briquetted; this ore contains no titanium, chromium, or vanadium, while phosphorus and sulphur amount to only 0·012 per cent in the concentrates; the production is expected shortly to reach 900,000 tons per annum. But of the $3\frac{3}{4}$ million tons of iron-ore shipped from Norwegian ports in 1913, $3\frac{1}{5}$ million tons were Swedish ore, mainly from Kirunavaara, exported via Narvik. About eighty pages are occupied by a full and detailed account of the mining districts of Arendal, Kragerö, Nissedal, Nordmöre, Trondhjem Fjord, Tromsö, and Sydvaranger, as well as the less important occurrences of Bogen and Dunderlandsdal. Owing to its importance to Norwegian export trade and commerce in general, a description is also given of the Swedish Kiruna ore, with analyses of the different grades, now reduced to four in number, A, C, D, and G. These range from a low-phosphorus ore (A) with 0·015 per cent P, to a type with 3 per cent or more of phosphorus, due to a high proportion of apatite in the differentiated mass. The highest quality contains about 69 per cent Fe, and is one of the finest ores in the world. By agreement with the Swedish Government this quality is reserved for home consumption in Sweden, where it is transported by rail to the amount of about 50,000 tons per annum. Over 80 per cent of the whole export via Narvik consists of high phosphorus ores, D and G, specially adapted for basic steel.

The last sixty pages of the memoir are occupied mainly by a discussion of the relative advantages of electric furnaces over ordinary blast furnaces for the home manufacture of pig-iron from

Norwegian ores. It is concluded that, owing to the abundance of water-power and absence of coal, the building of ordinary blast furnaces would be an economic mistake, since the fuel-consumption in an electric furnace is approximately only about one-third of that in a blast-furnace, and water power is cheap. It is estimated that the power consumption in an electric furnace is about 2,200 kilowatt-hours per ton of pig, which is equivalent to 3·98 tons of pig per kilowatt-year, or 2·92 tons per horse-power-year. Hitherto, the Swedish electric furnaces have been largely worked on charcoal, but coke is now extensively employed and gives good results. It is considered that small furnaces of the Tinfos type, working at about 1,500 kilowatts are not quite so economical as the larger Electro-metal furnaces of 3,500–4,000 kilowatts, but under certain circumstances they are perhaps better suited to a budding industry, being altogether on a smaller scale and needing less capital outlay.

From the data here supplied it is clear that in a country like Norway, with no coal and abundant water-power, electric furnaces offer great possibilities for the production of pig-iron for steel making for home consumption during periods of stress like the present time, when freights are high and dumping impossible, but it remains to be seen whether they will be able to compete with imported manufactured and half-manufactured goods on the return of more normal conditions of foreign competition and cheaper low-grade raw materials worked on a very large scale in England, America, and Germany.

R. H. R.

V.—Report on the Geology of the Hohoro District, Papuan Oilfield. By W. G. Langford. Bulletin of the Territory of Papua, No. 4, 16 pp., with 12 figs. and maps. Melbourne, 1918.

In this report Mr. Langford gives an account of the physiographic features and geology of part of the Vailala oil-bearing district of Papua, where the existence of gas-blows has been known for some time. The essential structure is an elongated dome or anticline traversed by faults and consisting of sandstones, mudstones, and limestones, with occasional seams of lignite of Middle or Upper Miocene age. The rocks are highly fossiliferous and the fossils are described in a separate report. Sites have been selected for trial bores, and development is now in active progress.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *June* 4, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Dentition of the Petalodont Shark, *Climaxodus.*" By Arthur Smith Woodward, LL.D., F.R.S., P.L.S., F.G.S.

The author describes the nearly complete dentition of a new species of *Climaxodus* from the Calciferous Sandstone of Calderside, near East Kilbride (Lanarkshire), now in the Royal Scottish Museum, Edinburgh. Nearly all the teeth are borne on the symphysis of the jaw, only the outer paired longitudinal series extending a little farther back over the rami. There are from three to five longitudinal series, each of five or six teeth of the ordinary *Climaxodus* type, covering the greater part of the symphysis; and the flanking paired series, which extends farther back, comprises more depressed teeth, in which the cutting-edge forms a low blunt ridge. The two jaws are nearly similar; but, as in *Janassa*, the upper seems to have been slightly wider than the lower jaw. The teeth rapidly increase in size backwards, also as in *Janassa*, but they must have been all retained in the mouth throughout life; while in *Janassa* only a single transverse row would be in function at one time, the older teeth being thrust beneath to form a supporting base. *Climaxodus* and *Janassa* are thus two distinct genera. These Petalodonts are especially noteworthy among the Elasmobranchii, because during the greater part of the life of each individual there cannot have been more than six or eight teeth in succession, a condition remarkably different from ordinary sharks and skates in which the successional teeth are always very numerous and rapidly replaced. The same limited tooth-succession is to be observed in the Carboniferous Cochliodontidæ, and perhaps also in the contemporaneous Psammodontidæ. Most of the teeth of *Climaxodus* are also interesting as showing a restricted area of highly vascular dentine much resembling a tritor in the dental plate of an ordinary Chimæroid. This character in Elasmobranch teeth which are peculiar for their slow and scanty succession, may have some special significance in connexion with the origin of the Chimæroids.

2. "A New Theory of Transportation by Ice: the Raised Marine Muds of South Victoria Land (Antarctica)." By Frank Debenham, B.A., B.Sc., F.G.S.

A series of deposits of marine muds are found on the surface of floating "land-ice" in the deep bays of Ross Sea (Antarctica). Similar deposits are also found on land up to a height of 200 feet, in some cases on old ice, in other cases on moraine. The deposits are briefly described, and former theories concerning them are discussed.

A new theory is put forward, prefaced by an account of the nature of the typical ice-sheet which bears them. The upper surface of the sheet is known to suffer a net annual decrease, and evidence is given to show that the lower surface has a net increase by freezing from below.

The theory is that the sheet will freeze to the bottom in severe seasons, and enclose portions of the sea-floor. Owing to the method of growth of the sheet by increments from below, the enclosed portions will ultimately appear on the surface, thus being raised vertically as well as translated horizontally.

The application of the theory to other localities is briefly sketched, with especial reference to the shelly moraines of Spitsbergen and the shelly drifts of the glacial deposits of Great Britain. The general results of such a method of transportation are shown to be the raising of marine deposits above their initial level, the preservation of the organisms, the deposition of small patches of muds with ordinary supra-glacial moraine, and the collection of remains of fauna from different depths in one horizon.

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2. *June* 25, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communications were read:—

1. "Outlines of the Geology of Southern Nigeria (British West Africa), with especial reference to the Tertiary Deposits." By Albert Ernest Kitson, C.B.E., F.G.S., Director of the Geological Survey of the Gold Coast.

The oldest rocks in Southern Nigeria comprise a series of quartzites, schists of various kinds, blue and white marble, grey limestones, altered tuffs and lavas, amphibolites and gneisses. Their strike varies from west-north-west and east-south-east to north-east and south-west. They occur in the north-western portion of the country (Yorubaland), north of lat. 7° N., and in the Oban Hills region in the east. They may be classed provisionally as Pre-Cambrian. Intruded into these are large masses of granites of various kinds, syenite and diorite, with pegmatite and aplite dykes. In some parts these rocks have shared in the dynamic alteration to which the oldest series has been subjected; but usually they are practically unchanged. There is no definite evidence to show to what period they belong, but they are certainly Pre-Cretaceous, probably Middle and Early Palæozoic.

So far as observed, there is a great hiatus between the Pre-Cambrian and the next known sediments, the Upper Cretaceous. Normally, these are slightly inclined rocks: they include (1) Marine fossiliferous shales, mudstones, limestones, and sandstones in the great valley between the Oban Hills and the Udi plateau. The fossils are principally ammonites and mollusca; (2) Estuarine fossiliferous carbonaceous shales, mudstones, and sandstones along the eastern foot of the Udi escarpment; (3) Lacustrine sandstones, shales, and black coal-seams, with numerous plant-remains; and (4) Fluvio-lacustrine sands, shales, and pebble-bands in the lower and upper parts of the Upi plateau.

Flanking this plateau on the south and south-east, and extending thence over the southern part of the great valley to the Cross River, is a series of Eocene estuarine shales, clays, and marls, with septarian nodules and pieces of coal and resin, and a rich fauna consisting principally of mollusca, but including fragmentary remains of whales, birds, fishes, and turtles.

A thick series of sandstones, mudstones, shales, and seams of brown coal forms a large portion of the basin of the Niger, west of the Udi plateau. These rocks appear to be of lacustrine origin, and are probably Eocene. They contain numerous remains of undetermined plants, largely of dicotyledonous types, Their relation to the Cretaceous and to the Eocene estuarine series is uncertain.

In the Ijebu Jebu district are bituminiferous sands and clays with Pliocene estuarine shells.

Extending over practically the whole of the country south of lat. 7° 10′ N., and west of the great valley of the marine Cretaceous is a varying thickness of (usually unstratified) clayey sands, probably late Pliocene—the Benin Sands Series of Mr. J. Parkinson.

Along the coast-line and extending for considerable distances up the Niger and Cross Rivers are fluviatile, deltaic, littoral, and swamp gravels, sands, and muds of Pleistocene and recent age. In the Cross-River basin, intruded into the marine Cretaceous, are volcanic necks of decomposed agglomerate, and sills (?) and dykes of olivine-dolerite. These are probably Pre-Eocene.

Faulting and local folding are visible in various portions of this district. Numerous silver-lead-zinc-iron lodes occur along these fault-lines, with brine-springs in several localities.

The Yorubaland crystalline rocks contain magnetite in considerable quantities, while these and the crystalline rocks of the Oban Hills show smaller quantities of cassiterite, gold, monazite, and columbite.

2. "Notes on the Extraneous Minerals in the Coral Limestones of Barbados." By John Burchmore Harrison, C.M.G., M.A., F.G.S., F.I.C., and C. B. W. Anderson.

Characteristic representative specimens of the fossil reef-corals and of the beach-rock of the high-level and low-level limestone terraces of Barbados were examined chemically and microscopically, in order to ascertain the composition, nature, and origin of their extraneous mineral contents. A special method was used, whereby the extraneous mineral matters were separated, practically without alteration, from large quantities of the limestones. Chemical analyses of the residua were made, and the results of these and of the microscopical examinations are tabulated in the paper. The extraneous minerals present were found to be apparently fresh and largely unaltered fragments of wind-borne volcanic minerals and glass. It was found that the volcanic minerals enclosed in the reef-corals on which they fell have been protected from change; those in the clastic limestone or bed-rock show signs of detrition and weathering prior to the consolidation of the limestone. Similar minerals separated from clay normally formed and accumulated in a pothole in the limestone supply evidence of weathering changes after being set free from the rock. It is shown that the composition of the sedentary residual soils on the higher limestone terraces of Barbados corresponds in its essential parts with the residua separated, either naturally or artificially, from the limestone.

The proportions of magnesium carbonate present in the coral-rock are briefly discussed, and complete analyses of the high-level and the low-level limestones are given. A note on the proportions of titanium oxide in the Barbados Oceanic clays and in some of the *Challenger* and *Buccaneer* deep-sea dredgings is appended to the paper.

II.—Mineralogical Society.

June 17, 1919.—Dr. A. E. H. Tutton, F.R.S., Past-President, in the Chair.

A. E. Kitson: "Diamonds from the Gold Coast." The crystals and their occurrence were described.

A. Brammall: "Andalusite (Chiastolite); its Genesis, Morphology, and Inclusions." In a survey of thermometamorphic "spotted" rocks evidence based on structural features, optical properties, and microchemical reactions is adduced to show that certain types of spots convergent towards such minerals as chiastolite, andalusite, cordierite, mica, and chloritoid record arrested development, and that they are probably ontogenetically related. The spot is a complex system containing a volatile phase, water, and its development involves metamorphic diffusion and differentiation controlled by changing conditions of temperature and stress, the tendency being towards the attainment of an equilibrium end-point in a metastable mineral. Thermal and stress conditions adequate to initiate the tendency may be inadequate to sustain it, the time factor also being involved; development may be arrested and abortive effort recorded as a mineral "spot", the nature of which is determinable, but is often vague or wholly conjectural. The chemical and physical characters of argillaceous sediments are considered with special reference to the genesis of chiastolite. Clays contain a high proportion of hydrated silicates of alumina readily soluble and in part probably colloidal. On rise of temperature diffusion effects the segregation of the primary clot; diffusion inwards of allied molecules and diffusion outwards of alien substances tend to promote homogeneity and reconstitution within the spot, the peripheral zone being maintained for a time in a relatively high state of hydration. In this connexion the peripheral zone of yellow-brown, non-pleochroic, and isotropic stain is significant; microchemical tests show that it is due to ferric hydrates, which are known to be liable to spontaneous dehydration, and it is suggested that the ferric hydrate in the peripheral stain acts as a catalyst, assisting dehydration within the spot and transmitting water to the base. For chiastolite (andalusite) a mechanism of formation is suggested to cover the observed facts, to explain the characteristic distribution of its opaque inclusions, and to account for crystals which have the superficial aspect of cruciform twins.

R. H. Rastall: "The Mineral Composition of Oolitic Ironstones." In many oolitic ironstones the ooliths contain more iron or are more highly oxidized than the matrix. Assuming that the iron-content of such rocks is introduced by metasomatism of calcium carbonate, this may be explained in the following way. Many ooliths and organic fragments in limestones consist of aragonite, while the cement is calcite. Aragonite is less stable than calcite and more readily decomposed by iron-bearing solutions, which therefore attack the aragonite first, while the calcite is replaced later. Hence we have the following scheme in successive stages:—

Ooliths.	Aragonite →	Chalybite →	Limonite.
Matrix.	Calcite —	Calcite →	Chalybite.

The ooliths are always a stage ahead of the matrix in replacement and oxidation. The origin of the green iron silicate, found in many ironstones, requires further investigation.

L. J. Spencer: "Eighth List of Mineral Names."

III.—Geologists Association.

July 4, 1919.—Mr. J. F. N. Green, B.A., F.G.S., President, in the Chair.

The following lecture was delivered: "The Geology of the Llangollen District." By L. J. Wills, M.A., F.G.S.

The lecture dealt with the following:—

1. *The General Sequence of Rocks.*—The Carboniferous, the Ludlow and Wenlock (Denbighshire type of Salopian Series), the Tarannon – Llandovery (Valentian Series), the Ashgillian and Caradocian (Bala Series). Notes on the fossils and zonal divisions and on the igneous rocks.

2. *The General Structure.*—The Carboniferous unconformity, the Llangollen synclinorium, the Berwyn and Cyrn-y-brain anticlines and the Bala fault, the cleavage and faulting.

3. *The Glacial History of this Part of the Chester Dee.*—The Welsh and Irish Sea ice-sheets in conflict, the phenomena of the retreat of the ice, the changes in the physical geography and effect on the human occupation.

CORRESPONDENCE.

THE CARBONIFEROUS LIMESTONE OF THE WREKIN DISTRICT.

Sir,—In the February number of the Geological Magazine, p. 77, Mr. Parsons states that with the exception of one or two references to the Lower Carboniferous rocks of the area made in *Geology in the Field*, there does not appear to be any published description of the limestone of the district.

This statement overlooks the fact that a paper on "The Carboniferous Limestone of Lilleshall" by Wheelton Hind, M.D., F.G.S., etc., is printed in the Trans. N. Staffs Field Club, vol. xxxv, pp. 107–9, 1900–1, giving a section of the beds nearer to Lilleshall Hill, just below the wharf.

And again, some members of the geological section of the same club visited these quarries on a subsequent occasion, and a list of Corals, Crinoidea, and Brachiopoda observed are recorded in vol. xliii, p. 109, 1908–9.

In the same number of the Geological Magazine, pp. 59–64, there is a paper "On the Discovery of a Quartzose Conglomerate at Caldon Low, Staffs" by J. Wilfrid Jackson, F.G.S., and W. E. Alkins, B.Sc. The writers of this paper report a discovery of an exposure of a quartzose conglomerate in a quarry at the Low.

This deposit was discovered in 1905 by members of the Geological section of this club, and the fact recorded in the Trans., vol. xl, p. 85, 1905–6.

F. Barke,
Chairman of Geological Section of N. Staffs Field Club.

Stoke-on-Trent.
June 6, 1919.

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THE SECRETARY OF STATE FOR INDIA proposes to make four appointments to the Indian Geological Survey Department in August or September this year if so many qualified candidates are available. Preference will be given to candidates who have served in His Majesty's Forces. Besides a good general education a sound education in Geology is essential; a University degree and a knowledge of French or German will be regarded as important qualifications. The age of candidates who have not served in His Majesty's Forces should not exceed 25 years on July 1, 1919, but this limit will not be adhered to in the case of those who have served for one year at least, or who have been discharged after less than one year's service on account of wounds or illness resulting from such service.

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HENRY WOODWARD, LL.D., F.R.S.

AND

R. H. RASTALL, M.A.

ASSISTED BY

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SEPTEMBER, 1919.

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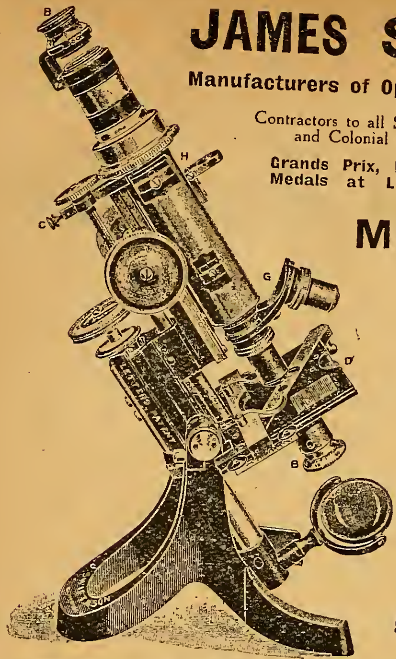

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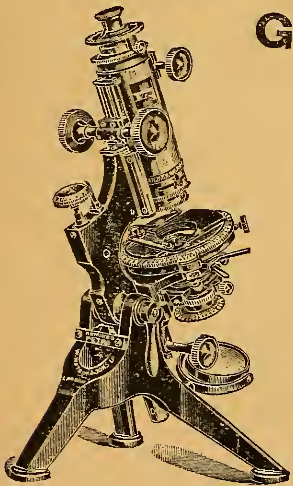

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GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. VI.

No. IX.—SEPTEMBER, 1919.

EDITORIAL NOTES.

AMONGST the long list of deferred Birthday Honours is that of a Knighthood to the well-known geologist (who has attained his 81st year), William Boyd Dawkins, M.A., D.Sc. (Oxford), Hon. D.Sc. (Man.), F.R.S., F.S.A., F.G.S., M.Inst.M.E., Assoc.Inst.C.E., Hon. Professor of Geology and Palæontology in the Victoria University, Manchester. Professor Boyd Dawkins is one of the few surviving geologists who, with Sir A. Geikie, Sir Ray Lankester, and Dr. Henry Woodward, assisted in giving birth to the first number of the GEOLOGICAL MAGAZINE on July 1, 1864, fifty-five years ago. We offer Sir William Boyd Dawkins our heartiest congratulations on this latest distinction conferred upon him by the King.

* * * * *

As a result of recent great developments in the Departments of Geology and Geography at Cambridge several new appointments have been made. In view of the recent establishment of a Geography Tripos, and in order to provide a single responsible head for the department, the General Board of Studies have recommended the establishment of a Royal Geographical Society Readership in Geography, to which it is proposed to appoint P. Lake, M.A., of St. John's College, hitherto Royal Geographical Society University Lecturer in Regional and Physical Geography. This latter lectureship is to be suspended for the present. F. Debenham, of Gonville and Caius College, has also been appointed Royal Geographical Society University Lecturer in Surveying and Cartography. It is to be noted that both these gentlemen are well-known geologists. In the Department of Geology a new University Lectureship in Economic Geology has been created, to which R. H. Rastall, M.A., of Christ's College, has been elected. The Woodwardian Professor has chosen as his assistant T. C. Nicholas, O.B.E., M.C., M.A., of Trinity College, while the new Demonstrator in Petrology is J. M. Wordie, M.A., of St. John's College.

* * * * *

EARLY in August it was announced that the Government have appointed a Departmental Committee to inquire into the present position of the non-ferrous mining industry in this country. This is a subject on which a great deal has been written in the technical and general press, and there can be no doubt that the changed conditions of the last few months have left matters in a very complicated and unsatisfactory position. This was probably inevitable under the circumstances, and we trust that the Committee will be able to find some way of putting the industry on a sounder financial basis. The writer of these lines has lately had an opportunity of seeing something of the tin-mining industry of Cornwall, and has formed certain opinions on the subject. However, in view of the approaching Government investigation this is not the time to expound these opinions. It must suffice here to say that geologists will await with much interest the results of the comprehensive scheme of exploration and development now to be undertaken in the hitherto untried region between Camborne and the sea. These investigations promise to yield results of great importance, and will in all probability throw some light on the question of the underground relations of the masses of granite now visible at the surface in Cornwall. This is a problem of much interest to petrologists and structural geologists, apart from its economic importance, in view of the fact that the richest deposits of tin are as a rule closely associated with the granite-slate contact.

* * * * *

In the list of members of the Committee mentioned in the preceding paragraph we are glad to see the name of Dr. F. H. Hatch, whose interesting lecture on recent developments in the iron-ore industry of this country we print in the present number. Dr. Hatch has a very wide knowledge of mining matters in many parts of the world in connexion with many kinds of metalliferous ores, and his help will be of great value to the Committee. As is well known Dr. Hatch rendered most valuable services to the country during the War in relation to the development of home iron-ores and other necessary materials to counteract the falling off in imported supplies, while he is also an active member of the recently instituted Mineral Resources Bureau.

* * * * *

It is perhaps not yet too late to remind our readers that the meeting of the British Association takes place at Bournemouth from September 9 to 13. This year the meeting will again be held under more or less normal conditions, although the programme of official functions is somewhat smaller than of old. Many members will no doubt consider this an advantage rather than otherwise. It is satisfactory to observe that it has been found possible to obtain accommodation for practically the whole of the work of the meeting in one building, namely, the Municipal College. A series of citizens' lectures are to be given in co-operation with the Workers' Educational Association, and one of these is to be delivered by Professor S. H. Reynolds on the scenery and geology of the Isle of Purbeck; this should prove an attractive subject. Several excursions have been arranged to places of geological interest, which abound in the neighbourhood, including such classic localities as Lulworth Cove and Kimmeridge. It would be difficult to find a region more attractive from this point of view.

ORIGINAL ARTICLES.

I.—Recent Iron-ore Developments in the United Kingdom.[1]

By Dr. F. H. Hatch.

WHILST the basis of the prosperity of a country is admittedly agriculture, its industrial growth is founded on mineral resources, and its participation in the world's markets is chiefly dependent on the extent to which these raw materials can be applied to home manufactures.

It is true that the first historical reference to this country mentions the export of tin from Cornwall and that Great Britain's production and export of copper in the early part of the nineteenth century were the largest in the world; but for its modern industrial pre-eminence this country is undoubtedly indebted to its coal and ironstone.

The cheap manufacture of iron and steel in this country was greatly aided by the providential dispensation that the ironstone was so closely associated in nature with the fuel required to smelt it that the factor of transportation was practically eliminated.

But the gradual exhaustion of the richer blackbands and clay ironstones of the Carboniferous formation, and the introduction of the Acid Bessemer Process of steel manufacture, which requires a pure ore free from phosphorus and sulphur, made it necessary to find other sources of iron-ore supply. For many years the United Kingdom has been dependent for 30 per cent of the iron-ore used in its blast-furnaces, on foreign countries. Foreign ore plays even a bigger rôle than at first sight appears, since it contains 50 per cent iron as against an average of 30 per cent for home ores. The importation of hæmatite, rich in iron and low in phosphorus, from Spain and the Mediterranean, has built up the big iron industries that are engaged in the manufacture of steel by the Acid process in South Wales, on the North-West coast, on the North-East coast, and in Scotland, where the ports of Cardiff, Port Talbot, Whitehaven, Barrow, Middlesbrough, Newcastle, and the Clyde, situated in close proximity to an ample supply of labour, enable foreign ore and native coal to be easily assembled and cheaply handed.

Cheap water-transport is the basis of the successful importation of foreign ore. Its importance may be illustrated by the development of the great iron and steel industry of the United States. In that country the ore is brought in 10,000-ton boats from the north end of Lake Superior, where it occurs in great abundance, to Chicago and Pittsburg, where there are ample supplies of fuel and labour. In 1916 as much as 64 million tons of iron-ore were conveyed in this manner.

In the case of the United Kingdom, ocean-transport was found to have its drawbacks when the War broke out; and the scarcity of ship-tonnage, which resulted from the activity of the enemy submarines, raised the cost of imported ore from about 20*s*. (at which Best Bilbao ore ruled in British ports in 1914) to an actual price of

[1] A lecture delivered at the Royal School of Mines on May 27, 1919.

over £6 per ton, although (under the cloak of Government subsidies) it figured at a lower level. At one period of the War the supply from these sources threatened to be cut off altogether.

To meet this situation an increased development of the Jurassic ironstones of this country was decided on. The chart shows the fall in production to the end of 1916, and the subsequent rise due to the introduction of this policy.

These ironstones, although abundant and cheaply worked, are what the ironmasters term "lean", that is to say they are low in iron, averaging only 28 per cent of that metal. Moreover, they have a high phosphorus and sulphur-content and, for the most part, are rather siliceous.

There are two classes of steel, which are named "acid" and "basic" respectively, according to the process used in their manufacture. Acid steel is produced from hæmatite pig-iron, practically free from phosphorus and sulphur, in furnaces provided with a siliceous (or acid) lining. Basic steel, on the other hand, is produced from pig-iron containing both these injurious ingredients, which are removed in the course of manufacture by means of a basic lining to the furnaces. The large increase in the production of phosphoric ores was reflected in an increased output of basic steel as shown on chart.

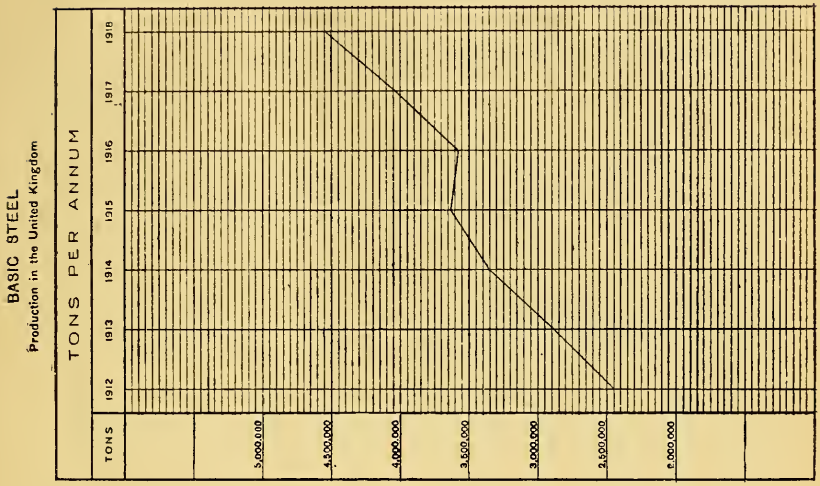
The increased production of the domestic phosphoric ores brought about by the War raised many difficult problems. In the first place it necessitated a different metallurgical treatment. This involved, as already explained, the substitution of basic-lined steel-furnaces for those of the acid type, with consequent increased supplies of suitable refractory materials. It also involved large additional supplies of fuel for smelting and of limestone for fluxing the ore in the blast-furnaces.

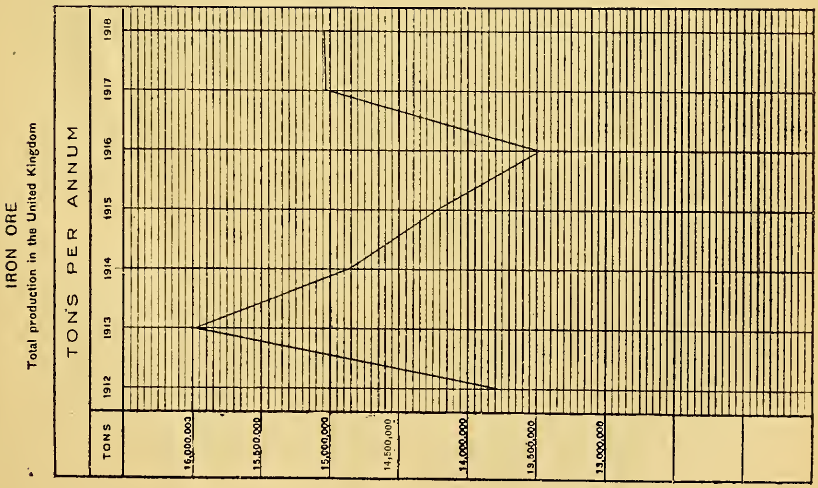
Special difficulties arose with regard to magnesite and magnesite bricks. Prior to the outbreak of war the magnesite brick industry was almost wholly in the hands of the Austrians. The Austrians possess in their own country extensive deposits of magnesite peculiarly suited for brick-making, and they have devoted both skill and money to the perfecting of their products, with the result that before the War they commanded practically the entire custom of the steel trade in this country. To make up for the loss of the Austrian material arrangements were made by the Ministry of Munitions for the manufacture in this country of magnesite bricks, and the raw material was obtained from Eubœa in Greece, and from Salem in Madras.

To furnish the required dolomite and limestone new quarries were opened up in this country.

With regard to labour a new supply had to be found not only to work the new quarries of ironstone, limestone, dolomite, etc., but also to build the railways required to open them up, to erect extensions to existing plant, to man the new works, to reline furnaces, etc., and this in face of the incessant and urgent calls of the Army to fill the gaps in the fighting line.

Considerable use was made of prisoner labour. The difficulty with prisoners was to induce them to work. On account of the Army


BASIC STEEL
Production in the United Kingdom
TONS PER ANNUM
1912
1913
1914
1915
1916
1917
1918
TONS
5,000,000
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000


IRON ORE
Total production in the United Kingdom
TONS PER ANNUM
1912
1913
1914
1915
1916
1917
1918
TONS
16,000,000
15,500,000
15,000,000
14,500,000
14,000,000
13,500,000
13,000,000

regulations work could neither be compelled by force nor by a reduction of rations. The difficulty was overcome by the introduction of piece-rates ; but only to a limited extent, as there was no outlet for surplus earnings in the canteens, food supplies having been cut down on account of the general food shortage.

The dearth of quarrymen led to active steps being taken in responsible quarters to supplement and to increase the efficiency of manual labour at the quarries by the provision of mechanical appliances for stripping, breaking, and loading the ironstone.

In these open-workings, the output per man employed varies with the thickness of the ironstone bed, the amount of cover to be removed, the use made of mechanical appliances, and the condition of the weather. The weather materially affects the output, especially where hand-labour is concerned. From returns made to the Ministry of Munitions in December, 1917, it appears that the average output in the Midlands per man employed was five tons per shift, and that it ranged from 3·8 tons where hand-labour was alone employed, to over fifteen tons where mechanical excavators were in use under favourable conditions. The actual saving of manual labour which resulted from the installation of mechanical plant in the ironstone quarries during the War is estimated to have been equivalent to over 3,000 men.

The Jurassic ironstones have a wide distribution both in this country and on the continent. In 1913 Germany mined, in Lorraine and Luxemburg, 28,000,000 tons of Minette ores of Jurassic age, out of a total production of 36,000,000 tons of iron-ore, while she imported in addition 3,800,000 tons of the same ore from Briey. Without the Lorraine iron-ore basin, which she stole from France in 1871, Germany would have been unable to go to war, and she took care to secure the remaining portion of the field (i.e. the Longwy and Briey basins) soon after the commencement of hostilities. One of the best guarantees for future Peace is the provision in the Peace treaty that no portion of this iron-ore field remains in German hands.

In England the Jurassic formation stretches as a broad band from the coast of Yorkshire to that of Dorset. The ironstones occur on four different horizons :—

The Jurassic Ironstones.

Name of Ironstone Bed.	*Position in Jurassic System.*	*Where worked.*
Westbury and Dover.	Corallian.	Not now worked for iron.
Northampton Ironstone.	Lower part of the Inferior Oolite.	Rutlandshire and Northampton.
Marlstone.	Upper part of the Middle Lias.	Cleveland in Yorkshire, South Lincolnshire, Leicestershire, and Oxfordshire.
Frodingham Ironstone.	Middle part of the Lower Lias.	North Lincolnshire.

The Corallian ironstones are at present not worked as a source of iron, although the Westbury bed is quarried for use in the purification of illuminating gas. In the Kent coalfield a bed of oolitic ironstone, 16 feet thick, has been cut in the shaft of the Dover Colliery at a depth of 593 feet from the surface. This stone contains, as mined, 33 per cent of iron, 15 per cent of silica, 9 per cent of lime, 0·45 per cent of phosphorus, and 0·05 per cent of sulphur. With regard to mechanical condition, it is rather friable and may have to be sintered or briquetted before use in the blast-furnace. On account of its favourable situation in a coalfield and on the seaboard it is most probable that steps will be taken to work this deposit in the near future.

The other Jurassic ironstones are all worked, and in 1917 accounted for over 80 per cent of the total output of iron-ore in the United Kingdom, the remaining 20 per cent being made up of Hæmatite, mined in Cumberland and Lancashire (10½ per cent); Blackband and Clay-ironstone, mined in the English and Scotch coalfields (8 per cent); and sundry ores mined in Wales, Forest of Dean, Devonshire, Weardale, and Ireland (1½ per cent).

TABLE SHOWING RELATIVE PRODUCTION OF DIFFERENT CLASSES OF BRITISH IRON-ORES.

	%
Jurassic ironstones	80·0
West coast (Hæmatite ore)	10·5
Blackband and Clay-ironstone in coalfields	8·0
Sundry ores	1·5
	100·0

Taking the Jurassic ironstones in descending order the proportion in which they were worked (in relation to the total production of the United Kingdom) in 1917, and their iron-content, are as shown in the table:—

TABLE SHOWING RELATIVE PRODUCTION AND IRON-CONTENT OF THE JURASSIC IRONSTONES.

Ironstone.	*Ratio to Total Production.* %	*Average Iron Content (as mined).* %
Inferior Oolite (Northampton and Rutland)	21	32
Middle Lias (Cleveland)	32	28
Middle Lias (South Lincolnshire, Leicestershire, and Oxfordshire)	9	25
Middle Lias (Raasay)	0·5	23
Lower Lias (North Lincolnshire)	18	23
	80·5	27·6

The average composition of the different Jurassic ironstones is shown in the following table:—

TABLE SHOWING AVERAGE ANALYSES OF JURASSIC IRONSTONE AS RECEIVED AT THE WORKS.

	Inferior Oolite (*Northampton*). %	*Middle Lias* (*Cleveland var.*). %	*Middle Lias* (*Leicester var.*). %
Fe	32·5	28·1	25·2
Mn	0·24	0·41	0·23
SiO_2	14·7	11·8	10·9
Al_2O_3	6·1	10·2	8·0
CaO	2·7	4·7	9·6
MgO	0·4	3·5	0·6
S	0·10	0·26	0·11
P	0·60	0·47	0·25
Moisture	15·2	6·8	16·4
	Middle Lias (*Oxfordshire var.*). %	*Lower Lias.* (*Frodingham Stone*). %	*Corallian* (*Dover Colliery*). %
Fe	24·0	22·7	33
Mn	0·27	0·96	—
SiO_2	10·2	8·1	15
Al_2O_3	7·6	5·1	—
CaO	12·2	18·2	9
MgO	0·6	1·0	—
S	0·06	0·16	0·05
P	0·23	0·31	0·45
Moisture	15·6	10·7	—

The *Northampton Ironstone* is, in general, high in silica and low in lime, and contains 0·1 of sulphur and 0·6 of phosphorus. In part, it is smelted locally with limestone or with limey ironstone, obtained in the district, to neutralise its siliceous character. Some is sent to Frodingham and some to Middlesbrough for smelting with the ironstone of those districts, but the greater proportion goes to furnaces in the coalfields of Staffordshire, Derby and Nottingham, South Yorkshire, and South Wales, to be smelted in admixture with the calcareous blackband and clay-ironstones of the Coal-measures and with tap-cinder.

The *Cleveland Ironstone* is also siliceous and requires lime to flux it. It is high in alumina and sulphur, and this feature militates against its use for making basic pig-iron, since the alumina-content makes it difficult to carry sufficient lime in the slag to ensure the production of a basic pig low in silicon and sulphur. To produce a suitable pig a considerable proportion of ores low in alumina, mainly of foreign origin, has to be added to the furnace charge. But, by using molten metal direct from the blast-furnace and desiliconizing it in a mixer, basic open-hearth steel can be made from Cleveland ores without admixture with foreign ores.

The *Frodingham Ironstone* almost invariably contains sufficient lime to be fluxed without the addition of limestone. It also carries about 1 per cent of manganese and can therefore be smelted without the addition of manganese ore. These self-fluxing properties make it a most valuable ore, in spite of its low iron-content, which averages only 22 per cent. The sulphur-content is 0·16 and the phosphorus 0·31.

The *Marlstone* of South Lincolnshire, Leicestershire, and Oxfordshire is on the whole a "limey" ironstone, and is often self-fluxing. In places, however, where the surface waters have leached out the lime, it is siliceous. Its phosphorus-content averages 0·25; sulphur, 0·1.

The following are average analyses of the limey and siliceous varieties respectively:—

	Limey Ironstone (*Unweathered Marlstone*).	*Siliceous Ironstone* (*Weathered Marlstone*).
Fe	22·43	27·91
Mn	0·24	0·28
SiO_2	9·39	13·28
Al_2O_3	7·36	8·03
CaO	14·89	3·79
MgO	0·61	0·42
S	0·06	0·05
P	0·23	0·22
Moisture	13·85	20·56
Difference (Combined Water, CO_2 and O)	30·94	25·46
	100·00	100·00

It will be seen that chemically the change from the limey to the siliceous type, which is brought about by weathering, consists of a loss of lime and carbon dioxide and an increase of all the other constituents—iron, silica, alumina, and moisture. Physically, the change is from a compact bluish-green ironstone, consisting of carbonate of iron and lime, to a porous brown hydrated oxide of iron or limonite. In the quarries the horizontal lime of demarkation between the two varieties is often clearly discernible. Where, however, the "cover" consists of clay, shale, or other impermeable material of sufficient thickness to hinder the downward percolation of the surface water, hydration and oxidation of the ironstone are prevented, and the green limey variety in that case extends right up to the junction of the ironstone with the cover.

Before charging into the blast-furnaces, the ironstone of all the districts is usually calcined, although a certain proportion is fed raw into the furnaces. The object of calcining is, in the case of the oxidized stone, to eliminate the water. In the case of the green carbonate stone, the effect is to drive off the carbon dioxide and convert the iron to peroxide. The loss on calcination is roughly 25 per cent of the weight. Consequently, calcination at the point of origin saves railway carriage. It has the disadvantage, however, on the one hand, that exposure to the weather may result in the calcined material absorbing a considerable amount of water on its journey to the furnaces, and, on the other, that the handling and transportation of the dry material may engender a considerable quantity of dust, which is objectionable to the men engaged in its discharging, and tends to choke up the furnaces.

Calcining raises the percentage of iron considerably. If the loss on calcination is 25 per cent, the increase is one third of the percentage of iron in the raw stone. Thus, the 32 per cent, which is the average iron content of the raw Northampton stone, becomes 43 in the calcined material; the 28 per cent of the Cleveland stone becomes 37; the 24 per cent of the Oxfordshire stone, 32; and so on. It follows that the use of calcined stone increases the output of pig-iron per furnace. Furthermore, there is a saving of fuel in the blast-furnace.

The calcining is either effected in Gjers or Davis Colby kilns, with or without forced draught, or in open heaps—"clamps", as they are termed in Northamptonshire. It is a slow roasting process, and the fuel required is about 1½ cwt. of coal to the ton of ironstone.

The Jurassic ironstones, although poor in iron, are valuable because of their considerable thickness and widespread occurrence at only a slight depth below the surface. With the exception of the Cleveland district of Yorkshire, where the ironstone is now mined underground, the workings are almost everywhere at the surface, the ironstone being quarried after stripping off an overburden of soil, sand, or clay as the case may be. Since the angle of the dip is usually small or, in other words, the beds are practically horizontal, considerable areas can be worked before the overburden becomes too great for removal at a reasonable cost. As much as 60 feet of soft material (sand or clay) can be removed and, under favourable conditions, probably 100 feet will be removed.

The different beds of ironstone vary considerably in thickness. The thickest is the Frodingham bed in North Lincolnshire. This ironstone is 25 to 30 feet in thickness, and consequently can be worked very cheaply by mechanical excavation. Before the War the cost of the stone in wagons at the quarries (exclusive of royalty) was not more than 1*s.* per ton. Probably it is double that now.

The workable part of the Northampton ironstone varies from 6 to 13 feet, averaging about 8 feet. The lower portion of the bed is generally too poor in iron for economic extraction. During the early part of the War it was sold at 3*s.* 3*d.* per ton of raw stone. Subsequently the price was fixed at 3*s.* 9*d.* per ton, plus ½*d.* for every 1*s.* 3*d.* rise in wages above the rate current on the 12th November, 1917.

The Cleveland Main Seam varies from 5½ to 12 feet. It is mined at depths ranging from 100 to 600 feet, the mines being worked on the bord and pillar system. The cost of the stone at the pit's mouth is now about 10*s.* per ton, as against 2*s.* to 4*s.* for the quarried stone.

The output per man employed on surface and underground in the Cleveland mines averages 2·2 tons per shift as against 4 to 15 tons for the quarried stone.

In addition to the Main Seam, other ironstone beds both above and below the Main Seam, have from time to time been worked on a small scale, in the Cleveland district. Their geological relation to the Main Seam is shown in the following table:—

IRONSTONES OF THE CLEVELAND DISTRICT.

Geological Formation.	*Name of Seam.*	*Thickness of Seam.*	*Thickness of intervening Strata.*
		Feet.	Feet.
Inferior Oolite . . .	Top or Oolite Seam	4–9	
Upper Lias . . .	Strata . .		. 260
	Main Seam	$5\frac{1}{2}$–12	
Middle Lias . . .	Shale . .		. 2–6
	Pecten Seam	$1\frac{1}{2}$–6	
	Shale . .		. 3–7
	Two-foot Seam	$1\frac{1}{2}$–$2\frac{1}{2}$	
	Shale . .		. 20–30
	Avicula Seam	0–3	

As compared with 1916 figures the production of the Jurassic ironstones as a whole was increased by 45,000 tons per week, equivalent to $2\frac{1}{4}$ million tons per annum. The increase reached this maximum in the first half of the year 1918. But it was not possible to maintain production at that figure on account of the calls of the Army on labour. The increase was made mainly in Northampton, Rutlandshire, and Leicestershire, the quarries in these counties accounting for 59 per cent of the total increase; but Cleveland was responsible for 26 per cent and Oxfordshire for 9 per cent.

The following table, showing the production of the Jurassic ironstones in relation to the total production of iron-ore in the United Kingdom during 1918, is compiled from returns made to the Ministry of Munitions.

PRODUCTION OF IRON-ORE IN THE UNITED KINGDOM DURING 1918.

	Tons.		%
Cleveland	4,570,892		
North Lincolnshire	2,639,712		
Midlands	4,954,087		
Raasay	88,047		
Total Jurassic Ironstones		12,252,738	80
Coalfields	1,119,215		
Wales and Forest of Dean	85,419		
Miscellaneous (Ireland, County Durham, and Devonshire)	37,039		
West Coast (Hæmatite)	1,549,962		
Total non-Jurassic Ores and Ironstones		2,791,635	20
Grand total . . .		15,044,373	

With regard to the non-Jurassic iron-ores of this country, the most important are the hæmatite deposits of Cumberland and Lancashire. These ores are remarkable for their richness in iron and their freedom from both phosphorus and sulphur, and therefore furnish a pig-iron very suitable for the Acid Bessemer process, and yield an exceptionally pure steel. They are consequently in great demand; and this demand was emphasized during the War by the difficulty at one time experienced in securing sufficient supplies of hematite ore from Spain. Every effort was therefore made to push production to the utmost and many abandoned mines were reopened in order to extract the pillars.

The deposits occur in masses of irregular shape in the Carboniferous limestone, a formation which in this district rests unconformably on the old Skiddaw Slates, and is itself concealed in places by overlying Coal-measures and red sandstones, or by boulder clay. The existing mines are situated between Lamplugh in Cumberland and Ulverston in Lancashire, a distance, from north to south, of 35 miles.

No doubt, besides the known deposits, many undiscovered ore-bodies exist in the Carboniferous Limestone, that can only be found by systematic prospecting by boring. Already before the War, borings through the red sandstones had disclosed, south of Egremont, some of the largest ore-bodies that have been found in either county, with the possible exception of that worked by the Hodbarrow Mine. The Beckermet, Ullcoats, and Ullbank companies are now engaged in developing and working these deposits.

Since the Carboniferous Limestone is of widespread occurrence in the United Kingdom, it might have been expected that valuable hæmatite deposits would have been discovered in other parts of the country. With the exception, however, of deposits of limited extent in South Wales and in the Forest of Dean, this has not proved to be the case. The South Wales hæmatite was worked fairly extensively to the north-west of Cardiff between the years 1840 and 1870, and yielded in the aggregate some three million tons of ore. But with the exception of the Llanharry mine, which still continues to produce about 60,000 tons of ore per annum, all work has stopped on these mines.

In the Forest of Dean the deposits, or "churns" as they are locally called, are chiefly characterized by their irregularity and small dimensions. The output of this field is quite unimportant, being less than 300 tons a week.

The only other important sources of iron-ore in this country are the blackband and clay-ironstones, associated with coal-seams in the English and Scotch coalfields. These ores, which once played so big a rôle in the British iron industry, are now of small importance owing to the exhaustion of the larger and more profitable seams.

The total output from Scotch and English coalfields amounts to 1,120,000 tons per annum, of which 357,000 tons come from Scotland and 695,000 tons from North Staffordshire. In Scotland the ore is derived from narrow seams of blackband and clayband and from "balls" of ironstone brought down in working the coal.

In North Staffordshire there are (1) small seams of blackband which are associated with sufficient combustible material to permit of calcination in the open without the addition of further fuel, and (2) seams of clay-ironstone which require the addition of fuel for calcination. By calcination of these ironstones two products are obtained, (1) a high-grade material, containing over 60 per cent iron, which is used for bottoming and fettling puddle-furnaces and for oxidizing purposes in the steel furnaces; and (2) a slightly inferior quality, containing 55 per cent of iron, which goes to the blast-furnaces.

In the industrial recuperation of this country now that the War is over, the working of the low-grade Jurassic deposits which it is fortunate in possessing, is destined to play a great part. This has been rendered possible by the great extensions to iron and steel works that have been initiated with Government assistance during the War. These works have been planned on the most modern lines, and possess on the same site by-product coke ovens, blast-furnaces, steel works, and rolling mills. They are designed for the basic process of steel-making and will be fed with home ores. In choosing the sites for these works regard has been paid to the situation of the raw materials—ore, fuel, and flux—required to supply them. On the completion of these extensions there should be no necessity for this country to import a single ton of foreign steel. Before the War something like 2½ million tons of steel, in the form of slabs, blooms, and billets, were imported into this country annually, mainly from Germany.

But for success in this great undertaking cheap ore and fuel are essential and these can only be obtained, in face of the greatly augmented cost of labour and material, which is a legacy of the War, by an all-round increase in efficiency, embracing capital, engineering, and labour—capital by the installation of up-to-date equipment, engineering by improved mining methods, and labour by an increased output per man per shift.

These are the outstanding problems of the immediate future.

II.—A Low-level Glaciated Surface in the Eastern Himalaya.[1]

By J. W. Gregory, F.R.S.

At Christmas, 1917, I had the privilege, owing to the kindness of the Hon. Mr. W. W. Hornell, of a short visit into Southern Sikkim, during which I observed glacial striation at a lower level than has been previously recorded in the Himalaya. This occurrence is the more worthy of record since striated rock-surfaces are reported as scarce or absent from the Eastern Himalaya even at much higher levels. For courteous help and the use of the library of the Geological Survey of India I am indebted to Dr. H. H. Hayden, and references to some of the literature I owe to him and also to Mr. E. W. Vredenburg.

1. Ancient Moraines in Sikkim.

The existing glaciers of the Eastern Himalaya do not descend below the level of about 14,000 feet (e.g. Hooker, 1854, vol. i, p. 260); that they formerly extended much lower has been well known since the journey in Sikkim of Sir J. D. Hooker, who described and figured "stupendous" ancient moraines in the Lachung Valley at about 8,000 feet above sea-level (Hooker, 1854, vol. ii, pp. 103–4), in the Lachen Valley at about 8,800 feet, and across the Yangma Valley at 11,000 feet (ibid., vol. i, p. 232, pl. opp. p. 232). The moraines in the Lachen Valley have been revisited by Blanford (1871, p. 395), by Bose (1891, p. 219), and by Garwood (1903, p. 298), who records their level as 8,790 feet; these Lachen

[1] The spelling of the place-names is in accordance with the map of Sikkim, 4 miles to 1 inch, Survey of India, 1916.

moraines appear to be the lowest known in Sikkim. Moraines are reported to occur in most of the high-level valleys of northern Sikkim. Thus Hooker remarked (1854, vol. i, p. 380), "I have described meeting with ancient moraines in every Himalayan valley I ascended, at or about 7,000 or 8,000 feet elevation, proving that at one period the glaciers descended fully so much below the position they now occupy."

Bose records abundant moraines, which were deposited by glaciers from Pandim, in the upper Jongri Valley about Thangme, 12,900 feet (Bose, 1891, pp. 55–9); but further down the valley at Yoksun, 5,500 feet, he failed (ibid., p. 61) "to find any evidence of glacial erosion". In his subsequent memoir on Sikkim Bose describes the moraines in the Lachen and Lachung valleys; he refers to the great terminal moraine in the Lachen Valley at the height of 8,790 feet as the lowest unmistakable evidence of former glacial action in Sikkim, though he remarks that the valley has "a glacial look about it" to the level of 7,000 feet (Bose, 1891, p. 219).

Professor Garwood's evidence is similar. During Mr. D. W. Freshfield's expedition around Kinchinjunga he crossed the Lachen moraines and confirmed their character and altitude (Garwood, 1893, p. 298 and map opp. p. 306).

2. Absence of Striated Surfaces.

Though moraines are abundant in the higher Himalayan valleys, striated rock surfaces appear very scarce. Their absence from Sikkim has been especially remarked by Blanford (1871, p. 401), who saw rounded rocks at about 15,000 feet near the Chang-o-Khang glacier, in the Lachung Valley; but he remarks, "I could never detect any polished or striated surfaces, such as are so common in Europe. Hooker has also noticed this"; and he adds that Medlicott failed to find them in the Western Himalaya.

Mr. P. N. Bose (1891, p. 57) repeats that ice-scratchings "are either indistinct or absent in the Himalayas"; he attributes the rapid destruction of moraines and removal of all traces of glacial action to the heavy rainfall (Bose, 1891, p. 219).

3. The Roche Moutonnée at Chakung.

Owing to the extreme wetness of the climate in Sikkim glacial striæ are doubtless soon obliterated when exposed to the weather. The glaciated surface at Chakung had been recently cleared during the reconstruction of the bridle-path owing to part of it having been carried away by a landslip. The locality (Fig. 1) is 8 miles north of Darjeeling, from which it is 22 miles distant by road; it is on the path from Chakung to Rinchenpong, on the steep descent from the Chakung bungalow to the Ratho River. The track passes some rounded surfaces of fresh rock, which are sharply separated from the overlying soil and are suggestive of glacial action. Four minutes before reaching the ninth mile post from Singla Bazar is a newly bared rock surface which shows typical glacial grooves and striæ. The rock is a dark phyllite: its strike is to 170° and its dip about 60° to south of west.

Both striæ and grooving trend to about 20° west of south. There has been considerable discussion as to whether it is possible to infer the direction of an ice movement from the shape of the glacial striæ; there is no single absolute criterion, but some of the scratches on this surface indicate that the movement was most probably from north to south and up the slope. The scratches are broadest and shallowest at the southern end. The possibility of the scratches having been made by some soil-cap movement down the hill-side was duly considered, but the evidence appears inconsistent with any such explanation and the striæ seem typically glacial.

FIG. 1.—Sketch-map of part of Southern Sikkim. ϕ, glaciated surface.

The hill faces north, opposite the valley of the Great Rangit River; the glaciated surface occurs at a point where ice coming down that valley would press against the hill-side. The nearest heights marked on the available maps, which were kindly shown me by Sir Sydney Burrard, F.R.S., then Director of the Trigonometrical Survey of India, are those of Chakung, 5,190 feet, and at the confluence of the Ratho and Rangit Rivers, 1,150 feet.

Being in India as a member of the Calcutta University Commission and not expecting any opportunity for geological work, I had not taken an aneroid with me and could only estimate the height above sea-level from these two records. Mr. B. G. Gwyther, the Executive Engineer at Darjeeling, by careful aneroid observations, checked by simultaneous readings at Darjeeling, has determined the level of the bridge across the Ratho River on the Rinchenpong track as 3,300 feet, and of the ninth mile post as 3,462 feet. According to these determinations the roche moutonnée would be at about 3,550 or perhaps 3,600 feet above sea-level. The glaciated zone on the hill-side below Chakung probably extends as low as about 3,500 feet above sea-level.[1]

The glacier which made these striæ may have come from one of two sources: it may have flowed down the Ratho Valley from the high ground a few miles to the west; or it may have come from the snow-clad mountains of the Kinchinjunga group, of which the nearest bearing perpetual snow is Narsing, altitude 19,130 feet, 25 miles north of Chakung up the Great Rangit Valley. Glaciers from the southern side of the Kinchinjunga group appear to be the most probable source of the ice which reached Chakung; the glacier would have a straight course down the Rangit Valley until it flowed against the Chakung spur and made these north to south trending grooves and scratches.

That the ice was a local glacier from the hills around the head of the Ratho Valley suggested itself as a possibility, for the mountains there rise to such heights as Helu Peak 9,370 feet, a summit further west of 10,580 feet, and still further west to Singale La, 12,110 feet. P. N. Bose of the Indian Geological Survey, however, passed close by the summit of Helu Peak (Bose, 1891, p. 65) and Singale La (ibid., p. 47), and though he was on the watch for traces of glacial action he records none at these localities.

Though as previously remarked, old moraines are abundant in the valleys of Northern Sikkim, the lowest hitherto recorded are those at 8,790 feet in the Lachen Valley, about 12 miles from the Zemu Glacier, one of the greatest glaciers of the Kinchinjunga massif. The Lachen moraines are about 45 miles in a direct line from Chakung; so that the striated surface there is far to the south and on a much lower level than the lowest glacial evidence previously described in Sikkim.

4. Other Indications of Glacial Action near Chakung.

There are further indications and suggestions of glaciation in the neighbourhood of Chakung. Thus the spur of Langyong (which rises from the Great Rangit River to Rufula, a peak north-west of the conspicuous summit of Tendong), when seen from Rinchenpong appears to have a rounded ice-worn northern face at a height of

[1] Mr. Gwyther's results give the height of the Chakung bungalow as 4,825 feet; the trigonometrical station at Chakung is 5,189 feet. Major Tandy, of the Trigonometrical Survey Office for India, kindly tells me that rays were observed from that station in all directions; it was therefore not at the bungalow but along the ridge at a somewhat higher level, which accounts for the difference between Mr. Gwyther's determination and that usually assigned to the bungalow.

about 5,000 feet. Again the long spur to the south of the Kulhait Valley to the north-west of Rinchenpong is hummocked suggestively of glacial action at the height of about 4,500 or 5,000 feet.

The existence of hill spurs which end in flat triangular facets (Fig. 2), such as are well developed in the Rangit Valley near Badamtam north of Darjeeling, might be regarded as evidence of glacial action; but the numerous faceted spurs in Southern Sikkim appear clearly due to the truncation of spurs by rivers. As I have remarked elsewhere they are not proof of glacial action.

FIG. 2.—View from Badamtam across the valley of the Rangit, showing the level-crested ridges of the Sikkim peneplane and two of the spurs (*f*) faceted by river erosion.

Another occurrence which should be mentioned in this connexion is a train of huge boulders on the floor of the Rumman River above its junction with the Great Rangit River. One boulder that I measured is eight feet in diameter, and some are larger; they are situated at the height of slightly over 1,000 feet above sea level. The largest boulders are of gneiss, which, according to the map by Bose (1891, (2)) does not occur on the Rumman River until six miles up stream. The nearest outcrop is three miles away in the valley of the Little Rangit River. This boulder train has been noticed by Bose (1891, (1), p. 68); he attributes it to torrential river action. He remarks that these impetuous rivers can transport enormous boulders far from the parent rock (ibid., p. 57). According to his map the boulders must have been carried six miles down stream; and yet their forms are subangular. These boulders cannot be due to a landslip, as gneiss does not occur here on the sides of the valley; and if the boulders had been carried six miles down stream at least their lower surfaces which are protected from the weather should have preserved some trace of water action. That the boulders were deposited directly by ice appears improbable; but they may have been brought to the locality by ice, and have been dropped at some higher level, and subsequently lowered to their present position during the deepening of the valley by denudation. These boulders do not prove that ice deposited them where they now are; and the lowest level for which there is clear evidence of glacial action in Southern Sikkim is that of the glaciated surface below Chakung, at about 3,600 feet above sea-level.

5. Claims for Low-level Glacial Deposits in N.W. India and in Bengal.

Glaciation at a comparatively low-level has been claimed in the Western Himalayas and in Ea tern Bengal, partly on the direct evidence of moraines and striated rock-surfaces, partly on the indirect evidence of boulder beds and drifts, and partly on biological evidence. (Fig. 3.)

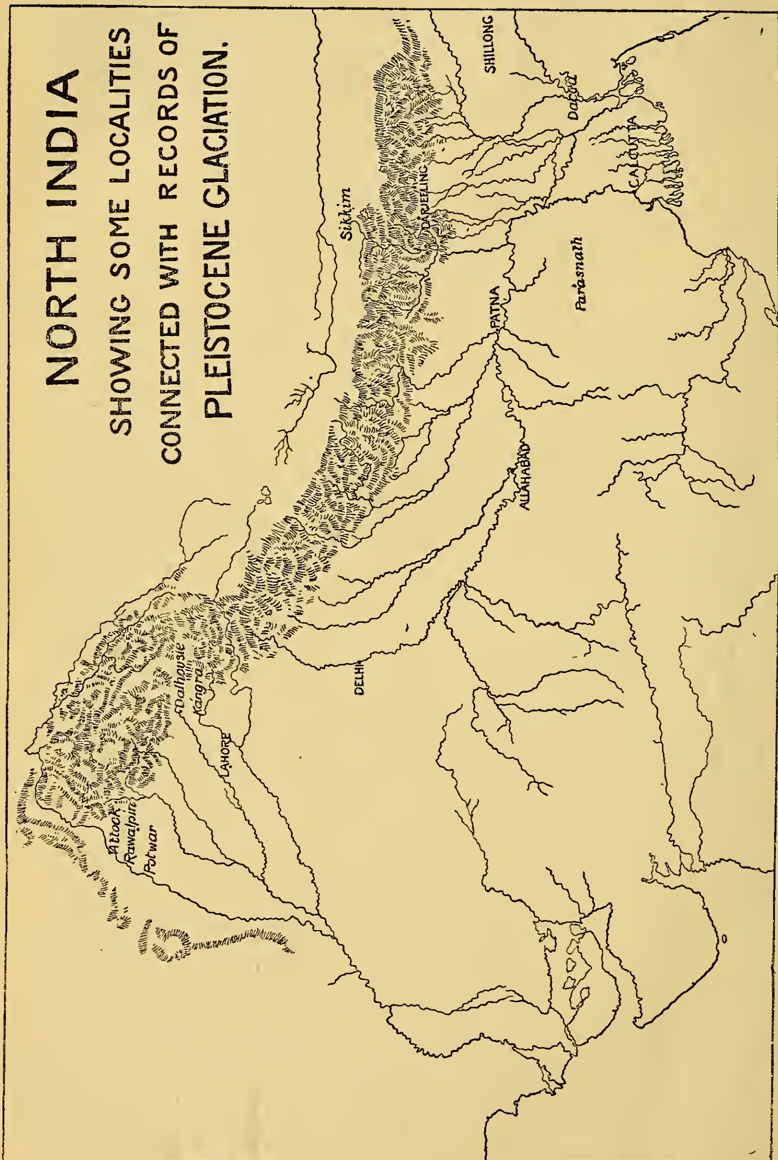


Fig. 3.—The names in capitals are inserted merely for reference. The State of Sikkim lies from the name southward almost to Darjeeling. For Rawalpin read Rawalpindi.

The lowest direct records of glacial action in the Himalaya appears to be those by the late General C. A. McMahon, who described ice-scratched and grooved rock-surfaces in the N.W. Himalaya, near Dalhousie in the Pangi Valley, at the level of 7,500 feet (McMahon, 1881, p. 310), and a moraine in the same district at the height of 4,740 feet at Mamul (McMahon, 1882, pp. 49–50). Mr. Middlemiss (1896, p. 46) mentions 5,000–6,000 feet as the lowest level at which he has seen reliable traces of glaciers in North-Western India. There appears to be no definite evidence of striated rock-surfaces in the North-Western Himalaya as low as that at Chakung in Sikkim.

The evidence of low-level Boulders and Drifts.—The extension of some form of ice to low-levels in India has been advocated to explain various large boulders and drift deposits. Thus Theobald attributed to transport by floating ice (Theobald, 1877, p. 141) some enormous boulders, as much as 40 feet in circumference, embedded in fine silt and overlying beds of sand and gravel, at the level of below 2,000 feet on the plains of the Potwár near Rawal Pindi in N.W. India. The extension of the same agency to below 1,000 feet above sea-level is claimed in his later paper (Theobald, 1880, p. 221), on the evidence of some large boulders at Attock, where they are marked on his map at a level of a little below 1,000 feet. Theobald (1874, p. 87) claimed the extension of glaciers to the level of about 2,000 feet on some huge erratics, as much as 140 feet in girth (ibid., p. 91), associated with some ridges of drift that he described as moraines, in the Kángra Valley, which is over 200 miles south-east from Potwár, and to the south-east of Dalhousie.

The boulders recorded by Theobald have been often accepted as due to some form of ice transport. Thus Mr. R. D. Oldham (1893, p. 484) remarks that "the erratics of Potwár show that ice in large quantities was not unknown there at one time". Mr. A. B. Wynne (1881, pp. 153–4) accepted the blocks as ice-carried but not as glacier-carried. Mr. Vredenburg has kindly referred me to the memoir on Hazara by Mr. Middlemiss, in which the boulders are explained, from their alignment, as the remains of a local ridge of gneiss, the crest of which had fallen to pieces before it was smothered by silt. Mr. Middlemiss (1896, pp. 46, 241–5) has shown that the erratics of the Sirun and Indus Rivers are outcrops of the Hazara gneissose granite, and he suggests that those of Potwár also are probably "blocks weathered out nearly in situ from a ridge of crystalline rocks covered sparingly by, or protruding through, the Upper Tertiary Sandstones". Middlemiss (ibid., p. 245) adopts the same explanation for the Attock erratics. He concludes (Middlemiss, 1896, p. 46), "I am bound to say that no reliable traces of glaciers at low levels (say below 5,000 or 6,000 feet) have ever come before my notice."

The Kángra Valley Moraine of Theobald is referred to by Medlicott (1876, p. 56) as "the supposed glacial deposits of the Kángra Valley". He regarded the moraine as a ridge left by erosion, though both he and Lydekker felt unable to explain the erratics except by glacial action; and Lydekker (1876, p. 158) quotes Colonel Godwin Austen as adopting the same explanation for the gneiss boulders along the bed of the Jhelum above Uri.

The evidence of the low-level boulders in North-Western India is apparently not conclusive of any form of glacier action. They were interpreted as implying, at the most, only ice rafts carried by floods; and Middlemiss has shown that this hypothesis is unnecessary.

An analogous claim has been advanced for Eastern Bengal by Mr. La Touche (1910, pp. 198–9). He explains the sheets of alluvium, 100 feet above present river-level, which form the Madhupur Jungle north of Dacca, as deposited by rivers choked with silt during the melting of the ice at the end of Glacial times. He claimed that they are as truly relics of the Glacial period as moraines. This evidence is, however, inferential and does not give any definite indication as to the level reached by the ice which fed the silt-charged rivers.

Biological evidence.—A climatic change in India during recent geological times, which would have enabled ice to exist in Northern India at lower levels than its existing limits, is indicated by various outliers of the Himalayan fauna and flora on the hills of Southern and Central India. Instances of Himălayan plants on Mount Parasnath in Chota-Nagpur, and in South India have been well known since the time of Hooker. The example that probably gives the most precise evidence is the Sikkim Lizard, *Lygosoma sikkimense* (Blyth), now found living on Parasnath to the south of the Ganges plain. Dr. Annandale (1912, pp. 46–8) has summarized and explained its evidence. This lizard is not known to descend lower than the level of 3,000 feet, and owing to its life-history it would appear impossible for it to have spread under existing climatic conditions, from the Himalaya to Parasnath across the low dry plains of the Ganges, for the lizard lays its eggs in wet moss on tree trunks during the rains. Yet a colony is now isolated on Parasnath, 200 miles from its main habitat. Dr. Annandale considers this occurrence as evidence that during the Glacial period the humidity in the Ganges plains was much greater than at present.

6. The Age of the Sikkim Gorges.

The occurrence of the glaciated surface at Chakung affords a useful measure of the age of the lower parts of the Sikkim gorges. The general structure of this part of Sikkim is a peneplane sloping southward to the valley, which runs east and west, and is traversed by the lower Rangit and the Rumman Rivers. The peneplane (Fig. 3) was at the level of about 7,000 feet at Pemionchi, and sloped down to about 5,000 feet along the Rangit–Rumman line, where it was joined by the slope northward down from Darjeeling. The Sikkim peneplane has been dissected by old broad valleys, on the floors of which are a series of narrow, steep-sided gorges. As Professor Garwood (1903, p. 295) has shown, the valley system and larger valleys are of great antiquity, while the gorges are relatively young. The gorges are being rapidly deepened by the corrosion of their beds by the torrential rivers; the valleys are being widened mainly by landslips. The glaciated surface shows that by glacial times the Great Rangit Valley had been deepened near Chakung to at least 3,600 feet above sea-level. The excavation of a considerable proportion of the 2,500 feet below that level may be post-glacial. That the V-shaped gorges, from 1,000 to 1,500 feet deep, along the bottoms of the main valleys are young, is shown by the sharpness of the faceted spurs and by the existence of high waterfalls, such as that by which the stream on the northern bank of the Great Rangit, a little east of Singla Bazar, leaps from a hanging valley directly into the Rangit River.

FIG. 4.—North bank of the Great Rangit Valley, looking upstream towards Singla Bazar to show the old high-level valley and sudden oversteepening and truncation of the spurs.

CONCLUSIONS.

A glaciated surface at Chakung, at the level of about 3,600 feet above the sea, shows that the glaciers of Sikkim once extended 45 miles south of and descended 5,000 feet lower than the lowest recorded ancient moraines.

The lowest undoubted traces of glacial action on the Western Himalaya appear to be in the Dalhousie district, where the late General C. A. McMahon described moraines as low as 4,740 feet, and glaciated rock surfaces at the level of 7,500 feet.

The glaciated surface at Chakung shows that by glacial times the valleys there had been excavated at least to 3,600 feet above sea-level. A considerable proportion of the excavation of the steep V-shaped gorges on the bottom of the older valleys is probably post-glacial.

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III.—Notes on Myriopoda. XIX.[1] A Revision of some Fossil Material from Sparth Bottoms, Lancs.

By J. Wilfrid Jackson, F.G.S., Assistant Keeper of the Manchester Museum, Hilda K. Brade-Birks, M.B., M.Sc., and the Rev. S. Graham Brade-Birks, M.Sc.

(PLATE IX.)

A CAREFUL examination of four fossil millipedes from the Middle Coal-measures of Sparth Bottoms, Rochdale, three preserved in the Manchester Museum and one in Mr. H. Howard's private collection, has revealed some striking features which seem to justify a re-description of the whole material.

These four specimens were originally described by W. Baldwin in Geol. Mag., 1911, pp. 74–80, Pls. III–V.

The first example to be dealt with is that described as

Acantherpestes giganteus. (Text-fig. 1, 2; Pl. IX, Fig. 1.)

[Nos. L 9941 and L 9942, Man. Mus.]

This specimen was obtained by Baldwin in June, 1910, and is the type of his species. The dimensions are those given in the original description.[2] The animal was preserved in a large nodule which, on being split, exhibited both an impression of the dorsal surface and a cast showing the structure of the dorsal plates as well as some of the more ventral features of the animal's body displaced somewhat to the left. A glance at the impression, which exhibits some nineteen body segments, is sufficient to show that we are

[1] The earlier papers in this series have appeared in various scientific publications.

[2] Baldwin, Geol. Mag., 1911, p. 76, Pl. IV, Fig. 1.

dealing with a "flat-backed" millipede,[1] the dorsal plates (or tergites) being furnished with definite lateral expansions. The anterior part of each segment (prozonite) is almost completely hidden by the segment in front. Thus little more is visible of each segment than the posterior portion (metazonite). Each metazonite is characterized dorsally by a definite transverse groove extending to within a short distance of the lateral margin, thus dividing the segment into two unequal parts, an anterior third and a posterior two-thirds. Most of the segments exhibit traces of lateral spine-bases; about the width of each metazonite from its lateral border its posterior portion shows definite traces of one of these lateral spine-bases, but we have been unable to find any trace of other spines on the tergites. This is definitely contradictory to Baldwin's interpretation (Baldwin, op. cit., 1911, p. 76).

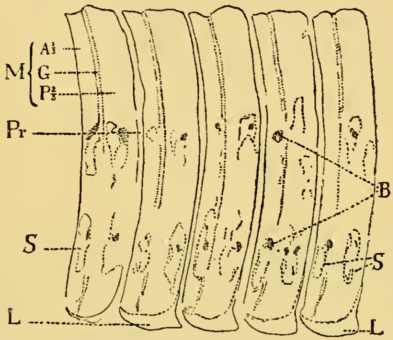


FIG. 1.—Five segments from the cast of *Palæosoma giganteum* (Baldwin sp.) seen from above, showing the undercrushing of the right side of the body and exhibiting most of the essential characters of the tergites and some of the more ventral features as seen through the decorticated dorsal surface. Owing to decortication no left spine-bases are visible, and those of the right side are not seen in this view. M, metazonite; A⅓, anterior third; G, groove; P⅔, posterior two-thirds; Pr, position of prozonite; B, casts of leg-bases; S, spiracles; L, L, lateral expansions. × 1. H. K. B.-B. del.

Turning to the cast we find some twenty-six of the posterior body segments represented. The anterior third of each metazonite is less elevated than the posterior two-thirds. The single row of lateral spine-bases is clearly visible on the right-hand side of the body. On the left, portions of the dorsal surface of each segment are wanting, and the underlying features are partially exposed. On this side of the body, lying beneath each metazonite, there are two elongated spiracle-bearing grooves nearly at right angles to the long axis of the trunk; close to these and corresponding to them are the hollow

[1] Owing to the direction of the relative displacement of the dorsal and ventral parts of the animal's body, it is clear that the right-hand side will be more convex than in life and the left-hand side will tend to be flatter than in life. It follows that when alive the animal was definitely convex dorsally from side to side, but the degree of convexity can only have been slight, and the animal is consequently correctly regarded as a "flat-backed" millipede.

bases of the walking legs, while two underlying ridges of material representing the pleural and sternal plates are exhibited in several cases. These ridges begin at points close to the median line of the dorsal surface of the body, and run obliquely forwards and outwards from the anterior and posterior borders respectively of the posterior more elevated two-thirds of the metazonite. Thus the anterior of the two ridges passes beneath the anterior portion of the metazonite, while the posterior ridge lies entirely underneath the posterior two-thirds of the metazonite. It is not improbable that these ridges are parts of the ventral plates brought into this position by pressure.

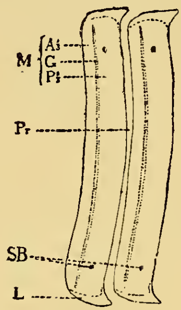


Fig. 2.—A partial reconstruction of two typical posterior segments (5th and 6th from end) of *Palæosoma giganteum* (Baldwin sp.). SB, spine-bases; other lettering as in Text-fig. 1. × 1. H. K. B.-B. del.

Near the anterior end of the fossil the lateral expansions of several of the segments are broken away on the left hand side of the body, and five pairs of legs are represented by five grooves in the matrix. There are clearly two pairs of legs to each typical tergite. On the right hand side one of the legs is seen in oblique section at the anterior end of the fossil, and by passing a bristle up the hollow centre of this leg its position relative to the spiracle close by can be determined beneath the decorticated dorsal surface. By a comparison of this arrangement with that of other segments, it is evident that each leg is associated with a spiracle.

The next specimen is recorded as:

Euphoberia armigera, Meek & Worthen. (Text-fig. 3; Pl. IX, Fig. 2.)

[No. L 9944, Man. Mus.]

This example was discovered by the late Mr. W. A. Parker. The dimensions are those given by Baldwin.[1] The impression alone is preserved in the Manchester Museum, and shows indications of about fourteen dorsal segments with some of the corresponding ventral parts of the body and a series of walking legs. Owing to the imbrication of the tergites, the prozonites are scarcely visible, and thus only the metazonites are to be clearly seen. Each of these is provided with a lateral expansion and is divided transversely by

[1] Baldwin, op. cit., 1911, p. 77, Pl. V, Fig. 4.

a ridge (a groove *in nat.*) into two parts, approximately an anterior third and a posterior two-thirds as in the previous specimen. The metazonites are provided with a lateral row of spine-bases on either side, occupying practically the same position as that of those found in *A. giganteus.* Each tergite is subtended by two pleural plates on either side of the body, and corresponding to each pair of pleurites is a pair of slender legs. The sternites are ill-defined.

We next come to the specimen described as the type of

Euphoberia robusta, Baldwin. (Pl. IX, Fig. 3.)

[No. L 9943, Man. Mus.]

In this example, discovered and presented to the Manchester Museum by the late Mr. W. A. Parker, some fifteen of the trunk-segments next to the head are represented. Owing to imperfect preservation practically nothing of the structure of the head can be distinguished. What Baldwin (op. cit., 1911, pp. 77–8, Pl. V, Fig. 3*a*) takes to be the tail is really the head, and in reading his measurements we must bear this in mind. The narrowest segments are those nearest to the head. The prozonites are

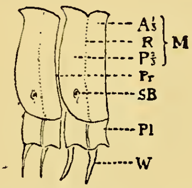


FIG. 3.—*Palæosoma robustum* (Baldwin sp.) (L 9944, Man. Mus.). Two typical segments. R, ridge; Pl, pleurite; W, external outline of walking-leg (segmentation of the appendage not distinguishable); other lettering as in Text-figs. 1 and 2. × 2. H. K. B.-B. del.

hardly visible, being represented by a narrow depressed band in front of some of the metazonites. Once again the metazonites are provided with lateral expansions, and are divided by a transverse groove into an anterior third and a posterior two-thirds. A row of lateral spines is definitely indicated, the remains of the spine-bases being situated about the width of the metazonite from each lateral border, and equidistant from the anterior and posterior limits of the metazonite. As in a specimen we have already mentioned (L 9941), the dorsal surface is considerably decorticated, and the fossil exhibits some of the more ventral features of the body. Thus, in five segments taken as an example, the underlying parts that are visible consist of ten equal ventral rings slightly displaced along the median line owing to crushing. These rings may be interpreted as the impressions of the underlying pleurites with the possible addition of the median sternites lying between the widely separated legs, the position of the bases of the legs being indicated by their hollow casts nearer the middle line, yet closely adjacent to the transverse ovate spiracles, which agree in structure with those of the first specimen described in this paper.

Finally we must consider the specimen described[1] as

Euphoberia woodwardi, Baldwin. (Pl. IX, Fig. 4.)

This example has been kindly lent to us by Mr. H. Howard, of Rochdale, to whom it belongs. The dimensions are those given by Baldwin. The specimen consists of an impression of the head and a cast of some thirty-eight segments of the trunk. In all important characters the structure of the tergites agrees with that of the two preceding specimens. Part of a ramifying series of small fractures of the dorsal surface, just behind the middle of the specimen, is interpreted by Baldwin as a bifurcating spine. We can find no support for this suggestion. The granulated surface of the tergites is exhibited in some places. Owing to the decortication of the dorsal surface, the spiracles, leg-bases, and duplicated pleurites are again visible, and all these agree with the description already given of the same features in the two preceding examples.

As a result of the re-examination of the material before us, we conclude that these millipedes can no longer be retained in that systematic position to which they have been assigned, and as a step in the right direction, we feel justified in establishing the following genus for their reception :—

PALÆOSOMA, gen. nov.

Segments numerous (more than thirty-eight), trunk parallel-sided, narrowing anteriorly and posteriorly, flattened dorsally with lateral expansions, the dorsal surface furnished with a row of lateral spines on either side, head approximately the same width as the anterior body segments, sternites large, two pleura to each tergite; of the tergites the prozonites are short, hardly visible from the dorsal surface, and the metazonites are large, about eight times as wide as long, divided by a well-marked transverse groove into a smaller anterior and a larger posterior portion, each lateral spine provided with a tubercular base.

Genotype: *Palæosoma giganteum* (Baldwin), **char. emend.** Brade-Birks et Jackson.

The two following species fall into this genus :—

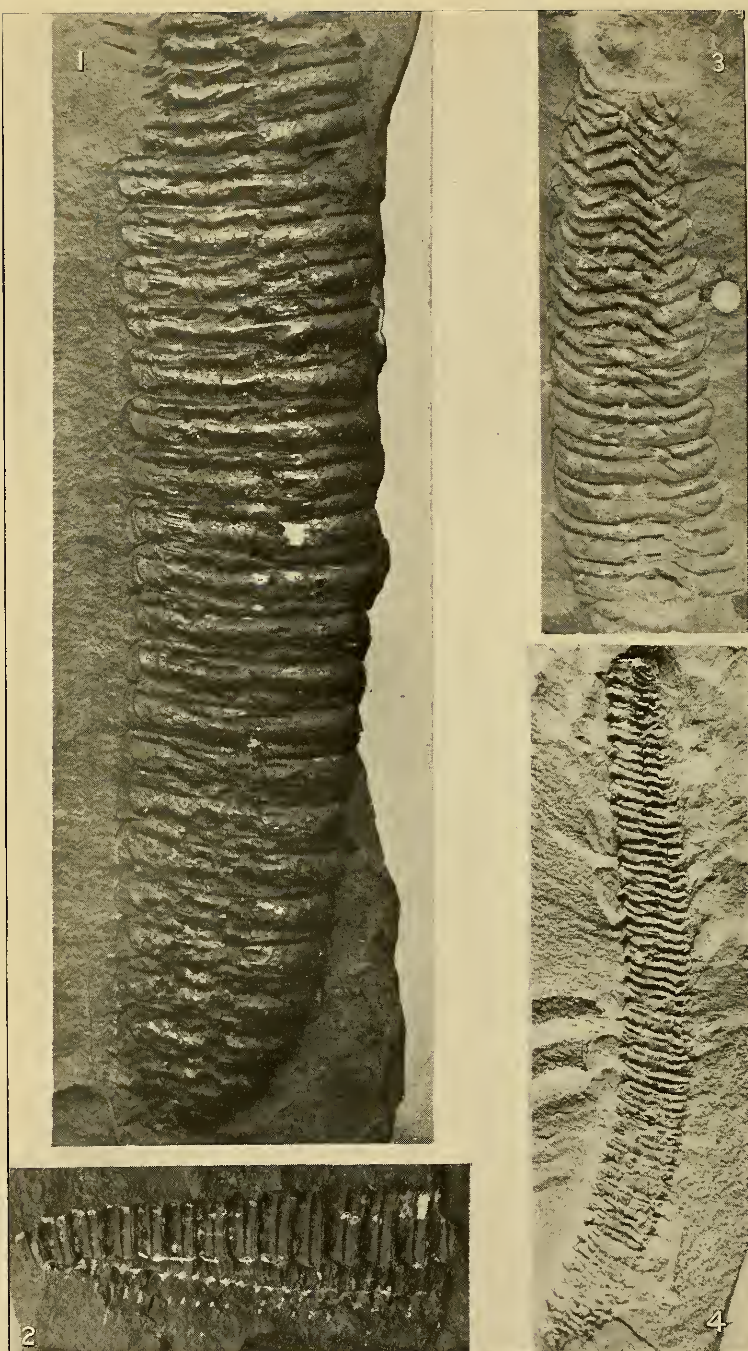
1. *Palæosoma giganteum* (Baldwin), **char. emend. infra.** (Text-fig. 1–2; Pl. IX, Fig. 1.)

SYN.: *Acantherpestes giganteus*, Baldwin, GEOL. MAG., 1911, p. 76.

Length of the last seven segments, 45 mm.; breadth of parallel-sided segments, including lateral expansions, 44 mm.; head unknown, prozonites smooth, metazonites only slightly convex from side to side, finely granulated, divided by the transverse groove into an anterior third and a posterior two-thirds, the groove deep near the median line, becoming shallow laterally, to disappear before reaching the lateral borders; lateral expansions prominent, externally foliaceous, and backwardly directed; the spine-base situated the width of the metazonite from its lateral border and equidistant from its anterior and posterior limits (except towards the posterior end of the body (8 segments), where the spines appear to be nearer the posterior border); anal segment small, the posterior end of the body obtuse.

Type: L 9941 and L 9942, Man. Mus.

[1] Baldwin, op. cit., 1911, p. 78, Pl. IV, Fig. 2.



J. W. Jackson, Phot. *Bale & Sons, Imp.*

FOSSIL MYRIOPODA FROM ROCHDALE, LANCASHIRE.

2. *Palæosoma robustum* (Baldwin), **char. emend. infra.** (Text-fig. 3; Pl. IX, Fig. 2–4.)

SYN.: *Euphoberia robusta*, Baldwin, GEOL. MAG., 1911, pp. 77–8.
E. armigera, Meek & Worthen, Baldwin, ibid., p. 77.
E. woodwardi, Baldwin, ibid., pp. 78–9.

Not SYN.: *Euphoberia armigera*, Meek & Worthen.

Length of anterior seven segments, 22 mm.; breadth of parallel-sided segment (19th from head) 14 mm.; head rounded; eyes present, ocelli in a group, antennæ closely adjacent to the eyes; prozonites smooth, metazonites slightly convex from side to side, divided by transverse groove into an anterior third and a posterior two-thirds, the groove deep near the median line, becoming shallow laterally, disappearing just before reaching the lateral border; lateral expansions narrow and backwardly directed; spine-bases as in preceding species.

Type: L 9943, Man. Mus.

We have made no attempt in the above study to indicate the systematic position of our new genus, but it is our intention to do so in a later paper, which will deal at some length with the classification of certain fossil forms.

EXPLANATION OF PLATE IX.

FIG. 1.—*Palæosoma giganteum* (Baldwin sp.). Genoholotype × 0·79. Cast of posterior end of the body (L 9941, Manchester Museum).

,, 2.—*P. robustum* (Baldwin sp.). × 1·36. Impression of some fourteen posterior segments (L 9944, Manchester Museum), showing tergites, pleurites, and walking legs.

,, 3.—*P. robustum* (Baldwin sp.). Holotype × 1·5. Cast of anterior end of the trunk (L 9943, Manchester Museum).

,, 4.—*P. robustum* (Baldwin sp.). × 0·76. Impression of the head and cast of some thirty-eight body segments. (In collection of H. Howard, Rochdale.)

IV.—BRACHIOPOD NOMENCLATURE: *CLAVIGERA*, *HECTORIA*, *RASTELLIGERA*, AND *PSIOIDEA*.

By J. ALLAN THOMSON, M.A., D.Sc., F.G.S., Director of the Dominion Museum, Wellington, New Zealand.

IN dissenting from Dr. C. T. Trechmann's procedure in rejecting the name of *Clavigera* for certain New Zealand Mesozoic Spirigerids and proposing the new name of *Hectoria* instead, I would like first to express the appreciation of New Zealand geologists for the painstaking work of Dr. Trechmann on the Trias of New Zealand.[1]

The reasons for his rejection of *Clavigera* are thus stated:[2] "*Clavigera* represents a group of specialized bisulcate Spirigerids the affinities of which are discussed later on. I have considered it advisable to rename this group, and have called it *Hectoria*. Hector's description was published without any illustrations, and his sub-generic name closely resembles that of *Claviger* given to a group of the Melanias."

The close resemblance between the names of *Claviger* and *Clavigera*

[1] C. T. Trechmann, "The Trias of New Zealand": Quart. Journ. Geol. Soc., vol. lxxiii, pp. 165–246, 1918.

[2] Loc. cit., p. 216.

does not necessitate the abandonment of the latter name. Buckman[1] discusses an analogous case in Brachiopods in these words: "On the ground that *Cryptopora* was pre-occupied by *Cryptoporus*, and *Atretia* by *Atretium*, Fischer and Oehlert proposed and used the name *Neatretia*. But though in the case of trivial names *cryptoporus* and *cryptopora* would have to be regarded as synonyms, because the termination must be governed by that of the generic name, in the case of the generic name itself there appears to be no necessity to make any change of termination; so that *Cryptopora* and *Cryptoporus* as generic terms ought to be quite distinct enough. It is true that such changes of generic termination were commonly made at one time; but such alterations are now discarded in favour of the original selection." Unless, then, *Clavigera* was accidentally or intentionally employed as a substitute for *Claviger* (in which usage it would be a synonym of *Claviger*), prior to the validation of the name by myself for the Brachiopods under question, the name must stand for the latter group, and *Hectoria* becomes a synonym.

As originally proposed by Hector in 1878,[2] *Clavigera* was a *genus cœlebs*, that is, it was a genus without any species. Hector partly remedied this omission in 1886,[3] when he figured two species, but he omitted to name them. In 1913[4] I discussed the genus and published plates which had been prepared and printed by Hector many years before, and gave names believed to be manuscript names of Hector to four species, viz. *Clavigera bisulcata*, *C. cuneiformis*, *C. gracilis*, *C. tumida*. Although my intention was to give credit to Hector, the responsibility rests with myself, and according to the opinions published by the International Commission on Zoological Nomenclature responsibility takes precedence over credit in publishing new names. In the publication referred to I did not select a genotype, nor has Trechmann designed a genotype for *Hectoria*. These omissions I now rectify as follows: *Clavigera*, Thomson, 1913; genolectotype. *Clavigera, bisulcata*, Thomson. Synonym *Hectoria*, Trechmann, 1918; genolectotype *Hectoria cuneiformis*, Trechmann = *Clavigera cuneiformis*, Thomson.

Hectoria tumida Trechmann is a synonym of *Clavigera tumida* Thomson, and *Hectoria bisulcata* Trechmann of *Clavigera bisulcata* Thomson. Should any subsequent author consider that *Clavigera cuneiformis* and *C. bisulcata* are not congeneric, *Hectoria* may stand for the former. *C. bisulcata* is Triassic and *C. cuneiformis* Jurassic.

Rastelligera equally with *Clavigera* was validated by me in 1913, and the sole species therefore becomes the genotype, viz. *Rastelligera elongata*, Thomson, of which *Spiriferina diomedea*, Trechmann, appears

[1] S. S. Buckman, "Antarctic Fossil Brachiopoda collected by the Swedish South Polar Expedition": Wiss. Ergebn. Schwed. Südpolar-Exped., 1901–3, Bd. iii, Lief. vii, p. 20, footnote, 1910.

[2] J. Hector, "On the Fossil Brachiopoda of New Zealand": Trans. N.Z. Inst., vol. xi, pp. 537–9, 1878.

[3] J. Hector, *Detailed Catalogue and Guide to the Geological Department's Exhibits at the Indian and Colonial Exhibition, and outline of the Geology of New Zealand*, Wellington, 1886, fig. 40, Nos. 2, 3.

[4] J. A. Thomson, "Materials for the Palæontology of New Zealand": Pal. Bull., No. 1, Geol. Surv. N.Z., 1913, p. 49–50, pl. i.

to be a synonym. If the genus is a synonym of *Spiriferina* as Trechmann supposes, the specific name *elongata* should still be used, unless it is preoccupied in that genus. Trechmann's explanation of the comb-tooth structure by partial weathering before fossilization does not appear convincing.

Psioidea stands on a different footing from *Clavigera* and *Rastelligera*, in that it was still left by me a *genus cœlebs*, the only species figured being labelled *Psioidea* sp. innom. It seems desirable to remedy this omission as, although this group is included in *Spiriferina* by Trechmann, the latter genus seems unwieldy and must be broken up. I therefore propose *Psioidea* gen. nov. with genotype *Spiriferina suessi*, Zugmayer, var. *australis*, Trechmann, this course having the advantage of making the invalid *Psioidea*, Hector, a synonym of the valid *Psioidea*, Thomson, 1919, since Trechmann states that the figure published by Hector under the name of *Psioidea* sp. appears to represent his sub-species. Apparently some European Rhætic forms, viz. the second group of Zugmayer's Dimidiatæ, may be transferred to *Psioidea*.

V.—Observations on the Northern Margin of Dartmoor.

By F. P. Mennell, F.G.S., M.I.M.M.

Many unsolved problems still remain in connexion with Devonshire geology, and there is no more interesting area in the county than that surrounding the Dartmoor granite mass. The investigation of this part of Devonshire has not been completed by the Geological Survey, and most of the northern margin of the Moor remains undescribed.[1] During 1914, 1915, and 1916 the writer at intervals spent a good deal of time in studying the metamorphosed sediments on the north side of the Moor, and although he left England with his investigations incomplete this brief account of the results obtained will, it is hoped, be of service, if only as an indication of what is to be found.

I. East Okement Section.

It will be convenient to take as a starting-point in the description one of those lines of section which offer fairly complete exposures of the rocks across the contact zone or the greater part of it. The best of these is that afforded by the valley of the East Okement River, not far from Okehampton. Above Fartherford railway viaduct this stream flows over the whole width of the metamorphic aureole almost directly at right angles to the strike. The total distance is just over a mile and a quarter, and the succession may be tabulated as follows:—

10. spotted and hardened shales, with gritty bands.
9. chiastolite hornfels.

[1] The Lyd Valley has been dealt with by the writer in Q.J.G.S., vol. lxxi, pp. 623–38. A few general observations are summarized in Q.J.G.S., vol. lxxii, pp. 83–4, 1917. Mr. R. H. Worth has recently read a paper before the Geological Society on the Meldon area, of which only an abstract has yet appeared.

8. altered limestone ("calc-flinta").
x. epidiorite (altered dolerite sill).
6. spotted hornfelses, etc.
5. banded hornfels.
x. epidiorite.
4. chiastolite hornfels.
3. tuff.
2. altered limestone.
1. andalusite hornfels (sericitized).

Intrusive Granite.

The beds on the outer edge of the contact zone, below Fartherford, well seen on Ball Hill, are alternations of thin bands of dark, somewhat fissile shale with lighter-coloured massive bands of grit, or rather, perhaps, of hard gritty shale. The softest dark shales sometimes show faint indications of spotting. The same beds, it may be mentioned, are well exposed in the Simmons Park at Okehampton. The highest beds which are distinctly altered are impure shales, of which an artificial exposure is afforded by an old quarry near the river on the left bank. A study of slices of these rocks does not reveal anything worth noting in the present brief account beyond a mottled appearance due to a cloudy distribution of secondary mica, etc. Gritty beds occur here and there in the river bed intercalated amongst those of a more argillaceous character, and some bands of hard white quartzite are seen. Thin sections of this last show much secondary muscovite. Some of the purer shales are conspicuously spotted, but they do not possess any features of much interest under the microscope. They appear, however, to represent an initial stage in the production of the chiastolite-bearing hornfelses, as the latter show minute chiastolite crystals in the centre of hazy spots, where least crystalline. The chiastolite hornfelses proper, which, unlike the overlying beds, appear to be quite free from gritty bands, are well exposed in an artificial cutting along a track running beside the stream. The beds dip at low angles and are sometimes nearly horizontal. The rock is extremely fresh, and as a consequence the chiastolite crystals are very inconspicuous, so that in the field it looks more like a compact basalt or dolerite than anything else. The altered limestone which underlies it has an outcrop over 100 yards wide. It has a banded structure, like most of the West of England "calc-flintas", and is generally highly silicified and never coarsely crystalline. Nevertheless, it shows occasional seams which contain augite, hornblende, epidote, axinite, and other silicates. Immediately below the limestone comes the upper epidiorite, a narrow band only seen in the actual bed of the river; it outcrops a little below the junction of the Moor Brook with the East Okement. Then we find somewhat varied types of hornfels, sometimes spotted, and much tourmalinized in places. These extend for a short distance above the Moor Brook junction and have among them, apparently, an altered representative of a band which further east contains cordierite. Just below the Moor Brook there is a very gently inclined thrust-plane among these rocks, which are nearly horizontal for some distance, and then resume a more pronounced dip to the north. A remarkable overfold is seen above the point where the Moor Brook flows into the Okement, close to the mouth of an old adit. Further on we find ourselves on a conspicuously banded type of hornfels, the bedding planes of which form gently sloping surfaces in the river bed. This sometimes contains much biotite or chlorite, while at other points it is extremely like some varieties of "calc-flinta", though it does not seem probable that any great thickness of it was appreciably calcareous. The banded hornfels has the appearance in the field of being the thickest member of the metamorphic series, but more than one overfold can be detected on close inspection. Its thickness may therefore be more apparent than real, a supposition which is borne out to some extent by its attenuation in the Taw section, though it is true it may there be replaced in part by other kinds of rock. The striped rocks are followed by some rather nondescript types of hornfels, though even these are sometimes brown and sometimes grey in different beds, and are here grouped with the banded series. Then comes the lower epidiorite, marked in the river by a waterfall. It is probable that a certain thickness of banded hornfels intervenes between the epidiorite and the lower chiastolite hornfels, but as several specimens selected for slicing proved to be merely highly hornfelsed varieties of the epidiorite this point requires further investigation. The epidiorite, it may be noted, sometimes contains small crystals of tourmaline as well as secondary biotite. The lower chiastolite hornfels, which is much more crystalline in appearance than the upper band, is well seen along the path on the left bank of the river, but apparently nowhere else. Beyond it there are only very fragmentary exposures. The tuff is not seen in situ, and its presence has to be inferred from fragments which are none too common anywhere, but are more abundant on the right bank of the river. The lower limestone, too, can only be discovered after careful search; in fact, I only found the outcrop in the river-bed after my attention had been drawn to the probability of its occurrence by what was to be seen in other localities. The andalusite hornfels is also poorly exposed, though some felspathized and silicified bands of it are to be seen on the river bank. Both this and the overlying limestone can, however, be studied a little to the east on Watchet Hill, near Belstone, the former in artificial exposures and the latter in a number of prominent outcrops.

The question now arises as to how far the section above described can be considered complete. There is nothing in the exposures themselves to suggest that there is any non-sequence, but we are led to that conclusion by the presence, less than half a mile to the east, of a band of tuff. Large masses of this rock are extremely abundant along the lane running from Belstone to Okehampton via Fartherford, and its position probably corresponds with the top of the upper chiastolite hornfels already referred to; indeed, it may be in situ above that rock on the top of the West Cleave, overlooking the Okement, a point which I did not have time to clear up. This is on the assumption that the conspicuous craggy outcrops of dark hornfels represent the chiastolite hornfels at that locality. It is true that the mineral can seldom be detected in the field, but its presence, often in curious skeleton crystals, is revealed by the microscope. Tuff at this horizon is well exposed at the Meldon railway viaduct, where it has been described by General MacMahon,[1] and fragments indicate its presence all the way from the village of Sourton (*not* Sourton Tors) to near Sticklepath, though it may be absent in places owing to thrusts, as appears to be the case in the bed of the Okement. The lower and more important bed of tuff (not recognized prior to the writer's observation[2] except at Sourton Tors) is only traceable by fragments in the Okement Valley, but is seen between the river and Belstone, and is extremely well exposed in the cliffs overlooking the River Taw.

Structure of the Rocks.

It is worthy of remark that we have here two bands of limestone, two of tuff, two of chiastolite hornfels, and two of epidiorite. In such a disturbed region it is necessary to consider whether this state of affairs may not be attributable to a great overfold of Alpine character. Assuming the axis of such a fold to be somewhere in the banded hornfels series, where there are certainly clear indications of overfolding, the positions of the epidiorite bands on either side of it would fit in quite well with the supposition, and, leaving the limestone out of account, the chiastolite hornfels and tuff would also be in the right position. The limestone, however, which is of considerable thickness on the north, is not recognizable on the south, though it is only right to say that the same appears to be the case with the upper limestone itself on the West Cleave, only a few hundred yards from the river. There is, however, the other (lower) limestone to be accounted for, which occurs in quite the wrong position below the tuff, and also the fact that this is underlain by andalusite hornfels, which can scarcely be a metamorphosed equivalent of the beds above the upper tuff, as these are often of a sandy nature. Moreover, this succession of tuff, limestone, and andalusite hornfels in descending order is seen along the margin of the granite all the way from near South Zeal to beyond Lake, with a regularity which is strongly against such important disturbances having taken place as would be required to account for the want of correspondence north and south of the axis of an overfold. It may also be noted that it would be necessary to assume that some representative of the beds numbered 6 occurs between the hornfels and lower epidiorite. There is no indication of this, and in the Taw section, which is clearer at this point, there is certainly nothing of the kind. What is very suggestive that there is no such simple major overfold as has been discussed, is the fact that so many signs of overfolding are to be seen, and yet in no case do the plicatious result in distinct beds being brought into juxtaposition. This is more in keeping with the idea of minor puckerings of the strata than that of orogenic movements on a grand scale. It may be concluded, therefore, that the apparent order of succession is also the true one.

[1] Q.J.G.S., vol. xlix, p. 380, 1893.
[2] Q.J.G.S., lxxii, p. lxxxiv, 1917.

II. The Taw Section.

Turning now to the River Taw, which crosses the granite contact about a mile east of the Okement, we have a very good section of the lower beds, though scarcely anything is to be seen of the outermost members of the series we have been discussing. The river ceases to flow at right angles to the strike as soon as it gets into the lower limestone, and this fact has also to be taken into account. There are some interesting minor differences between the Taw and Okement sections, but on the whole they correspond very well. Taking what can be seen above the road west of Sticklepath, as well as what the river shows, we have this succession, in which the beds are numbered, where they can be identified, in the same way as along the Okement:—

8. silicated limestone.
x. epidiorite.
7. cordierite hornfels.
x. epidiorite.
6 (?). chiastolitic and spotted hornfels.
x. porphyritic epidiorite.
5. banded hornfels.
4 (?). radiolarian rocks.
3. tuff.
2. silicated limestone.
1. andalusite hornfels.

Some of the beds worst seen along the Okement are extremely well exposed along the banks of the Taw. The lowest member of the series is, however, scarcely recognizable, apart from the artificial exposures at Birchy Lake, and in stray fragments. The limestone is splendidly exposed along the right bank of the stream and shows a very varied mineralogical composition; specimens containing coarsely crystalline garnet, axinite, epidote, augite, hornblende, etc., being readily obtained. There are in it some small mine workings (for copper) now abandoned. The tuff is well seen on both sides of the Taw, though thrusts are no doubt responsible for the fact that it is absent, for a short distance, from the high ground between Belstone and the river. Its total thickness seems to be about 60 feet. It varies in grain from a fine ash to a coarse agglomerate, and, especially at the top, there are numerous alternations of sedimentary material with coarse ash bands a few inches thick. It is therefore clearly the result of a lengthy period of volcanic activity and not of a single paroxysmal eruption.[1] The rock fragments are of acid and intermediate types, to the complete exclusion of basalts, as far as I have examined them under the microscope, and are often highly amygdaloidal. They include some very interesting rhyolites and trachytes, surprisingly little affected by thermal alteration except for

[1] Mr. R. H. Worth has, since these notes were written, put forward the theory that the tuff is of an intrusive nature. I am not aware of any evidence in favour of that view unless the disconnected nature of the outcrops is considered as such. The facts noted here are entirely incompatible with the rock being anything but a true ash bed accumulated under the sea.

the development of minute biotite flakes. The eruptive materials were clearly of classes quite unlike those represented by the lavas now seen in situ at Was Tor and near Brent Tor on the western side of the Moor. The porphyritic augite-andesite of Doddiscombleigh is also quite different from anything to be seen here. Some of the largest fragments in the tuff, which are upwards of 2 feet in length, are of a light-coloured, inconspicuously banded, sedimentary rock of unknown provenance.

Blackish flinty rocks outcrop in the river bed above the tuff, and a specimen sliced was found to contain numerous and quite well preserved radiolarian remains. It is, in fact, a typical radiolarian chert. Two specimens from the sedimentary bands interbedded with the tuff also proved to contain radiolaria. The occurrence of these radiolarian rocks is of considerable interest, as although I have not detected radiolaria elsewhere in the contact zone, they are no doubt to be found by careful search and would serve as useful indices of this horizon. Outside the metamorphic aureole, on what is probably the western extension of these very beds, a band of radiolarian rock occurs along the edge of a patch of woodland, on the main road between Bridestowe and the railway station of the same name.

The dark-coloured beds grade off into the banded types of hornfels so conspicuous in the Okement section. They dip much more steeply, and this is perhaps chiefly responsible for their comparatively narrow outcrop. There is no chiastolite band under the striped rocks corresponding to that of the Okement Valley, and it may be surmised that it is represented by the dark beds, including those with radiolaria. Curiously enough, a well-marked chiastolitic band occurs directly above the lowest epidiorite seen here. This last is a beautiful porphyritic type, containing much secondary biotite, and is well exposed in the river bed under the private footbridge leading into Skaigh Warren. This does not correspond in its position with either of the intrusions seen in the Okement section, though what is evidently the lower of these is exposed close by at Brinemoor just outside Belstone, with numerous fragments indicating banded hornfels overlying it and chiastolite hornfels below. There is some dislocation, however, at Belstone, as chiastolite hornfels occurs near the village on the high ground on the left bank of the river. This must have reached its present position by faulting, as it does not occur on the opposite side, which has perfectly regular bands of altered limestone in its proper position between andalusite hornfels and tuff. The chiastolite-bearing rock, exposed at Skaigh, is also well seen in the bed of the river, which runs along its strike from Skaigh Warren to near Sticklepath. It has some beds above it, very thin at Skaigh, but much thicker at Sticklepath, where they are worked for road-metal, which are often conspicuously spotted, and appear to correspond to the beds numbered 6 in the Okement section. Above them comes the cordierite hornfels, of which very fresh specimens can be obtained alongside the road just below Skaigh. At this point a narrow epidiorite intervenes between it and the underlying strata. The intrusion is quite different in structure from that exposed in the river bed, and occasionally shows a little secondary axinite along its margins. The beds above the chiastolite band do not cross the river in this neighbourhood, owing partly to the direction taken by the stream, and partly to the fact that the strike swings round somewhat to the north, so that the representatives of the beds numbered 9 and 11 in the Okement section are here right outside the aureole of metamorphism, and it is therefore difficult to identify or define them with any certainty. West of Sticklepath there is still another band of epidiorite above the cordierite hornfels. Then follows limestone, chiefly altered to a yellowish garnet rock, at one time worked for copper with some success at the Belstone mine. Beyond, indications of contact alteration are absent, and the exposures are so poor that it is difficult to determine where any of the upper beds cross the Taw. The rock burnt for lime near South Tawton is very possibly the unaltered continuation of the metamorphosed upper limestone. It may also perhaps be identified with the limestone formerly worked for lime in the quarry at Drewsteignton, which is said to be fossiliferous. The lower limestone bed has been actively worked for copper in the Ramsley mine at South Zeal. It has been converted into black garnet rock for the most part, but other very interesting types are to be seen. One of these is a garnet-augite-axinite rock in which the garnets show the most remarkable examples of zoning that I have ever seen. This "calc-flinta" probably corresponds with that which is still worked for road-metal further east at Nattenhole Quarry, where the more crystalline bands consist of a very interesting augite-axinite rock containing some felspar.

The andalusite hornfels is seen in a fresh condition along the stream running through Ford Farm, where there are some small openings made to obtain building stone. The rock is interesting petrographically from the fact that it is here a biotite-andalusite hornfels, whereas further west it is muscovite-bearing. The exposures have revealed from time to time the presence of numerous veins emanating from the granite varying from several feet to a fraction of an inch in width, and containing visible pink crystals of derived andalusite. The lower "calc-flinta" has also been exposed in a prospecting shaft (said to be for arsenic) at Ford Farm. In addition to the usual silicates, sections from this locality sometimes show a very strongly birefringent mineral, which is no doubt datolite. The tuff seems to die out in the neighbourhood of Sticklepath. All the rocks are poorly exposed beyond South Zeal, and I have not attempted to trace the various beds beyond that village.

III. Westward Continuation of the Series.

West of the Okement the beds are not at first very easy to follow. Near Okehampton fragments of tuff and epidiorite are to be found in abundance on the golf links, but it is not easy to say where they occur in situ except that there is an outcrop of epidiorite just below the Artillery Camp. A number of narrow seams of garnetiferous rock with shale partings probably represent the upper limestone, and are well exposed at the Camp Hill Quarry. These dip south and thus indicate a sharp local synclinal fold. Both red and black garnets are present, and these are embedded in a matrix which is sometimes chiefly hornblende and sometimes a fine felt of wollastonite fibres. One variety shows in thin slices beautiful rosette-shaped sections of pink garnet scattered through an aggregate of pale-green hornblende crystals. Fragments of chiastolite-bearing rocks are to be found below the quarry and also occur plentifully on the fields to the east. These no doubt link up with the uppermost beds containing that mineral in the Okement section. Above the camp masses of tuff are the most conspicuous feature, and obscure the other beds until the andalusite hornfels is reached.

Better exposures are to be seen along the Redaven brook, which runs from the foot of Yes Tor to join the West Okement above the village of Meldon. The succession of andalusite hornfels overlaid by limestone and succeeded in turn by tuff, which is again covered by blackish and banded types of hornfels, is as clear as in the Taw Valley along the banks of the Redaven, and also those of the West Okement. It may be traced beyond the village of Lake, where the beds begin to pass out of the contact zone, and lower horizons are represented along the edge of the granite. These latter are of a more gritty character, generally speaking, though they include what may be altered radiolarian chert above Lake Viaduct, and crystalline limestone on the north-western slopes of Great Nodden, where we encounter the rocks described in my paper on the Lyd Valley. There is probably more than one fault in this neighbourhood, of which I was not able to complete the examination.

Returning to the Meldon area, the well-known intrusion of fine-grained topaz-bearing granite or granophyre may be noted as intrusive in what is here called the banded series, which is unusually calcareous at this point. Further west, in the cliffs overlooking the Okement, veins connected with it invade the lower tuff. Above these rocks comes the upper limestone, which has been worked for lime in a large quarry now abandoned, but which thins out to the east into narrow seams interstratified with shale. Westward it is represented along the strike by coarsely crystalline calc-flinta, full of interesting minerals, which affords a good instance of undoubted introduction of silica in the course of the contact metamorphism of limestone. These beds are in all probability the same as worked in the large quarry near Bridestowe, outside the metamorphic area. It may be noted that wollastonite, rare further east, is occasionally abundant in the upper limestone, while the lower limestone is sometimes converted into idocrase-wollastonite rock, which is also to be found among the numerous xenoliths in the "aplite" quarry. Datolite and scapolite are also known to occur. In this section chiastolite-bearing rocks seem again to be the uppermost sediments that have undergone marked alteration. The upper tuff, first described by MacMahon, outcrops near the railway and is well exposed on one side of the viaduct. No epidiorites are seen along the Redaven, but a narrow sill, much tourmalinized, is seen in the big quarry worked by the railway company for ballast a little to the east, as to the horizon of which I am by no means certain.[1] A much more prominent basic

[1] Restrictions connected with the War prevented me re-examining the quarry or inspecting the railway cuttings.

igneous intrusion outcrops on Sourton Tor and on the high ground north of it, where it is of a porphyritic type, like that seen at Skaigh, and apparently on the same horizon.

NOMENCLATURE.

For convenience of reference it may be well to give local names to the rocks that have been dealt with in these pages. The rapidly alternating shaly and gritty rocks, so well seen along the Okement at Ball Hill and in the Simmons Park, may appropriately be named the *Okehampton Beds.* The underlying strata, to which most attention has here been devoted, and which are essentially a calciferous shale series, are perhaps best termed *Sticklepath Beds.* Their upper limit may be defined as the point where the gritty bands first make their appearance. The series itself is, so far as I have been able to see, entirely free from grit. The base is that of the shales which in the metamorphic area are represented by andalusite hornfels. They appear to rest near Lake[1] on beds of which a considerable thickness is gritty throughout, as seen near the railway at Lake and Southerley, though they include sharply folded (? radiolarian) rocks near Lake Viaduct, banded calcareous shales east of Southerley, as well as the purer shales represented by the andalusite hornfels of Great Nodden, where a seam of limestone and some grit bands also occur. These *Southerley Beds,* as they may be termed, rest on the *Lydford Beds,* which have at their top the Downtown calc-flinta. They are essentially, however, a thick succession of shales of the type which are rather chloritic than strictly argillaceous in character, and are represented in the contact zone almost exclusively by cordierite hornfels.

Before concluding, it is both a duty and a pleasure for me to acknowledge the constant aid and frequent companionship of my friends Dr. E. H. Young and Mr. H. J. Ward, of Okehampton, during the investigation of the interesting rocks which form the subject of this paper.

REVIEWS.

I.—THE PALÆONTOGRAPHICAL SOCIETY. Vol. LXXI, April, 1919. Volume issued for 1917. 4to; pp. 170. Printed for the Society. Agents for the Society, Dulau & Co., Ltd., 34–36 Margaret Street, W. 1.

THE volume issued this year, although lacking in its usual bulk, owing to the further rise in printers' prices and the general shortage of paper, etc., does not suffer as to the quality either of its printed matter, its plates, or the authors' contributions of valuable text.

1. Dr. Arthur Smith Woodward presents part iii (the concluding part) of his monograph on the Fossil Fishes of the English Wealden and Purbeck Formations (pp. viii, 105–48, and 12 pages of explanation of pls. xxi–vi). The text also carries seven additional

[1] There are probably several faults or thrusts about here.

figures; amongst these latter may especially be referred to figs. 36–9 and 41, the restorations of the skeletons of *Pleuropholis formosa*, *Leptolepis dubius*, and *Lepidotus minor*, as fine examples of delicate drawings by Miss G. M. Woodward. So far as known, the fishes of the Wealden and Purbeck formations are essentially Jurassic and not mingled with any typically Cretaceous forms. Most of them are indeed (in the author's opinion) specialized and evidently final representatives of the Jurassic families to which they belong, not to be regarded as possible ancestors of the fishes of Cretaceous and later times.

2. The index and title-page complete the first volume of Mr. F. W. Harmer's great work on the "Pliocene Mollusca of Great Britain", with a systematic list of genera and species (pp. xii and 463–83). A view is added of the pit of "Waltonian" Crag at Little Oakley from which the author obtained the shells of about 650 species of Mollusca and upwards of 100 specimens of Polyzoa. This concludes the Crag volume for the year.

3. Dr. W. Spencer follows with part iv of his monograph on British Palæozoic Asterozoa (pp. 169–96), illustrated by twenty-five text-figures of anatomical details of *living* and *fossil* forms, which greatly assist the student in understanding the structure of these very interesting organisms and their life-history and functions, so that the dry bones of the Palæozoic starfishes, interpreted by their modern representatives, live again.

4. Mr. Philip Lake adds part v of his monograph on the British Cambrian Trilobites with four excellent plates and 31 pages of text, embracing *Ctenopyge*, *Leptoplastus*, *Eurycare*, *Peltura*, *Beltella*, *Parabolinella*, *Angelina*, *Dikelocephalus*, *Dikelocephalina*, and *Apatokephalus*. Mr. T. A. Brock's figures are excellent.

We trust the splendid work carried on by the Palæontographical Society may not be permanently hindered by the evils arising as an "aftermath" of the War, which has affected the cost of printing and publishing of all scientific work more or less severely.

II.—The Lower Cretaceous Floras of Queensland.

1. Mesozoic Floras of Queensland. By A. B. Walkom, D.Sc. Part II: The Flora of the Maryborough (Marine) Series. pp. 18, with 2 plates. And a Geological Note, Map, and Section, 2 pp., by B. Dunstan. Queensland Geological Survey, Publication No. 262, 1918. Parts III and IV. The Floras of the Burrum and Styx River Series. pp. 70, with 7 plates. And a Geological Note and Sections, by B. Dunstan, pp. 6, with 1 plate and 2 text-figures. Ibid., Publication No. 263, 1919.

2. The Geology of the Lower Mesozoic Rocks of Queensland, with special reference to their Distribution and Fossil Flora, and their Correlation with the Lower Mesozoic Rocks of other Parts of Australia. Proc. Linn. Soc. New South Wales, vol. xliii, pt. i, pp. 37–115, 2 plates and 6 text-figures, 1918.

1. These memoirs form further instalments of Dr. Walkom's valuable work on the Triassic, Jurassic, and Cretaceous plants of

Queensland (see Geol. Mag., Dec. VI, Vol. V, p. 516, 1918). The author's analysis of the different floras, showing the percentages in which the chief plant groups are represented, are particularly suggestive.

Large collections of marine fossils have been obtained from the Maryborough Series (Lower Cretaceous), the predominant forms being Pelecypods and Cephalopods. In association with these animal remains, there are a number of fragmentary plants; about 34 specimens have been obtained, representing 14 species. Of these 34 specimens, 11 are of *Pagiophyllum*, 8 of *Tæniopteris*, 4 of *Araucarites*, 2 of *Ginkgo*, 2 of ? *Taxites*, 2 of indeterminate roots, and 1 each of *Equisetites*, *Sphenopteris*, *Ptilophyllum*, ? *Pterophyllum*, and silicified wood. This list indicates a flora in which Gymnosperms largely preponderated.

The flora of the Burrum Series, which was formerly described as Lower Trias–Jura in age, is found by Walkom to be typically Lower Cretaceous and undoubtedly homotaxial with such floras as the Wealden of Europe and the Lower Cretaceous (Neocomian) of North America. Thirty-six species have been obtained, 22 of which are Gymnosperms, while 13 belong to the Filicales. Walkom draws attention to the fact that one leaf-type, which he describes as "? *Dictyophyllum* sp.", may possibly be Dicotyledonous.

The Styx Series proves to be somewhat younger than the Burrum Series, and it is suggested that it may be the equivalent of the Albian stage. The association of Dicotyledonous leaves with a number of typical Mesozoic plants makes it clear that the age of the strata is Cretaceous, probably Lower Cretaceous. The flora shows considerable resemblance to the Patapsco Flora of Maryland and Waikato Heads Flora of New Zealand. The species represented include Equisetales (1), Filicales (4), Cycadophyta (3), Coniferales (3), and Dicotyledons (3).

2. In the general paper cited above, Walkom discusses the conditions prevailing in Queensland in Lower Mesozoic times, and the geography of the Australasian region during that period—basing his conclusions in part upon his detailed study of the palæobotanical evidence.

A. A.

III.—The Maidenhair Tree in Spitsbergen.

Ginkgo adiantoides (Unger) Heer im Tertiär Spitzbergens nebst einer kurzen Übersicht der übrigen fossilen Ginkgophyten desselben Landes. By A. G. Nathorst. Geol. Fören. i Stockholm Förhandl., Bd. xli, H. iii, pp. 234–48, 4 text-figures, 1919.

THIS paper records the occurrence of *Ginkgo adiantoides* in Spitsbergen, associated with *Populus arctica* and other leaves characteristic of the Tertiaries of this region. This species, which is probably identical with the living *G. biloba*, has been obtained from many localities in Europe, from horizons ranging from the Eocene to the Upper Pliocene. The present discovery carries its known range further to the north, since Braganza Bay and Green Harbour (lat. 78° N.), where it has now been found, lie considerably nearer the Pole than the locality in Greenland which has hitherto been its most northerly recorded station (lat. 70° N.).

Professor Nathorst follows his account of *Ginkgo adiantoides* by a general review of the Mesozoic Ginkgophytes of Spitsbergen. He points out that genera belonging to this group are abundantly represented in beds between the Jurassic and the Cretaceous, equivalent to the Wealden and uppermost Portlandian. He draws attention to the singular fact that the Wealden beds of Europe display no corresponding richness in Ginkgophytes, which, on the contrary, have here passed through their period of abundance in the Rhætic and Lower and Middle Jurassic. Why, he asks, do the Ginkgophytes reach their maximum in the Polar regions later than in Europe? He does not propose any answer to this riddle, but points out that its solution is bound up with the problems of climatic changes and plant migrations.

A. A.

IV.—The Iron and Steel Industry of the United Kingdom under War Conditions. By F. H. Hatch, Ph.D. pp. xii + 167, with plates and diagrams. Privately printed, 1919.

THIS handsome and well-illustrated volume, which has been privately printed for Sir John Hunter, K.B.E., is described on the title-page as a record of the work of the Iron and Steel Production Department of the Ministry of Munitions. Out of the ample material at his disposal Dr. Hatch has constructed a remarkably interesting story of well-directed enterprise and success in the face of overwhelming difficulties of all kinds. It is not easy for the non-technical reader to grasp the magnitude and complexity of the task to be faced by the band of self-sacrificing and courageous men who undertook to evolve order out of chaos, to reconcile conflicting interests, and to carry out schemes which not only contributed in the highest possible degree to the military and naval successes of the Allies at the moment, but also kept in view the needs of the future, so that after the War, in spite of everything, the iron and steel trades of the country might be in a stronger position than they were before. It is that wise and statesmanlike foresight that forms, perhaps, the most remarkable feature of the fascinating story unfolded by Dr. Hatch in these pages.

When the formation of the Iron and Steel Production Department was undertaken by Sir John Hunter the demand for steel was growing rapidly, while the supply of raw materials from abroad was seriously curtailed: the demands of the military authorities on labour were urgent, and in many places industrial unrest was making itself felt. It was necessary to balance all these conflicting factors so as to obtain the best possible results with the means available. Home resources of material had to be utilized to the full, and methods modified to suit their special characters, while labour-saving devices of every possible kind were introduced. Prisoner labour was also utilized to some extent, but with not very satisfactory results.

The most remarkable feature of the whole scheme was the immense increase in the production of steel from phosphoric ores by the basic processes. This was necessitated by the shortage in the supplies of foreign Bessemer-grade hæmatite ores, which had to be replaced by British supplies, derived mainly from the Jurassic ironstones of the Midlands and Cleveland. While the output of ore from the latter region remained more or less normal the tonnage from Lincolnshire and the Midland counties increased largely, and noteworthy developments took place in Northamptonshire, and especially in Oxfordshire. Even the Upper Lias stone of the island of Raasay was drawn on to some extent, though this is unlikely to be an important source of future supply. A considerable amount of the more phosphoric grade of Kiruna ore was also purchased in Sweden through the efforts of the Department.

The immense increase in steel-production also necessitated the development of British resources of limestone, dolomite, and refractories, as well as the building of a large number of new coke-ovens of improved types. All this was also carried out successfully by the officials of the Department in the face of great difficulties as to transport, labour and financial questions.

It should be fully recognized that the country owes a debt of gratitude also to the iron and steel makers, who loyally co-operated with the Ministry of Munitions, often against their own personal interests, and rendered great services to the nation at large by their readiness to assist the Government and each other to make the best of the available resources. The organization called into existence for the special purposes of the War has done notable work in laying the foundations of ultimate victory, and we trust that its wise and far-seeing measures will in time of peace lead to a permanent increase in the prosperity of the iron and steel trade, which is one of the mainsprings in the industry of this country.

V.—The North Riding of Yorkshire. By Capt. W. J. Weston, M.A., B.Sc. Cambridge County Handbooks. pp. viii + 161, with illustrations and diagrams and two coloured maps. University Press, Cambridge, 1919. Price 2*s*. 6*d*. net.

THIS volume forms another of the excellent series of county geographies issued by the Cambridge University Press, and deals with the fourth in size of the English counties, the North Riding being only exceeded by the West Riding, Devonshire, and Lincolnshire. An area of this size naturally shows wide variations in structure, topography, climate, soil, and industry, as is well brought out by the author. The North Riding is clearly divisible into three main regions, the hills in the west consisting of Carboniferous rocks, the central plain of Trias and drift, and the Jurassic moorlands of the east, with the lower ground on the same formation extending from Helmsley, Pickering, and Scarborough to York. All this is classical ground to the geologist, since it is associated with the names of William Smith, Young and Bird, Phillips, and other pioneers of the heroic age, while even in recent times many problems of the greatest interest have there been studied with effect. In speaking of the topography of the county, it may, perhaps, be noted that even within the recollection of the present reviewer the name Cleveland Hills has received a very wide extension, mainly at the hands of geologists. Strictly speaking the Cleveland Hills are only the northern escarpment of the great Jurassic area, overlooking the plain of the lower Tees, but now by customary usage the name has gradually encroached towards the south, extending first to the line of the Esk, while by some writers it is apparently made to include the whole of the moorland region down to the Vale of Pickering, more properly known as Blackamoor. It is probably now too late to enter an effective protest against this proceeding, which has received the sanction of high scientific authority.

There are few more remarkable features in the history of this country than the development of the Cleveland district proper. A hundred years ago Middlesbrough was an uninhabited mud-flat. It is now a town of 120,000 inhabitants and the centre of a world-wide industry. This development is solely due to the occurrence of iron-ore in the Lias. Serious mining began about 1837 at Grosmont, though cargoes had been shipped from the coast platform about Kettleness many years before. The commencement of working at Eston in 1850 was not the first start, as stated by Captain Weston, although it was undoubtedly of the greatest importance. As every one is aware, the Cleveland output of ore is now far greater than that of any other British ironfield, and it is possible that in the immediate future the older workings in the Esk Valley may be restarted.

The author of this book has been on the whole very successful in bringing out the great importance of geology in the North Riding: a few minor slips occur, but nothing of much significance. Perhaps the worst feature of the book is the coloured geological map; a geologist may well ask, why is the tint of the "Lower Oolites" made practically indistinguishable from that assigned to the Whin Sill, and still more, why is this latter labelled "granite"? Without a very careful scrutiny the non-geological reader would certainly gain the impression that the eastern moorlands consist for the most part of granite: it needs a keen eye to detect the difference of tint and stippling.

Captain Weston has succeeded in his difficult task of giving a brief, clear, and interesting account of a very large subject, preserving a due balance between the different parts, and presenting a most readable account of a region which can yield to none in beauty of scenery and historic interest, and as a happy hunting ground for the geologist, the botanist, and those interested in all the other branches of natural history in the broadest sense of this much-abused term.

R. H. R.

VI.—The Mineral Industry of the Union of South Africa and its Future. By P. A. Wagner. South African Journal of Sciences, September, 1918. pp. 34, with a map.

THIS is a reprint of Dr. Wagner's Presidential Address to Section B of the South African Association for the Advancement of Science. It consists essentially of two parts, the first being a comprehensive review of recent developments in the mineral industries of the Union, while the second part is mainly devoted to the future and the possibility of further discoveries. It is difficult to know what to select for special comment from the great mass of valuable information contained in the first part, but one or two points may be briefly mentioned. Dr. Wagner takes a distinctly optimistic view as to the development prospects of the metalliferous deposits of the great Insiswa intrusion in Zululand, which may perhaps turn out to be a notable rival to Sudbury. This appears to be an excellent example of gravitative differentiation accentuated by the immiscibility of sulphide and silicate magmas. Another local industry which has of late actually reached a position of world-wide importance is asbestos mining. South Africa now leads the world in the production of this useful mineral, as also of corundum. It is interesting to note that the phosphates of Saldanha Bay are now being actively exploited on a large scale with successful results. With regard to the phosphate beds in the Ecca Series in Natal, it might have been mentioned that these were described by Dr. Hatch nine years ago in his Report on the Mines and Minerals of Natal. South Africa is now beginning to take a place among the iron-smelting countries of the world, four blast furnaces being now in operation.

The second part of the address is occupied by a consideration of the geographical distribution of minerals: the Union is divided into nine provinces, mainly based on geological formations. It is pointed out that large tracts of country are still virtually unprospected, and the future may yet hold surprises in store, though probably nothing equalling in importance the diamond pipes of Kimberley or the Rand goldfield remain to be discovered. Yet there is always hope.

R. H. R.

VII.—Notes on the Formation of certain Rock-forming Minerals in and about Glass Furnaces. By G. V. Wilson. Trans. Soc. Glass Technology, vol. ii, pp. 177–216, 1918.

THIS paper contains an account of some interesting and important observations made by the writer in connexion with recent work on glass-making in Scotland. The opportunity was afforded for the most part by the accidental bursting of a tank furnace at the Kinghorn Bottle Works in Fife; the molten material, amounting to about 70 tons, flowed into a space below the furnace and took several days to cool. During this slow cooling several types of crystalline material were formed and reactions took place between the molten glass and the bricks of the furnace, leading to the formation of a series of minerals, mainly silicates of lime and alumina. Other specimens obtained from various sources were also examined petrographically, and the results obtained are here discussed from the theoretical and practical points of view.

The following are the chief minerals observed: wollastonite, quartz, tridymite, melilite, augite, sillimanite, corundum, biotite, and magnetite, as well as a mineral having the composition $3CaO.2SiO_2$, not known to occur in nature. In the general body of the glass the chief minerals found were wollastonite and tridymite, and their presence is of much interest as indicating that owing to the presence of other substances acting as fluxes the crystallization took place below the inversion-points of pseudowollastonite to wollastonite and of cristobalite to tridymite. Wollastonite was very abundant in the specimens and showed a strong tendency to spherulitic aggregation, a feature noted also in other cases of a similar nature. Augite and quartz were found only in thin strings of glass injected into cracks in the bricks or at the junctions of glass and brick. The augite is a variety containing a good deal of manganese.

Under certain conditions wollastonite, augite, tridymite, and quartz, can all crystallize out from the same melt, while felspar, magnetite, and biotite are formed by the corrosive action of glass on brick. Wollastonite, melilite, augite, and the $3CaO.2SiO_2$ compound were produced in partly assimilated limestone fragments enclosed in molten glass. The action of molten glass on aluminous materials used to contain it in the form of glass-house pots, furnace linings, and crown bricks leads to the formation of sillimanite and corundum in considerable quantities, some specimens examined containing very well developed crystals of both mineral.

It is impossible here to detail all the results following from this careful examination of the material available and the theoretical deductions to be drawn from it: the paper is of great interest and should be studied carefully by all petrologists interested in the genesis of the minerals of the igneous and metamorphic rocks.

VIII.—The Geology of Northern Norway.

Sulitelmatrakten. By G. Holmsen. Norges Geol. Undersök. Aarbok for 1917, iii, pp. 44, and 2 plates (with English Summary).

Fjeldströket Fauske-Junkerdalen. By J. Rekstad. Ibid. iv, pp. 66, with 7 plates and a coloured map (with English Summary).

THESE two memoirs give an account of the geology of the tract of country between the Saltenfjord and the Swedish frontier, which includes the well-known copper-mines of Sulitelma, now being extensively worked. It is an area of high mountains and plateaux, some points rising to 6,000 feet above the sea, and supporting several important glaciers. The region consists of gneisses, crystalline schists, amphibolites, and marbles, penetrated by igneous rocks of Caledonian age, ranging from serpentine to granite, the latter occupying the largest area. Some interesting examples of sheared and folded conglomerates are described and figured. The ore-deposits of Sulitelma occur in highly metamorphosed rocks of Cambrian and Silurian age in close association with amphibolites (sheared gabbros). The origin of the ore-bodies is still a matter of controversy, Vogt considering them to be derived directly from the gabbro magma, while Sjögren holds that they have been formed metasomatically by the action of aqueous solutions.

IX.—Yorkshire Type Ammonites. Edited by S. S. Buckman. Photographs by J. W. Tutcher. Part XVIII. London: Wesley and Son. March, 1919.

THIS part completes the second volume of this most useful publication. Accordingly it furnishes a table of contents, the precise dates of publication of each page and plate, zoological and chronological lists of the genera dealt with, an index, and other necessary matter. It is noted that the first two volumes contain 163 plates, illustrating 137 species. There are still some type-ammonites of Yorkshire to be redescribed, but it is proposed now to extend the scope of the work by including type-specimens of Jurassic ammonites from other localities in the British Isles. The price will be raised to 10*s.* net for each part, consisting of 10 to 12 plates and text, but should circumstances permit the number of plates may be increased.

The chief species figured in this part are: *Ammonites impendens*, Young & Bird, referred to *Arietites*; *Ammonites longævus*, Bean, cit. Leckenby, which gives rise to two new genera, the lectotype becoming *Longæviceras longævum* and the other syntypes becoming *Pseudocadoceras boreale.* Supplementary plates are given of *Gagaticeras funiculatum*, *Beaniceras costatum*, and *Fimbrilytoceras fimbriatum.*

X.—Recent Advances in Rhodesian Geology. By H. B. Maufe. Pres. Add. Proc. Geol. Soc. S. Africa, 1919, pp. xxi–xxxvi.

IN this address Mr. Maufe gives a comprehensive general account of the geology of Rhodesia, as worked out by himself and his colleagues on the Geological Survey. The subject is treated mainly from the stratigraphical point of view, and the petrographical characters and probable origin of the leading rock-types are discussed. The outstanding feature of Rhodesian geology is the enormous preponderance of the oldest systems, composed of crystalline schists and intrusive bathyliths, which occupy most of the country, while newer formations are scantily developed. Hence there are many gaps in the geological history of the country. Special attention is drawn to the curious problem of the origin of certain types of banded ironstones, which have been shown to be altered felsites, while it is also believed that many of the so-called conglomerates are really of intrusive igneous origin, the "pebbles" being lenticular masses of rather more basic composition derived from the same magma as the base. A noteworthy feature of the older series is the enormous volume of basic igneous rock, now represented by epidiorite, and perhaps exceeding in magnitude even the Karroo dolerites. The Umkondo formation is referred by Mr. Mennell to the Waterberg, which it resembles lithologically. The Karroo system covers a good deal of ground in Rhodesia, but no tillite has been found. The age of the red sandy Kalahari Beds is still uncertain: they represent a period of very arid conditions at some time between the close of the Stormberg and the present day: it is impossible as yet to be more definite than this.

R. H. R.

CORRESPONDENCE.

A QUARTZOSE CONGLOMERATE AT CALDON LOW, STAFFS.

SIR,—In the August number of the GEOLOGICAL MAGAZINE, p. 384, Mr. F. Barke, Chairman of the Geological Section of the North Staffs Field Club, states that the quartzose conglomerate recently described by us (GEOL. MAG., February, 1919, pp. 59–64) "was discovered in 1905 by members of the Geological Section of this club, and the fact recorded in the Trans., vol. xl, p. 85, 1905–6".

When our note was being written we had before us the article to which Mr. Barke refers, and which reads: "In opening out the new quarry at Caldon Low, on the eastern side of the hill, an interesting section has been exposed. The beds of limestone dip steeply to the east, and are badly faulted; traces of lead can be seen in some of the fissures, and there were signs of old workings on the side of the hill. At the southern end of the quarry occurs a limestone breccia containing Bunter pebbles; a swallowhole, now filled with cave earth, has been cut across, communicating with a fissure; the latter is said to have been traced for a considerable distance down the hill until the explorers were stopped by water—it has been partially filled up by refuse from the railway cutting; towards the northern end the limestone becomes deeply stained with hæmatite. The beds are almost unfossiliferous; amongst the fossils noticed were *Productus humerosus*, *Orthotetes crenestria* (*sic*)."

We fail to understand how the description given by us of the position occupied by the conglomerate section can be made to agree with the above-quoted statements. It may be observed that:—

1. The quarry in which occurs the conglomerate section is situated on the north-west flank of the hill, and not on the eastern side.

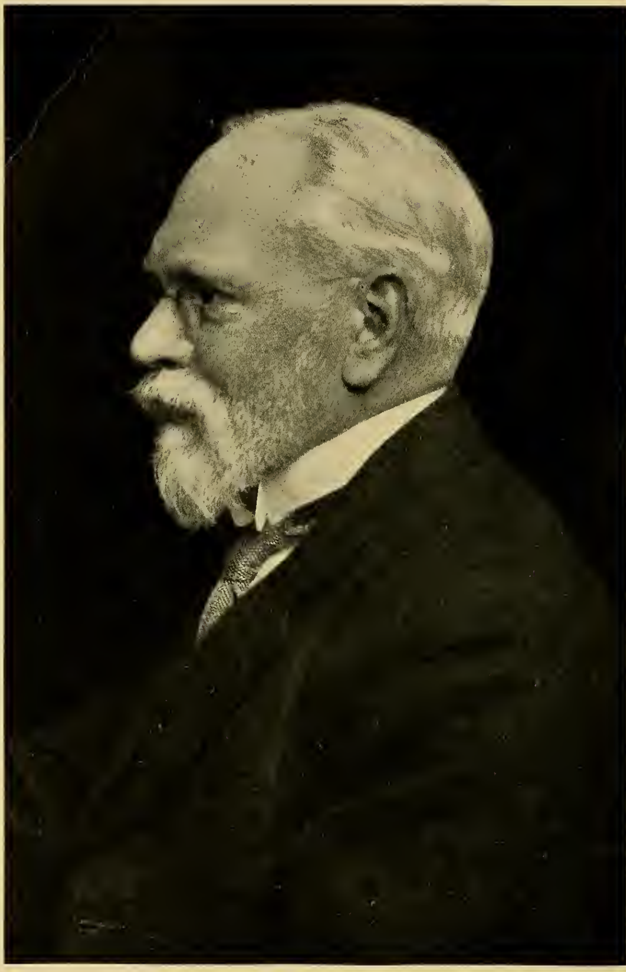
2. The beds of limestone do not dip steeply east: the underlying *humerosus*-limestones are practically horizontal; the conglomerate is obscurely bedded in its lower portion, while the upper beds dip N.N.W. at an angle of 30°.

3. No definite evidence of faulting is visible.

4. The conglomerate extends round the north-east flank of the Low from the north-east end of the quarry.

5. Finally, the pebbles present do not resemble the typical Bunter pebbles in general facies, while the presence of an abundant and highly characteristic Upper Carboniferous fauna places them very considerably earlier than Bunter times.

Thus, we venture to think we were justified in concluding that the breccia with Bunter pebbles recorded by Mr. Barke in 1906 was



John Hopkinson

a deposit totally different in character and in significance from that described by us.

J. WILFRID JACKSON.
W. E. ALKINS.

MANCHESTER.
August 13, 1919.

OBITUARY.

JOHN HOPKINSON, F.L.S., F.G.S., F.Z.S., F.R.M.S., ASSOC. INST. C.E.

BORN 1844. DIED JULY 5, 1919.

(PLATE X.)

BY the death of Mr. John Hopkinson English geologists have lost an excellent fellow-worker, and many of them (like the writer) a valued friend.

Born at Leeds in 1844 John Hopkinson came south while still young, residing, with his family, for the greater part of his life in Hertfordshire, first at St. Albans, and afterwards at "Weetwood", near Watford, the home of his grandfather.

Although engaged in business in London[1] John Hopkinson possessed a keen interest in every branch of natural science, and gave all his leisure to their study and advancement, devoting himself more particularly to the pursuit of geology, palæontology, microzoology, and meteorology.

His love of open-air studies led him to associate with the members of various field-naturalists clubs, and his training and education in early life well fitted him for the management of their affairs, and he speedily became interested in the promotion and welfare of these societies which have done so much in the past fifty years to nourish the pursuit of science in this country.

In conjunction with the late Dr. A. Brett he founded the Hertfordshire Natural History Society in 1875, and served it in various capacities up to the time of his death, being President in 1891–3. It was while residing in St. Albans that John Hopkinson took a prominent part in founding the Herts County Museum, where, at his own expense, he provided the instruments and equipment for the Meteorological Station. It was mainly on his initiation that "the Conference of Delegates" at the British Association was founded in 1880, and he served as its Chairman in that year and as its President in 1917.[2] He did much valuable work for the Ray Society, being its Treasurer from 1899 to 1902, and its Secretary since that time. He published in 1913 a *Bibliography of the Tunicata*, and was part author with J. Cash and G. H. Wailes of a monograph on *British*

[1] As a partner in the well-known firm of J. & J. Hopkinson, piano manufacturers, retiring only a few years ago on the business being converted into a limited liability company.

[2] An abstract of his address (presented on July 6, 1917) was given in the GEOLOGICAL MAGAZINE for that year, pp. 371–4.

Freshwater Rhizopoda, of which three volumes have been already issued.

John Hopkinson was one of the pioneers in the study of Graptolites and their zonal distribution; the GEOLOGICAL MAGAZINE (between 1870 and 1881) contains a valuable series of papers by him on this subject. He was joint author with Professor C. Lapworth of an important paper "On the Graptolites of the Arenig and Llandeilo Rocks of St. Davids", published in the Quarterly Journal of the Geological Society (vol. xxxi, pp. 631–72, pls. xxxiii–xxxvii, 1875). He was elected a Fellow of the Geological Society in 1869, and served on the Council from 1884 to 1886. As a member of the Geologists Association he read papers and conducted excursions. He was a Vice-President of the Royal Microscopical Society, and a Fellow of the Linnean Society (1875) and served on its council (1908 to 1911). He wrote the article on the Geology of Hertfordshire for the Victoria County History (1888), and Hertfordshire Geology for the Jubilee Volume of the Geologists Association. In collaboration with I. Saunders he also wrote the article on the Geology of Bedfordshire.

The Reports of the British Association contain numerous abstracts of Mr. Hopkinson's geological papers, but the full range of his versatile talents is best seen in the series of Transactions of the Herts Natural History Society, in which he published most useful annual reports from 1876 onwards, on the meteorology of the county with phenological observations, and papers on its land and freshwater mollusca, its birds and insects, on its scientific bibliography, and many other subjects. He was Chairman of the Watford Field-path Association, which has issued (by Stanford) a useful pocket map of the Watford district for naturalists and ramblers in this pleasant country area.

In 1877 Mr. Hopkinson married Miss Kate Willshin, daughter of Mr. Thomas Willshin, of Kingsbury, St. Albans. He leaves a widow and two married daughters to lament his loss. His memory will be long held in esteem by a wide circle of friends and acquaintances, who found in him an excellent authority upon all scientific matters in the county, and one ever ready to impart to others the knowledge he had acquired by careful study and trained observation.

PIERRE JOSEPH JULES BERGERON.

BORN —— DIED MAY 27, 1919.

WE regret to record the death of Professor P. J. Jules Bergeron, which occurred at his residence, 157 Boulevard Haussmann, Paris, on May 27 last. He was lately Professor of Geology at the Central School of Arts and Manufactures, President of the Society of Civil Engineers of France, and of the Geological Society of France, and a Chevalier of the Legion of Honour. He contributed numerous papers to the Geological Society of France, and is chiefly known from his work on *La Montagne Noire, Cabrières, and Languedoc.*

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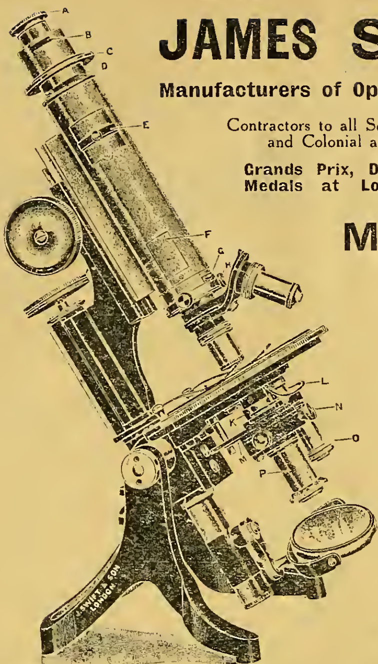

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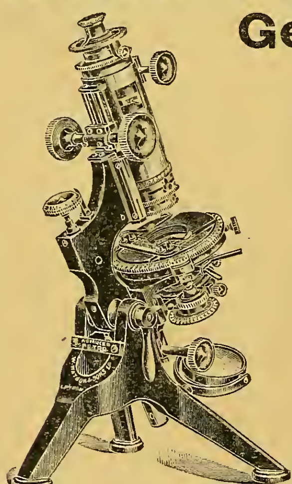

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THE
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No. X.—OCTOBER, 1919.

EDITORIAL NOTES.

IT is with very great regret that the Editors find themselves compelled to announce to their friends and subscribers that a crisis has arisen in the affairs of the GEOLOGICAL MAGAZINE, gravely imperilling its future existence. For some years past the Magazine has been conducted on an extremely narrow margin between profit and actual loss, and now, owing to a further sudden rise in the cost of production, the former trivial, almost negligible, profit will be converted into a considerable loss on next year's working unless some further economic steps are taken. The whole situation has been most carefully considered between Editors, publishers, and printers, and certain minor adjustments are suggested in connexion with business arrangements. As to these it is not necessary to enter into detail here. But these measures of economy alone would be quite inadequate to make up the deficit: some considerable increase of revenue is indispensable, and the only possible source for this is an increase in the price of the Magazine. The sole alternative is to cease publication at the end of the present volume. The Editors feel, however, it is hoped without undue egotism, that this course would be a serious blow to the science of geology, and after long and anxious consideration they have decided to raise the price of the Magazine as from January next to 2*s*. 6*d*. per copy or 30*s*. per annum. In taking this step they are compelled to rely on the loyalty of friends and subscribers, and feel confident that this trust will not be misplaced. The Editors venture to appeal most earnestly to present subscribers to continue their subscriptions, and to use every effort in their power to obtain fresh support, so that the GEOLOGICAL MAGAZINE may be enabled to continue unbroken its career, which it is hoped and believed has been one of usefulness and honourable effort in the cause of progress in geology. The Editors on their part will spare no effort to maintain the traditions of the past, and by strict attention to business to carry on the Magazine through the period of storm and stress, which is perhaps only of a temporary nature. Such is the present situation: the future rests with our readers.

*   *   *   *   *

WE understand that the department that was set up by the Ministry of Munitions early in 1917 for the development of the mineral resources of this country, in the first instance under the control of Sir Lionel Phillips, has been taken over by the Board of Trade, and will be continued as a branch of its Industries and Manufactures Department under the care of Dr. F. H. Hatch.

"After three years of anxiety and stress," says Sir Charles Parsons, the President, at the Bournemouth Meeting of the British Association, the meetings for the intervening years having been cancelled, the Association accepted the renewed invitation of friends and colleagues to Bournemouth for September 9–12, 1919. The President (after referring to the critical time of the meeting, when after the great upheaval the elemental conditions of organization of the world are still in flux) pointed out in what way the British Association could best assist in the great work of reconstruction and progress now lying before us. (1) By requisitioning and printing reports on the present state of different branches of science; (2) by granting sums of money to small committees or individuals to enable them to carry on new researches; (3) by recommending the Government to undertake expeditions of discovery, or to make grants of money for certain national purposes, which were beyond the means of the Association. [As a matter of fact it has, since its commencement, paid out of its own funds upwards of £80,000 in grants of this kind.]

* * * * *

He proceeded to discourse on some of the developments in engineering during the period prior to the War, in engines and turbines, in Naval architecture, on tungsten steel, on gaseous explosions, on the science of war, the advance in artillery and aircraft, on sound-ranging and listening devices, and on electricity. The President referred to the problems of the future, especially on the relative cost of producing a given amount of electrical power from coal and from water-power. It is estimated that the average capital required to produce electrical power from coal is less than half the amount that is required in the case of water-power; but the running costs in connexion with water-power are much less than those in respect of coal. The cost of harnessing all the water-power of the world would be about 8,000 millions, or equal to the cost of the War to England.

* * * * *

Sir Charles devoted the penultimate section of his address to borehole projects (which he had studied in 1904). He proposed to sink a shaft 12 miles in depth—about ten times the depth of any shaft in existence. The estimated cost was £5,000,000, and the time required about eighty-five years, a period not often reached in one lifetime! One question raised was: would the rocks at this great depth crush in and destroy the shaft? Professor Frank Adams, of McGill College, Montreal, published some results of his experiments on crush-strains on rocks in the *Journal of Geology*, 1912, from which he estimated that in limestone a depth of 15 miles would probably be practicable, and in granite a depth of 30 miles might be reached. Little is at present known of the earth's interior except by inference from a study of its surface, upturned strata, shallow shafts, the velocity of transmission of seismic disturbances, its rigidity and specific gravity. Some attempt, he suggests, should be made to sink a shaft as deep as may be found practicable at some locality selected by geologists as the most likely to afford useful information. In Italy, at Lardarello, boreholes have been sunk, which discharge large volumes of high-pressure steam, which is being utilized to generate about 10,000 horse-power by turbines. At Solfatara, near Naples, a similar project is on foot to supply power to the great works in the district. It seems, indeed, probable that in volcanic regions a very large amount of power may be, in the future, obtained directly or indirectly by boring into the earth, and that the whole subject merits the most careful consideration.

* * * * *

From motives of strict economy in printing and paper on the part of the Treasury, the Annual Reports of the Keepers of the various Departments in the British Museum which accompany the Return of Receipts and Expenditure presented to the House of Commons have been reserved to a future and more prosperous time. The statement relating to the British Museum, Bloomsbury, shows the precautions taken to protect the collections from air-raids, etc., in 1916–18, and the parts, still closed to the public, lent to the Registry of Friendly Societies. Precautions were also taken to protect the most choice specimens in Bloomsbury and in the Galleries of the Natural History Departments at Cromwell Road, but with the exception of the Northern Galleries of Geology all the exhibits in the latter building were open, and the public have been admitted on week-days from 10 till 4 o'clock. An exhibition of the boring Mollusca and Crustacea destroying wood and stone, and those attached to piers and ships below the water-line, has been arranged by Dr. W. T. Calman for Government and public information. Reports have also been prepared on Fishes valuable as food, and on the utilization of whale-flesh. The preservation of elephant seals and the reintroduction of fur-seals, also the acclimatization of the reindeer in South Georgia, are instances in which scientific advice has been afforded to Government by the Museum staff.

* * * * *

Mrs. Hinde has presented to the Geological Department the valuable collection of fossils, chiefly from the Silurian and Ordovician rocks of Canada, the United States, and Sweden, made by the late Dr. George J. Hinde, F.R.S., together with his unique series of microscopic preparations of rocks and fossils.

* * * * *

The Royal Microscopical Society have given 1,000 slides of samples of "oozes", spread over the ocean-floor at great depths, collected by the late Dr. G. C. Wallich, and an additional series from Mr. E. Heron-Allen, F.R.S., with maps and charts.

* * * * *

A large collection of fossil shells and vertebrate remains from the Ameki cuttings on the Port Harcourt Railway, Southern Nigeria, have been presented by Mr. A. E. Kitson, Director of the Geological Survey of the Gold Coast.

ORIGINAL ARTICLES.

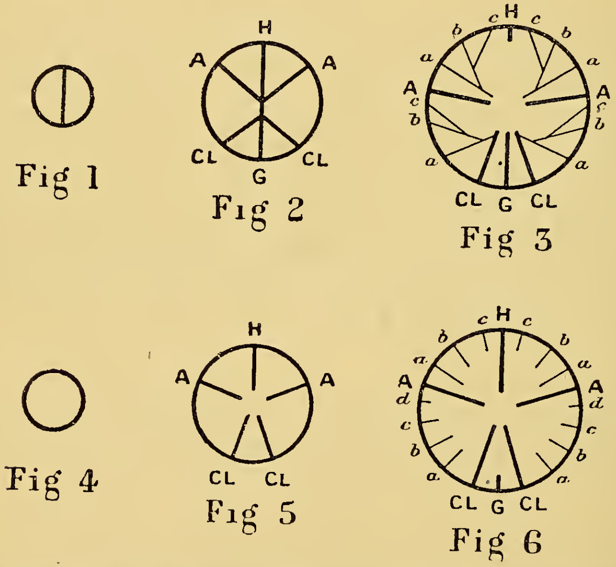
I.—A Remarkable Carboniferous Coral.

By R. G. Carruthers, F.G.S., Geological Survey of Scotland.

(PLATE XI.)

AMONGST the Carboniferous corals, not the least interesting are those species which, for one reason or another, may be difficult to classify, or at any rate diverge somewhat from the common order. It is with one of these aberrant members that the present communication is concerned; and it is, perhaps, not altogether unfitting that most of the material happens to be of Irish origin.

The peculiarities under review are essentially of a developmental nature: as a preliminary, therefore, it is as well, even at the risk of needless repetition, to outline the normal order of septal development characteristic of the Rugosa in general.



Development of the major septa in a normal Rugose Coral (Figs. 1–3) and *Cryptophyllum* (Figs. 4–6). H, main or cardinal septum; A, alar septum; CL, counter-lateral septum; G, counter septum; *a*, *b*, *c*, etc., metasepta.

The initial growth-stages of a Rugose coral are frequently obscured, for it is obvious that if the basis of attachment be relatively large there will be a corresponding increase in the number of septa first seen. In the most favourable circumstances, the first stage shows a single septum (the "axial septum") stretching across the diameter of the corallum from wall to wall (Diagram, Fig. 1); later on this separates into the main and counter primaries, opposite one another. At each end of the axial septum a pair of new septa then appear, which eventually become the alar and the counter-lateral primaries (A and CL in Diagram, Fig. 2). One of these pairs may precede the other, or they may appear simultaneously, but in any case they move outwards until approximate symmetry is attained; the primary stages, resulting in the formation of six septa, are then complete (Diagram, Fig. 2). All subsequent major septa ("metasepta" is the convenient term for them proposed by Duerden) are inserted according to an invariable rule: in the two "main" sectors H–A (Diagram, Fig. 3) the newest are those next to the main septum H, in the alar sectors A–CL they are next to the alar primaries A, in the counter-lateral sectors CL–G none ever appear. From this results the well-known pinnate disposition of the septa seen after removing the epitheca from the conical portion of a Rugose coral (the part, that is, wherein there is a continuous addition of new septa).

In addition to the major septa, many species have a cycle of *minor septa*. These are relatively short and are most often a feature of adult growth-stages. They appear simultaneously, one between each major septum, those in the two counter-lateral sectors CL–G often being longer than the others: sometimes there are two minor septa only, in which case they are restricted to the two counter-lateral sectors, one on each side of the counter-primary G. Where seen, this factor is of much value in the orientation of transverse sections.

The foregoing scheme of septal development is applicable to all manner of Rugose corals, but in the genus *Cryptophyllum*, now under review, it is very curiously modified.

Development of *Cryptophyllum*.

Cryptophyllum hibernicum is a small solitary coral, tortuous in habit, with a smooth concentrically ribbed epitheca (Pl. XI, Fig. 5). It is easy to distinguish from other Carboniferous corals, immature specimens displaying five septa only, while even in adults these five septa remain predominant (Pl. XI, Figs. 1*j*, 2*c*, 3*h*). The special developmental features of the genus are easily followed in a set of serial transverse sections.

Very commonly there are no traces of septa whatever in the earliest growth stages, the corallum being purely tabular (Pl. XI, Fig. 1*a*). Later on septa appear, initially as minute protuberances from the wall, each with a dark centre (Pl. XI, Fig. 1*b*): generally they increase in length until five septa are formed, meeting in the centre of the corallum (Pl. XI, Figs. 1*f* and 3*f*). These five septa are not inserted in any regular order, and they are frequently affected by growth-constrictions (or "rejuvenescence") of the corallum, leading to a retraction or even obliteration of one or more of their number (cf. Figs. 3*c* and 3*d*, Pl. XI): not infrequently, the rejuvenescence is so extreme that a resumption of the tabular, non-septal condition is brought about. Eventually, however, the five-septal stage is established on a more or less stable footing, and may persist for some time. It has been arrived at, as we have seen, in an altogether hesitating, wayward manner, and is so unlike anything seen in the early stages of normal Rugose corals that were no further evidence available, one might justifiably suspect that an entirely new order was under observation. From now onwards, however, the addition of new septa follows a definite plan. Let the five-septal stage be provisionally regarded as primary: on inspection it will be noticed that two of the septa are set out from the epitheca more closely than the rest (i.e. those lettered CL in Figs. 1*f* and 3*f*, Pl. XI), an arrangement emphasized in later stages. Using the terminology applied to normal Rugosa, these two septa, throughout the metaseptal stages, behave as if they were the counter-lateral primaries, the septum directly opposite as if it were the main (or cardinal) septum, the remaining two as if they were the two alar primaries (cf. Diagram and Pl. XI); that is to say, once the five-septal stage is completed, of all septa appearing in the sectors A–H the last-formed is the one nearest to what, for the sake of argument, has been termed the main septum H; in the two sectors A–CL the youngest septum is the one closest to A.[1] It is obvious that such an arrangement is strictly in accordance with that governing the insertion of metasepta for the Rugosa in general. This is satisfactory enough, but there still remains one respect in which *Cryptophyllum* shows a remarkable divergence from the normal. It will be seen, on referring to the serial transverse sections 1*a*–1*j*, Pl. XI, that in not one of these, not even in those of the final growth stages, can any trace of a counter primary septum be detected: yet in other Rugose corals, this would have been present throughout, from the earliest stages onwards. The omission is at first puzzling, but a clue is obtained in the next set of serial sections (Pl. XI, Figs. 3*a*–3*h*), cut from what is apparently a more advanced type: here, in the final section, 3*h*, a single septum (lettered G), relatively small, at last appears between the two counter-laterals CL. The same thing happens in another set of serials (Pl. XI, Figs. 2*a*–2*c*).

The conclusion that the septum which appears so tardily between the two most closely approximated of the five primaries of *Cryptophyllum*, is in reality the missing counter-primary, is confirmed by the study of one more set of serials (Pl. XI, 4*a*–*d*). In these it will be noticed that in the final growth-stage (Fig. 4*d*) two new septa, quite small, have come in, one on each side of the "counter septum". In an early paragraph of this paper, it will be remembered that when commenting on the scheme of septal development characteristic of Rugose corals it was stated that the minor septa "are relatively short, and are most often a feature of adult growth-stages", and that "sometimes there are two minor septa only, in which case they are restricted to the two counter-lateral sectors, one on each side of the counter-primary G". If, therefore, the two small septa, one on each side of G in Fig. 4*d*, Pl. XI, be regarded as minor septa (which their appearance at such a late growth-stage would indicate), all difficulties vanish: their development agrees with that characteristic of minor septa in other Rugose corals, and supports the conclusion arrived at on other grounds, that the septum G is in reality the counter-primary.

[1] Naturally this cannot be fully demonstrated in the sections figured, but it has been confirmed by the examination of specimens from which the epitheca was removed by acid.

Specimens of *Cryptophyllum* showing anything in the nature of minor septa are not very common; in the few cases I have observed two septa only were found, developed exactly as in the foregoing example.

Summing up, one may say that *Cryptophyllum* may be classed with the Rugose corals, with the reservation that the development of the primary septa is quite abnormal, for the counter-primary is either altogether absent or else does not appear till a relatively late period. Resulting from this, a stage with five septa only, all primary, is a marked feature of the genus: these five septa are inserted in an irregular manner, but once established usually remain prominent throughout the remaining growth-stages. The development of both metasepta and minor septa proceeds exactly as in other Rugose corals.

Formal diagnoses, with remarks on distribution, affinities, etc., are appended below.

Genus Cryptophyllum, gen. nov.

Diagnosis.—Corallum simple. Five septa, all primary, but variable in sequence, appear before the others, and remain predominant until the growth of the corallum is completed: their disposition is not quite symmetrical, two (the counter-lateral primaries) being closer than the others. The remaining primary (the counter septum) appears subsequently, or may be entirely absent. The development scheme of both metasepta and minor septa (if any) agrees with that of other Rugose corals. There are tabulæ, but no dissepiments.

Affinities.—Several genera bear a superficial resemblance to *Cryptophyllum*. In 1872 de Koninck[1] proposed *Pentaphyllum* for a genus with five septa much more developed than the rest. Two species were described and figured, *P. armatum* and *P. caryophyllatum*, both from the Carboniferous Limestone of Tournai; but in the course of a visit to the Musée d'Histoire Naturelle at Brussels many years ago I was unable to find the originals. The species first dealt with by de Koninck (and presumably, therefore, his genotype) is *P. armatum:* the epitheca is covered with spinose outgrowths, well portrayed in one of the figures (*loc. cit.*, pl. iv, fig. 8), but with regard to the septa the illustrations are at variance with the text: in his Plate, Fig. 8*a* shows six, not five, leading septa, three at right angles to one another, the remainder closely approximated: the species appears to be a spinose Zaphrentid or Campophyllid. In the case of *P. caryophyllatum*, the figure of the calyx (*loc. cit.*, pl. iv, fig. 9*a*) again differs from the text, four leading septa only being shown. The discussion need not be carried further, for Dr. G. J. Hinde, while noting the conflict between the text and figures of de Koninck, has pointed out that the name *Pentaphyllum* was preoccupied in 1821 for a genus of Coleoptera.[2] At the same time, he

[1] de Koninck, *Nouv. Rechs. anim. foss. terr. carb. Belgique*, p. 58, Brussels, 1872.

[2] G. J. Hinde, "Notes on the Palæontology of Western Australia": Geol. Mag., 1890, p. 195.

proposed *Plerophyllum* for a somewhat similar group of Australian corals, and in his diagnosis (*loc. cit.*, p. 195) states that "there are usually five prominently developed septa (in some species only four). . . . In the species with five prominent septa, the cardinal septum is small and is bounded on either side by a large septum, and the remaining three large septa represent the alar and counter septa". A pronounced stereoplasmic thickening of structures within the body of the coral is noted as one of the generic characters. This latter feature is known to be a most variable quantity in other genera, but the septal arrangement alone is a sufficient distinction from *Cryptophyllum*, in which the main (or cardinal) septum is long, with no prominent septa on either side, and the counter primary is often absent altogether: the orientation, in fact, is reversed. Judging from Dr. Hinde's figures (*loc. cit.*, pl. viii*a*, figs. 1*a–f*), I am inclined to agree with Mr. Etheridge[1] that *Plerophyllum* should rather be classed as a sub-genus of *Zaphrentis*: it has much in common with such forms as *Zaphrentis* (*Lophophyllum* auctt.) *eruca* (M'Coy).

The Lower Palæozoic genera *Anisophyllum* and *Baryphyllum* of Milne-Edwards and Haime have only three prominent septa.

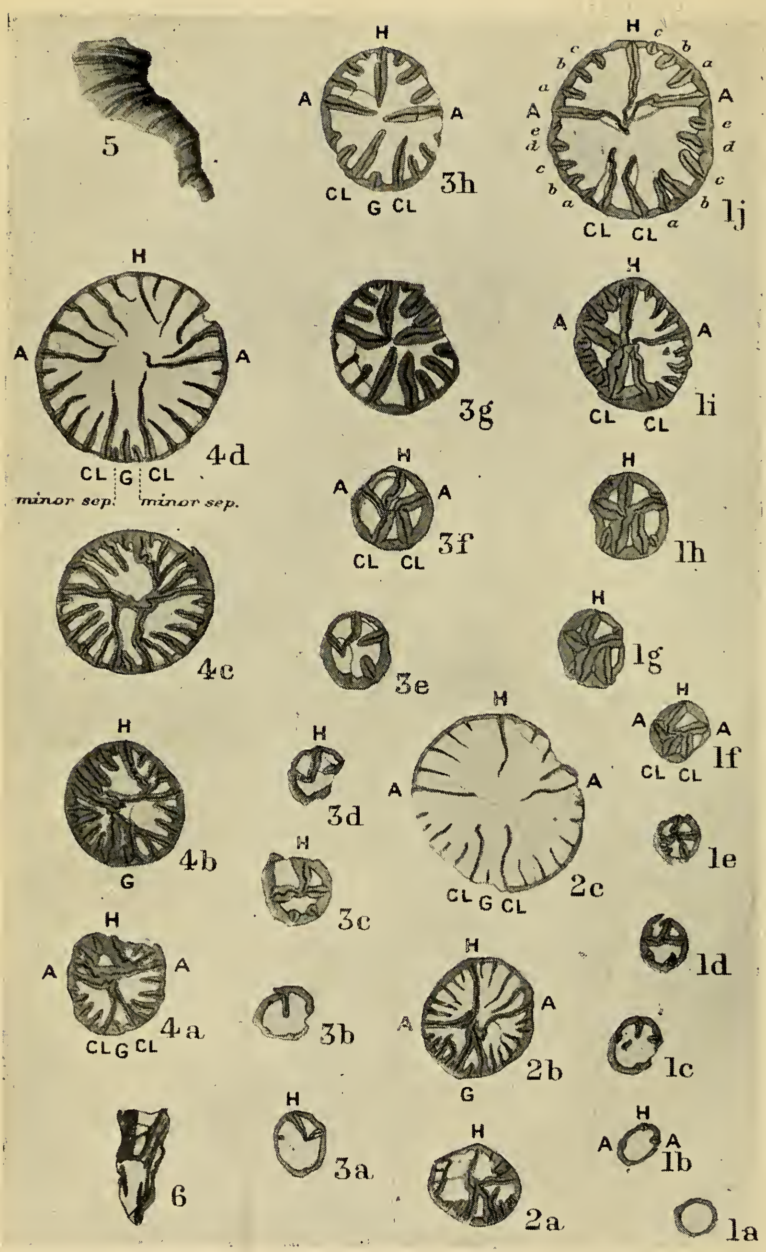
Sections of *Caninia cornucopiæ* sometimes have a superficial resemblance to Fig. 4*c*, Pl. XI of this paper, but there is no risk of confusion if attention be paid to the orientation and nomenclature of the septa, which is entirely different in *Cryptophyllum*, quite apart from the profound distinctions of the primary stages.

Cryptophyllum hibernicum, *sp. nov.*

Diagnosis.—Corallum simple and averaging an inch or less in length: a tortuous habit is common. Strong, smooth epitheca, with frequent growth-lines and constrictions (Pl. XI, Fig. 5). Major septa stout, tapering at their inner ends, frequently wavy and irregular in cross-section. The first five septa are all primary: their development shows much individual variation, but they remain longer and more conspicuous than other septa throughout the life-history of the corallum: it is only in the gerontic period, when, as with so many other Carboniferous corals, an amplexoid type of septation is approached, that there is any difficulty in singling out the five primaries from the rest. The sixth primary, the *counter septum*, does not appear until several metasepta have developed, and may be absent altogether. The metasepta themselves are relatively short. As a rule there are no minor septa: if present, they are two only, one on each side of the counter primary: they are rudimentary, and confined to the final growth-stages. A stereoplasmic thickening of the septa below the calyx is common, but it is not so pronounced as to fill in the body of the coral. The tabulæ are few and irregular (Pl. XI, Fig. 6).

Remarks.—Referring to Plate XI, illustrating this paper, the fact that the serials 2*a*–2*c* and 4*a*–4*d* show an earlier appearance of the

[1] R. Etheridge, *A Monograph of the Carboniferous and Permo-Carboniferous Invertebrata of New South Wales*, pt. 1, Cœlenterata, p. 8. Mem. Geol. Surv. New South Wales, Sydney, 1891.



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CRYPTOPHYLLUM HIBERNICUM, GEN. ET SP. NOV.

counter-primary than in the set $1a$–$1i$ or $3a$–$3h$ suggests a more advanced type, for which separation may eventually be desirable; while noting this possibility, it is thought better, for the present, to refer all the figured examples to one species only.

Distribution.—*Cryptophyllum hibernicum* is locally abundant along a bed of limy shale, 3 or 4 inches thick, towards the base of the Lower Calp Shales at Bundoran, Donegal Bay, Ireland: the best exposures are in the sea cliff immediately north of the Bradoge River. Associated fossils are *Caninia cornucopiæ* and *Cyathaxonia cornu*, and in terms of Dr. Vaugham's zones the horizon approximates to C_2–S_1, locally developed as a γ phase.

In the Geological Survey Collections, London, amongst an extensive suite of Upper Tournaisian corals procured by Mr. Pringle, on the Pembrokeshire coast of Stackpole Quay, and near Blucks Pool, four specimens of *Cryptophyllum hibernicum* were noticed. The horizons given by Mr. Pringle range from Z_2 through γ to C_1: in all cases *Caninia cornucopiæ*, *Cyathaxonia cornu*, and the gens of *Zaph. omaliusi* were found in association.[1]

In Scotland, small, immature examples of *Cryptophyllum* are not uncommon in the shale above the Middle Skateraw Limestone at East Barns Quarry, Dunbar. One or two have also been obtained from the shale above the Acre Limestone at Ancroft, Northumberlandshire, which is probably on the same horizon. At both localities *Caninia cornucopiæ* (practically identical with Tournaisian specimens) *Cyathaxonia cornu*, and Zaphrentids of the *omaliusi* gens are associated in abundance. Zonally the level is about D_2. None of the specimens are fully developed: they rarely get beyond the five-septal stage, but so far as can be seen agree perfectly with *C. hibernicum*.

It will be noted that the vertical range of the species is wide, and it is probably safe to say that *C. hibernicum* may be expected whenever a γ phase is met with in British Carboniferous Limestone rocks.

In concluding this paper, I wish to express my indebtedness to my colleague Dr. G. W. Lee, of the Geological Survey of Scotland, and to Mr. W. B. Wright, of the Geological Survey of Ireland: their assistance in the collection of specimens, during a joint examination of the Bundoran sections, proved invaluable. Dr. W. D. Lang, of the British Museum (Natural History), has very kindly helped me in the matter of nomenclature.

EXPLANATION OF PLATE XI.

Reductions of camera-lucida drawings of *Cryptophyllum hibernicum*, gen. et sp. nov., from the Lower Calp Shales (Carboniferous Limestone) of Bundoran, Donegal Bay, Ireland: intersections of tabulæ are omitted in one or two cases where they interfere with a clear presentation of the septa.

Figs. $1a$–j, $2a$–c, $3a$–h, $4a$–d: serial transverse sections from four specimens. $\times 2\frac{1}{2}$. Index to lettering: H, main or cardinal septum; G, counter septum; A, alar septum; CL, counter-lateral septum.

Fig. 5. External aspect of an average specimen. Nat. size.

Fig. 6. Vertical section, showing tabulæ. Nat. size.

[1] The registered numbers are Pg. 1715, Pl. 928, Pl. 2339, and Pl. 2432, and particulars of the exact localty are given in the Survey records.

II.—Morphological Studies on the Echinoidea Holectypoida and their Allies.

By Herbert L. Hawkins, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

IX.—*Pyrina*, *Conulus*, and *Echinonëus*.

The three genera (or generic terms) that serve for the title of this paper comprise a series of Cretaceous and Tertiary Echinoids which are morphologically similar, and, in consequence, systematically chaotic. Although the time is not yet ripe for an attempt to disentangle the nomenclature of the various genera and species from the knot in which it is involved (a condition not to be wondered at in view of the early description and variable qualities of the forms), it seems desirable to publish the following comments on the group, making use of current names for the examples quoted. *Pyrina*, Desmoulins, as Lambert[1] has shown, is typified by *P. petrocoriensis*, Desm., a species that might well pass for a young member of the *Conulus* series. *Conulus*, Leske, has for genotype *C. albogalerus*, Leske, and the forms to which that name is usually applied in this country seem sufficiently like the original figure to pass muster. The genotype of *Echinonëus* is of course *E. cyclostomus*, Leske, and there has never been serious confusion as to the application of the generic name.

Under the name *Galerites*, Lamarck, *Conulus* became extended to cover practically all the Holectypoida, and to include considerable numbers of Clypeastrids and Echinolampids; but the original type has always been correctly placed, either under one of the two foregoing names or that of *Echinoconus*. *Pyrina* was more than usually unfortunate in the series of species included in it by its author. Of the seven species cited by Desmoulins, *P. petrocoriensis* is the only one that is either recognizable or conformable to the diagnosis, although another (*Nucleolites ovulum*, Lamarck) is almost, if not quite, admissible. The long rejected *Globator*, Agassiz, 1840, has been revived (with subgeneric rank) by Lambert (l.c.), and the latter author has proposed the name *Pseudopyrina* for the large number of more or less ovoid Echinoids that have usually been placed in *Pyrina*. Before proceeding to analyse the morphological qualities of the genera, a brief comment on this proposed taxonomy is necessary.

Lambert (l.c., p. 141) shows that Desmoulins, in founding the genus *Pyrina*, twice emphasized the "symmetrical" character of the peristome, and even proposed to exclude *Nucleolites ovulum*, Lam., because of the slight obliquity of the peristome in that species. Further, *Pyrina* had a perignathic girdle ("système buccal interne") analogous to that of *Galerites* (*Conulus*). It may be remarked that in Desmoulins' time, and for long afterwards, the belief was always maintained that the possession of masticatory apparatus (including the perignathic girdle) was restricted to Echinoids with "symmetrical" (i.e. circular, pentagonal, or decagonal) peristomes. Unfortunately for this belief, however, *Conulus* itself, which has a perignathic girdle

[1] "Étude sur les Echinides crétacés de Rennes-les-Bains et des Corbières": Bull. Soc. Études Sci. Aude, vol. xxii, pp. 66–183, pls. i–iii, 1911.

in large, though peculiar, development, has an undoubtedly oblique peristome. In *C. rhotomagensis*, *C. castanea*, and *C. subrotundus* this character is quite marked; it is less clear in *C. albogalerus*, but among hundreds of specimens (of very varying shapes and sizes) that have passed through my hands, every one has shown appreciable ellipticity of the peristome. *Echinonëus*, in spite of the unfortunate name of its genotype, has a strongly oblique peristome when adult. As far as my experience goes, I am convinced that the "obliquity" or "symmetry" of the peristome are merely relative in all the forms usually comprised under the three names in the title. Lambert says of *P. petrocoriensis* that its peristome "est en effet semblable à celui des *Conulus*"—that is to say, it must be slightly oblique. If this is so, why should not *Nucleolites ovulum*, Lam., whose peristome is slightly more oblique, be admitted into the genus? A yet more marked obliquity characterizes the peristome of *P. desmoulinsi*, d'Arch., but the difference is merely one of degree. The species last named has a "système buccal interne" sufficiently "analogue à celui de" *Conulus*. I have not succeeded in dissecting out the girdle of *P. desmoulinsi*, but by sectioning a test and its infilling matrix I have determined that a raised and thickened rim surrounds the peristome within. It has yet to be suggested that *Conulus subrotundus* and *C. albogalerus* are not congeneric, but I have studied undoubted examples of the former species in which the peristome was no less oblique than it is in *P. desmoulinsi*, or, for that matter, in *Trematopygus*. But if these two common species of *Conulus* are to be allowed to share the same generic name, it seems illogical to attempt a separation of the various species commonly called *Pyrina* on the ground of variable obliquity of the peristome. That there may be other features that would warrant the generic distinction of some of the species I am prepared to admit, but *Pseudopyrina* seems to me to be based on false premisses and so unacceptable.

Globator, with type *G. nucleus*, Agassiz, included a series of forms (with relatively pronounced peristomial obliquity) that may be roughly described as "roundish *Pyrinas*". *G. nucleus* is always a little longer than broad, and a little less in height, but it is at least as "regular" in shape as, say, *Holectypus depressus* or many forms of *Conulus subrotundus*. Certainly the difference in ambital outline between *Globator* and such a species as *Pyrina desmoulinsi* is very marked, but all possible gradations link the two species, and the species of *Conulus* vary but very little less in this respect. If the globular character can be shown to have any phyletic, or even stratigraphic, meaning, *Globator* might be recognized as a valid genus, but I am unaware that either quality has been demonstrated.

As a consequence of the arguments given above, I prefer to follow the old-fashioned, and apparently natural, use of the name *Pyrina*, and to include in it as unnecessary or unsubstantiated groups the two so-called genera *Globator* and *Pseudopyrina*. In passing, it seems advisable to draw attention to a statement made by Lambert (l.c., pp. 142–3) concerning *Pyrina houzeaui*, Cotteau. "In spite of the presence in this circular species of a small, imperforate, fifth genital," Lambert does not feel justified in separating it from *Globator* (i.e.

Pyrina). It is perhaps reasonable to complain of the laxity of Agassiz, Desor, and de Loriol in not allowing sufficient weight to the characters of the peristome, but surely the apical system deserves a little notice. If there is one constant feature that differentiates the *Pyrina–Conulus–Echinonëus* series from the other Holectypoida, it is the absence of a posterior genital plate. All three genera have almost identical apical systems, and to admit a species that *normally* differs in so important a character as the presence of an additional plate is to subvert taxonomy. However, there is at least a possibility that the "small, imperforate, fifth genital" of *P. houzeaui* may be an individual variant, even if it has any real existence. Such supplementary plates do occur occasionally in the apex of *Conulus*, presumably as expressions of regressive variation, and cases have not been wanting when a fifth genital has been ascribed to that genus as a normal feature. Lambert (l.c.) corrects the figure of the apical system of *Globator nucleus* given by Desor, stating that the fifth, imperforate genital *does not exist*. However (p. 149), he refers to a "rudiment of the fifth genital" as occurring between the posterior oculars in *Pyrina atacina* (*atacica*, Cotteau), but it is not clear whether his description is based on one specimen or is a generalization. If this is a normal feature in the species, it constitutes not merely a morphogenetic point of the utmost interest, but, to my mind, a reasonably sound basis for generic separation. However, at present I incline to regard the occurrence of posterior genitals in these forms as individual variants, interesting and instructive, but abnormal.

The foregoing paragraphs are intended to explain the meaning here attached to the three generic terms used as the title of the paper. That further subdivision of *Pyrina* and *Conulus* will prove necessary in the future I not only expect, but believe; but for the present they serve as well-marked, though closely similar, genera. It is important to lay stress upon the striking resemblances that all three types show to one another, since it is usual and orthodox to admit *Conulus* into the Holectypoida, and to relegate *Pyrina* and *Echinonëus* to the Spatangoida. One purpose of the present paper is to contend that the three genera are too closely related to be separated by even family distinction, and that the ruling of an ordinal line through the group is unnatural.

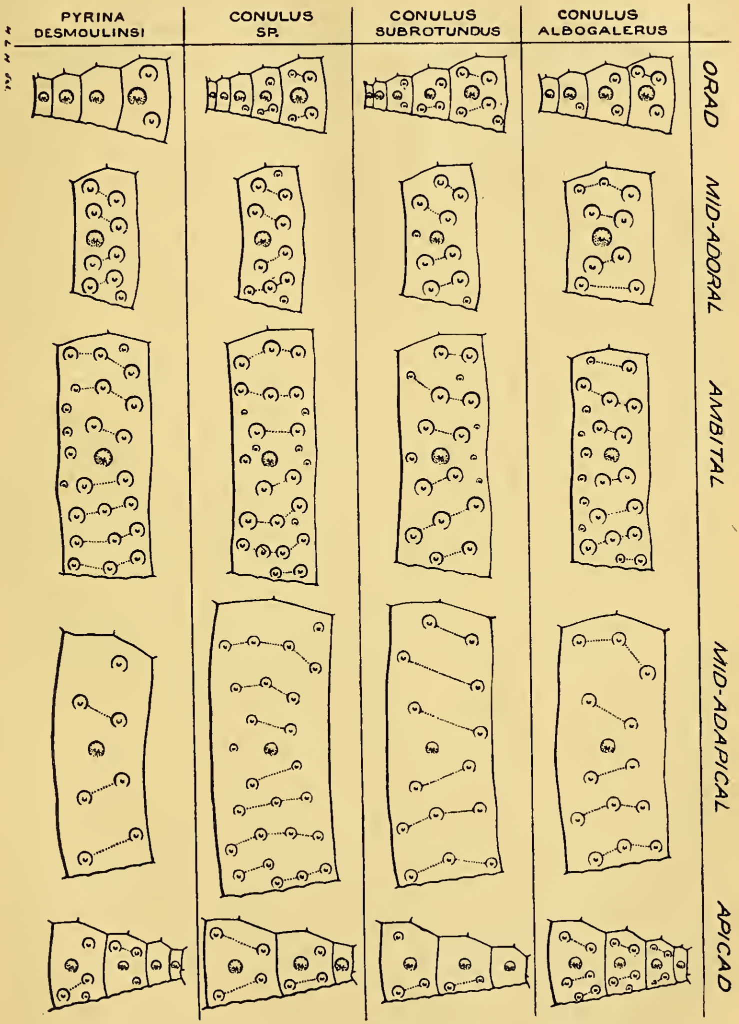
The following are the chief morphological resemblances:—

Shape.—Antero-posterior diameter always greater than transverse. The degree of elongation of the test varies much within the genera, but the two diameters never become quite equal, save perhaps in very young examples. Height extremely variable, usually less than the transverse diameter except in late species of *Conulus*.

Peristome.—Always to some degree oblique, elongated approximately on the axis II, 4. The obliquity is most marked in *Echinonëus*, where, however, the peristome of the young is almost perfectly symmetrical (decagonal).

Perignathic girdle.—Discontinuous, strongly inclined, and well buttressed in *Conulus*, apparently similar in *Pyrina*, but wholly wanting in adult *Echinonëus*, where the vestigial girdle of the young is very imperfectly developed.

Periproct.—Ovoid or elliptical, comparable with the peristome in area. Supra-marginal, or on a posterior surface, in *Pyrina*, marginal in *Conulus*, infra-marginal in *Echinonëus*. (In young forms of *Conulus* it may be as high as, or higher than, in adult *Pyrina*.)



Analysis of interambulacral tuberculation in *Pyrina* and *Conulus*.

Apical system.—Squarish in outline, built normally of four genitals (the madreporic one being the largest) and five oculars, of which the three anterior plates are minute, while the two posterior ones are transversely elongate, and by their meeting form the entire posterior margin of the system. The proportions and disposition of the nine plates are practically identical in all three genera.

Ambulacra.—Narrow and lanceolate, with narrow pore-fields and relatively wide, thickly ornamented, perradial tracts. Pores similar throughout, constantly minute; completely uniserial except near the peristome in *Conulus*. Plates grouped in threes, comparable with the "Echinoid" type of triads (Duncan), practically throughout the areas. There is never more than one demi-plate in a group, however reduced in height the smaller primary may become. Ornament similar in character to that of the interambulacra, very regularly distributed as far as concerns the main tubercles.

Interambulacra.—Relatively broad, built of fairly low, usually bent, plates thickly covered with ornament. Primary tubercles well-scrobiculate (especially near the ambitus and adorally), arranged in a definite sequence. The central series in each column is not sensibly different from the rest except in position. Adradially and interradially the other series are developed in more or less distinct chevron pattern. The tubercles are perforate in *Pyrina* and *Conulus*, imperforate in *Echinonëus*. Smaller ornament profuse and very diverse in character, always including "glassy tubercles".

Excluding variation in the shape of the test (which is probably due to the influence of surroundings and consequent mode of life), the differences that exist between the three genera can be regarded as of two kinds. The position of the periproct changes in a direct sequence chronologically, since *Pyrina* is the first of the three to appear and *Echinonëus* the last. The nature of the change is very suggestive of evolution along a line parallel to that which led from *Plesiechinus*, through *Holectypus* to *Discoidea*, and to that proved in the ontogeny of several Spatangoids. Curiously enough, the other features of difference do not seem to follow the same sequence. The perignathic girdle of *Conulus* is more massive than that of *Pyrina* (though the greater thickness of the test in the former may perhaps in part account for this), while it is completely absent from the adult *Echinonëus*. From *Pyrina* to *Echinonëus* the sequence is maintained, but *Conulus* fails to take its place in the series in this respect. Again, in the matter of the ambulacra, *Conulus* has strongly triserial (almost phyllodal) pore-pairs near the peristome, while in *Pyrina* and *Echinonëus* simplicity is retained throughout. In interambulacral ornament *Pyrina* and *Conulus* agree in the perforation of the tubercles, but all three genera are alike (save for details) in the order in which the tubercles are grouped on the plates. It is interesting to note that, by the often bewildering confusion of its tuberculation, *Conulus* is slightly less "Holectypoid" than the other two genera, whereas its differences from them in other points seem all to trend towards the true Holectypoid characters. Regularity of tubercle sequence is a diagnostic feature in the order, and is not met with in the adults of any other kinds of Irregular Echinoids—that is, if *Pyrina* and *Echinonëus* are admitted into the Holectypoid fold. It can always be recognized in *Conulus*, but in some species, notably *C. castanea* and large examples of *C. subrotundus*, it is very difficult to trace.

It appears, then, that *Conulus* is rightly regarded as an Holectypoid, although its tuberculation brings it dangerously near the border-line: while *Pyrina* and *Echinonëus* differ from the normal character of the order merely in shape (a purely relative and very variable quality, as "*Globator*" shows) and in the absence of any marked triserial arrangement of the orad pore-pairs. The latter feature can be fairly regarded as the successful completion of the tendency towards podial simplification that is persistent in the order. If it is admitted that the resemblances between the three genera are so many that they must surely be closely related in phylogeny, the two insignificant items in the construction of *Pyrina* and *Echinonëus* cannot be permitted to exclude them from the Holectypoida.

That *Echinonëus* is practically a lineal descendant from *Pyrina* seems evident. The *Pyrina* group ranges through the Cretaceous, and species of *Echinonëus* are restricted to the Tertiary. Save for the position of the periproct and the perforation of the tubercles, there is little difference between the two that could warrant their distinction even as genera. Periproct position points to *Conulus* as a transitional stage from one to the other, but no other morphological features support that indication. It is true that *Conulus* occurs chiefly in the Upper Cretaceous, and is definitely of later origin than *Pyrina*, but its peculiar characteristics make it impossible to believe that *Pyrina–Conulus–Echinonëus* represents a genetic series. To suggest that *Conulus–Pyrina–Echinonëus* is the true sequence seems more plausible, since *Conulus* is an accredited Holectypoid, while *Pyrina* and *Echinonëus* are much alike and usually considered to be Spatangoids. But there are insuperable difficulties in the way of acceptance of such a hypothetical line of evolution. In the first place, it violates the known stratigraphical order of appearance of the forms, and although such risks may reasonably be taken when ancient and relatively unfossiliferous systems are concerned, it is unjustifiable to call in the "imperfection of the palæontological record" in the case of thick tested marine forms from the Lower Cretaceous. Secondly, *Conulus* shows specialization of the orad parts of the ambulacra, and complication of interradial ornament, that are definitely in advance of the normal conditions in the Holectypoida, and certainly far more elaborate than the corresponding features in *Pyrina* and *Echinonëus*. It would seem in the last degree improbable that such specialization should be evolved merely to sink back to, and even beyond, the level from which it rose. What, then, can be the relation between *Conulus* and the *Pyrina–Echinonëus* series?

At this stage it is profitable to consider the problem from a different point of view. *Echinonëus*, the only one of the three genera whose habits can be directly observed, lives (according to H. L. Clark) at or about low-tide mark in sheltered lagoons, clinging feebly to the under surfaces of rocks and picking up small pebbles and other fragments as a protective covering. It is eminently a shallow-water form. There is every reason to believe that the habits of *Pyrina* were essentially the same. I know of no record of the occurrence of the genus in this country at an horizon higher than the Chloritic Marl—the last well-defined littoral deposit in the English Cretaceous system. In France, on the other hand, the genus ranges well into the Upper Chalk (Senonien), but occurs only in those districts where the deposits are full of detrital matter. In this respect it resembles most of the Holectypoida (excluding *Discoidea* and *Conulus*), and the deduction is surely sound that it was a genus confined to the littoral tracts of the sea. The extremely close correspondence in structure between *Pyrina* and *Echinonëus* thus seems associated with a similarity in habitat. *Conulus*, on the contrary, was certainly not restricted to shore-lines, or even to shallow water. The distribution of the recognized English species is particularly instructive. *C. rhotomagensis*, which occurs in the Selbornian, is superficially like a typical *Pyrina*, both in ambital outline and relative height. *C. castanea*, from the Lower Chalk and lower parts of the Middle Chalk, is still elongated, but shows almost *Globator* proportions in height. *C. subrotundus* is low and roundish in the zone of *R. cuvieri* (save for very large, almost globular, specimens, probably representing a distinct species, and here called *C.* sp.) but grows surprisingly tall in the zone of *Terebratulina*. *C. albogalerus* is relatively low (though markedly conical) in the lower zones of the Upper Chalk, but becomes exceedingly high, especially when large, towards the top of the zone of *M. coranguinum*. *C. rhotomagensis* is definitely a *Conulus*, but its "Pyriniform" characters suggest, not merely that it may have descended from *Pyrina*, but that it was living under conditions similar to those surrounding that genus. The two horizons at which species of *Conulus* attain their greatest height are those that seem to mark the deepest conditions that obtained during the dominance of the Chalk-sea over Britain; while the comparatively depressed forms from the lower parts of the Upper Chalk can be correlated with the Chalk-Rock uplift. The tendency for Echinoids, and other organisms, to become vertically elongate in deep water has often been remarked, and there seems every reason to consider *Conulus* as a clear illustration of that phenomenon. But for the present purpose it is important to recognize that *Conulus* departed morphologically from a Pyriniform character progressively as it adapted itself to a changing habitat. The reduction in size, and increase in numbers and irregularity of distribution, of its radioles invite comparison with the bristle-like nature of the radioles of most Irregular Echinoids that dwell in sand or ooze; while the elaboration of the tube-feet nearest to the peristome also points to an analogy with the phyllodes of the Echinolampidæ or the "pseudophyllodes" of Spatangoids. A logical deduction from these points is that, if *Conulus* had remained in the littoral zone, it would have kept the essential shape and characters of *Pyrina*, while its periproct, in obedience to the principle that seems always to influence that aperture, would have become first marginal (as, in fact, it did), and then infra-marginal. In brief, it would have developed into a form very much like *Echinonëus*. But by its desertion of the shore, and its preference for the oozy depths of the open sea, it underwent modifications that led it far away from the *Echinonëus* direction, and that produced more than a superficial likeness to the *Echinolampas* series.

In passing, it is of great interest to find that *Conulus*, the deep-water member of the group, is in so many respects the most "Holectypoid". The so-called "Cretaceous" fauna of the deeper parts of the Atlantic Ocean has often been regarded as owing its "antediluvian" character to the similarity of conditions in the ooze-belt of deposition, at whatever period it exists. This explanation, and the companion one that the reduction in the struggle for existence in thinly populated depths encourages the persistence of types whose extinction is overdue, seem reasonable enough, but they can hardly account for the revival of Holectypoid qualities in *Conulus*. Excepting *Discoidea*, *Conulus* is the only genus of the Holectypoida, as far as can be ascertained, that was not absolutely littoral in habitat. Its reassumption of Holectypoid features cannot, then, have been due to a return to "Holectypoid" surroundings; nor is there any reason to regard it as moribund. Perhaps, since the trend of normal Holectypoid evolution was one of improving adaptation to shore-line existence, *Conulus*, in abandoning that sphere of life, allowed the specially adaptive features to lapse and degenerate, while spurring on others for accommodation to the new and unfamiliar surroundings. In some such way it is possible to reconcile the combination in *Conulus* of some features more Holectypoid than those of its presumed ancestor, *Pyrina*, and of others far less Holectypoid than those of its sister *Echinonëus*.

The relationship between the three genera suggested in the preceding sentence appears to me to be the only one possible. It can hardly be said to be proved, but it accords with all known qualities of the forms concerned. The detailed analysis of some tubercle-patterns in certain species of *Conulus* that follows adds further points of support to the hypothesis. The taxonomic corollary which would follow its acceptance is clear. If *Conulus* is an Holectypoid (it would be unfortunate to exclude it from an order that was once called "les Galérites"), and if *Conulus* was derived through *Pyrina*, how much the more must *Pyrina* be an Holectypoid? *Echinonëus* must surely be placed in the same order with *Pyrina*. The only serious difficulty in the way of such a systematic grouping (assuming the phyletic foundation to be sound) comes in the uncertainty as to the ancestry of *Pyrina*. That genus may well have arisen from some such Pygasteridæ as *Macropygus* or *Anorthopygus*, but it is unlikely to have included any of the *Holectypus* series in its ancestry. The tubercle-pattern of *Anorthopygus* is distinctly Pyrinid, and its peristome is far from circular. But various Jurassic genera, among which forms called *Desorella*, *Nucleopygus*, or *Pyrina* are most noteworthy, might perhaps be claimed as forerunners of the Cretaceous group. If such a claim were substantiated, *Anorthopygus* would be too late to fall into the phyletic line. However, it would seem that the Jurassic forms that resemble *Pyrina* in shape and some other characters are always covered by tubercles whose order of inception is indeterminable. It would be very strange to find Irregular Echinoids, that had advanced so far beyond Holectypoid limits in this direction, reverting to the "Regular" quality of sparse, coarse, and serial tuberculation. In default of definite evidence, the preponderance of probability favours an Holectypoid origin for *Pyrina*; so that, provisionally at least, *Pyrina* and *Echinonëus* must be included among the Holectypoida.

In the second paper of this series an account was given of the details of ornament developed in *Conulus*, particularly in *C. albogalerus*. The following notes deal with the main tubercles only, and treat of those morphogenetically, so that in a sense they supply particulars that were omitted in the previous account. But the purpose of this return to the subject of the ornament of *Conulus* is different. As Jackson has clearly shown, the "law of localized stages of development" is often very well illustrated by the tuberculation of the interambulacra of Echinoids. The plates towards the peristome, being ontogenetically young, show recapitulatory stages in ornament which (subject, of course, to modifications introduced after their formation) give valuable aid in tracing the ancestry of the form concerned. The plates of the mid-zone show the full "species-characters", while those near the apex, being morphogenetically young, provide a less convincing, but recognizable and partly prophetic, type of recapitulation. With a view to discovering the probable relationships of *Conulus* I have analysed interambulacral columns of three types (probably distinct species) from the English Chalk (see Figure, p. 445). A similar analysis of *Pyrina desmoulinsi* is given to show the similarity, and difference, between the genera in this matter. The species of *Conulus* are arranged in stratigraphical order—*C.* sp. (a large, subglobular form) is from the zone of *R. cuvieri* near Reigate, *C. subrotundus* (a tall variety) from the zone of *T. lata* near Wallingford, and *C. albogalerus* (a large, acutely conical form with a wide periproct—Gravesend type) from the sub-zone of *C. albogalerus*, about 20 feet below the zone of *Uintacrinus*, at Whitway, Hants. In all types supernumerary tubercles occur near the ambitus. These supernumeraries, which occur equally in *Discoidea cylindrica*, are clearly hypertrophied secondaries, and have no place in the fundamental scheme of tuberculation. They are interesting as showing one method whereby tuberculation may become multiplied and disordered, while the apicad pattern in *C.* sp. (and to a less degree in the two other species) show a second method producing a comparable result.

The interambulacral plates figured have been selected from the same columns and parts of columns as far as possible. For convenience in spacing on the page the columns of each species run horizontally. In the first vertical row the proximal orad plates are shown. Next comes a plate from the "mid-zone" of the adoral surface, and in the middle row a plate from the ambitus. The two right-hand columns represent plates from the "mid-zone" of the adapical surface, and the apicad plates. It has proved more satisfactory to select the plates in this way than to choose mid-zonal plates in the literal sense. The ambitus in all these forms has various specializations associated with it, and the disposition of the tubercles is usually very different on the two surfaces of the test. It is true that this tendency somewhat vitiates the application of the law of localized stages, but it cannot be avoided in forms with sharp ambital angles. In *Pyrina*, where the ambitus is rounded, and comes about midway between the apex and the peristome, conditions are more favourable for a strict application of the law.

The diagram (p. 445) is practically self-explanatory, but a few points will bear verbal emphasis. In the orad plates, *Pyrina* shows three "Cidaroid" members, with one central tubercle each. These are followed by the fourth plate, which has one tubercle developed on each side of the median one, both being apicad in relation to the central tubercle. In *C.* sp. there are only two "Cidaroid" plates, and on the fourth plate the first orad additional tubercle appears on the adradial side. *C. subrotundus* is practically similar, but the third plate has assumed the full characters of the fourth in *Pyrina*. In *C. albogalerus* only one "Cidaroid" plate remains.

Turning to the second column of figures, which show the mid-adoral plates, *Pyrina* proves to have developed the regular chevron characteristic of *Anorthopygus*. The median tubercle is distinctly orad in position, and is in the same transverse line with the other orad tubercles of the plate. *C.* sp. is closely similar, but a "triplet" occurs on the adradial side, and the median tubercle is above the average level of the orad series, though still far from central. In *C. subrotundus* the median tubercle is nearly central, and a supernumerary occurs below it. This supernumerary is always present in ambital plates of both genera, and is strongly reminiscent of the similarly placed tubercle (usually sunken) on some adapical plates of *Holectypus depressus* and *Discoidea cylindrica*. *C. albogalerus* shows the "hour-glass" pattern so characteristic of the species; the relative simplicity of the tuberculation may be correlated with the small extent of the adoral surface in proportion to the length of the columns.

In the ambital plates *Pyrina* shows the true mid-zonal character. The median tubercle is nearly central, there are many supernumeraries, and a considerable proportion of triplets. *C.* sp. has a group of four, but otherwise the series of *Conulus* are very similar. It must be remembered that these three ambital plates are situated well below the true mid-zone of their columns.

Half-way up the adapical surface the tuberculation of *Pyrina* has recovered its simplicity, and, save for the smallness of the tubercles and the central position of the median one, is very like the corresponding tuberculation of the adoral surface. But *C.* sp. shows elaboration, passing beyond its ambital quality, while the two other species show little, if any, simplification.

In the apicad (newly formed) plates a strong likeness is seen in all four cases, but *Pyrina* introduces extra tubercle series most slowly, and *C. albogalerus* by far the most rapidly.

The fundamental agreement of all four species in the ontogenetically young plates (columns 1 and 2) is strongly suggestive of their phyletic relationship, while the introduction of additional tubercles is progressively accelerated. The morphogenetically young plates towards the apex may be regarded as showing prophetic characters (coupled inevitably with those due to immaturity), and from them it may therefore be deduced that *Pyrina* has reached it full specialization in tuberculation, while *Conulus* is tending towards an increase in elaboration. The extremely rapid introduction of new tubercles in *C. albogalerus*, the latest species considered, suggests that any descendants of that form would have such complex and multiple tuberculation that the original "Holectypoid" quality of recognizable order in the pattern would disappear.

The results of this, and of the earlier, part of the paper may be tersely summarized as follows: *Pyrina* gave rise to *Conulus* early in the Cretaceous period. Later, in the Tertiary, *Pyrina* became modified into *Echinonëus*. The *Pyrina–Echinonëus* stock was almost static in evolution; but *Conulus*, with changed habitat, diverged rapidly along a new path which must have led away from the Holectypoida. Both *Pyrina* and *Echinonëus* must be classed with the Holectypoida.

EXPLANATION OF TEXT-FIGURE, p. 445.

All the figures in each horizontal line (i.e. representing a single species) are drawn to the same magnification; but the different species are variously magnified to aid comparison. The median tubercles on each plate are shaded. Apart from the dotted lines linking the elements of the chevrons, there is nothing diagrammatic in the figures (unless the omission of all smaller ornament be so regarded). Tubercles without shading or linking lines are either supernumeraries or members of chevron patterns whose associates are undeveloped.

III.—The Magnesian Limestone of Durham.

By David Woolacott, D.Sc., F.G.S.

Part I.

Conditions of Deposition — Former Presence of Sulphates — Formation of "Demagnesified" Rocks—Development of Concretionary and Segregated Structures,[1] etc.

In my paper on "The Stratigraphy and Tectonics of the Permian of Durham (northern area)"[2] I endeavoured to give a description of the stratigraphical and structural features of these rocks with as little discussion of the theoretical questions involved as possible. I regarded a thorough examination of the strata in the field as the only way in which to obtain a knowledge of the divisions of this system, and as essential for elucidating the structural, physical, and chemical changes that have taken place in the Magnesian Limestone. It was my intention to describe similarly the southern area, and afterwards to discuss theoretical and general questions relating to the Durham Permian. Although a great part of the southern district has been surveyed by me, I have decided to leave the description of that area and give in this paper a general summary of recent work on the Magnesian Limestone of Durham, with a discussion of the theoretical views that may be advanced to explain the observed facts,

[1] In Part I of this paper a general acquaintance with the divisions of the Magnesian Limestone and with certain structural features of this rock is presupposed; readers not having such preliminary knowledge will find these subjects summarized and discussed in Part II.

[2] Proc. Univ. Durham Phil. Soc., vol. iv, pt. v, 1911–12.

and a statement of our present knowledge of these rocks. I am able to do this more readily as part of the southern Permian has been described and much careful work done on the lithology and composition of these rocks by Dr. Trechmann[1] (to whose work I must record my indebtedness in the preparation of parts of this paper), and two borings that have lately been put down have given an opportunity for the examination of one of the least known facies of the Middle Limestones.[2]

The uneven floor of the broad syncline of the Northumberland and Durham Coalfield was covered by a series of dunes on the edge of the Permian sea, which was advancing from the east. These were gradually planed down by the incoming waters, the Yellow Sands being formed. This deposit usually consists of large rounded grains set in a finer angular-grained matrix. The basin in which they were laid down extended far to the east, but on the west it was bounded by the Pennine area, and on the south by an anticline of Lower Carboniferous rocks which then lay across the south of Durham. Fragments of the latter rocks with derived encrinite stems occur in the Yellow Sands in the south of the county, proving that this ridge was being denuded when these sands were being deposited. On these reassorted sands a finely laminated calcareous and dolomitic mud—the Marl Slate—was laid down under tranquil conditions in fairly deep off-shore waters. Eventually the southern ridge was covered by deposits of the limestone facies and the sea thus overspread the country to the south, and deposition went on continuously from Durham to Central England.

The Magnesian Limestone, which reached a thickness of about 1,000 feet, was deposited in an inland sea which was gradually drying up, so that conditions were brought about which led to the gradual precipitation of the dissolved salts. The strata originally varied from nearly pure calcareous rocks to pure dolomites, along with which were beds, veins, and intercalations of gypsum and anhydrite, and in the later formed rocks of marls, marly sandstones, and rock salt. The main mass of the Magnesian Limestone thus consists of (*a*) thick and thin beds—often lenticular—of nearly pure calcium carbonate, (*b*) beds of nearly pure dolomite, (*c*) beds composed of mixtures in varying proportions of dolomite and calcium carbonate—these are the dolomitic limestones consisting of dolomite and interstitial calcite, and (*d*) (where they have not been removed) beds, veins, etc., of calcium sulphate.

Irregularly distributed throughout the limestone are various substances, some of which are due to original deposition, while others are of secondary origin. Among such substances are alumina, chert, iron oxides, manganese dioxide, grains of quartz (both of detrital and non-detrital origin), and, in a lesser degree, of mica, tourmaline, zircon, etc. In geodes and cavities crystals of calcite are common, while dolomite is only occasionally found. Ankerite, fluorite, galena, iron pyrites, malachite, heavy spar, and limonite (pseudomorphs

[1] Q.J.G.S., vol. lxix, pp. 184–218, 1913, and vol. lxx, pp. 232–65, 1914.

[2] "Borings at Cotefield Close and Sheraton": Geol. Mag., March, 1919, pp. 163–70.

after chalybite) also occur. Parts of the limestone contain a small amount of carbonaceous matter of organic origin, and some of the limestones are fetid.

The limestones vary in colour, texture, macroscopic and microscopic structure considerably. These variations are partly due to the differences in composition and partly to the different methods of formation of the beds, but also largely to the nature of the physical, chemical, and structural changes that have taken place in them. In colour they range through dark and light brown, yellow, grey to pure white rocks, and the numerous varieties of their texture include fine, soft and powdery, hard and compact, close-textured, porous, coarsely cellular, concretionary, crystalline, segregated, brecciated, pseudo-brecciated, etc. Thick beds of granular dolomite occur, and in the Middle and Upper divisions strata of dolomitic oolite reach a considerable thickness. Parts of the limestone consist of the remains of organisms with a dolomitic or calcareous matrix. In microscopic texture they vary from rocks showing little or no structure to beds built up of allotriomorphic grains and idiomorphic rhombs of dolomite and crystalline grains of calcite. In some parts of the limestone crystallization has gone on to such an extent (quite apart from the highly altered concretionary, segregated, and other limestones where the change is evident in the field) as to entirely alter the internal structure. Original oolitic rocks have been altered so as to leave but little trace of their structure, and from parts of the Bryozoa Reef the fossils have been entirely obliterated.

Parts of this limestone are of organic origin, this being notably the case in the shell bank of the Bryozoa Reef, which consists of remains of invertebrate life that flourished under the protection of the Bryozoa, together with an infilling of calcareous or dolomitic sediment. The pure calcareous inorganically formed rocks, and some of the dolomitic limestones are the result of sedimentation. The oolites of the magnesian limestones, which attain a considerable thickness (100 feet) in parts of the Middle and Upper limestones, are specially interesting. The concentrically arranged material of the ooliths is dolomite with centres of calcite, gypsum, or fluorite.[1] Gypsiferous oolites have been proved in the borings in South Durham, and the hollow oolites of Roker and Hartlepool had originally gypsiferous centres. The fluorite is probably secondary, being deposited after the solution of the gypsum. These dolomitic and gypsiferous dolomitic oolites were produced by the deposition of material round crystalline grains or nuclei either as they fell through the water or lay on the bottom of the sea.[2] They show no trace of current bedding,[3] were probably laid down in fairly deep water, and do not appear to have been produced through movement by current action, nor were they formed by organic agency.

The dolomitic limestones when the sulphates have been removed

[1] Trechmann, Q.J.G.S., vol. lxx, p. 250.

[2] "On Oolites and Spherulites": H. Bucher, *Journ. of Geol.*, vol. xxvi, No. 7, Oct.–Nov., 1918.

[3] Current bedding is traceable locally in the Roker oolite, and I have noticed it slightly developed in an altered oolite in Silkworth Quarry.

are really mixtures of dolomite and calcium carbonate in varying proportions. Analysis of this rock have been published giving a higher percentage of magnesian carbonate than the dolomitic ratio, viz. 45·7.[1] I always thought these wrong and misleading, and the work of Dr. Trechmann on the composition of these rocks has definitely proved them to be so.[2] The best way, therefore, to state their analyses for geological work is to give, as Trechmann has done, the percentage of dolomite and calcite, together with the smaller amounts of other substances present. The relative proportion of dolomite and calcite in the rock along with the original presence, of calcium sulphate has probably had, as I shall endeavour to show most important influences on the nature of the changes—segregational, concretionary, etc.—that have taken place on such a marked scale in these rocks. The presence of impurities has also had an effect on the structural changes, e.g. the presence of argillaceous and siliceous impurities appears to have deterred the formation of the concretionary structures, and Dr. Trechmann has suggested that the dolomitization of certain parts of the Reef has been arrested by the occurrence of manganese dioxide.

The original presence of calcium sulphate in the Permian rocks is not now a matter of conjecture. In 1875 Dr. T. Sterry Hunt [3] and in 1881 Wilson [4] suggested that calcium sulphate was a subsidiary product of the deposition of dolomite and it has been known for many years that gypsum and anhydrite were associated with the Permian rocks. These substances are found in Permian strata in the Vale of Eden,[5] near St. Bees Head, and in the Zechstein of Germany, and have been proved to occur in the Magnesian Limestone of South Durham, Yorkshire and North Lincolnshire.[6]

The precipitation of calcium sulphate would appear to have been a product of the deposition of dolomite and dolomitic limestones,

[1] Analysis by Browell and Kirkby, Nat. Hist. Trans., vol. i, pt. xi, p. 204, 1866.

[2] Q.J.G.S., vol. lxx, p. 232, 1914.

[3] *Chemical and Geological Essays*, 1875.

[4] "The Permian Formation of N.E. England": Mid. Nat., vol. v, p. 202, 1881.

[5] Regarded as Trias by some geologists.

[6] Anhydrite and gypsum have been proved by borings in the Permian at Seaton Carew (Wilson, Q.J.G.S., vol. xliv, p. 781, 1888); Whitehaven, near Norton (Tate, Q.J.G.S., vol. xlviii, p. 488, 1892); Hartlepool (Trechmann, Q.J.G.S., vol. lxix, p. 184, 1913); Leeming Lane; near Stockwith, North Lincolnshire (G. Dunston, Fed. Inst. Min. Eng., vol. xii, p. 578, 1896–7); in borings in South Yorkshire. Concealed coalfield of Yorkshire and Nottingham (Walcot Gibson, Mem. Geol. Surv., 1913); at Market Weighton (Walcot Gibson, Summary of Progress, Geol. Surv., p. 43, 1917). Trechmann gives the following analysis of the Seaton Carew boring (Q.J.G.S., vol. lxix, p. 193, 1913):—

	Feet.
Sulphate-free limestone	480
Limestone impregnated with gypsum and anhydrite .	358
Pure anhydrite and gypsum	35
Total thickness of magnesian limestone .	878

The mass of anhydrite and gypsum at Hartlepool was 267 ft. 2 in. It was overlaid by glacial deposits, so it may have been originally much thicker.

calcium sulphate forming and being deposited when the solution became saturated. In areas where the magnesian limestone is still covered by a mantle of later rocks the sulphates remain intact, but from this limestone in the greater part of Durham they have been removed. Trechmann's analyses show that many of the limestones in Durham (in areas where the beds and intercalations of gypsum or anhydrite have been removed) contain a small percentage of sulphates, and lately crystals of gypsum have been found in geodes in the lower limestone at Raisby Hill Quarry in South Durham. The evidences of the former existence of sulphates is to be found in the letting down of beds,[1] in some of the extensive disturbance and brecciation of the strata, in the hollow oolites of Roker and Hartlepool, and in cavities left by crystals and crystalline aggregates. Indirectly their solution had most important influences, not only did it render the rock highly cavernous, cellular, and porous, but at the time of its removal the strata would be saturated with solutions of calcium sulphate, which appear to have had marked effects on certain parts. As I shall endeavour to show, the stewing of the magnesian limestone in warm solutions of calcium sulphate, sometimes under high pressure, has been the factor that has altered large parts of it into a more calcareous rock.

The conditions in which the magnesian limestone was deposited were those of an inland sea containing various salts in solution. According to chemical theory these salts would be existing as ions, and so the solution would contain Ca'', Mg'', K', Na', H_2CO_3'', SO''_4, Cl'. When in equilibrium various compounds would be existing, such as $CaCO_3$, $CaCl_2$, $MgCO_3$, $MgSO_4$, $NaCl$, Na_2SO_4, etc., together with disassociated ions. Owing to varying conditions of temperature, pressure, and concentration, there would be a tendency for the formation of the least soluble and most soluble salts, thus calcium carbonate and magnesium sulphate would be formed. The magnesium sulphate afterwards acted on part of the calcium carbonate to form either free magnesium carbonate or the double salt, dolomite. If free magnesium carbonate were deposited, then the two separately precipitated carbonates must at a later stage have combined to form dolomite. Calcium sulphate would be formed as a subsidiary product, and deposited according to the concentration and temperature. Gypsum or anhydrite were deposited with the variation of conditions in thick beds, in veins, in irregular pockets,[2] or were irregularly intercalated throughout the limestone.[3]

[1] A considerable thickness of limestone (some 200 feet) appears to be absent on the west side of Cleadon Hills, and it may be that a thick bed of sulphate has been removed here. The extensive slipping down of beds and consequent brecciation along the eastern side of the Reef, which can be seen at several places along the Durham coast, is most probably due to this cause. Trechmann has noted several vertically slickensided surfaces (Q.J.G.S., vol. lxix, p. 201).

[2] Geodes containing gypsum with dolomitic rhombs disseminated through them have been observed by Trechmann.

[3] Anhydrite was deposited in periods of drought and higher temperature. See discussion of this subject by B. Smith in "The Chellaston Gypsum-breccia and its relation to the Gypsum-anhydrite deposits of Britain": Q.J.G.S., vol. lxxiv, p. 195.

Similar conditions of deposition held good through a protracted period, during which some 600 to 700 feet of rock were formed. The Permian Sea became shallower, marls, marly false-bedded sandstones and sodium chloride were deposited, and finally all the calcium and magnesium carbonates having been laid down, the more soluble salts were precipitated. These are represented by the Stassfurt deposits, which probably extend far to the west of their present proved position, or by deposits of similar nature now denuded.

The field evidence is in favour of some of the dolomite being originally deposited as a precipitate. Thick beds of powdery dolomite (some of which are called "marl")[1] occur in a very fine state of subdivision which would appear to have come down as dolomite, otherwise it would be expected that in the slow process of formation by the association of the carbonates after deposition, crystallization would have taken place in these rocks, and rhombs of dolomite have been formed. The dolomitic oolites also appear to me,[2] as Trechmann has already asserted, to support the view that the dolomite was originally deposited round the centre of the oolith. On the other hand, some of the more coarsely granular dolomitic rocks composed of coarse dolomite rhombs[3] may have been formed by the slow crystallization of the dolomite from the association of the free carbonates after precipitation. It may thus be that in the Durham Permian dolomite has sometimes been precipitated, while at other times the two free carbonates have been laid down to subsequently combine into that mineral.

It has already been stated that the beds of magnesian limestone differed considerably in composition at the time of their deposition, but since then important changes have taken place on various horizons. Dolomitization of certain parts has been brought about either pene-contemporaneously with the deposition of the strata or long after they were formed,[4] portions have been silicified,[5] other

[1] Trechmann gives an analysis of the Great Marl bed of Fulwell Quarries—

Dolomite	78·42
Calcite	13·04
Insoluble residue	5·02
Calcium sulphate	trace
Iron or manganese	2·41

[2] Trechmann gives an analysis of dolomitic oolite from Haswell—

Dolomite	96·49
Calcite	3·80
Anhydrite gypsum or sulphur trioxide	0·07
Iron or manganese	0·57
Insoluble residues	0·02

[3] The coarse granular dolomite occurring in the Cotefield Close boring gives (analysis by A. D. N. Bain, B.Sc.)—

Dolomite	62·38
Calcite	30·10
Ferric oxide	3·88
Insoluble residue	3·46

[4] [For note see next page.]

[5] Silicified limestones occur at the south end of Marsden Bay, Hendon, etc., and Trechmann has noticed silicified oolitic limestones.

parts have been decalcified by manganese or other solutions,[1] but the most interesting alteration is, as I stated in my paper some years ago, that large areas and considerable thicknesses of the magnesian limestone of Durham are more calcareous than they were originally. This latter change has been brought about by solution and also by the mechanical removal of dolomite. I first referred to it in my paper on the Permian of North Durham as "dedolomitization", a term the use of which in this connection was objected to by Garwood and Evans, as it has been used by Teall and others in another sense. If, however, the alteration of a limestone into dolomite is "dolomitization", then surely the alteration of the latter rock into a calcareous one is the simplest case of dedolomitization. As long as it is recognized that large masses of the magnesian limestone are more calcareous than they were originally, I have no desire to use any term, but as some word would be useful (if dedolomitization is inadmissible) I would suggest "demagnesification" for the processes—solution and mechanical—by which parts of this rock have been rendered more calcareous. As I shall show, "demagnesified" beds, both due to solution and mechanical processes, are of wide occurrence and thickness. The mechanical removal of dolomite by running water from the magnesian limestone has been admitted by Professor Garwood, Dr. Evans, and Dr. Trechmann. It is obvious as a result of the setting free of dolomitic powder in the rocks in which the concretionary and segregated processes have taken place. Objection has, however, been taken to my views regarding the solution of magnesian carbonate out of dolomite. Dr. Evans has asserted that "there is in the case of the Magnesian Limestone absolutely no evidence that magnesia has anywhere been abstracted

[4] Parts of the Bryozoa Reef have been dolomitized, e.g. Trechmann records the shell substance of a *Productus* as containing 95·88 per cent of dolomite, and of an *Arca* 98·68. Much of the sediment which fell on the reef was calcareous, and there is little doubt that the highly dolomitic nature of parts of the reef is due to subsequent dolomitization. This may have gone on pene-contemporaneously with deposition by the magnesium waters of the sea, lime being removed and replaced by magnesia, in the same way that the coral reefs of the present day have been proved to undergo a process of dolomitization (Judd, "Atoll of Funafuti," Royal Soc. London, 1904). Certain observations on the decalcified rocks in the reef, however, lead me to think that the dolomitization of parts of it may have taken place long after deposition. It is possible, if the solution changes which are discussed in this paper have taken place, that the magnesium may have been transferred from one part of the limestone to another. This appears to be so in the case of parts of the reef, and in some of the dolomitized highly calcareous rocks known as "bluestones" both in the upper and lower limestones. I have lately examined breccias occurring in the lower calcareous limestones of Raisby Hill Quarry which have been formed by the alteration of these rocks by magnesium and other solutions (see Breccias, Part II of this paper).

[1] Portions of the reef have been partially decalcified by manganese solutions, Tunstall Hill, Fox Cover Quarry, Beacon Hill. Trechmann gives an analysis of a decalcified rock from Tunstall Hill—

Dolomite . . .	3·94
Calcite	89·03
Insoluble residue . .	·19
Manganese dioxide .	7·00

from dolomite ".[1] The evidence can be clearly studied in the field, and a discussion of it is given in the following pages. Dr. Trechmann admits the solution of dolomite, and while saying that he finds no evidence for the leaching out of magnesian carbonate from dolomite, yet adds "the question as to whether in the presence of saturated solutions of calcium sulphate the dolomite was as stable as it is under present conditions remains a problematic one."[2] I think that the evidence in the field is clear that under certain conditions the magnesian carbonate in solution has been carried away as a soluble salt from the dolomitic limestones is clear. The important point, however, is not the manner in which these changes were produced, but the the fact that large portions of these rocks—both cellular and non-cellular—are more calcareous than they were originally, and that the chief cellular types of the limestone were not produced by dolomitization.

There are five rock types occurring in these limestones which have a less content of magnesian carbonate than they had. They are (1) dolomitic rocks and breccias altered into calcareous rocks chiefly in regions of pressure at the time of thrusting without the production of a cellular structure, (2) the concretionary limestone, (3) the segregated limestone, (4) the "fractured cellular" rocks, and (5) the "negative breccias". The last four usually result in the production of a highly cellular calcareous rock. As each of these rocks present certain characteristic features, it may be well to consider them separately.

(1) In the area affected by the thrusting and locally at other places, parts of these dolomitic limestones have been rendered more calcareous without the production of either a cellular, concretionary, or segregated structure. These changes are mainly found in the area affected by the thrust-movements and would appear to be due to solubility-conditions set up in the rock in the regions of pressure and heat developed at that time. These alterations are best seen in the dolomitic rocks above and beneath the thrust plane at Hendon. Sunderland, and in the mass of highly slickensided calcareous breccia (originally a dolomitic limestone) forming Jean Jiveson's Rock south of this thrust plane and probably connected with it, and in other areas. The dolomitic Flexible Limestone at Hendon becomes a hard, non-cellular, calcareous rock, and then a calcareous brecciated mass on the underside of the thrust plane, the change taking place within 100 feet and being easily traceable.[3]

The breccia of Jean Jiveson's rock occurs in another area of pressure relief, and it is here possible to trace the gradual change

[1] Q.J.G.S., vol. lxx, p. 264.

[2] Ibid., p. 253.

[3] This section is noticed in my paper on "The Permian of N. Durham", op. jam. cit., p. 267, 1912, and is drawn and described in fig. 10, where I refer to the change as having been brought about by the leaching out of the magnesium carbonate from the dolomite. Dr. Trechmann also fully describes it (Q.J.G.S., vol. lxx, p. 252, 1914), and explains the alteration as being due to the solution of dolomite. The amount of interstitial calcite in the Flexible Limestone is usually very small, so that solution of dolomite demands the

from a dolomitic rock to a highly compressed, slickensided, compact, calcareous breccia.[1] The change here has been similar to that in the case of the Flexible Limestone. In Fox Cover Quarry, Seaham Harbour, in rocks apparently not affected by pressure, a large mass of the Reef has been changed by solution from a dolomite into a nearly pure limestone. The dolomite can be seen to pass gradually into the calcareous rock, and when the alteration is complete the fossils are entirely obliterated. Other altered rocks and breccias of a similar nature occur. These changes have not been brought about by the mechanical removal of dolomite from the magnesian limestone, but by solution. There would appear to me to be two methods of explaining this: (1) the dolomite has been dissolved and metasomatically replaced by calcite, or (2) the magnesium carbonate has been carried away as a soluble salt out of the dolomite, calcium carbonate metasomatically replacing it.

(1) That direct solution of dolomite may have gone on in a small degree is undoubted, but I do not think that it has taken place on any large scale in the magnesian limestone, and am of the opinion that the carrying away of the magnesium as a soluble salt is in the main the explanation of these altered rocks. If these changes were brought about by direct solution of dolomite, more of this mineral would occur in geodes, as such a slightly soluble substance (in comparison with calcite) would be redeposited in other parts of the rock if the pressure conditions were the factor determining its solution. Another significant fact is that most of the altered limestones originally contained a very small percentage of interstitial calcite. It is also difficult to conceive of a solution dissolving dolomite under these conditions and at the same time containing calcite to replace it—if it was not immediately replaced owing to the small percentage of interstitial calcite the rock would have been broken up and the strata disturbed. Alteration of the Flexible Limestone occurs, however, without any disturbance, and the brecciation of other altered rocks was brought about by thrusting and is not directly due to solution changes. In the solution of magnesium carbonate from dolomite in the presence of calcium sulphate, calcium carbonate is produced in the reaction, and there is besides the interstitial calcite and calcite of the dolomite.

solution of almost the entire rock and its replacement by calcite, e.g. Flexible Limestone, Marsden, interstitial calcite 0·71. The analyses given by Dr. Trechmann of this bed above the thrust plane at Hendon are—

	Flexible Limestone.	Hard Calcareous Rock (altered Flexible).
$MgCO_3$ . .	43·78	10·92
$CaCO_3$ . . .	55·01	88·56
Fe_2O_3 . . .	0·61	0·19
Insoluble residue .	0·88	10·92
Dolomite . .	95·91	23·93
Calcite . . .	2·88	75·55

[1] This section is drawn and described in my paper on "The Permian of N. Durham", op. jam cit., fig. 10.

(2) The second explanation is that the magnesium has been carried away as a soluble salt out of the dolomite, calcium metasomatically replacing it. It appears to me, that under certain conditions, the reaction represented by the following reaction took place: $CaCO_3\ MgCO_3 + CaSO_4 = 2Ca\ CO_3 + MgSO_4$.

If dolomite was precipitated, as suggested in a former part of this paper, by the formation of calcium carbonate and magnesium sulphate in solution and their reaction on one another, then the process of formation of dolomite has been reversed at the time of solution of the magnesium carbonate. On this hypothesis the reaction represented by this equation, $2CaCO_3 + MgSO_4 \rightleftharpoons CaMg\ (CO_3)_2 + CaSO_4$, is considered to be a reversible one. The reversibility will depend on the temperature, pressure, and concentration of the solution. It is impossible to be dogmatic on such changes, as little is known regarding the exact way in which dolomite is produced in nature. The reaction for the formation of dolomite by the action of magnesium sulphate on calcium carbonate has been obtained at fairly high temperatures (120°), but F. W. Pfaff has shown that when a current of carbon dioxide is passed for a long time through a warm solution of the sulphates and chlorides of magnesium and calcium, and slowly evaporated at a temperature of 20° to 25°, a residue is produced which contains the double carbonate, i.e. under conditions approximately parallel to those which occur in the concentration of sea-water, dolomite may be formed (*Centralblatt. Min. Geol. u. Pal.*, p. 659, 1903).

The same authority says that it is a well-known fact that dolomite with gypsum solution is changed to magnesium sulphate and calcium carbonate at ordinary temperatures and pressures. He describes a simple experiment in which the reaction can be proved. Powdered gypsum and dolomite are mixed with one another, placed in a funnel, the stem of which is stuffed with cotton wool, and water is poured on the mixture and allowed to trickle through. In the clear filtrate magnesium can be proved in appreciable quantities (F. W. Pfaff, "Ueber Dolomit und seine Entstehung": Neues Jahrbuch für Mineralogie, Geologie, und Paläontologie, p. 563, May, 1907). The experiment has been verified by Mr. A. D. N. Bain, B.Sc., who finds that the reaction can be proved to take place quite easily if the temperature of the solution is raised. Snce arrivin g at the idea of the reversibility of this equation I have noticed the following statement:—

"A. von Morlot by heating powdered calcite with magnesium sulphate to 200° in a sealed tube, transformed the carbonate into a mixture of dolomite and gypsum. This reaction has been suggested by Haidinger in order to account for the frequent association of the two last-named species. The process, however, is reversible, and solutions of gypsum will transform dolomite into calcium carbonate and magnesium sulphate. Efflorescences of the latter salt are not uncommon in gypsum quarries, and H. C. Sorby has observed them in Permian limestones. Because of this reaction, according to Sorby, the upper beds of magnesian limestone are often more calcareous than the lower. Their content in magnesia has been diminished in this way" (*Data of Geo. Chemistry*, p. 535).

Sorby suggests that probably the alteration of some magnesian limestones was affected by the percolation of magnesium salts, and adds: "a process the very reverse of that just described is now taking place by the action of dissolved gypsum, by which sulphate of magnesia, frequently efflorescing on the surface of the rock, and carbonate of lime are produced" (Reports Brit. Assoc. Sci., p. 77, 1856). This geologist had evidently arrived at the same conclusion as I have from direct observation in South Yorkshire regarding the action of gypsum on dolomite.

(If it is objected that the calcium sulphate solutions were all removed from the rock at the time of thrusting, it must be remembered that in the natural waters contained in the rocks there would be other dissolved substances, e.g. common salt, etc., which may have had an influence in bringing about the solution of the magnesium, and that under the high pressures existing at that time —which I have endeavoured to prove reached in the Marsden area a pressure of some 300 tons per square foot—the solution effects of carbonic acid would be greatly increased. I, however, see no reason for doubting that the main factor for the solution of magnesium carbonate from dolomite was the presence of calcium sulphate solution in the rock.)

The dissolved magnesium salt may have dolomitized other parts of the limestone in regions of less pressure and lower temperature, or where the concentration was different, or have been carried entirely away in the same manner as the calcium sulphate.

It should be noticed that in this type of demagnesified rock, where the alteration is complete owing to the non-production of a cellular texture, no mechanical removal of dolomite is taking or has taken place.

2. The concretionary limestones were originally dolomitic limestones, and there can be little doubt that these rocks were impregnated with sulphates and that the solution of these brought the bed into a condition which gave the concretionary forces full play; and further it would seem highly probable that the complicated structures occurring in these rocks were mainly produced when the beds were saturated in solutions of calcium sulphate containing colloidal organic matter.[1] It is the presence of this latter material that causes the spheroidal condition. Colloids readily permit the diffusion of crystalline salts through them. The effect of colloids on calcium carbonate in producing concretionary growths has been proved by Rainey, Harting, Ord, and Stocks.[2] I have before referred to the presence of colloidal matter as a factor in causing the concretionary limestone,[3] and Trechmann has also suggested that the spherical concretions are due to the presence of organic matter when they were forming.[4] The Bryozoa Reef probably formed the reservoir from which the organic matter came. I have divided the concretions

[1] The concretionary limestones often contain organic matter and are sometimes strongly fetid.

[2] Stocks, Q.J.G.S., vol. lviii, pp. 46–58, 1902.

[3] Univ. Durham Phil. Soc. Proc., vol. iv, pt. v, p. 271, 1911–12.

[4] Q.J.G.S., vol. lxix, p. 198, 1913.

into two types, the spherical and the cellular, which are associated together in the same beds, and similar conditions would appear to have brought them about. The large irregular spherical concretions, the cannon-ball, botryoidal, and stellate types, do not occur on any definite horizons, but are found irregularly through the Concretionary Limestone. It seems probable that the more spherical calcareous growths were produced in parts of the solution where the colloidal organic matter was more concentrated. While the calcite which forms the concretions is in the main part the interstitial calcite, it is possible that if the rocks were saturated in sulphate solutions part of the dolomite has been decomposed, the magnesium being carried away as a sulphate and the calcite crystallizing along with the interstitial calcite. It is difficult to understand how the large, irregular, spherical (often more than 2 ft. across), non-cellular concretions and the smaller compact cannon-balls can have been formed without such solution having taken place. The matrix and loose dolomitic material surrounding the spherical concretions and found in the cellular concretionary rocks is always fine and powdery, and the question arises was the dolomite in these concretionary rocks always powdery and never granular or oolitic.[1] The calcium carbonate in certain of the concretions does not appear to have come together out of the rock, but the change seems to have been brought about by gradual alteration outwards from the centre. Specimens can be obtained varying from soft, yellow, unaltered highly dolomitic beds to rocks in which clearly defined spherules of calcite have been formed (the dolomitic limestones around these remaining unaffected), such rocks finally by coalescing of the spherules becoming grey, concretionary, calcareous, and only slightly cellular. It is very questionable to me whether this particular change is only due to the crystallization of the interstitial calcite and does not imply solution of the magnesium carbonate. As specimens showing such variations can readily be obtained, observers are inclined to think that changes of this character are taking place at the present time, but this is exceedingly doubtful; indeed, it is much more probable that these complicated rock-structures are now more or less stable, and that in the main the concretions were produced at some time in the past under the conditions just defined. As Sedgwick pointed out in 1835, the concretions were formed after deposition, and I have shown that they must have been mainly produced before the folding and dislocation of the strata took place. In one case a brecciated mass, which occurs on the coast just north of Byers Quarry, Marsden, has had a crystalline concretionary structure developed in it subsequent to brecciation, but this is quite exceptional. Whether any solution of the magnesium content of the dolomite has gone on in these rocks by the action of solutions of calcium sulphate on them or not, it should be noticed that the loose dolomitic powder, which is at present being removed mechanically from them under existing conditions of denudation (and in Durham similar conditions over more extensive areas would hold good before the country was

[1] Trechmann lays emphasis on the very fine state of the powdery material in both the concretionary and segregated rocks (Q.J.G.S., vol. lxx, pp. 252, 256).

covered by the boulder-clay), is not in any way connected with the cause of the formation of the concretions, but is set free as the result of the alteration of these beds by the concretionary processes.

3. The segregated limestone are also due to the crystallisation of calcium carbonate from dolomitic limestones, but here the growth of the calcium carbonate is irregular, assuming no definite forms.[1] They are specially characteristic of the Middle Limestone on both sides of the Reef, reach a thickness of at least 90 feet, and have a considerable extension in these beds. They were originally dolomitic limestones of intermediate composition and probably were always originally gypsiferous. During the metamorphism the entire structure of the rocks has been altered, the fossils when present obliterated, and the composition, texture, and colour changed. This alteration of these beds had also largely taken place before the thrusting (although solution and segregation of calcium carbonate can also be proved to have gone on both during and after the deformation of the strata). Dr. Trechmann has said that loosening of dolomitic grains would be brought about merely by the leaching out of the gypsum, and this would be so, but it appears to me probable that in these rocks the segregation of the calcareous portion of the rock may have taken place in sulphate solutions, and much solution of the magnesium carbonate of the dolomite may have gone on. The dolomitic matter found in the cavities is always in a fine state of subdivision as it is in the concretionary limestone, while in the Middle division of the limestones thick unaltered beds of coarse granular dolomitic grains occur, and of dolomitic oolite, and the question arises what was the original nature of the dolomite in parts of these highly altered beds. It is again also noticeable that the unsegregated dolomitic limestones from which the altered rocks were formed do not contain a high percentage of interstitial calcite.[2] Another point of interest is whether the non-concretionary nature of the calcite in these rocks is owing to the solution not having contained collodial organic matter. In this connexion it is significant that the concretionary limestones lie above the segregated. In the latter rocks—whatever may be the way in which they were altered —the calcium carbonate has segregated out, and as a result loose powdery dolomitic material has been set free, which has been, and

[1] Trechmann gives the following analyses from the coast near Horden—

	Dolomite—soft, yellow, well bedded.	Calcareous Segregation.
Dolomite . .	96·08	31·94
Calcite . . .	0·58	65·50
Insoluble residue .	3·14	3·14
Iron or manganese	0·61	·61

[2] An analysis of a hand specimen by the late R. C. Burton, B.Sc., of fossiliferous dolomite passing into a segregated limestone from which the fossils were obliterated gave—

	Dolomitic Limestone.	Segregated Limestone.
$CaCO_3$ . .	50·39	91·92
$MgCO_3$ . .	40·93	8·01

In both the unaltered rocks the interstitial calcite is small, in the first case exceedingly so.

is being, mechanically removed. The rock as a whole is thus finally losing the greater percentage of its magnesium-content. These segregated rocks are often broken up without much displacement, being generally compactly recemented, thus forming one class of pseudo-breccias.

In the case of both the concretionary and segregated rocks the solutions must have been saturated so that solution and precipitation were going on at the same time, otherwise the stability of the rocks would have been affected and the strata broken up. The water which filled every cavity and pore would also help to prevent the collapse of the rocks at the time the structures were forming. The pseudo-brecciation, brecciation, and disturbances of the strata can generally be proved to have taken place after the structures were developed in them.

4. The other type of cellular limestone from which dolomite has been removed is the rock I have named the "Fractured-cellular". Here again alteration of dolomitic limestone into a calcareous rock has taken place along fractures and lines (apparently necessitating solution and segregation changes similar in nature to those already discussed) and the loose dolomitic rock is then mechanically removed. This type is well exposed along the coast to the south of Seaham Harbour.

5. Between Frenchman's Bay and Marsden dolomitic rocks have been brecciated along a thrust plane, and subsequently bound together by a calcareous cement. This material may have been derived by solution from the dolomitic powder produced at the time of thrusting, when there would be both high temperature and increased pressure, or may have been segregated out of the fragments, or may have been brought in from the rocks above. At the present day the dolomitic limestone of the breccia is loose and powdery, and is being removed mechanically. The original dolomitic breccia thus becomes a highly, and very coarsely cellular, calcareous rock, i.e. a "negative breccia".

The evidence for these alterations in the magnesian limestone can only be studied in the field, and there is no doubt that the more these rocks are observed, the more striking do the extensive changes become. The theories advanced in this paper are not put forward in any dogmatic manner, but merely as an attempt to explain them.

(*To be continued.*)

ADDENDUM.

1. Where statements are made regarding the composition of rocks and analyses were not available they have always been analysed, generally by post-graduate students of Armstrong College.

2. In connexion with solution changes in the magnesium limestone, it is perhaps worthy of note that Sunderland Water contains on the average—

	per 100,000.	Grains per gallon.
CaO . .	10·99	7·69
MgO . .	6·38	4·47
SO_3 . .	3·83	2·68
CO_2 . .	12·42	8·69

As a very large and busy manufacturing district obtains all its water from this formation, large quantities of both calcium and magnesium must yearly be dissolved out of the magnesian limestone.

IV.—The Distribution of '*Terebella*' *cancellata*.

By Dr. F. A. Bather, F.R.S.

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'*Terebella*' *cancellata* was the name given to some supposed worm-tubes from the Cenomanian of the East and South-east of England, in the Geological Magazine for December, 1911 (p. 553, pl. xxiv, figs. 3–5). The chief feature of the species is an obscure cancellate ornament formed by transverse and longitudinal folds.

At that time these fossils were recorded from the *Holaster subglobosus* and *Actinocamax plenus* zones of the Cenomanian. The only exception was the British Museum specimen A 1638 from the Upper Greensand (Albian) of Betchworth, Surrey. Some other horizons can now be added.

Aptian: Specimen A 1702, collected from the Lower Greensand of East Shalford, Surrey, by Caleb Evans.

Turonian: a specimen submitted in June, 1917, by Mr. H. C. Brentnall, of Marlborough College, and obtained "just N. of the main road over Overton Hill and S. of the short stretch of Roman Road, just W. of the 4th milestone. On the 6 in. map, Wiltshire, Sheet XXVIII S.W., the actual shallow excavation is shown under the word Tumuli". This is probably the "small pit" in the Chalk Rock, zone of *Holaster planus*, mentioned on p. 197, par. 5, of Mem. Geol. Surv., Cretaceous Rocks of Britain, Vol. III.

Lower Eocene, Thanetian: Specimens A 1936 – A 1940, collected by Captain P. R. Lowe, R.A.M.C., in July, 1917, from the quarries near Wizerne, on the south side of the River Aa, near St. Omer. The matrix is a soft, friable, glauconitic sandstone, of a pale yellow colour. Among the associated fossils are internal casts of *Thracia* and of a *Pholadomya*, probably *P. konincki* (*fide* R. B. Newton). The map of the French Geological Survey applies the name Sables de Bracheux to this outcrop, but the fauna is not that of the type-locality. In some of the specimens the cancellate ornament is well defined, and in A 1939 the lines run diagonally (compare op. cit. p. 551, line 4 from end, and fig. 4).

The first point brought out in this note is the extended range in time of *Terebella cancellata* from Aptian to Thanetian.

The second point is the constant association of this form with a glauconitic facies and a fauna relatively rich in mollusca.

V.—Iceland—a Stepping-Stone.

By E. B. Bailey, M.C., B.A., F.G.S.

1. Introduction.

When in 1897 Sir Archibald Geikie published his important monograph on the *Ancient Volcanoes of Great Britain* he devoted chapter xl to a description of Iceland—so largely does our North Atlantic neighbour bulk in the eyes of British vulcanologists.

Geikie drew the greater part of his informatiom from Thoroddsen's writings, supplemented by those of Helland, Tempest Anderson, and Johnston-Lavis. His theme throughout was the conspicuous and abundant evidence afforded of fissure eruptions.

Since then various other publications have appeared dealing in English with the volcanic phenomena of Iceland. Of these we may mention three in particular:—

In 1901 Thoroddsen brought out his *Geological Map of Iceland* on the scale of 1 : 600,000. It is a truly magnificent achievement, representing much of its author's life-work in the field from 1881 onwards to 1898.

In 1909 Suess supplied further summaries of Thoroddsen's results, especially in regard to ring-fractures, cauldron-subsidences, and earthquakes. His descriptions, accompanied by two of Thoroddsen's small-scale maps, will be found on turning to vol. iv, p. 262, of the Sollas (English) edition of *The Face of the Earth.*

In the same year Clough, Maufe, and the present writer contributed a resumé of Spethmann's 1908 paper[1] on Askja, Iceland's greatest volcano. This short account is illustrated by Spethmann's own map, and starts on p. 666, vol. lxv (1909) of the Quarterly Journal of the Geological Society. Its intention is to facilitate comparison between the cauldron-subsidences of Askja, in Iceland, and of Glen Coe, in Scotland—Askja, of post-Glacial age, with its deep caldera and its rim-craters and solfataras; Glen Coe, of Lower Old Red Sandstone age, with its caldera form obliterated by erosion and its external ring of intrusions bared by the same agency.

Since Glen Coe was described much has been written by members of the Scottish Geological Survey on ring-fractures and ring-intrusions; notably by Maufe in relation to Ben Nevis, and by Wright, Richey, Clough, and myself in regard to Mull. As time goes by the value of a knowledge of Thoroddsen's observations in Iceland becomes more than ever apparent. Accordingly some years ago I prepared an abstract of "Die Bruchlinien Islands und ihre Beziehungen zu den Vulkanen",[2] a paper already referred to by Suess. This abstract, rearranged, forms Part 2 of the present communication. Part 3 is a definitely speculative venture, in which Suess is in large measure adopted as guide, though in certain important matters his conclusions are set aside.

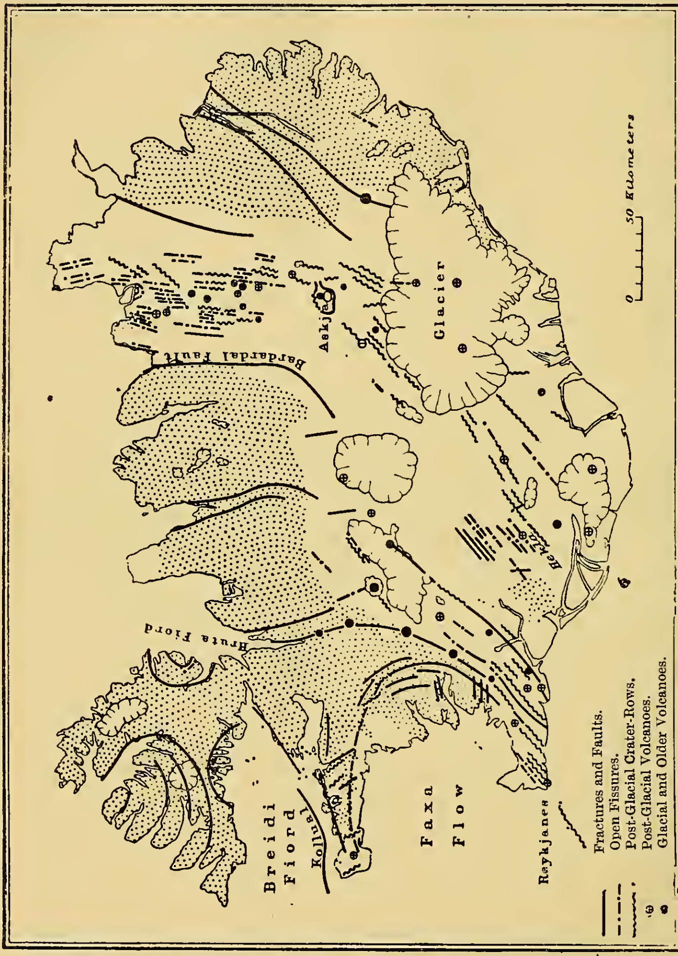
The map of Iceland, p. 468, is based essentially on Thoroddsen's 1905 map, somewhat reduced in scale, and with the earthquake districts and much of the topography omitted. The outcrop of the Older Tertiary Lavas is an additional feature derived from Thoroddsen's 1901 map. It should also be pointed out that Thoroddsen merely shows the Askja Caldera as a geographical feature, whereas in accordance with Spethmann's observations I have ventured to surround it by a ring-fault, with a minor subsidence indicated inside.

[1] "Vulkanologische Forschungen im östlichen Zentralisland": Neues Jahrb., xxvi, Beilage-Band, p. 381, 1908.

[2] Peterm. Mitth., Band li, pp. 49–53, with map and crater-plans.

2. Thoroddsen on Icelandic Fractures and Volcanoes.

Geologically, Iceland is divisible into two, an Old and a New. The Old is not continuous, but is separated by the New into an eastern and a western province. In Old Iceland basaltic lavas of early Tertiary date, comparable with those of Antrim and the



Iceland, after Th. Thoroddsen. The Early Tertiary Basalts are stippled. The more recent volcanic rocks, from the Pliocene Breccia Formation onwards, are left plain.

Hebrides, are everywhere exposed to view. In New Iceland these ancient lavas are concealed by widespread volcanic accumulations reaching down, in point of time, to our own day. The difference finds expression in many other ways than in the nature and age of the prevailing surface rock. As a volcanic district New Iceland is active, whereas Old Iceland is extinct.

The differentiation of the New Iceland from the Old seems to have been effected at the close of the Miocene Period, when the basaltic plateau developed fractures and began to sink. In Pliocene times numberless outbursts gave rise to a great bow of palagonite tuff and breccia, which, with its later associated lavas, is the country rock of New Iceland from coast to coast. Since then volcanic activity has been more or less continuous, always within the same restricted area: in late Pliocene times and probably also during the Glacial Period, extensive lava fields of dolerite were produced, followed throughout post-Glacial time, by widespread outpourings of basalt with very subordinate liparite; the post-Glacial basalts, considered by themselves, cover an area of little less than 11,200 sq. km.

Erosion has stripped Old Iceland of much of the spectacular accoutrements of vulcanicity. What meets the eye for the most part, is an immense pile of basalt flows dipping very gently inwards from either side towards the arcuate belt of tuff, breccia, and later lavas. Often, indeed, the early lavas are practically horizontal, more especially in the much-faulted coastal region lying between the Bardardal and Hruta Fiord Faults.

In some ways the most interesting feature of Old Iceland is the ring-fracture system (*Kreisbrüche*) of the north-west peninsula. There, lignites, clays, and leaf-beds, interbedded with the lavas, serve as valuable indices to the displacements the country has undergone. The lines of ring-fracture are sometimes marked by warm springs and parallel open cracks. And according to Suess, who evidently relies on the paper in which Thoroddsen elaborates his discovery, each ring-fault steps both the geology and the topography down towards the centre, while the intervening annular strips slope gently outwards towards the periphery.

In harmony with the ring-faults of the north-west peninsula are the cauldron-subsidences of Breidi Fiord and Faxa Flow.

The Snaefellsness Peninsula, separating these two great bays, is a horst, and consists mostly of old basalt, in part covered by the Breccia Formation and later basaltic lavas. It is cut by cross-faults locally depressing the old basalt platform below sea-level.

The sunken area of Breidi Fiord on the north, includes on its bottom a grabe called Kollual, 75 km. long and 9 km. broad. That of Faxa Flow, on the south, is bounded by faults, with a downthrow of 200–300 m., lined with hot springs and crater-rows. Faxa Flow is very liable to earthquakes, and altogether, both in its rocks and in its behaviour is perhaps in as close alliance with the New Iceland as it is with the Old. In Old Iceland, close fractures, faults, and lines of hot alkali springs occur, but not solfataras; while, except about Faxa Flow, earthquakes and glacial and recent volcanoes, including crater-rows, are rare. In New Iceland, gaping fissures, graben, and solfataras (with subordinate alkali springs) are all common; so too are earthquakes, crater-rows, and big volcanoes.

There are five earthquake districts in Iceland. All border the coast, and all, save Faxa Flow, belong to New Iceland.

About as extensive as the Faxa Flow district, but reaching in the other direction, east from the base of the Reykjanes Peninsula, is a particularly complex field of subsidence and unrest. The district is broken into segments which behave independently during earthquakes, the while the great neighbouring volcanoes stand passively indifferent. Far away on the northern coast are three more earthquake districts. In the interior highlands earthquakes are rare unless in obvious connexion with volcanic activity.

The boundaries of New Iceland now deserve attention. The western margin, where not concealed by superficial accumulations, is seen to be largely determined by two arcuate faults, each with a downthrow towards the convex eastern side. The opposite margin is less definite, for here the early Tertiary lavas dip gently beneath the Breccia Formation. Of the two border-faults on the west of New Iceland the outer one is the older. It runs from the Reykjanes Peninsula northwards to the Hruta Fiord. Its course is marked by the ruins of great extinct volcanoes. The inner fault, known as the Bardardal Fault, first originated after great areas had been covered beneath post-Breccia dolerite lavas. The boundary of New Iceland where it runs east and west between the Hruta and Bardardal Faults is very obscure owing to its being hidden beneath glacial and similar surface deposits.

The topographical character of New Iceland is distinctive in the extreme. Every feature in the north runs from north to south, and in the south from north-east to south-west. This is all due to the course taken by volcanic fissures, too numerous for individual representation on a map. Many parts of the district, lowland and highland, are literally striped by them.

Often lava-flows cut by the fissures have undergone considerable subsidence. Near the head of the northern branch of the long inlet east of the Reykjanes Peninsula, an old subsidence 60–70 sq. km. in extent, and 30–50 m. in depth between two fissures known as Almannagja and Hrafnagja, sunk two or three additional metres during a violent earthquake in 1789. Of more recent date and more considerable magnitude are certain graben of the Odadahraun—the district neighbouring Askja—where, in one instance a fault-scarp 30–40 m. high continues for a distance of several kilometres.

In two instances fissures which have yielded lava, remain open and craterless; Eldgja, one of the two, in a single outburst yielded 9 c.km. of lava. But almost always a crater-row has been erected along the course of an active fissure. Such rows extend sometimes from 10 to 35 km. The craters vary greatly in form: they may be elongated, or they may have one ring within another, or one wall collapsed, the other standing. Their height is commonly from 10 to 200 m.

A fissure sometimes continues open for as much as 15 km. at a stretch. Looking down into it one generally notices water or snow. It is difficult to separate the non-volcanic from the volcanic, for many a fissure of non-volcanic aspect where first encountered is found to have poured out lava at some other part of its course. Small parallel fissures without volcanic activity often accompany the more important volcanic fissures.

Generally a fissure is only used once, but the well-known Laki fissure, with its crater-row dating from 1783, carries upon itself a crater of prehistoric age.

Most of the volcanic fissures are not accompanied by faulting, though this is a rule to which there are numerous exceptions. Two more examples may be quoted.

One of a series of graben occurring 25 km. east of Myvatn—north of Askja—had for a time fault-scarps 10–20 m. high, 15 km. long, and 400–500 m. apart. During a great earthquake in 1875 lava rising along the western wall, filled this depression. Then a crater row 22 km. long was developed, and poured out 300 c.km. of lava. The Ögmundarhraun lava in the neighbourhood of Krisuvik—east of Reykjanes—is also interesting in this connexion. It issued in 1340 from two parallel fissures. The southern part of the strip between these fractures has sunk 66 m. since the beginning of the outflow, and on the western wall overlooking the subsidence are the halves of four bisected craters of which the corresponding halves have been carried downwards.

A major fault has not always located the volcanoes of its neighbourhood. These are often situated on parallel fractures, *especially on the upthrow side of the great dislocation.* I have ventured to italicize the foregoing statement, as it is so reminiscent of the distribution of the intrusion which rose along the fault boundary of the cauldron subsidence of Glen Coe. The Icelandic examples chosen by Thoroddsen to illustrate this tendency are as follows :—

For 50 km. a fracture reaches from Krisuvik (east of Reykjanes) to Hengill, where the northern side has sunk 200–300 m. Parallel with it on the upthrow side is a wonderfully continuous system of crater-rows borne on subsidiary fractures. A similar case occurs on the south side of the Snaefellsness Peninsula overlooking Faxa Flow. Here too the craters are mostly on the upthrow side.

At the same time Thoroddsen does not wish to emphasize this point. In the Odadahraun, craters mostly occur on the margins of horsts. In Myvatn, farther north, the marginal position recurs, though other crater-rows are found upon the mountain horsts. What is clear about the distribution of contemporary vulcanicity in Iceland, viewed as a whole rather than in detail, is that it characterizes a great field of subsidence—to which in the present summary the name New Iceland has been assigned.

Choked eruption-fissures and the ruins of major volcanoes persist from Tertiary and Glacial times, but crater-rows of any but post-Glacial age have been dismantled. The following statistics refer solely to post-Glacial occurrences of various types of volcanoes. Thoroddsen has counted 87 major eruption-fissures with their attendant strings of craters; 6 strato-volcanoes (Vesuvius type); 16 lava-domes (Kilauea type); 13 explosion craters and crater-groups (Puy type); 2 sub-Glacial outbursts. Of these 130 post-Glacial volcanoes 25–30 have been active during historic times.

The accumulation of material that goes to make up a great volcano, whether of the Vesuvius or Kilauea type, often renders the original dependence of the volcano upon a fissure a matter of hypothesis rather than of observation. This cannot be said, however, of the strato-volcano Hekla (1,557 m. high), which extends 27 km. parallel to the local fissures, and only 2–5 km. at right angles to them. Regarding the Kilauean domes, where the difficulty of interpretation is admittedly great, Thoroddsen summarizes his position as follows: "The geological evidence shows above all that the Icelandic domes have been built on fissures where the eruption canal has been opened so wide as to give unimpeded egress to the lavas." Askja, with its caldera 55 sq. km. in extent, he points out, is situated at the crossing of two major fissure-systems; and he indicates on his map that its caldera is margined to some extent by a crater-row (Spethmann on his large-scale map shows additional rim-craters and solfataras). He further mentions an explosion-crater as having arisen on an obvious open fissure near the edge of a considerable subsidence which in 1875 affected about a quarter of the bottom of the Askja Caldera.

The 1875 eruption at Askja, and another of earlier date, 1724, at Viti, are the only two known to have given rise to explosion craters during historic times. Both eruption centres produced nothing but ash; but the relief of pressure in each case seems to have upset the equilibrium of neighbouring districts, leading to great subsidence and fissuring, and to an immense outpouring of lava.

Viti enjoys the rare distinction of being to all appearance unconnected with any fissure that has reached the surface. It has built but a small cone, so that the surrounding country is open to observation.

3. Suess on Lunar Craters and Terrestrial Arcs.

In the paper already referred to, read before the Geological Society of London, Clough, Maufe, and the present writer suggested an analogy "between the Glen Coe cauldron of Old Red Sandstone times, with its girdle of fault-intrusion, and the Pacific Ocean of to-day, with its fringe of marginal volcanoes". The source of inspiration is not far to seek. While we were mapping in Glen Coe we felt as though we were reading Suess again, and that our discoveries had already been in large measure described in vol. i of that author's masterpiece.

Naturally, on the appearance of vol. iv of the Sollas edition of *The Face of the Earth*,[1] we turned with keen anticipation to those passages in which Suess develops his earlier conceptions of cauldron-inbreaks and arcuate structures in general. We found there an introduction to Thoroddsen's work on the ring-fractures of Iceland, dealt with in Part 2 of this communication, and also much additional matter which serves as the basis of the discussion that follows.

After recalling how, at the conclusion of vol. i, he had already

[1] The many page references that follow all refer to this volume. In its footnotes the original sources may often be traced. For additional information, including several very helpful illustrations, the reader may advantageously consult the corresponding parts of tome iii of the de Margerie edition, *La Face de la Terre*.

stated that the oceanic basins of the earth originate and increase through subsidence and inbreak, Suess turns his attention to the "seas" and craters of the moon, and suggests that Iceland with its ring-fractures and cauldron-subsidences may furnish us with a true conception of the lunar surface (p. 598). He develops this comparison in some detail, and then passes on, as one might expect, to Southern Italy, and claims the Calabrian earthquakes as marking the growth of a caldera of lunar type under our very eyes, with the Lipari volcanoes at its centre and Etna on its periphery.

Suess also refers (p. 595) to a well-known tendency of major craters of the moon to carry minor craters "riding" upon their margin—as Etna may be said to ride upon the Calabrian cicatrice. He suggests that this riding on the ancient rampart may be accounted for as a result of peripheral fissuring. His terrestrial analogues he derives from Italy; but, had he known, he might have pointed once more to Iceland, to the rim-craters of the Askja Caldera; or he might have invoked the aid of Scotland, and interpreted the riding craters as the surface manifestation of ring-dykes of the kind now known to occur at Glen Coe, Etive, Ben Nevis, and Mull.[1]

It appears from what Suess says that he had no hesitation in classifying together cauldron-subsidences of the most diverse dimensions. On the one hand, he compares the cauldron-subsidences of Iceland with certain sinkings which have followed in mining districts upon the extraction of salt, or the draining of a substratum of quicksand (p. 264); on the other hand, he links them with lunar craters and with depressions of oceanic extent, whether lunar or terrestrial—although admittedly with increased extent the circular form tends to disappear (p. 598).

This grouping of large and small may be quite mistaken, but it is likely to be accorded a very general sympathy. The most diminutive of the phenomena chosen by Suess for comparison is a series of arcuate fissures found by him in an asphalt pavement which was sinking differentially as compared with its curbstone (p. 503). "The subsidences of the asphalt pavement take place," he says, "on the concave side of each of the several arcuate fragments. . . . A similar process seems to have occurred in the north-west of Iceland." One should not forget, however, that important exceptions are afforded along the western margin of New Iceland, where Thoroddsen finds the downthrow on the convex, and not the concave, side of the boundary faults.

Leaving Suess for a minute it may perhaps be profitable to draw attention to other instances of what appear to be ring-fractures on a small scale. About 3 per cent of the older cracked picture surfaces of a collection such as that of the National Gallery in

[1] The investigation of these occurrences has been among the happy duties of the Scottish Geological Survey. Those mainly employed on the work have been H. B. Maufe, C. T. Clough, H. Kynaston, W. B. Wright, J. E. Richey, and myself. Many of our results are given in two Survey publications, *The Geology of Ben Nevis and Glen Coe* (1916) and *Summary of Progress for 1914* (1915).

London show very well-defined groups of circular fractures. They occur in concentric systems side by side with the more usual irregular cracks of the type known to geologists as suncracks—from their frequent development in drying clay. Circular fractures play a much greater rôle in the general crack system of less carefully guarded canvases. In fact, almost every out-of-door painted canvas, or linoleum, carrying a notice or advertisement, or stretched to cover a tradesman's cart, shows circular fractures at one place or other of its surface. Perhaps these fractures are analogous to the circular cracks of a broken pane of glass, and in any case great care should be taken in their interpretation. Indeed, they may not deserve the name of ring-fracture at all. A ring-fracture in geology follows a more or less cylindrical surface, and it should be remembered that quite other fractures, better styled cone-fractures, have an equally marked tendency to arcuate outcrop. Cone-fractures are now well known through Harker's work on the inclined sheet system of Skye and the later researches of others on the analogous systems of Mull. But returning from this digression, let us recall the most numerous ring-fractures of recent times. They originated in concentric systems within and about shell-craters, when the impalpable dust of the inner slopes contracted, and no doubt at its lower levels flowed, after its first wetting by a shower of rain.

The occurrence of arcuate volcanic fractures in Iceland, sometimes with a great radius of curvature and determining the site of major volcanoes, seems to lead naturally to a comparison with other volcanic arcs such as that of the Aleutian Isles. But Suess does not follow this line of approach. For him Icelandic arcs are a phenomenon of subsidence, whereas the mountain arcs, with which he classes the Aleutian Isles, are a phenomenon of lateral compression. I venture to think that if he had lived much longer he would have claimed a community of origin for the two systems of arcs. His ideas in this connexion seem to have been undergoing evolution as he wrote.

Early in his scientific career Suess started out to study the development of the Alps. He travelled far, and, though outstripped as time went on by certain of his comrades, he had good reason to be content. He could afford to let others struggle on towards the coveted summits of Alpine interpretation, while he lingered at a lower level; for he had learnt to use the writings of others as an astronomer uses a telescope, and through them to gaze upon the face of the earth from chosen vantage points, and thus to enrich two generations of geologists with a wisdom and knowledge gathered from every corner of the globe.

It is not surprising that at first he should regard the arcuate form of the Alps as a combined result of push and obstruction. Nor is it surprising that at first he should think of the Alps as typical of the other arcuate chains of the earth's surface, and extend his conception of push and obstruction to account for the configuration of the whole class.

If, like Darwin, he had learnt his geology on the borders of the Pacific Ocean he might well have had quite a different outlook in this particular. And as it is he seems to have turned increasingly to the

Pacific ranges for information regarding the essential features of arcuate mountain chains. The account he gives of them can best be realized by reproducing certain of his statements.

"Three arcuate and concentric elements occur in the Asiatic island festoons, namely, the foredeeps, the folded chains (cordilleras), and the volcanic lines" (p. 504).

In the Bonin Islands of the Pacific, concentric zones are recognized as follows:—

1. Foredeep.
2. Tertiary belt, often folded.

3*a*. Folded cordilleras, the innermost sometimes backfolded.

3*b*. The volcanic arc "*always in the cordillera, and more precisely in the zone of forefolding*, never in that of backfolding, and never in the foredeep.

"The same structure is also present in the Northern Antilles, but in these islands no cordilleras occur within the volcanic zone. In general, the cordilleras are the first to show a tendency to disappear, as may be seen in the Bonin islands, while the volcanos hold their ground with great tenacity as in the Aleutian islands" (p. 516).

"As a result of these comparisons we see that the North Antilles (probably also the South Antilles), the Alaskides and all the island festoons as far as the Philippines, the Oceanides also, and in Asia the oppositely-curved Burman arc, present a similar structure, and this structure, although less sharply defined, is also perceptible in the southern marginal arcs situated in great part on the mainland.

"The constant occurrence of the arc of active volcanos within the zone of forefolding is a remarkable fact" (p. 524).

It is not only in his descriptions of mountain chains that Suess seems to contradict his old theory. We have already referred to his observations regarding certain arcuate fractures developed during the partial subsidence of an asphalt pavement under conditions wherein tangential pressure played no part whatsoever. As stated above, he compares these arcuate fractures with those of Iceland, but he is obviously more interested in their reproduction of the phenomena of *linking* and *syntaxis*, so characteristic of the mountain systems (p. 503); moreover, he returns to their consideration when he discusses the origin of foredeeps (p. 505).

And yet his views in regard to the cause of the arcuate form of the various elements of mountain ranges do not seem to have altered. The arcuate mountain fronts he compares with certain moraines described from Greenland, where inland ice, forcing its way between nunataks, sometimes carries ground moraine up from the bottom, and spreads it in arcs over ice in front, acting the part of foreland (p. 528); and the foredeeps, he says, "are subsidences of the foreland beneath the folded mountains" (p. 295).

The difficulty of this theory is that it gives scant recognition to the volcanic arc, the Cinderella of the piece. Other workers, less acquainted with the Alps, have held that the line of volcanoes and its frequent underground equivalent in the denudation series, the line of batholiths, must be afforded a very prominent position in any interpretation of mountain structure. The references that might be given in this connexion are legion, among them chapters vi and ix of Daly's recent book *Igneous Rocks and their Origin* (1914). It is not intended here to make a general survey of the subject, but rather to sketch certain conclusions which seem to follow naturally from Suess's presentation of this phase of world geology. The main suggestions offered are as follows:—

1. The arcuate form characteristic of many of the great mountain chains can scarcely have originated through forward movement of these chains, since it characterizes the Aleutian Isles, and other typical examples, where the occurrence of forward movement has been denied.

2. Iceland, with its volcanic arcs, large and small, may well supply a stepping-stone between arcuate fractures of the type so familiar in Scotland, with their accompaniment of ring-dykes, and the vastly greater Aleutian Arc, with its serial volcanoes.

3. The development of volcanic arcs suggests tension rather than compression. The arcuate fractures of an asphalt pavement, the circular cracks of a painted canvas, the miniature landslip fissures on the slopes of a shell crater, all support this contention.

4. Arcuate fractures have often served as guides for the uprise of igneous magma. Volcanic accumulation is the surface manifestation; batholithic intrusion the corresponding subterranean phenomenon.

5. Where, as in Iceland, the magma has been predominantly basaltic, its mobility has favoured volcanic expression. Where, as in the American cordilleras, a vast supply of granitic magma has been drawn upon, or developed, its viscosity has determined intrusion on a magnificent scale. The date and manner of origin of the granite is not involved.

6. The association of a folded cordillera with a volcanic arc suggests the collapse of an unconsolidated axial batholith—a closing together of its two walls and a corresponding compression of its roof. By analogy the same suggestion holds even where the volcanic arc is absent.

In polar regions the cooling of an ice-flow often leads to a development of tension-cracks. Into these, sea-water rises to be frozen over at the surface. A return of warm weather brings the walls together, and the roof of the temporary fissure is driven up to form a ridge. The analogy between such a ridge and the Alps, though obviously very imperfect, seems to merit a passing notice.

7. The cause of a batholithic collapse need not be strictly local. At Kilauea the solid floor of the crater, after ascending gradually for years, will suddenly subside a thousand feet or so, in the course of a few days. On occasion a volcanic outburst at some point on the island accompanies this subsidence, but at other times nothing of the kind is seen, and a submarine eruption is postulated. Perhaps the outpourings of lava in the Brito-Icelandic province had a share in the upheaval of the Alps.

8. Once folding and thrusting have been developed, the outline and almost every other feature of the mountain arc must be profoundly modified. There is not only the revolution in what may be termed the home country of the chain, but also the concomitant

invasion of neighbouring territories, often on a truly grandiose scale.

9. Obstruction must be admitted as an additional factor in determining the form of a folded range. There may be much truth in the statement that several arcs of the Jura Mountains press forward into the gap furnished by the subsidence of the Rhine "like waves into a bay" (p. 526).

10. Subsidence of a foredeep may, in many cases, have resulted in part from the advance of the cordillera. Or it may, on the other hand, have helped to guide such advance. It is well to remember, however, that at present the Andes are interpreted as furnishing an illustration of back-folding turned eastwards, away from the long belt of subsidence which seems to merit the designation foredeep (p. 497). And also that central subsidences are claimed in well-known cases, such as that of the Lombardy Plain, to which Salomon ascribes the peripheral uprise of the tonalite of Adamello (p. 560).

VI.—Some American Papers on Volcanoes.

"The Present Condition of the Volcanoes of Southern Italy," by H. S. Washington and A. L. Day. Bull. Geol. Soc. America, vol. xxvi, pp. 375–88, 1915.

A study of the conditions prevailing at Vesuvius, Etna, and the Æolian Islands in the summer of 1914.

Puff Cones on Mount Usu," by Y. Oinouye. Journ. Geol., vol. xxiv, pp. 583–6, 1916.

The writer watched the eruption of July–August, 1910, and paid several later visits. He describes puff-cones formed on mud-flows from small craterlets: they developed about a year after the eruption and are attributed to escape of gas.

"An Unusual Form of Volcanic Ejecta," by W. E. Pratt. Journ. Geol., vol. xxiv, pp. 450–5, 1916.

A description of concretion-like bodies found in the ash of the Taal volcano, Luzon, in February, 1911. They appear to have been formed by the coalescence of dust and water vapour in the air, forming mud-balls, and may be described as "volcanic hailstones".

"Notes on the 1916 Eruption of Mauna Loa," by H. O. Wood. Journ. Geol., vol. xxv, pp. 322–36 and 467–88, 1917.

An amplification and correction of earlier observations, giving a large amount of detail as to the special features of this eruption, which included an outburst of fumes followed by lava-flows.

"Activity of Mauna Loa, Hawaii, December–January," 1914–15, by T. A. Jaggar, jun. Amer. Journ. Sci., vol. xl, pp. 621–39, 1915.

An amplification and revision of a previous paper, with a description of an ascent of Mauna Loa and the phenomena observed. It is concluded that this outbreak was a preliminary summit-ebullition of an eruptive period.

"Explosive Ejectamenta of Kilauea," by S. Powers. Amer. Journ. Sci., vol. xli, pp. 227–43, 1916.

Ash deposits are found on the flanks of all the volcanoes of Hawaii. Those of Kilauea represent two eruptive periods, one prehistoric, the younger dating from 1789. The products of the latter consist of bombs, ash, and "thread-lace" scoria, this being the extreme phase of pumice, lava froth carried by the wind.

"Effects in Mokuaweoweo of the Eruption of 1914," by H. O. Wood. Amer. Journ. Sci., vol. xli, pp. 383–408, 1916.

A description of the effects in the summit crater of Mauna Loa of the eruption of November–December, 1914, as observed on three ascents. Maps and photographs are given, showing the changes produced by this outbreak.

"Volcanological Investigations at Kilauea," by T. A. Jaggar, jun. Amer. Journ. Sci., vol. xliv, pp. 161–220, 1917.

The writer recognizes two types of lava in Halemaumau pit; bench magma, which is the main filling of the lava column, and lake magma, which fills saucers and shafts. The former is a product of solidification above normal viscosity, the latter is liquefied below normal viscosity. Measurements of the temperature of the lava are recorded.

"The Lava-flow from Mauna Loa, 1916," by T. A. Jaggar, jun. Amer. Journ. Sci., vol. xliii, pp. 255–88, 1917.

A very detailed description of the lava-flow of May, 1916, which brought to a close the eruptive period of 1914–16. Diagrams are given summarizing the relations of the outbreaks to local seismicity and to the fluctuations of the lava-level in Kilauea. Mauna Loa and Kilauea are believed to be connected as correlated gas vents and not as hydrostatic siphons.

"A Few Interesting Phenomena in the Eruption of Usu," by Y. Oinouye. Journ. Geol., vol. xxv, pp. 258–88, 1917.

After a preliminary earthquake phase, explosions gave rise to mud-flows, which later developed puff-cones. Marked changes of level occurred in the neighbourhood, and an increase in the height of the cone is attributed to the upthrust of a spine or dome.

"The Active Volcanoes of New Zealand," by E. S. Moore. Journ. Geol., vol. xxv, pp. 693–714, 1917.

There are five more or less active volcanoes, namely, White Island, Tarawera, Ruapehu, Ngauruhoe, and Tongariro, lying along a great N.E.–S.W. fissure. These are described in general terms, with a special account of the eruption of Tarawera in 1886.

"Physiographic Development of the Tarumai Dome in Japan," by H. Simotumai. Amer. Journ. Sci., vol. xliv, pp. 87–97, 1917.

A description, with maps, photographs, and drawings, of the dome formed in April, 1909, which is taken as the representative specimen of its type.

CORRESPONDENCE.

RECENT PAPERS ON THE DURHAM COALFIELD.

Sir,—In the Geological Magazine of July there is a letter from Mr. J. T. Stobbs criticizing two papers which appeared in the April and May numbers. I desire to give a short reply to this letter. The chief reason for publishing the paper dealing with the borings at Cotefield Close and Sheraton was that the cores gave information regarding an almost totally unknown facies of the Middle Magnesian Limestone, and therefore more stress was laid on the description of the Permian rocks than on those of the Coal-measures, which were only dealt with in a general manner. It may, however, be possible to deal with these and other sections in the latter strata on a subsequent occasion. I came to the conclusion after consultation with the mining engineer that the boring at Cotefield Close had entered the Coal-measures beneath the Brockwell Seam from comparison with other sections, from the character of the strata and from the structure of the country. It is true that the coals in the Ganister Series have been worked in the western part of the coalfield, but over a large portion of it the exact nature of the strata occurring beneath the Brockwell Seam are not well known. The coal-seams in these beds are not constant, are thin, and seldom worked. There are a few borings in the Ganister Series, but the strata have never been properly correlated or described. The late Professor Lebour wrote some years ago, "As a consequence of the small importance of the coal-seams known to exist in the Ganister Beds not many detailed sections of sinkings and borings can be referred to for details in the strata." These words are still true and especially true for the deeper parts of the coalfield beneath the Magnesian Limestone of Durham. Further, from a palæontological standpoint, not only the Ganister Series but the whole of the Coal-measures of Northumberland and Durham may be said to be little known. No exact knowledge of the zones in this coalfield has yet been obtained. *Aviculopecten* (*Pterinopecten*) *papyraceus*, *Carbonicola robusta*, and *Anthracomya Phillipsi* appear to be confined to definite horizons, but there still remains much work to be done on the palæontology of these rocks. I think that when the Coal-measures of the Northern Coalfield are zoned it will be found that *Aviculopecten papyraceus* is confined to the Ganister Series in this area. My note regarding it may not be found to be so quaint as Mr. Stobbs supposes. I used the generic name *Aviculopecten* because I was referring to Professor Lebour's discovery of this fossil. If Mr. Stobbs knows anyone who is thoroughly acquainted with the Ganister Series of Northumberland and Durham and could prevail upon him to write an account of these beds I am sure geologists would feel indebted to him.

In the paper "The highest Coal-measures in the Durham Coalfield" an attempt was made to give an exact description (which had never been done) of the section in which *Anthracomya Phillipsi* occurs; also to show the relation of *Ancylus Vinti*, Kirkby (*Carbonicola Vinti*, Hind), to *Anthracomya Phillipsi* as they occur associated together in this section, and to give as complete a list of the fauna and flora as possible. Dr. Trechmann and I certainly never thought we were the first to record *Anthracomya Phillipsi* from this bed, and are sorry if Mr. Stobbs thinks we have done him an injustice by omitting to refer to the papers he mentions.

David Woolacott.

August, 1919.

GAPS IN THE *MUCRONATA* CHALK OF THE ISLE OF WIGHT.

Sir,—Last autumn I happened to be in the neighbourhood of Ryde Waterworks and paid a visit to the "pit" there (No. 45 of Dr. Rowe). I found on the talus two fossils, which, owing to a long illness which has left me crippled, I was only recently able to examine thoroughly. They proved to be unmistakable specimens of *Echinocorys scutatus* var. *subconicus*, a typical and exclusive fossil of the zone of *Bel. mucronata.* They were found at the extreme south end of the talus and presumably came from the south end of the exposure. This end of the exposure is at least 150 feet from the Chalk boundary as mapped, and though the dip at this point appears to be unusually low for the central ridge it should be safe to take it as at least 60°, which would give a *minimum* of 100 feet of *mucronata* Chalk at this point.

This makes the third of the five alleged instances of a breach completely through the *mucronata* zone to be definitely discredited. The other two instances, near Freshwater, remain subject to the criticism which I passed on them in the Geological Magazine for August, 1918, reinforced by the fact that in the northern part of the pit, west of Freshwater, I have found *Membraniporella manonia*, which in my experience is rigidly confined to the lower part of the *mucronata* zone, and *Herpetopora*, a genus which is extremely rare in the *quadratus* zone, but in the Isle of Wight is almost abundant in the *mucronata* zone.

May I take the opportunity of recording that I have found brachials, presumably of *Uintacrinus*, in the upper part of pit 36 of Rowe, who does not record *Uintacrinus* there, although he maps it, and at the head of Freshwater Bay on the west side, which involves some shifting of the mapped boundary, and that the Isle of Wight has had scant justice done to it as a locality for *Stephanophyllia*. I have examined the *T. lata* Chalk of Compton Bay on three occasions for periods ranging up to three-quarters of an hour, and my smallest bag was ten specimens. I found two specimens in my only search of the same zone at Culver Cliff, and five in a short search of the *H. subglobosus* zone of Compton Bay. With specimens from the Chalk Marl and Chloritic Marl of the Isle of Wight, and of course elsewhere, and a specimen from the *quadratus* zone of Sussex to bridge the gap between the well-known *cor-anguinum* occurrences of Kent and the abundance of Studland (where, after Dr. Rowe's party had swept the section, I once found sixteen specimens in a day) and Weybourne, *Stephanophyllia* is much more freely distributed in the Chalk than is likely to be generally realized.

R. M. Brydone.

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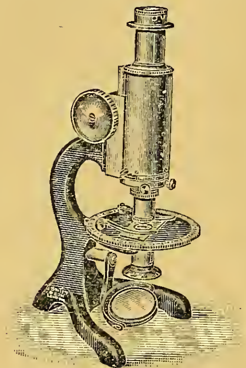

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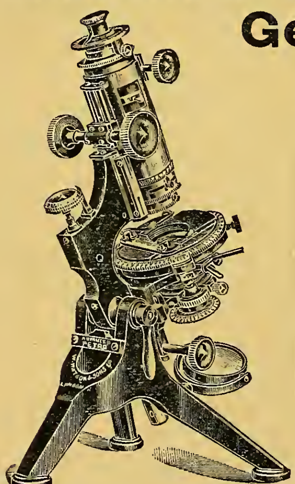

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EDITORIAL NOTES.

THE Editors have no doubt that readers would attribute to its true cause the remarkable lateness in appearance of the October number of the Magazine. The reason, of course, was the railway strike, which upset the mails at the period of the month most critical from the editorial point of view. One set of proofs took no less than nine days in transit from printer to editor and after that had to be sent to the authors and returned. Besides the delay, another consequence followed, namely, that the final contents of the number were not at all what the Editors originally designed them to be. After much waiting for delayed proofs, it was finally decided to make up the number from what material was ready, regardless of the traditional plan; this accounts for the absence of any Reports and Proceedings or Reviews in that number. It was hoped to give abstracts of papers read at the British Association and a portion of the Presidential Address to Section C, but fate willed otherwise and the final result was a number almost entirely composed of original papers, which is quite contrary to the usual practice. This procedure will not, it is hoped, be taken as a precedent, and every endeavour will be made in future to maintain the established features of the Magazine, so far as the disturbed conditions of the time allow.

* * * * *

HEARTY congratulations to Sir Norman Lockyer, K.C.B., F.R.S., who on November 4 will, as editor, issue the "Jubilee" Number of *Nature*, which he commenced in 1869. The Editor of the GEOLOGICAL MAGAZINE was present amongst his numerous friends at the "sending off" dinner given by Mr. Macmillan, the publisher of this worldwide serial, which will on November 4, 1919, issue its 2,600th weekly number. This journal embraces in its pages information on every branch of natural knowledge during the past half-century. Long may *Nature* flourish, and may its editor and publisher still share the continued prosperity of this cosmopolitan and successful scientific weekly.

* * * * *

WE feel sure that all those geologists who make use of the library of the Geological Society will hear with much regret that Mr. C. P. Chatwin has resigned his post as Librarian to the Society in order to take up a teaching appointment at Liverpool University. Mr. Chatwin came to Burlington House in May, 1913, and soon won golden opinions in every quarter, both on account of his wide knowledge of geological literature and his unfailing courtesy and helpfulness to those in search of information. During the War, owing to the depletion of the staff he took on his shoulders the principal weight of the Society's business, attending to many of the duties which ordinarily devolve on other officials, in addition to heavily increased work in the Library, largely owing to the demands of the naval and military authorities for maps and publications dealing with the geology and geography of the various theatres of war. Mr. Chatwin leaves Burlington House with the hearty good wishes of his colleagues and friends for his future prosperity in his new sphere of work, which will doubtless give him opportunities of continuing and extending the researches in palæontology on which he has long been engaged.

* * * * *

The annual course of twelve lectures on geology under the direction of the Swiney Trustees and in connexion with the British Museum (Natural History) will be given by Dr. J. D. Falconer, the subject being the Geology and Mineral Resources of the British Possessions in Africa. The lectures will be given in the Theatre of the Imperial College of Science (Royal College of Science, Old Building), Exhibition Road, South Kensington, on Mondays, Wednesdays, and Fridays, at 5.30 p.m., beginning Monday, November 10, and ending Friday, December 5. The lectures will be illustrated by lantern slides and admission is free. We cannot afford space to reproduce the whole of the interesting syllabus, but the following dates and titles of the lectures may be found useful. November 10, The Continent of Africa. November 12, 14, and 17, The Union of South Africa. November 19, Bechuanaland and British South-West Africa. November 21, Rhodesia and Nyasaland. November 24, Uganda, British East Africa, and Somaliland. November 26 and 28, Egypt and the British Sudan. December 1 and 3, British West Africa. December 5, Summary and Conclusion.

* * * * *

Two important geological collections of more than local interest have recently been acquired by the Hull Municipal Museum, viz. the Drake and Bower Collections. The first was formed by the late H. C. Drake, F.G.S., who spent many years in the Scarborough district, and also collected largely among the Saurian and other vertebrate remains of the Oxford Clay in the Peterborough area. Mr. Drake was an exceptionally keen and patient collector and was very successful in extracting difficult specimens from their matrix. From the Oolites of the Scarborough and Malton districts he obtained a remarkably fine series of fish and reptilian teeth and bones, some being of altogether exceptional interest. He also carried out original work among the Cephalopods. Many additional records to the fauna of these rocks have been made as a result of Mr. Drake's researches. He was also successful in securing many important vertebrate remains from the Chalk of North Lincolnshire, which have been described in the Palæontographical Society's memoirs, the Geological Magazine, the *Naturalist*, and other publications. Some years ago he considerably augmented the geological collections in the Hull Museum, several cases being entirely occupied by his gifts. He also assisted in preparing the catalogues of this collection. The specimens recently obtained will be shown with his other fossils in due course. The other collection was formed by the Rev. C. R. Bower. Many of the specimens are described and some figured in his paper on "The Zones of the Lower Chalk of Lincolnshire" in the Proceedings of the Geologists' Association for 1918. This collection consists of over a thousand excellently cleaned Chalk fossils, carefully labelled and localized, including many of those which have been figured in his paper, as well as one of the two known examples of *Actinocamax Boweri*, the other specimen being in the British Museum. The collections are largely from the Lower Chalk of Lincolnshire and from the Chalk of Yorkshire, and there is an interesting series from the Upper Cretaceous of Dover, Folkestone, Kent, and Norfolk. Most of these specimens have been examined and verified by Dr. A. W. Rowe and Mr. C. Davies Sherborn.

* * * * *

The Cambridge University Press will shortly publish a new work by Mr. J. Y. Buchanan, whose earlier volumes of scientific and other papers are well known. It is entitled *Accounts Rendered of Work done and Things seen*, and consists of a variety of papers on geographical, oceanographical, and other subjects, such as "The Colour of the Sea", "The Sperm Whale and its Food", "Air-tight Subdivision in Ships", "The Daintiness of the Rat", etc.

* * * * *

Mr. Frederick Chapman, A.L.S., has been appointed part-time lecturer and demonstrator in palæontology at the University of Melbourne. He will take up his duties in March, 1920.

Imperial Mineral Resources Bureau.

With reference to the announcement of the Minister of Reconstruction that the Imperial War Conference, after considering the report of a Committee of which Sir James Stevenson, Bart., was chairman, had made a recommendation in favour of the constitution of an Imperial Mineral Resources Bureau, this body was set up and charged with the duties of collecting information regarding the mineral resources and metal requirements of the Empire, and of advising the various Governments and others concerned from time to time what action might appear to be desirable to enable those resources to be developed and made available to meet the requirements of the Empire.

In accordance with this recommendation the Governors of the Bureau were appointed, one by the Home Government (whose representative is the Chairman of the Bureau), one by each of the five self-governing Dominions, one each by the Government of

India and the Secretary of State for the Colonies, while six representatives of the mineral, mining, and metal industries were appointed by the Minister of Reconstruction after consultation with the principal Institutes and Institutions representing those industries.

Pending the grant of the Charter to the Bureau, the Governors lost no time in laying the foundations of their work and organization. Four Committees of Governors were appointed to deal with:—

1. Intelligence and Publications,
2. Research and Development,
3. Legal Matters,
4. General Purposes and Finance,

and the further scope and development of the Bureau were outlined and decided upon.

The Governors have now received their Charter of Incorporation, and at the moment are busily engaged in putting into effect their scheme of organization.

Correspondence has been entered into between the Bureau and the Overseas Governments of the Empire, with a view to obtaining at an early date all possible information affecting the mineral and metal industries of the countries concerned. In addition certain statistical information on this subject from foreign countries is being obtained through the Foreign Office.

The Governors look forward, when the information is available, to issuing from time to time various statistical and other publications which will be of the greatest service to those engaged in the mineral and metal industries, and it will be one of the chief aims of the Bureau to issue this information as soon as it is available.

In order that the Bureau may be able successfully to discharge its functions, and issue information of an up-to-date character, the Governors are seeking the closest co-operation and assistance of the various Government Departments, Scientific Institutions, Societies, and other bodies with which the Bureau hopes to be associated.

It is the intention of the Governors at an early date to arrange for the co-option on committees of representatives of the various Government Departments, Scientific Institutions and Societies, as decided upon at the Conference which was held at the Home Office on the 14th day of February, 1919, the object aimed at being the consideration of the best means to be adopted to bring about the co-operation between the various agencies that is so much desired, and to deal effectively with special branches of the mineral and metallurgical industries.

The offices of the Bureau are at 2 Queen Anne's Gate, S.W. 1, and all communications should be addressed to the Secretary.

ORIGINAL ARTICLES.

I.—The Magnesian Limestone of Durham.

By David Woolacott, D.Sc. F.G.S.

(PLATE XII.)

Part II.

The Divisions of the Limestone—The Thrusting in South-East Northumberland and North-East Durham—The Breccias.

1. Divisions of the Magnesian Limestone of Durham.[1]

<table>
<tr><th></th><th>East.[2]</th><th></th><th>West.</th></tr>
<tr><td>Upper Red Beds.</td><td colspan="3">Marls, red marly false-bedded sandstones, thin fossiliferous dolomitic limestones, and beds of salt, anhydrite, and gypsum, 300 feet (only occur in South Durham).</td></tr>
<tr><td rowspan="2">Upper Limestones.</td><td colspan="2">Oolites (originally gypsiferous) of Roker and Hartlepool, 100 feet.</td><td>Gypsiferous oolites (proved by boring in South Durham).</td></tr>
<tr><td colspan="2">Concretionary limestone, 250 feet of bedded concretionary dolomitic and calcareous rock.</td><td>[3]</td></tr>
<tr><td>The Flexible Limestone.</td><td>12 feet.</td><td rowspan="2">Unbedded dolomitic and calcareous shell-bank of Bryozoa Reef, over 300 feet.</td><td rowspan="2">Segregated limestones.
Dolomitic limestone.
Dolomitic oolite.
Granular oolite.
Fossiliferous dolomite.[4]
240 feet.</td></tr>
<tr><td>Middle Limestones.</td><td>Yellow-bedded dolomitic and segregated limestones, 150 to 200 feet.</td></tr>
<tr><td>Lower Limestones.</td><td colspan="3">250 feet of bedded yellow dolomites and dolomitic limestones, with which are interbedded in the south of the county lenticles of grey calcareous limestone. These beds thin out rapidly to the north of Sunderland.</td></tr>
</table>

[1] Gypsum and anhydrite were probably present on all horizons, as proved by their presence throughout the limestone in the Seaton Carew boring. The Lower Limestones were probably the least gypsiferous, the eastern equivalents of the reef the most, while the segregated and concretionary rocks were in all likelihood impregnated with gypsum, and the hollow oolites of Roker and Hartlepool were originally gypsiferous.

[2] East and west refer to east and west of the reef.

[3] The exact nature of the original Upper Limestones is as yet unknown to the west of the reef. They are totally denuded north of a line drawn through Hartlepool. They have been passed through by borings in South Durham, but nothing very definite can be gathered from the description of these. The Upper Red Beds occur to the west of the reef, and the Upper Limestones are gypsiferous and in part oolitic. The concretionary limestones probably do not occur, being represented by gypsiferous rocks.

[4] Maximum proved thickness as obtained in the Sheraton and Cotefield Close borings. These beds are largely denuded in North Durham and in the south of the county are covered by drift.

The Lower Limestones reach a thickness of over 250 feet in the south of the county, and usually appear as a series of bedded dolomites or dolomitic limestones, with which are interbedded lenticular masses of highly calcareous grey limestone. They thin westwards towards the shore-line of the Permian sea, which lay on the flanks of the Pennine ridge, then partly developed. The dolomitic limestones reach a thickness of over 100 feet, but sometimes the two types are interbedded in irregular bands. The calcareous rocks are locally, as in Thickley Quarry, composed of fossils in a well-preserved state, but inorganic limestones with an occasional specimen of *Productus horridus* occur in Raisby Hill Quarry, over 100 feet in thickness. The dolomitic beds of the Lower Limestone are chemical precipitates, and the calcareous beds represent conditions when the dolomitic precipitation was arrested. When followed northwards the Lower Limestones maintain their thickness as far as Sunderland, but they thin rapidly north and west of this area; in some sections it is, however, difficult to estimate their original thickness in these directions, as their upper beds have been disturbed and displaced along the major thrust-plane of this deformed area. They are, however, only about 30–40 feet thick in Frenchman's Bay, South Shields. Many of the geodes in this limestone now lined with calcite originally contained gypsum or anhydrite. Pockets containing these minerals have been proved in the borings in South Durham.

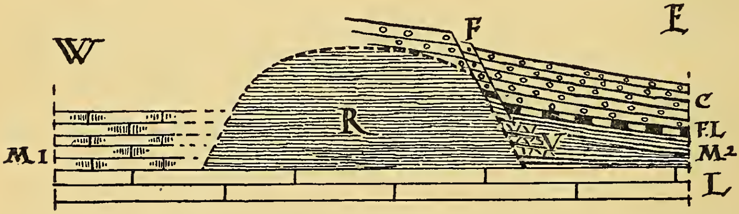

Fig. 1.—Diagrammatic section across the Bryozoa Reef to show the relations of the different divisions of the Magnesian Limestone to it. L, Lower Limestones. M_1, the western equivalents of the Reef, fossiliferous and unfossiliferous dolomites, granular dolomites, dolomitic oolite, and calcareous segregated rocks. R, the Bryozoa Reef. M_2, the eastern equivalents of the Reef, unfossiliferous dolomitic limestones, dolomitic oolite, calcareous segregated rocks, breccias, and pseudo-breccias. V, interbedded fossiliferous breccia—the Vor-reef. FL, the Flexible Limestone. C, the Concretionary Limestone. F, slickensided slip-planes. The length of the section is about two miles. The Bryozoa Reef is over 300 feet thick.

The Middle Limestone is of special interest as it exists under three distinct facies, and it was undoubtedly this fact that was one of the main difficulties in understanding the stratigraphy of the Magnesian Limestone. Running right through the division is the shell-bank of the Bryozoa Reef, usually called the Shell or Fossiliferous Limestone. It is generally about a mile across, and its total original thickness was over 300 feet. In the north it has been highly denuded, appearing as a series of rounded knolls, and is distinctly traceable, running across country for a distance of 20 miles. It is dissected on Down Hill (Boldon Hills) and Claxheugh, near Sunderland, and to the south can be seen on the knolls and old quarries of Humbledon and Tunstall Hills, and in Fox Cover Quarry, Seaham Harbour. One of the best fossiliferous exposures occurs on the flanks of Beacon Hill, and it is exposed in old quarries at Easington and Horden, finally disappearing beneath the upper beds south of Castle Eden Dene. The sinking at Blackhall Colliery went right through this reef on its eastern flank, and Trechmann was able to study its fauna in an exceptional way. It was there 335 feet thick and was overlaid by Concretionary Limestone. In appearance and fauna it is similar to the Bryozoa Reef of the Zechstein of Thuringia.[1] Trechmann considers it to have been formed 10 or 12 miles from the western shore of the Permian sea.[2] It was originally a shell-bank—the Brachiopods and other forms sheltering among the Bryozoa—upon which was settling fine calcareous and dolomitic sediment. A great portion of the organically formed part of the limestone has undergone secondary dolomitization, either pene-contemporaneously with deposition or long after (both processes may have taken place), but some parts of the whole limestone are still calcareous. Near the reef in the off-shore equivalents there is an interbedded fossiliferous breccia, which was a Vor-reef formed of blocks broken off by the waves,[3] i.e. the Shell-Limestone Conglomerate of Howse exposed at Blackhall Rocks and in Hesleden Dene[4] (Photograph, Pl. XII, Fig. 2). On its western side current-bedded oolitic dolomites have been noticed in Silksworth Quarry, and some of the fossils in parts of the western equivalent of the reef appear to have been drifted from it. The fauna of the Permian sea of Durham received a sudden influx of species along the area now occupied by this shell-bank owing to the depth, temperature, and salinity of the water offering fairly congenial environment. About thirty invertebrate species lived in the Lower Limestone sea in small numbers, but in the reef a hundred flourished in the greatest profusion under, however, rather hard conditions, as they never reached any large size and gradually underwent extinction, only about sixteen species being left to continue a protracted existence during the deposition of the Upper Limestones, finally disappearing from the area when the Upper Red Beds with salt were being deposited. Brachiopods, polyzoa, corals, echinoids, and cephalopods all died out with the passing away of the reef conditions, none of these ever being found in the Upper Limestones. On its east or off-shore side the reef is replaced by yellow, bedded, unfossiliferous dolomites and segregated limestones, which

[1] E. Kuste, *Geologisches Wanderbuch für Ostthüringen und Westsachsen*, p. 141. J. G. Bornemann, "Von Eisenach nach Thal und Wuther": Jahrb. königl. preuss. geol. Landesanstalt, 1883. In 1913 Trechmann and I visited Thuringia in order to compare the Permian rocks of Durham and South Germany.

[2] Op. jam cit., vol. lxx, p. 259.

[3] A Vor-reef also occurs in Thuringia (E. Kuste, op. jam cit., p. 141).

[4] The coarse fragments in this bed are more or less rounded.

are so well exposed along the middle part of the Durham coast, and which often appear as breccias and pseudo-breccias, so that they have been called the Brecciated and Pseudo-Brecciated Limestones. On the west it is represented by a stratified series of scantily fossiliferous dolomites, granular dolomites, dolomitic oolites, and segregated calcareous rocks. This series only occurs fully developed under the drift in the south of the county; in the north it has been highly denuded. It can be studied in quarries near Silksworth and in Haswell Quarry. Occasional inroads of the fauna of the reef must have taken place into the lower beds of this facies when they were laid down, but some of the fossils in them were probably drifted in from the reef.

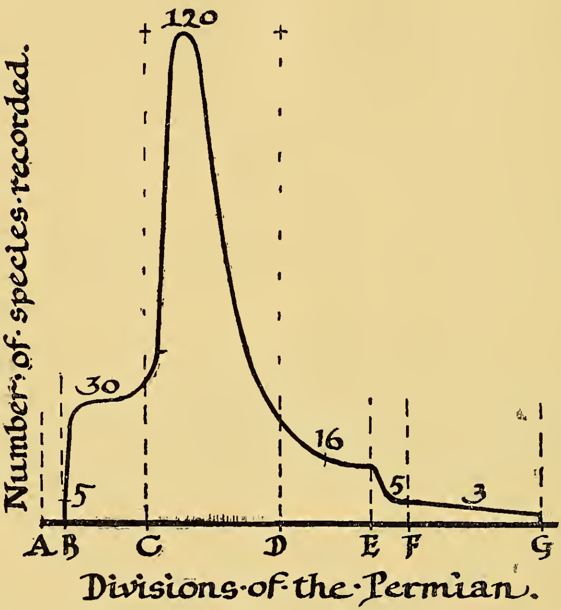

Fig. 2.—Curve showing the number of invertebrate species recorded in the different divisions of the Durham Permian. A curve showing the number of individuals would be of similar form with the height of the apex in the Bryozoa Reef enormously increased. A–B, the Yellow Sands. B, the Marl Slate. B–C, the Lower Limestones. C–D, the Bryozoa Reef. D–E, the Concretionary Limestone. E–F, the Roker and Hartlepool Oolite. F–G, the Upper Red Beds with salt.

The base of the Upper Limestone is marked by the Flexible Limestone, which I have traced all over the northern area, and the equivalent of which Trechmann has proved to occur in the south of the county. It marks a decrease in the depth of the Permian sea, recalling the Marl Slate in its laminations, occasional fish-remains, and high percentage of impurities, and seems to have been deposited under similar tranquil conditions in fairly deep off-shore waters.

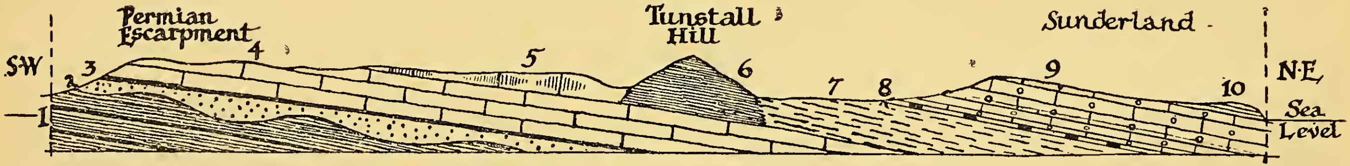

FIG. 3.—Diagrammatic section across the Permian outcrop.

1. Coal-measures.
2. Yellow Sands.
3. Marl Slate.
4. Lower dolomitic and calcareous limestones.
5. Middle fossiliferous dolomite, the western equivalent of the Reef.
6. Bryozoa Reef.
7. Middle unfossiliferous dolomitic limestones, calcareous breccias, and segregated rocks, the eastern equivalent of the Reef.
8. The Flexible Limestone.
9. The Concretionary Limestone.
10. The Roker Oolite.

The length of the section is 6 miles. The height of Tunstall Hill above sea-level is 373 feet.

It probably, however, marks a decrease in the depth of the Permian sea on the east side of the reef, due to infilling by sediment and desiccation of the area. The Upper Limestones, which thicken eastwards, were thus laid down in shallower water and over a more restricted westward area than those below. They are thus retrogressive with respect to both the Lower and Middle Divisions. Their lower beds are equivalent to the higher parts of the reef. This can be proved by a study of the sections along the coast, and from the fact that in Blackhall Colliery sinking the Concretionary Limestone rested directly on the reef.[1] They lie in a broad syncline stretching from Marsden to the south of Sunderland, and are faulted-in at Seaham Harbour. Along the coast to the south one or two small synclines and faulted-in areas occur, and at Hartlepool they are well exposed. They consist of the highly altered concretionary limestones and of the Roker and Hartlepool oolites. The latter consist mainly of strata composed of minute hollow spheres, which were originally gypsiferous oolites.[2] These oolitic beds were probably not formed in water of any great depth, as King records ripple-marked limestones from their upper layers.

Above the Upper Limestones occur red marls, false-bedded sandstones, thin fossiliferous dolomitic limestones with salt, gypsum, and anhydrite. They occur to the west of the reef, but are of limited westward extension, which was pointed out by Lebour some years ago. They were also deposited to the east of their present Permian outcrop, as Trechmann has proved that similar beds were carried in by the Scandinavian ice-sheet and left in the glacial deposits near Castle Eden Dene.[3] They mark the drying up of the Permian sea, the final stages of which are represented by the deposits of the more soluble salts of calcium, magnesium, sodium, potassium of the Stassfurt area, which were probably deposited far to the west of their present proved position.

The Permian of Durham can be readily correlated with that of Thuringia.[4] The similarity of the Magnesian Limestone with the Zechstein proves the conditions of deposition were the same. In both cases they were laid down on the edge of the Permian sea, which must have stretched during a contracted period continuously between the two areas.

In the examination of any subsequent borings that may be made in South Durham or Yorkshire there are several points of interest

[1] Trechmann, Q.J.G.S., vol. lxix, p. 213, 1913.

[2] The hollow spherules in parts of this rock are very irregular, and have been referred to as being pseudo-oolitic and concretionary. The study of the oolites in other parts of the limestone and their microscopic structure prove that both the regular and irregular spherules are ooliths. They are inorganically-formed oolitic limestones formed by the deposition of dolomite round gypsum. When this substance dissolved out the dolomitic spherules was also partly removed. The ooliths with the gypsum still remaining in them from the cores of borings in South Durham show perfect oolitic structure.

[3] Q.J.G.S., vol. lxxi, p. 65.

[4] See table giving this correlation in my paper on Permian of North Durham, op. jam cit., p. 254.

that may be looked for, having a direct bearing on some of the questions discussed in this paper. (1) Are concretionary and segregated structures developed in the gypsiferous limestones? (2) Are the gypsiferous beds demagnesified? (3) Do gypsiferous oolites occur? (Gypsiferous oolite was proved in the Newcastle Chemical Works boring north of the Tees. The cores are now in Middlesbrough Museum.) (4) Can the reef be traced southwards? *Strophalosia* and *Dielasma* (both reef fossils) are recorded by Trechmann in the Warren Cement Works boring at Hartlepool from beneath the anhydrite. It should, however, be noticed that the Magnesian Limestone as exposed in Yorkshire and further south is a shallower-water deposit than that of Durham, so that the reef may never be reached by borings through strata to the south of this county.

The Thrusting in the Northern Area.

The northern area of the Durham Permian differs from the southern in a more extensive brecciation and disturbance of the strata. This results from the horizontal movements which can be proved to have acted in the northern area, but which appear to have had little effect in South Durham. Thus in the latter region unshattered segregated rocks occur, while in the northern area these rocks are usually brecciated. There is also much less general deformation and disturbance of strata in the south than in the north, and major and minor thrust-planes are not noticeable.[1] It is, however, probable that many of the fissures which form a feature of the middle and southern part of the Durham coast are tension phenomena produced at the end of the period of thrusting, when the pressures were relieved by the movement and the shattering of the strata.

The evidence proves that the horizontal movements, the effects of which are so clearly exposed in the Coal-measures along the south-east coast of Northumberland,[2] and the similar displacements which have produced such marked structural features in the Permian of South Northumberland and North Durham, were produced by the same cause. The effects of the thrusting can be clearly seen at many points along the coast from the north of Whitley to a few miles south of Sunderland, a total distance of about 15 miles, and inland on the Boldon Hills, at Claxheugh, and under the Sunderland district over an area of several square miles.[3] Stratigraphically the thrusting has affected several hundreds of feet of strata, and structures,

[1] It should, however, be noticed that the line of principal thrusting in the north (i.e. the junction between the Lower and Middle Limestones) is not exposed along the coast in the southern area.

[2] Lebour & Smythe, Q.J.G.S., vol. lxii, p. 530, 1906; Haselhurst, Proc. Univ. Durham Phil. Soc., vol. iv, pt. iii, p. 162, 1912; and Woolacott, "Geology of N.E. Durham and S.E. Northumberland": Proc. Geol. Assoc., May, 1912.

[3] The thrust at Marsden is described in Univ. Durham Phil. Soc. Mem., No. 1, 1909; at Claxheugh and on Down Hills in Trans. Nat. Hist. Soc. of Northumberland and Durham, N.S., vol. v, pt. i, p. 155, 1919; and a detailed account is given in my paper on the northern area of the Durham Permian, Proc. Univ. Durham Phil. Soc., vol. iv, pt. v, 1912.

displacements and disturbances caused by it can be seen in the Coal-measures, Yellow Sands, Marl Slate, Lower, Middle, and Upper Limestones. The remarkable feature about the thrusting is that it is directed to a more or less central area to the south of Marsden. The only exception recorded to this is the well-known case of thrust and unconformity in the Coal-measures at Whitley.[1] At this place Lebour and Smythe regard the thrusting as being directed towards the north, the massive upper sandstone having moved over the shales, etc., beneath it from south to north, but from my detailed study of the district I have for a long time regarded the Whitley section as a "lag fault", i.e. the under beds have moved south under a southerly directed pressure, leaving the massive sandstone behind. The result is the same, but this explanation of this section is necessitated, as the force acting along the Northumberland and Durham coast towards Marsden was a general southern one, and the movement of the strata was in that direction.[2] In my paper on the Permian of North Durham I give a map showing the direction of the thrusting movements that have been recorded in the Coal-measures and Permian of this area.

The Magnesian Limestone of Durham offers exposures of some of the structures which have been proved to exist in other regions of more intense thrusting, in so far as they could be impressed on these rocks by the magnitude of the pressures acting and on beds of such little variation in mineral composition. It is noticeable that in the strata affected by the thrusting flow-structures are not extensively developed.[3] It is only in portions of the softer rocks and along thrust-planes that incipient flow-structures occur, while brecciation, fracturing, etc., are developed on an extensive scale. These rocks are therefore of interest as giving an example of thrust movements affecting beds within the zone of fracture,[4] although locally parts of the rocks lay within their zone of flow. I have endeavoured to prove that the magnitude of the pressures acting in the Marsden area reached 300 tons per square foot.[5]

The marked effects produced by these horizontal movements in the Permian—movements which do not appear to have been greater than some 300 feet in displacement—are probably partly due to the cavernous, cellular, and porous nature of the rock caused by the removal of the sulphates which probably had been largely removed before the thrusting took place, although I think the rocks contained sulphate solutions at the time the pressures acted (Geol. Mag., October, 1919, Pt. I, p. 459).

[1] Q.J.G.S., vol. lxii, p. 530, 1906.

[2] Haselhurst gives evidence proving the pressure was from the north at Cullercoats, Univ. Durham Phil. Soc., vol. iv, pt. i, 1910–11, and I prove that the movement at Marsden was from the north-east.

[3] Flow-structures occur in the Coal-measures at Whitley, in the limestone above the thrust-plane at Hendon, in the Yellow Sands at Claxheugh, etc., but never on a large scale.

[4] Van Hise, "Principles of North American Pre-Cambrian Geology": Sixteenth Ann. Rep. U.S. Geol. Surv., p. 589, and Leith, *Structural Geology*, p. 3.

[5] Memoir on Marsden area, op. jam cit., p. 5.

The thrust-planes, folding, compression-structures, and other evidence of horizontal movement in these rocks are quite distinct, affect beds beneath which sulphates were laid down, and cannot have been directly caused by the removal of beds of gypsum or anhydrite, although a certain instability of the strata had most probably been produced by solution of such beds before the thrusting took place. The general effect of the thrusting has been to produce a decrease in the lateral extension of the Magnesian Limestone; the rocks—Coal-measures and Permian—which have not been fractured and brecciated have been bent into broad folds. The syncline of the Permian strata beneath Sunderland appears to be the direct result of these movements (see section, fig. 9, in my paper on North Durham, op. jam cit.).

The horizontality or general low hade of the thrust-planes, the damping down of the folds, the shear and flow structures prove that a considerable weight of rock lay above the thrust horizons at present exposed at the surface, when the deformation of the area took place.

It will probably be useful to geologists and geological students if I give a brief summary of the phenomena I have observed as being directly due to thrusting, with a short discussion of one or two points to which my attention has been drawn since I first wrote my account of this district.[1] They may be summed up as follows:—

1. Major and minor thrust-planes, with slickensided surfaces both above and beneath them. These planes occur on certain horizons, the most continuous being the top of the Lower Limestone. The top layers of this limestone have acted as a base on which the more cellular cavernous rocks of the Middle Limestone have been moved. The thrust-planes are not, however, confined to this horizon: sometimes minor fractures cut down through the Lower Limestone and affect the Marl Slate and Yellow Sands beneath, so that large masses of the Lower Limestone are displaced. These planes do not pass into the Yellow Sands, which as a rule appear to have given freely to the movement. In the railway cutting at Claxheugh highly disturbed beds of Lower Limestone are thrust over beds of the reef. Thrust-planes, however, occur at other horizons than at the junction between the Lower and Middle Limestones, the most marked being exposed in the cliff at Hendon at the southern limit of the broad syncline of the Concretionary Limestone beneath Sunderland. At this place the Middle Limestone is thrust over the Flexible and lower part of the Upper Limestone.[2]

2. Mylonized rock occurs along the thrust-planes. It is best developed at the Trow Rocks and in Frenchman's Bay. This peculiar layer of rock, an inch or two in thickness, which runs along the top of the disturbed beds or along the thrust-planes, is quite distinct in colour, appearance, and texture from the cementing material

[1] Fuller evidence is detailed in my memoir on the Marsden district, my general paper on the Permian of North Durham, and the paper in the Proc. Geol. Assoc. Photographs of many of the structures described will be found in these.

[2] See section, fig. 10, in Permian of North Durham.

of the breccias or from the calcite of the segregated rocks or from the powdery dolomite in other parts of the limestone.

3. The Magnesian Limestone has seldom been deformed without fracture, so that flow-structures[1] are not produced in it on a large scale, but at one or two places shear and flow structures and strain-slip planes are developed, and at Claxheugh the Yellow Sands were sheared up for several feet over a mass of breccia. At Hendon, along the thrust-plane, incipient flow-structures (a kind of megascopic pseudo-stromatic or phacoidal structure) has been developed in it.

4. At Claxheugh shear-planes on a large scale can be seen in the reef, the rock having given under the horizontal pressures into large lenticular masses.[2]

5. Folding due to thrusting is developed on a broad scale and on a very minute one. The broad syncline of the rigid Upper Magnesian Limestone beneath Sunderland, which extends from Marsden to Hendon, and is 6 miles across, was produced by these horizontally directed pressures,[3] and the dome in Cullercoats Bay is also due to them. Folding on a smaller scale is common at Marsden, and in one part of this section overfolding can be seen. At Claxheugh and in Cullercoats Bay overfolding on a very minute scale occurs in the softer beds of the Marl Slate.

6. Compression-jointing and fracture-cleavage are developed in the Magnesian Limestone at Marsden and slightly in other areas. At Marsden the distance between the parallel partings varies from a few inches to a minute fraction of an inch, the rock fracturing along these close parallel planes and the structure being seen for over a quarter of a mile along the coast (see Memoir on the Marsden area, section, fig. 8). In my paper on that section I have referred to this fissility of the rock as cleavage, a term which has been objected to by one geologist, who obviously had not seen the Marsden section, as inapplicable in connexion with these rocks. In that paper I defined the term clearly as "the flattening of the mineral particles by pressure, so that they have a parallel arrangement with their shorter axes in the direction of greatest stress".[4] As the word cleavage is now used in connexion with rocks in two senses—"fracture-cleavage" and "flow-cleavage"[5]—I gave this definition in order to show clearly that I was using the term simply to denote a compression structure, i.e. fracture-cleavage, close-joint-cleavage, etc., and not flow-cleavage. I showed that this compression-jointing (when coarse it may be called this) or fracture-cleavage was developed at Marsden at right angles to the pressure after the folding, but before the brecciation of the rock took place.

7. Crush breccias, where beds have been thrust against a horst-like

[1] i.e. permanent change of form without conspicuous fracture.

[2] See section of Claxheugh in Trans. Nat. Hist. Soc., op. jam cit., 1919.

[3] A general section of the coast is given in my paper on North Durham, fig. 9.

[4] Memoir on Marsden, p. 10. Sorby showed that this structure had been impressed on Devonian Limestones by pressure "On Slaty Cleavage as exhibited in the Devonian Limestone of Devonshire": Phil. Mag., vol. xi, p. 20; vol. xii, p. 127, 1856.

[5] Leith, *Structural Geology*, p. 10.

mass, and shattered when the pressures developed reached the compressive strength of the rock, e.g. Marsden.[1]

8. Thrust breccias, where beds have been horizontally moved along a thrust-plane and shattered during the movement. These rocks in some cases appear to have been cellular, segregated rocks before the thrusting took place, and so were easily shattered. Such beds are seen in Frenchman's Bay, on Boldon Hills, at Claxheugh, etc.

9. Intruded breccias. Breccias which have been forced up into beds above (Jean Jiveson's rock, Ryhope),[2] or down into beds beneath (seen in a section near the Church, West Boldon).

10. Missing strata, often of considerable thickness, e.g. at Claxheugh, Down Hill.

11. Highly disturbed masses of limestone which have been moved horizontally out of their original position, e.g. near Hylton Castle, Claxheugh, Frenchman's Bay.

12. At Marsden and Hendon, on the edges of the syncline beneath Sunderland, the limestone has been fractured into large irregular blocks without appreciable displacement. These rocks I have called the "block fractured".

13. Slickensided surfaces are common and are usually found in all exposures where thrust movements have taken place. Minute slickensided surfaces have been observed in the Marl Slate at Cullercoats and Claxheugh, while a horizontal slickensided surface of some extent is exposed beneath the base of the reef at Claxheugh. The breccia of Jean Jiveson's rock is cut by several vertical slickensided planes (Photograph, Pl. XII, Fig. 1).

14. Many of the fissures, breccia-fissures, and (probably also the breccia-gashes) where formed by tension when the pressure was relieved by movement and shattering of the strata.

The Breccias.

The brecciation of the strata is one of the most pronounced features of the Durham Magnesian Limestone. In the course of this paper four or five types have been mentioned, and several causes have been referred to as having produced these autoclastic and clastic rocks. It has also been asserted that sometimes two causes may have contributed to the production of some of these shattered beds.

In a rock which over a large area has been deformed by thrusting within the zone of fracture by forces of some magnitude, and which has had removed from it beds generally more or less lenticular and probably of considerable extent, and sometimes also of great thickness (probably reaching two or three hundred feet), veins, and intercalations of one of its original constituents, it is evident that such shattering of the strata must have been brought about by these two causes, and that it may sometimes be impossible to decide how far only one of these was operative in producing particular breccias. The cause of the brecciation is further complicated by the fact that segregation and solution changes have also contributed in bringing

[1] Memoir on Marsden, p. 5 and photograph.

[2] I regard the breccia of Jean Jiveson's rock as being directly connected with the thrust-plane at Hendon about half a mile to the north.

about an unstable condition of the strata, and that contemporaneous brecciation also occurs.

The breccias may be classified as follows:—

1. *Contemporaneous Breccias.*—In the Lower Limestone as recorded by Trechmann and myself, incipient brecciation occurs.[1] The rock is minutely fractured without any appreciable displacement, a feature most probably due to shrinkage of the rock on drying.

2. *Clastic Breccia.*—The interbedded fossiliferous breccia-conglomerate of Blackhall Rocks and Hesleden Dene, i.e. the Vor-reef, is an example of this type (Photograph, Pl. XII, Fig. 2).

3. *Pseudo-breccias.*—(*a*) Some dolomitic rocks in the Magnesian Limestone assume a brecciated appearance due to the patchy development of fine yellow dolomite among the crystalline calcite.[2] These are true pseudo-breccias, and have been brought about by segregation processes.

(*b*) Some of the rocks which were called pseudo-breccias by King[3] are segregated rocks which have broken up, (1) by mere collapse due to their cellular nature when the sulphates were removed and the segregation processes complete, (2) by the letting down of these beds due to the removal of the sulphates,[4] and (3) by shattering produced by movement at the time of thrusting.[5]

4. *Autoclastic Breccias.*—Breccias directly due to thrusting include (*a*) crush breccias, (*b*) thrust breccias, (*c*) brecciated folds, and (*d*) rocks which have been broken up after having had compression-jointing impressed on them.[6]

5. *Solution Breccias.*—Breccias due to the collapse of the strata caused by the removal of beds of anhydrite or gypsum.[7]

6. The gypsiferous breccias occurring in the Warren Cement Works boring are probably due to the breaking up of the rock caused by the expansion produced by the alteration of anhydrite into gypsum.

7. *Vein-dolomitized Breccias.*—The coarse dolomitic breccias exposed in the bluestones of Raisby Hill Quarry (calcite 98–9 per cent) are due to the alteration of these rocks by magnesium, copper, and manganese solutions.

8. Breccias filling breccia-fissures and breccia-gashes. These are well exposed in the Marsden district. The vertical fissures filled with coarse breccia are sometimes 40 and 50 feet wide, and large blocks have fallen considerable distances into them.

[1] Woolacott, Geol. Mag., March, 1919, pp. 164–5.

[2] Similar rocks have been noticed by L. M. Parsons in Carboniferous dolomites. "Dolomitization and Leicestershire Dolomites": Geol. Mag., 1918, p. 250.

[3] King, Monograph of Permian Fossils, Pal. Soc., 1849.

[4] Broken up segregated rocks of the first two types occur on the eastern flanks of the reef. Vertical slickensided surfaces produced by the slipping down of these beds have been noticed by Trechmann.

[5] Shattered rocks of this type occur in the Marsden area and in the Claxheugh and Boldon Hills districts.

[6] These are all best developed in the Marsden district.

[7] The very coarse breccias south of Seaham Harbour where brecciation associated with faulting is extensively developed are probably the best example of this type.

The most widespread breccias are the autoclastic breccias in the north of the county, the broken-up beds due to the removal of the sulphates, and the pseudo-breccias. It is a very noticeable feature of many of the breccias that they are more calcareous than the dolomitic limestones from which they were formed.

Summary.

The main conclusions that have been arrived at by recent work on the Magnesian Limestone of Durham are:—

1. That the series of bedded dolomites, dolomitic limestones, and calcareous beds which form the main mass of these rocks are the result of chemical precipitation, and that they originally contained thick and thin beds, veins, pockets, and impregnations of anhydrite and gypsum.
2. That the main mass of the dolomite and dolomitic limestones was either precipitated as a double salt or formed by the combination of the associated carbonates after precipitation, and that it is possible that examples of both of these methods of formation occur.
3. That the Bryozoa Reef and small beds and lenticles in the Lower and Upper Limestones were organically formed, and consist of remains of organisms on which dolomitic or calcareous sediment settled.
4. That calcium sulphate appears to have been a subsidiary product of the deposition of dolomite and dolomitic limestone.
5. That while the main mass of the dolomite was chemically precipitated some parts, e.g. parts of the reef, etc., may have been dolomitized pene-contemporaneously with deposition and others long after.
6. That the Middle Magnesian Limestone exists under three distinct facies, consisting of a Bryozoa Reef and its bedded in-shore and off-shore equivalents.
7. That (except in the case of parts of the reef, etc.) the cellular structures in the Magnesian Limestone were not produced by subsequent dolomitization.
8. That parts of the Magnesian Limestone are more calcareous than they were originally; the non-cellular type of these "demagnesified rocks" occurs principally within the zone of thrusting, while the cellular types are the highly altered concretionary, segregated, and other rocks.
9. That the chief non-cellular "demagnesified rocks" and breccias were probably produced by the action of solutions of calcium sulphate on the dolomite, the magnesium being dissolved out as a sulphate and metasomatically replaced by calcium.
10. That the concretionary rocks may have been produced in solutions of calcium sulphate containing colloidal organic matter, the more definite spherical types being formed in regions where the organic matter was concentrated.
11. That the calcareous segregated rocks may have been formed in sulphate solutions free from organic matter.
12. That solution of part of the magnesium-content of the concretionary and segregated rocks has probably gone on, and that

(whether it has or not) the dolomitic powder, which has been or is being carried away mechanically, was set free as a result of the concretionary and segregated processes, and its removal has nothing to do with the cause of these structures.

13. That the dolomitic and gypsiferous dolomitic oolites were produced by deposition of material round crystalline grains or nuclei either as they fell through the water or lay on the bottom of the sea.

14. That the northern part of the Durham Permian (and the Coal-measures and Permian of South-East Northumberland) form a region of thrusting in which many of the phenomena of areas of more intense thrusting are exposed, and that these rocks afford an example of deformation produced within the zone of fracture.

15. That the breccias and pseudo-breccias which form such a marked feature of these rocks were produced in several distinct ways, each exposure of them requiring to be separately examined before their mode of formation can be elucidated.

Addendum.—I desire to thank Dr. Trechmann and Dr. Smythe for reading the first draft of this paper through and adding one or two notes which aided me in preparing the final paper. I do not, however, wish to make either of them responsible for any of the views expressed in this paper, except those of Dr. Trechmann which are directly quoted and referred to in the text.

EXPLANATION OF PLATE XII.

Fig. 1.—The Shell-Limestone conglomerate at Blackhall Rocks. Portion of Vor-reef of the Bryozoa Reef.

Fig. 2.—Jean Jiveson's Rock. Coast one mile south of Sunderland. This is a mass of compact calcareous breccia cut by several slickensided planes, one of which can be seen on the left. The rock was originally a dolomitic limestone, and has been altered by solution.

II.—Geology of Kinkell Ness, Fifeshire.

By David Balsillie, F.G.S., University, Edinburgh.

(PLATE XIII.)

THE largest, best exposed, and most interesting volcanic vent along the northern shores of Fife is that which has been laid bare at the headland of Kinkell Ness, and a portion of whose enclosed material has been sculptured into the picturesque shore stack known as the Rock and Spindle. ("These two words," as Sir A. Geikie points out, "are generally misunderstood. 'Rock' is the Scots word for a distaff; and 'Spindle', as here used, has reference to the stellate mass of basalt resembling a spinning wheel.") Reason for this appropriate designation will be readily gathered from the accompanying photograph (Plate XIII).

There would appear little doubt that this curious volcanic relic, whose characters are sufficiently striking to arrest the attention of the non-geological observer, was the cause of speculation and controversy in the early days of geological science—certainly before the luminous teachings of Hutton and Playfair had attained a definite ascendency over the enunciations of the Neptunists. Thus in the year 1813 the Rev. John Fleming, minister of Flisk parish on

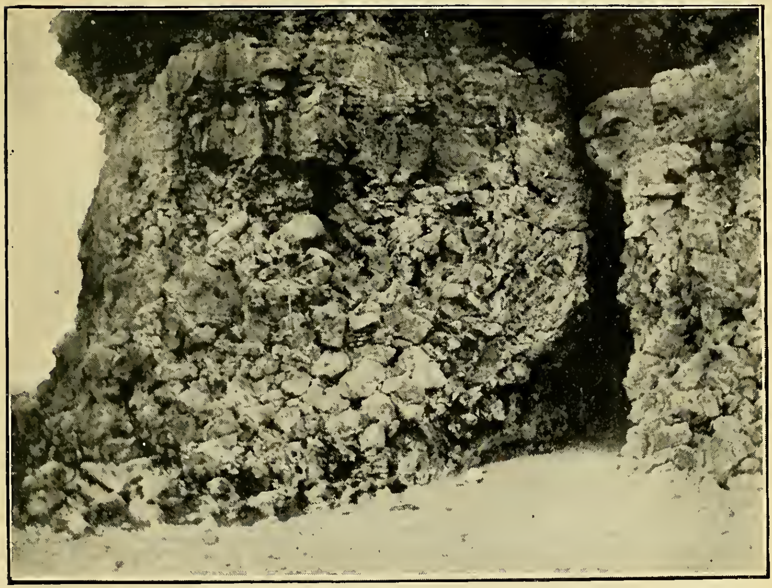

Photo. D. W.

FIG. 1.

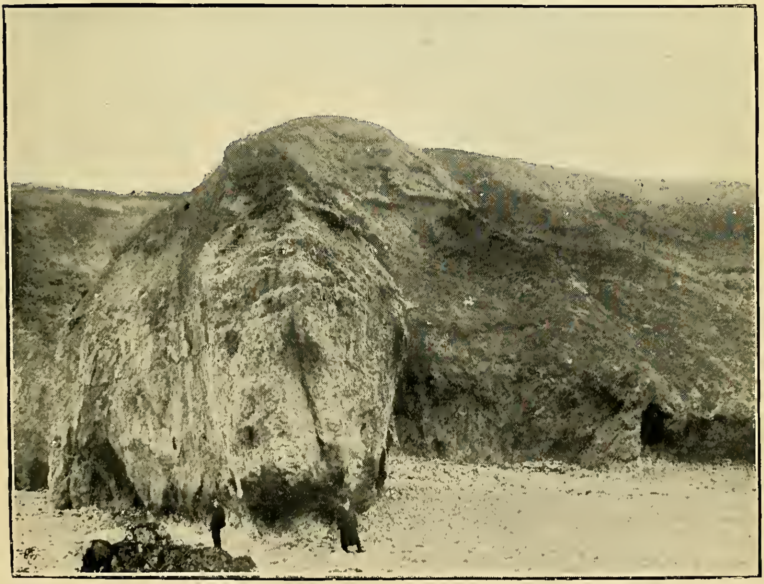

Photo. O. C. Wilmot.

FIG. 2.

the southern shores of the Firth of Tay, in a contribution to the Memoirs of the Wernerian Society,[1] gave descriptions of the remarkable "trap tuffs" in the neighbourhood of St. Andrews and relegated them in characteristic Wernerian terminology to the newest Floetz-trap formation. Referring to the agglomerate and "spherical concretion" of basalt at the Rock and Spindle he maintained that the two rocks could be seen to pass insensibly into one another, and accounted for the whole in the light of his adopted hypothesis by inferring that it was "partly a mechanical and partly a chemical deposit".

From the time of Fleming for over the next sixty years little appears to have been accomplished towards any correct elucidation of the natural history of the tuffs in East Fife. They were mapped by the officers of the Geological Survey as masses interbedded with the rocks among which they occur, and this idea found expression on the 1 inch map, sheet 41, published in 1861. Eighteen years later, however, a change in concept was brought about by the appearance, in 1879, of Sir A. Geikie's well-known paper "On the Carboniferous Volcanic Rocks in the Basin of the Firth of Forth; their Structure in the Field and under the Microscope".[2] In that paper the author, turning to account, as he himself admits, valuable experience gained on the East Lothian coast and in Ayrshire, clearly recognized the intrusive nature of many of the tuffs, and asserted that these represented the sites of former active volcanoes which must have come into eruption long after the deposition of the Carboniferous strata which they penetrate. More recently the same writer has again given an account of them in his *Ancient Volcanoes of Great Britain*, also, with amplification, in the Geological Survey memoir,[3] published in 1902.

The general outline of the Rock and Spindle vent, as may quickly be ascertained, is altogether irregular and suggests a shifting of the focus of the volcanic forces by which it was produced. Thus two nearly detached areas of agglomerate on the north may mark independent orifices. Only on the eastern and northern sides are the margins of the opening available for examination, they being concealed elsewhere beneath the grassy cliff-line and by the sand and shingle above high-water mark.

The rocks surrounding the neck, which consist in large part of thinly-bedded sandstones with thick intervening shale bands, one of which is crowded with *Naiadites*, lie not far above the Encrinite-bed, which is an easily recognizable stratum in the Calciferous Sandstone Series of East Fife, and which crops out on the beach about 300 yards to the east of Kinkell Ness. On the Anstruther–St. Monans foreshore, which is taken as the typical area for the study of the Calciferous Sandstones in East Fife, Mr. Kirkby estimated the depth of the Encrinite-bed beneath the base of the Carboniferous Limestone Series as being about 2,280 feet.[4] On the north coast of the county,

[1] Vol. ii, 1813.
[2] Trans. Roy. Soc. Edin., vol. xxii, 1879.
[3] *The Geology of Eastern Fife*, Mem. Geol. Survey, 1902.
[4] Q.J.G.S., vol. xxxvi, 1880.

however, the intervening thickness of sediments is certainly a good deal less than this.

The strata that form the northern walls of the vent have, as has been pointed out by Sir A. Geikie,[1] been "violently disrupted". Enormous masses and blocks of sandstone and sandy shale are here to be seen standing at all angles in a matrix made up in the main of non-volcanic detritus, though containing abundant pieces of white trap, which has inserted itself into cracks and fissures in the sedimentary fragments, behaving, in fact, as if it were an intruded igneous rock. These curious fragmental rocks, exhibiting always the same general characters, are to be seen over and over again along the Fife shores. They were probably at one time liquid volcanic muds, their present mode of occurrence being merely an expression of a former high degree of mobility.

To the student of volcanic geology these peripheral non-volcanic areas in the larger vents afford considerable interest. It is obvious they must have lain permanently clear of the actively erupting channel; otherwise they could not have been preserved. There is thus the implication that the actual shape of the volcanic chimney towards the earth's surface is that of an expanding cone; in other words, that in vertical section it would resemble in some degree that of a filter-funnel held the proper way up. There is, however, the alternative explanation, and one that seems very likely, that sometimes they may not have been formed early in the history of the vent at all but rather towards its close, when the upstanding sedimentary walls were undergoing disintegration and were sending down their debris into the ash around the margins of the neck.

The major portion of the opening is occupied by a dark tuff made up of lapilli and nut-like fragments of basic lava and fine ash. In this ground-mass, which is sometimes almost black from the amount of intermingled coal-dust, are distributed numerous blocks of basalt and of various sedimentary rocks. Conspicuous among the latter are rounded or subangular fragments of a grey limestone weathering white. A curious interest attaches to these. Some years ago it was found by careful examination that they contain the remains of forms of marine life such as *Lithostrotion junceum* and *L. irregulare*, as well as other corals, brachiopods, and lamellibranchs, the species being common forms in the Carboniferous Limestone Series.[2] The significance of this will be appreciated when it is recalled that the strata now surrounding the opening belong to an inferior group of sediments, namely, the Calciferous Sandstone Series. The interpretation to be placed on the observed facts would appear to be that some, at least, of the basement beds of the Carboniferous Limestone Series formerly overspread this portion of the county and were actually penetrated by the vent. The disrupted fragments became enclosed in the agglomerate which subsequently subsided within the orifice, while the overlying and surrounding sedimentary rocks have been entirely swept away. Support for this opinion is obtained from the fact that wedged in

[1] *The Geology of Eastern Fife*, p. 208.
[2] Geol. Mag., 1911.

almost vertically in the seaward extension of the agglomerate are several large masses of coral-bearing limestone whose parent stratum must have measured at least 10 feet in thickness. These almost certainly belong to the base of the Carboniferous Limestone Series.

Throughout the greater part of the vent the infilling materials show an obvious assortment. Standing about 10 yards to the east of the middle of the three conspicuously protruding masses on the beach a concentric disposition of the outcrops of the tuff layers will be visible (Plate XIII). The concentricity is, however, not perfect, the imperfection occurring towards the north, where the outcrops, instead of swinging round to complete their respective circles, are prolonged in that direction and become apparently considerably displaced. Additional reference to this fact will be made further on.

The tuff layers are often irregular and show false bedding and occasional unconformity, the latter probably pointing to prolonged intervals of quiescence in the history of the vent. Layers of fine ash alternate with zones of coarser material and frequently preserve by their indentation under a large block or bomb an interesting record of some old aerial journey that was terminated by descent into the soft accumulations along the inner slopes of the cone.

The materials of the vent have apparently suffered a good deal of faulting and displacement. Sometimes also they are traversed by veins of dark-bedded ash that transgress the stratification proper of the neck. Of these the writer has arrived at no completely satisfactory explanation. At one part there is a coarse grit containing abundant blue opaline quartzes, a number of lava fragments, and at least one large block of white limestone. The mode of occurrence of this mass would suggest that it was laid down in some old crater pool during a period of quiescence, and that the materials from which it was built up were derived from some coarse, easily disintegrable grit, while down the adjacent ash-slopes there rolled into the water an occasional lava fragment or other block of non-volcanic origin.

While, as Sir A. Geikie mentions,[1] "there is no evidence that lava was ever discharged from this vent, the ascent of molten rock in the chimney of the volcano is impressively shown by the numerous intrusions of olivine basalt and limburgite that intersect the tuff." These, as further pointed out by the same authority, are not all of one date, but belong at least to two and perhaps three different epochs of injection. The older basalt is generally a dark-green decomposing felspathic olivine-bearing rock that in the majority of cases has involved so many included fragments in its substance that its simulation of an agglomerate is complete. The only possible mode of origin of such curious and thoroughly deceptive material would appear to be that the basalt had risen in the chimney in a highly liquid condition, and that having caught up a large amount of extraneous material early in its ascent had inserted itself among the ash of the higher parts of the neck, not as a homogeneous medium but rather as a species of mobile "concrete" (if it is permissible to apply such a term to a natural product). On cooling

[1] *The Geology of Eastern Fife*, p. 210.

it will be obvious that any portion of such a mass which by chance had remained clear of xenolithic ingredients would tend to display its characteristic symmetrical jointing, the jointed igneous rock passing insensibly, as observed by Fleming, into the "agglomerate".

FIG. 1.—Diagram to illustrate structure of Rock and Spindle shore stack as seen from the east side. TT, older bedded tuffs of the vent forming the beach platform. A, intrusive basalt with included fragments. B, a portion of the basalt—forming the spindle—which, remaining clear of fragments, has jointed symmetrically. C, dyke cutting both A and B. Further references in text.

In light of what has just been said, Fig. 1 is given as representing the structure of the Rock and Spindle shore stack. The appearance of B as intrusive into A may be due merely to movement of one part of the mass against the other. The opinion is, of course, perfectly admissible that B has been introduced, while A was still uncooled and had become welded on to it. There can be no question as to the posteriority of the dyke C which stretches far out into the eastern wall of the opening, and indeed cuts another neck. It appears to belong to the final chapter in the volcanic history at this part.

The geologist walking over the beach platform of ash at Kinkell will have no difficulty in detecting by their prominence—contingent upon their superior durability—other masses of similar kind to the Rock and Spindle itself. Among these may be mentioned specially the first large stack that meets the eye on coming round Kinkell Ness from St. Andrews. This, at a first inspection, appears to be an exceedingly coarse agglomerate that encloses fragments of the older dark tuff. Careful examination, however, will again, it is believed, make clear that this is not really a fragmental rock in the ordinary sense but is intrusive in nature, some of the marginal parts of the intrusion being unmistakably basaltic both mega- and microscopically. It can readily be imagined that if any mass were to originate in the manner described and that before cooling all excess of liquid rock were to be drained away, how thoroughly deceptive in appearance it might ultimately become. Many of the smaller necks in East Fife are, one is inclined to think, filled with material of this kind and ought not to be regarded as being subaerial pyroclastic accumulations, as ordinarily understood, at all. The extreme alteration of the sedimentary fragments in such instances (as also in the corresponding parts of the Rock and Spindle) would then find satisfactory explanation, for it is difficult to understand how this could have resulted from any mere transient experience of high temperature.

Petrographically the basalt of the Spindle is interesting. It is an exceedingly black compact rock that, like the basalts of St. Monans and Elie, encloses numerous crystals of glassy felspar and dark hornblende. Being desirous of ascertaining whether it further resembled the similar rocks on the south coast of the country in containing any felspathoid the writer had several sections of it cut and submitted these to Dr. Flett. He reports, as the result of his examination, that though the olivines are too greatly altered for one to expect nepheline to be now recognizable, nevertheless he believes that in one of the slides he can identify this mineral. He remarks on its strong resemblance to the Elie rocks and further compares it with the crystalline rock that occurs in the neck on the foreshore at John o' Groats.[1] Dr. Robert Campbell, who has also examined the slices, concurs in this opinion, and says that whether nepheline is now recognizable or not is a matter of small importance, as the general resemblance of the Spindle basalt to the Chapel Ness and other neck basalts of Elie is so remarkably close as to place their related origin beyond question.

Another curious and perhaps somewhat unusual fact is that the basalt of the Spindle contains numerous fish-teeth, enclosed apparently directly by the igneous rock; at all events no example has ever been found with attached sedimentary matrix. They appear to have been caught up directly by the basalt and ought thus to afford, if they could be specifically identified, important evidence as to the geological age of the vent. In the hope, therefore, that at last it might be possible to settle definitely a much controverted question a number of these remains were collected and handed to Dr. Flett, who forwarded them to Dr. Smith Woodward. This distinguished palæontologist thought at first that he could identify one of the specimens as belonging to *Rhizodus*, but further reported: "I have now an excellent micro-section of the tooth (in basalt) which I supposed to be Rhizodont, but, although I think there is no doubt about its being a tooth, all the structure has been destroyed and the specimen shows only the pulp cavity and cracks. Unless,

[1] *Geology of Caithness* (Mem. Geol. Surv. Scot.).

therefore, specimens can be got with the outer contour preserved it will not be possible for me to name or determine the age of these teeth." Unfortunately I have not so far had opportunity of searching for better specimens.

In further reference to the age of the Rock and Spindle vent it may at first serve some useful purpose to regard it merely as one of a great connected series and discuss briefly the general question of the antiquity of the necks in East Fife.

As has been pointed out by Sir Archibald Geikie,[1] not only are the necks later than the strata through which they rise, they are later also than the development of the tectonic features, i.e. the plication and faulting of the area. One particularly interesting example confirming this which does not formerly appear to have been brought to notice occurs on the beach just where the Encrinite-bed comes to the surface east from Kinkell Ness. Here it can be seen that a vent has risen along the line of a fault but has not had its enclosed materials shifted by the fracture, although the Encrinite-bed and its overlying *Naiadites* limestone are cut off and have been displaced considerably to the north-west. Sir A. Geikie believes, and, one is inclined to think, rightly believes, that if we regard the vents as belonging to one period, and that is an important point, then not only are they later, but a good deal later, than the youngest Carboniferous strata of the district. The next matter, therefore, to settle is, how long posterior to the youngest Coal-measures are they?

Further, briefly summarizing Sir A. Geikie's opinions on the matter it may be stated that he correlated the vents in East Fife with certain vents in Ayrshire which are believed to be of Permian age. He argued that the now visible parts of the necks, consisting in many cases of bedded ashes and tuffs, could not be far removed from the actual crater bases of the old volcanoes, and that therefore there could not have taken place since Permian times such an amount of erosion as one might reasonably expect. He concluded that the whole district must have been buried under younger—possibly Mesozoic—deposits, and in this way preserved. The removal of these younger sediments had restored the topography approximately to what it was in the days of active vulcanicity. Memorials of the vanished formation he thought he could detect in the staining and reddling of the rocks in the eastern portion of the county, and in support of that opinion cited similar evidence of staining in Dumfriesshire, where it could be demonstrated that Triassic sandstones and marls had been stripped off from an area over a hundred square miles in extent.

To Sir Archibald Geikie's long and masterly discussion the writer can presume to add but little. It does not seem easy to admit that all the vents in East Fife can belong exactly to one period, even although petrographically their materials present such uniformity of character. Thus, for instance, a series of boreholes on the outer flanks of Largo Law has afforded clear indication that there was contemporaneous volcanic activity in that area in Carboniferous

[1] *The Geology of Eastern Fife*, p. 279.

Limestone times and that possibly this vent ought to be relegated to that period. Notwithstanding the significance which must be attached to this kind of evidence, however, it seems exceedingly hard to question the validity of the contention that, in cases where the stratified rocks have been folded and faulted anterior to their disruption by active volcanic forces, deposition must have been followed by diastropic change more closely than by igneous action. Now, as is well known, the period of comparatively stable equilibrium that obtained over Western Europe during the Carboniferous Period was brought to an end at the close of Westphalian times by a powerful series of earth movements, the direction of maximum stress over the Northern British area being approximately from east to west. It would appear to have been at this time that the folding and thrusting of the Scottish Carboniferous rocks was inaugurated and carried to completion. We may be sure that such a major readjustment of internal forces as then took place would not be unaccompanied, as integral in the sequence of events, by its concomitant or subsequent cycle of igneous activity, and it is to this period of terrestrial instability, as it affected our own country in the northern part of its extent, that probably should be relegated the necks of East Fife. Such a relegation—which is really only bringing the vents a little nearer the Carboniferous Period than has been done by Sir Archibald Geikie—in close association with a great series of crustal disturbances would explain how it is that we find among the igneous phenomena of the Carboniferous rocks in Central Scotland so much apparently conflicting evidence, e.g. vents later than dolerite sills, east and west dolerite dykes later than vents, dykes rising along faults or being shifted by them, etc.

Referring particularly to the Rock and Spindle, there is no clear evidence that this vent is necessarily later than the tilting of the strata through which it rises. If the fossil fish-teeth which, as mentioned, have been found to occur in the Spindle should prove not to have been derived, but have been caught up directly by the ascending basalt, from the floor of some old crater pool to which the sea had access, they may yet be expected to afford an important clue as to the age of the neck. There is one other matter also in the case of this vent which may possibly suggest a somewhat earlier age. Reference has been made to the concentric bedding of the ash and to the fact that the outcrops of successive layers did not form perfect circles. It will be clear that if the chimney were rising vertically through already tilted strata the circularity of the outcrops ought to be perfect, they being the traces of a series of conical shells with vertical axes upon a horizontal plane. On the other hand, should the chimney be tilted along with its surrounding sediments, then one might expect that the outcrops should be elliptical, the degree of ellipticity being an expression of the inclination of the pipe to the vertical. It is perhaps some explanation of this kind that accounts for the irregularity discernible in the ash at Kinkell, though it may readily be argued that it is altogether unwise to reason in such fashion about the deposits of an old volcano that obviously have suffered considerable disturbance subsequent to their accumulation.

Probably an acquaintance with modern active volcanoes would lead one to attribute the phenomenon solely to a breaching of the cone on its northern side by later explosions. Such speculation, however, does not appear quite without interest, especially where other evidences are so little available.

For the photographs which illustrate this paper it is a pleasure to express indebtedness to Mr. John C. Caldwell, M.A., of the Madras College, St. Andrews.

EXPLANATION OF PLATE XIII.

FIG. 1.—Rock and Spindle shore stack, 2 miles east from St. Andrews. The fossil fish-teeth reported on by Dr. Smith Woodward were collected from the centre of the Spindle.

,, 2.—Concentric arrangement of ash layers, Rock and Spindle. In the distance may be seen the stratified rocks beyond the eastern margin of the vent.

III.—Chromite in Beer Stone.

By G. M. Davies, M.Sc., F.G.S.

The Beer Stone is a gritty limestone, made up largely of shell fragments with some foraminifera, quartz grains, and soft chalky material, occurring in the *Rhynchonella Cuvieri* zone of the Middle Chalk near Beer Head in the south-east of Devon. It has long been worked for building purposes in underground galleries about one mile west of the village of Beer, and has been described by W. Hill and W. F. Hume in the Geological Survey memoir on the Lower and Middle Chalk.[1] Dr. Hume records the following minerals as present in the insoluble residue of the stone: quartz, muscovite, glauconite, chalcedony, pyrites, tourmaline, rutile, andalusite, and possibly anatase.[2] A. J. Jukes-Browne[3] says the residue "contains a variety of minerals which have clearly been derived from land consisting of granite and Palæozoic rocks such as occur in South Devon and Cornwall".

Samples collected by me last year in the underground workings have yielded additional evidence which is of some interest.

A sample weighing 157 grammes was treated with dilute hydrochloric acid and yielded 3·1 per cent muddy residue and 0·32 per cent sand. The latter consists chiefly of quartz, up to 2·1 mm. diameter, the larger grains being well rounded. There is also a fair amount of felspar, mainly orthoclase, and of muscovite and glauconite, as well as a little flint.

The sandy material was treated with bromoform, and the heavy residue was found to amount to 0·012 per cent of the stone. Coarse red and black grains are conspicuous in it. The former consist of limonitic matter, and the latter were tested in borax beads on the supposition that they might contain manganese. The beads, however, showed the fine green colour, somewhat yellowish in the oxidizing flame, characteristic of chromium. On crushing the

[1] *Cretaceous Rocks of Britain*, vol. ii, 1903.
[2] Ibid., pp. 509, 513.
[3] Ibid., p. 545.

FIG. 1.

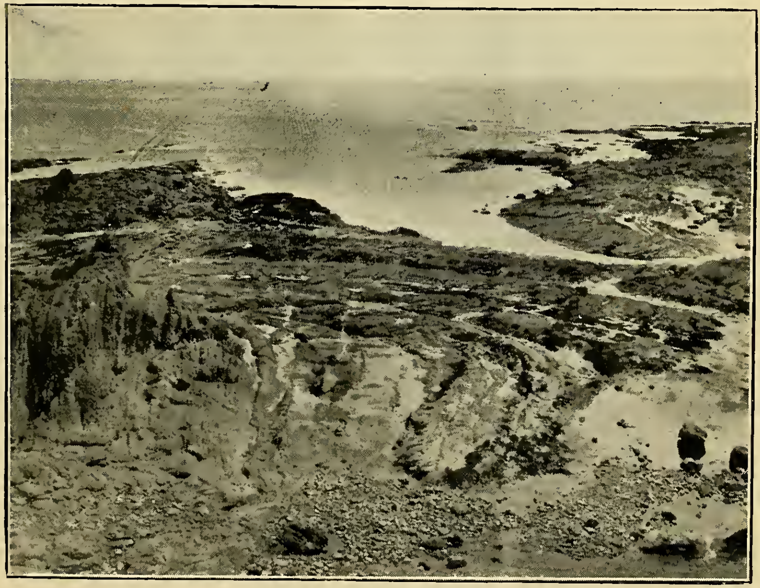

FIG. 2.

black grains and examining them under the microscope the fragments exhibit the deep brown colour in transmitted light and the isotropic character of chromite. In several instances a green serpentine is associated with the chromite. The other heavy minerals present are tourmaline, staurolite, biotite, zircon, rutile, and andalusite, none of which call for special comment.

A second sample gave 0·28 per cent sandy residue, but no chromite was seen in it. A thin section of the stone showed as many as seven fairly large quartz grains in an area of about half a square inch.

Detrital chromite does not seem to have been recorded in any Cretaceous or older deposits in England. From this fact, as well as from the coarseness of the grains and the patchy nature of the occurrence, we may conclude that the chromite was derived directly from some area of ultra-basic rocks, possibly the Lizard, possibly an area now submerged beneath the English Channel; and the occurrence is of interest as showing that serpentines as well as granites were being eroded in Turonian times.

IV.—On the Occurrence of *Productus humerosus* (=*sublævis*) in Dove Dale; and its Value as a Zone-fossil.

By J. Wilfrid Jackson, F.G.S., Manchester Museum.

During a recent examination of the Carboniferous Limestone in the Dove Dale district I have met with an abundance of *Productus humerosus*.[1] This species is a common fossil in the cliffs extending for a distance of quite 2 miles from the top end of Nabs Dale to beyond Tissington Spires. It is most prolific at and near Reynard's Cave, where the shells occur in clusters, often cupped into each other.

The beds containing this fossil are apparently not far below the top of the limestone, probably not more than some 500 feet.

The limestone is dark-grey in colour, with very obscure bedding. It breaks up irregularly into angular fragments, and contains some crinoid debris in places. Here and there occurs an organism of the nature of a Stromatoporoid, which invests the various fossils. There is an absence of chert, the limestone being very pure.

In addition to *P. humerosus* the beds contain *Amplexus coralloides* (very common), and several interesting Brachiopods, Gastropods, and Lamellibranchs; also Trilobites and Fenestellids, the fossils occurring in nests in certain places.

The specimens of *P. humerosus* include several varietal forms, which may or may not deserve distinctive names. Pending an exhaustive study of the material from Dove Dale and Caldon Low I here use the specific name *humerosus* to cover all such variations. Four such forms may be distinguished, but these are linked together by intermediates:—

1. *P.* aff. *sublævis*, de Kon., almost smooth, narrow and highly convex, with no trace of median sinus; flattened down median area from the beak to the anterior margin.

[1] First recorded in Geol. Mag., July, 1919, p. 335.

2. *P. sublævis*, de Kon., highly convex, characterized by a very definite median sinus (without a central spinous ridge) and concentric ribbing on umbonal region.

3. *P.* aff. *christiani*, de Kon., narrow and broad forms, with indistinct central spinous ridge (represented in some by a row of well-spaced spine-bases, which very late on are situated on a ridge); indistinct, or no, median sinus; concentric ribbing as in last.

4. *P. christiani*, de Kon., large, broad forms, with distinct central spinous ridge commencing near beak, sometimes in a sinus; concentric ribbing as last.

The same four variations are present at Caldon Low, but of the specimens I have examined the majority appertain to var. (2); whereas at Dove Dale the dominant form is (3).

From what I have seen of the Breedon (Leicester) specimens they seem referable to (3) or (4); but being mainly casts, it is difficult to be sure. Some certainly show evidence of a median ridge.

Examples of the variant (1) (which I here term *P.* aff. *sublævis*), are figured by Delépine ("Calc. Carb. Belg.," Mém. Facult. Cath. Lille, 1911, pl. xiv, figs. 3, 3*a*), and by Vaughan (Q.J.G.S., vol. lxxi, pl. vii, fig. 8, 1915).

Among the other Dove Dale Brachiopods the most interesting are: a giant papilionaceous *Chonetes* (190 + mm. along the hinge-line); a remarkable variety of *Productus mesolobus* (quite unlike the form from the "Brachiopod-beds"); and a striking form of a semi-reticulate *Productus* with narrow, highly-convex umbonal region, square-cut flanks, strong reticulation near the beak, and with the striæ thickened at intervals by spine-bases. This form seems to be near *P. doulaghensis*, Vaughan (Q.J.G.S., vol. lxxi, p. 47, pl. vii, fig. 7), but has straighter sides and a flatter venter.

The following also occur: *Dielasma* sp., *Athyris glabristria*, *Reticularia lineata*, *Spirifer pinguis*, *S. striatus*, *S. attenuatus*, *S. planatus*, *S.* cf. *convolutus*, *Camerophoria pleurodon*, *C.* (?) *tumida*, *Pugnax acuminatus* var. *plicatus*, *Orthotetes* sp., *Schizophoria resupinata* (large), *S. gibbera*, *Productus margaritaceus*, *P. cora*, *P.* cf. *concinnus*, *P.* "*pustulosus*", *Chonetes* aff. *comoides*.

The Gastropods belong to the genera *Euomphalus*, *Straparollus*, and *Phymatifer* (*Ph. pugilis*); *Bellerophon* also occurs; the Lamellibranchs are *Pterinopecten eximius*, *Pt. granosus*, and *Conocardium aliforme*.

With a few exceptions the assemblage of forms recalls, in part, the fauna of the "Brachiopod-beds" of the Midland area, allocated by Sibly to the sub-zone D_2 (*Lonsdalia* subzone), (Q.J.G.S., 1908).

Many of the forms occur in knolls of both Tournaisian and Viséan age, and are such as were regarded by Vaughan as indicating conditions only (Q.J.G.S., lxxi, p. 13). It would appear, from the abundance of *Productus humerosus* with such a fauna in Dove Dale, that this species has every right to be included as a knoll-form, and the species therefore loses its value as a zonal index. It is of interest to note that this species (as *P. sublævis*) is recorded from beds at Visé containing *Pugnax acuminatus* and *Phymatifer pugilis*. The massif at Visé is now regarded as equivalent to the "Brachiopod-beds" of the Midland.

The examples of the "early smooth form" of *Productus sublævis* (aff. *sublævis*, mihi) figured by Delépine and Vaughan are used by them as a zone-fossil indicating horizon δ—Basal Viséan. Such a course can only be reliable if the "smooth form" is unassociated with any other varieties.

It is hoped that further work in the Dove Dale area will result in defining the exact position of the "*Humerosus*-beds" with regard to the "Brachiopod-beds".

V.—British Association for the Advancement of Science, Bournemouth, 1919.

Address to the Geological Section. By J. W. Evans, D.Sc., LL.B., F.R.S., President of the Section.

ONE of the most striking features of our science is the need in which it stands of a large and widely distributed body of workers, and the opportunities which it affords to every one of them of making important contributions to scientific knowledge.

Every locality has its geological history stretching away into the "dark backward and abysm of time", and this history has left its records in the rocks of the earth's crust; an imperfect record, it is true, for much of it has long since been destroyed, but enough remains to reward long years of patient labour in deciphering it.

Everywhere some one is needed who will devote his spare time to the examination of the quarries and cliffs, where the materials that build up the solid earth are exposed to view, and who will record the changes that occur in them from time to time; for a quarry that is in work, or a cliff that is being undermined by the sea, constantly presents new faces, affording new information, which must be recorded if important links in the chain of evidence are not to be lost. It is equally important that some one should always be on the look-out for new exposures, road or railway cuttings, for instance, or excavations for culverts or foundations, which in too many instances are overgrown or covered up without receiving adequate attention. It is, again, only the man on the spot who can obtain even an approximately complete collection of the fossils of each stratum and thus enable us to obtain as full a knowledge as is possible of the life that existed in the far-off days in which it was laid down. In his absence many of the rarer forms which are of unique importance in tracing out the long story of the development of plants and animals, and even man himself, never reach the hands of the specialist who is capable of interpreting them. It was an amateur geologist, a country solicitor, who saved from the roadmender's hammer the Piltdown skull, that in its main features appears to represent an early human type, from which the present races of man are in all probability descended. Another amateur, who was engaged in the brick-making industry near Peterborough, has provided our museums with their finest collections of Jurassic reptiles. A third, a hard-worked medical man, was the first to reveal the oldest relics of life that had at that time been recognized in the British Isles; and many more examples could be instanced of the services to geological science by those whose principal life task lay in other directions.

Such workers are unfortunately all too few—fewer, I fancy, now than they were before the pursuit of sport, and especially of golf, had taken such a hold upon the middle classes and occupied so considerable a portion of their leisure hours and thoughts. One might hope that the extended hours now assured to the working classes for recreation would lead to a general increase of interest in science among them, if it were not that the students of that admirable organization, the Workers' Educational Association, seem almost invariably to prefer economic or political subjects to the study of nature, a choice in defence of which they could no doubt advance most cogent arguments. In a large county in which I am interested the number of those in every condition of life who are able and willing to take part in geological research might be told almost on the fingers of one hand, and so far as I am aware there has not been a single recruit in recent years from the ranks of the younger men or women.

It seems strange that there are so few of our fellow-countrymen or countrywomen who feel a call to scientific research, especially in a subject which, like geology, makes a strong appeal to the imagination, telling us of the strange vicissitudes through which our world and its inhabitants passed before they assumed the guise and characters with which we are familiar. How few are there who realize that the prolific vegetation to which we owe our wealth of coal was succeeded after the lapse of incalculable years by far-stretching deserts, and these, after continuing for a period still longer in duration, were submerged beneath wide inland semi-tropical seas, under whose waters were accumulated the sediments of sand and mud and calcareous débris out of which the fertile valleys of Central England have been carved; or that the conditions under which we now live were only reached through the portals of bleak, desolate ages of excessive cold, the reasons for which we are still at a loss to understand.

Even if the appeal to the imagination were not a sufficient incentive to the cultivation of geology, one would have thought its economic importance would have been effective. Its intimate bearing on the problems of agriculture, engineering, water supply, and hygiene is too obvious to need emphasis here, and it is scarcely more necessary to point out that all our fundamental manufacturing activities, without exception, are dependent on adequate supplies of materials of mineral origin, so that we need not be surprised that one of the earliest administrative acts of the Imperial Conference was the constitution of an Imperial Mineral Resources Bureau to secure that the whole mineral resources of the Empire should be made available for the successful devolopment of its industries.

It might be suggested that the prevailing indifference to the attraction of geological research was due to a conviction that after eighty years of work by the Geological Survey, as well as by University teachers and amateurs, there was little left to be done, and that all the information that could be desired was to be found in the Survey publications. Such a belief can hardly be very widespread, for, as a matter of fact, comparatively few of the general public realize the value of the work of the Geological Survey, and still fewer make use of its publications. Municipal libraries, other than those of our largest provincial centres, are rarely provided with the official maps and memoirs relating to the surrounding areas, and in the absence of any demand the local booksellers do not stock them. This cannot be attributed to the cost, for though most of the older maps are hand-coloured and therefore expensive, the later maps—at least those on the smaller scales—are remarkably cheap, and the memoirs are also issued at low prices.

The true explanation appears to be that a geological map conveys very little information to the average man of fair education who has received no geological instruction. This is certainly not the fault of the Survey maps, which compare very favourably with those of other countries, and have been greatly improved in recent years. In particular, the introduction of a longitudinal section on each map and the substitution of the vertical section drawn to scale for the old colour index must greatly assist those into whose hands it comes in obtaining a correct view of the succession of the strata and the structure of the country. Some of the maps are, it is true, so crowded with information—topographical and geological—that it is frequently difficult, even for the trained geologist, to read them without a lens. This is largely due to the fact that they are printed over the ordinary topographical maps in which there is a great amount of detail that is not required in geological maps. In India the Trigonometrical Survey are always ready to supply, as a basis for special maps, copies of their own maps printed off plates from which a portion of the topographical features have been erased.

The best remedy, however, would be to extend the publication of the maps on a scale of 6 inches to a mile. For many years all geological survey work has been, in the first place, carried out on maps of this scale, but they have not been published except in coal-mining areas. There the geological boundaries are printed, but the colouring is added by hand, which makes the maps comparatively expensive. In other localities manuscript copies of the geological lines and colouring on the Ordnance Survey maps can be obtained at the cost of production, which is necessarily considerable. There is, I believe, a wide sphere of usefulness for cheap colour-printed 6 inch geological maps, especially in the case of agricultural and building land, for which the 6 inch Ordnance maps are already in demand. They afford ample room for geological information, and, accompanied by longitudinal sections on the same scale without vertical exaggeration, their significance would be more readily apprehended than that of maps on a smaller scale. It may be noted that this is the favourite scale employed by those engaged in independent geological research for their field work, and, when the area is not too great, for the publication of their results.

It would be of great advantage if there were a uniform usage by which the position in the stratigraphical series of rock outcrops were indicated by colour and their lithological character by stippling (in black or white or colour), following the ordinarily accepted conventions. This course has been pursued by Professor Watts in the geological map prepared by him to illustrate his *Geography of Shropshire.* This increases the practical value of the map for many purposes, but is only possible when it is not overburdened with topographical detail.

Some explanation, apart from the maps themselves, is, however, needed if they are to be rendered, as they should be, intelligible to the general public. The official memoirs which deal with the same areas as the maps do not afford a solution of the difficulty. Excellent as they are from the technical standpoint and full of valuable information, they convey little to the man who has not already a considerable acquaintance with the subject. What is needed is a short explanatory pamphlet for each map, presuming no previous geological knowledge, describing briefly and in simple popular language the meaning of the boundary-lines and symbols employed, and the nature and composition of the different sedimentary or igneous rocks disclosed at the surface or known to exist below it in the area comprised in the map. A brief account of the fossils and minerals visible without the aid of a microscope should also be included. The probable mode of formation of the rocks and their relation to one another and the subsequent changes they have undergone should be discussed, and at the same time their influence on the agricultural value of the land and its suitability for building sites, as well as on the distribution and level of underground water, should be pointed out. Some account too should be given of the economic mineral products and their applications.

These pamphlets should be illustrated by simple geological sections, views of local quarries and cliffs showing the relative positions of the different rocks, figures of the commoner fossils at each horizon, and, where they would be useful, drawings of the forms assumed by the minerals. Each pamphlet would be complete in itself. This would involve a considerable amount of repetition, but it must be remembered that different pamphlets would have as a rule different readers. An alternative plan would be to follow the example of the United States Geological Survey and reprint the same brief résumé of geological principles in every case with such additions as are required to explain the meaning of individual maps. There can, however, I think, be no doubt that an explanation written expressly for each map can be made at once more easy to understand and more interesting to those without special geological knowledge.

That something further is required to render the information contained in the Geological Survey maps generally available to the public is illustrated by a correspondence that took place some years ago in one of our leading provincial papers with reference to the achievement of a manipulator of the hazel twig in discovering water in the Triassic rocks of the south-west of Derbyshire. No one seemed to realize that with the help of the Geological Survey map published forty years before and the contoured Ordnance Survey map more recently issued it was possible for anyone who possessed a little geological knowledge and common intelligence to predict within narrow limits the depths at which it would be possible to find water at any point within the area under consideration.

When measures such as I have suggested have been adopted for rendering the publications of the Geological Survey easily comprehensible to the general public, it should be the policy of the Government to obtain for them the widest circulation, so that the information they contain should be generally known, a consummation not only desirable for its own sake as tending to increase the general interest in geology, but because it would be an important factor in developing the industries of the country.

During the War publications containing desirable information were circulated widely and gratuitously by the authorities to all public bodies concerned, and there seems no reason why the information laboriously gathered by the Geological Survey in the national interests and paid for out of the public funds should not now receive the same treatment. All Municipalities, District Councils, public libraries, colleges and schools, both secondary and elementary, should receive free copies of the Geological Survey publications dealing with the area where they are situated or with those immediately adjoining it.

When a new publication is issued the same measures should be taken to make it known locally as a private firm would employ; copies should be sent to the local press, which should be assisted to give an interesting and intelligible account of its contents, with a selection from the illustrations. There should also be a standing notice in the *Publishers' Circular* of the Survey publications, so that local booksellers may know where to apply for them. I am told that at the present they are sometimes completely ignorant on the subject.

Every facility should, of course, be afforded to the public to make use of the Survey publications. They should not only be on sale at the post offices in the areas to which they relate, but it should also be possible to borrow folding mounted copies of the maps as well as bound copies of the explanations and memoirs, on making a deposit equal to their value. When they were no longer required, the amount of the deposit, less a small charge for use, would be repaid on their return to the same or any other post office and the production of the receipt for cancellation. It would thus be possible, when traversing any part of the country, to consult in succession all the Geological Survey publications of the districts passed through. This system would also enable the permanent residents to refer to the more expensive hand-coloured maps, including the 6-inch manuscript maps, at a comparatively small cost.

The preparation and printing of the explanations of the Survey maps, and the increase in the numbers printed of other publications, would obviously involve additional expenditure. This would be to some extent set off by increased sales; but even if there were a net loss on the balance, it would be worth while if it enabled the fullest advantage to be taken of the expenditure incurred in any event by the Survey in investigating the mineral resources of the country.

The Survey publications should be illustrated in every museum and school in the districts with which they deal by small collections showing the characters of the local rocks, and of the minerals and fossils that occur in them, and care should be taken to see that these collections are maintained in good order and properly labelled.

It would be a good plan for the Survey to appoint a local geologist, an amateur or member of the staff of a university or college, in every area of twenty or thirty square miles[1] to act as their representative and as a centre of local geological interest. He would be expected to give his assistance to other local workers who stood in need of it. He would receive little official remuneration, but inquirers in the neighbourhood would be referred to him, and where commercial interests were involved he would, subject to the sanction of the Central Office, be entitled to charge substantial fees for his advice. He would report to the Survey any event of geological importance in the area of which he was in charge—whether it was the discovery of a new fossiliferous locality, the opening of a new quarry,[2] the sinking of a well, or the commencement of boring operations. Many of these matters would be adequately dealt with by local workers, but in other cases it might be desirable for the Survey to send down one of their officers to make a detailed investigation.

One of the most important duties of the Survey, or its local representative, would be to see that the records of well-sinkings and borings are properly kept, and that where cores are obtained the depth from which each was raised is accurately recorded. At the present time the officers of the Survey make every effort to see that this is done, but they have no legal power to compel those engaged in such operations to give the particulars required. Equally important is a faithful record of the geological information obtained in prospecting or mining operations. This is especially necessary where a mine is abandoned.[3] If care is not then taken to see that all the information available is accurately recorded, it may never be possible later to remedy the failure to do so.

Probably these objects would be much facilitated if engineers in charge of boring or mining operations had sufficient knowledge of geology and interest in its advancement to make them anxious to see that no opportunity was lost of observing and recording geological

[1] I am afraid that in many parts of the country there are so few amateur geologists that this area would have to be increased, at any rate at first.

[2] It is very desirable that arrangements should be made for the co-operation of the Geological Survey or their local representatives with the Inspectors of Quarries appointed by the Home Office, and that the annual official list of quarries should describe the rocks which are worked, not only by their ordinary economic designations, but also by their recognized geological descriptions.

[3] Those engaged in mining are already required to furnish mining plans to the Mining Record Office, but there is no obligation to give any geological information that may have been obtained. This office was formerly attached to the Geological Survey, but was transferred some years ago to the Home Office.

data. This would be in most cases ensured if every mining student were required to carry out geological research as part of his professional training. It is now recognized that no education in science can be considered to be up to University standard if it is limited to a passive reception of facts and theories without any attempt to extend, in however humble a way, the boundaries of knowledge. In the case of geology such research will naturally in most cases take the form of observations in the field. The important point is that the work must be original, on new lines, or in greater detail than before, and not a mere confirmation of published results. It is only by the consciousness that he is accomplishing something which has not been done before that the student can experience the keen pleasure of the conquest of the unknown and acquire the love of research for its own sake.

At present it is disheartening to realize how few of those who have received scientific instruction understand the obligations under which they lie of themselves contributing to the growth of knowledge. If they have once had the privilege of achieving individual creative work they will henceforward desire to take advantage of every opportunity of continuing it.

There is one respect in which geological workers suffer a heavy pecuniary handicap—the cost of railway fares. This affects both the staff and students of colleges, as well as local workers who are extending their radius of work—an inevitable necessity in the investigation of many problems. It also seriously interferes with the activity of local Natural History Societies and Field Clubs, the Geological Societies and Associations of the great provincial towns, and, above all, that focus of amateur geological activity—the Geologists' Association of London. It is difficult to exaggerate the importance of these agencies in the promotion of geological education. Both professional and amateur geologists are deeply indebted to the excursions which are in most cases directed by specially qualified workers, with whom it is a labour of love. At the same time one of their most valuable results is the creation of interest in scientific work in the localities that are visited. Now that the railways are, if report speaks truly, to be nationalized, or at any rate controlled by the State, the claims of scientific work carried out without reward in the national interest to special consideration will surely not be ignored. All questions as to the persons to whom such travelling facilities should be extended and the conditions that should be imposed may safely be left to the decision of the Geological Survey, which has always had the most friendly and sympathetic relations with private workers and afforded them every facility and assistance, which their comparatively limited staff and heavy duties permitted.

It is impossible to speak in too generous terms of the Geological Survey[1] and its succession of distinguished chiefs (the last of whom, I am glad to say, is with us to-day), or of the work it has

[1] Since 1905 the Irish Survey, a small but enthusiastic band led by one of the most broad-minded of modern geologists, has been separated from that of the remainder of the country.

accomplished, in spite of somewhat inadequate financial support from the powers that be, who have taken every precaution that the Honours graduates who join its ranks should do so for the pure love of science and not for the sake of worldly advantage. With increased staff and less straitened finances the Survey would be in a position, not only to discharge the additional duties my suggestions would impose on them, but to extend still further the sphere of their usefulness. There is, for instance, at the present time a very urgent need for the provision of further facilities for the analysis of rocks and minerals to assist and complete the researches both of the official surveyors and of private persons engaged in research. The work is of a very special character, and the number of those who have given sufficient attention to it and understand its difficulties and pitfalls is very limited. The chemical staff at our Universities are chiefly concerned with organic chemistry, and private analysts devote themselves mainly to the examination of economic products. The effect of a hasty excursion of workers of either of these categories into the analysis of such complex silicates as augite or biotite or any of our ordinary igneous rocks is apt to be disastrous, only exceeded in this respect by the results obtained when, as not infrequently happens, a student is given a similar task by way of practice. A certain amount of good work is undoubtedly done in College laboratories, but it is very little in comparison with what is needed.[1]

At present the analytical work of the Survey is organized on a very modest scale in comparison with the personnel and equipment of the laboratory of the United States Geological Survey, though the quality of the work has been as a rule in recent years quite as high. There are two analytical chemists attached to the Geological Survey, and some of the other members of the staff are capable of doing good analytical work. The demand, however, for analyses for economic purposes is so great that it is impossible to carry out all the analyses that would be desirable in connexion with the purely scientific work of the Survey itself. There is consequently no possibility of their being able to assist private investigators.

Strictly speaking, the individual minerals of a rock should be separately analysed and their relative amounts determined, but this is at present a counsel of perfection that we cannot hope to attain; and when the difficulty of obtaining pure material, especially in the case of fine-grained rocks, and the zoned character of practically all complex rock-forming minerals are considered, it is seen that intrinsically it is not quite so important as it would seem to be at first sight. The bulk analysis, intelligently interpreted in connexion with the actual mineral composition of the rock as revealed by the microscope, is, in fact, at present the most practical method of determining the composition of the minerals. I need scarcely say that volatile constituents still retained by the rock should be separately

[1] I should like to refer in this connexion to the excellent analytical work of Dr. H. F. Harwood, of the Chemical Department of the Imperial College of Science and Technology.

determined, and the amount reported as water should not include any other substance given off at the same time.

In the absence of facilities for obtaining rock analyses, petrological work in this country is at present seriously handicapped. A striking illustration of the inadequate provision for analyses is revealed in the fact that for the whole of the early Permian granitic intrusions in the South-west of England, covering nearly 2,000 square miles, and including numerous different types and varieties, there are only four analyses in existence, and of these two are out of date and imperfect. This is all the more remarkable in view of the fact that these rocks are closely connected with the pneumatolytic action that has given us almost all the economic minerals of the South-west of England, comprising ores of tin, tungsten, copper, lead, and uranium, as well as kaolin. If the Survey, by increasing its staff of analysts, were in a position, not merely to multiply the number of analyses illustrating its own work, but to help others engaged in research, they would only be proceeding on lines which have long since been followed in some of our Dominions.

(*To be continued.*)

REVIEWS.

I.—Mountains. By C. A. Cotton, D.Sc., F.G.S. New Zealand Journal of Science and Technology, vol. i, No. 5, pp. 280–5, 1918.

In this paper Dr. Cotton points out that the distinction commonly drawn between fold-mountains and mountains of circumdenudation needs qualification in those cases where the denudation is now in a second or later cycle, owing to superposition of block-structure with uplift on original folding. He considers that in many cases the erosion directly due to uplift was a comparatively short-lived process, and that the present mountains owe their elevation and relief to causes operating long after the folding had ceased. It is shown that certain of the mountains of New Zealand owe their present condition mainly to the Kaikoura orogenic movements, which were differential uplifts and not folding. New Zealand may, in fact, be described as a concourse of earth-blocks, the highest on the north-eastern and south-western axis of the land mass, and in places portions of the old marine plain of deposition can be recognized on the denuded surfaces of the uplifted and tilted blocks. This is an idea which has perhaps been insufficiently considered by physiographers, and the points raised are worthy of careful study, as they may be equally applicable to other regions.

II.—Observations on a Florida Sea-beach, with special reference to Oil Geology. By G. F. Kemp. *Economic Geology*, vol. xiv, pp. 302–23, 1919.

During a residence of two winters on the coast of Florida Mr. Kemp devoted a considerable time to the detailed study of the character and formation of the beach and the changes produced in it by varying weather conditions; the special object in view was the comparison with the phenomena observed in oil-bearing strata, but the results obtained are of much interest to all physical and stratigraphical geologists. At Melbourne Beach, the place in question, a broad stretch of stagnant fresh water, without visible outlet, is separated from the open Atlantic by about half a mile of blown sand, covered with palmettos and other scrub; beneath this is everywhere found artesian water. The sands of the open sea-beach show several features of interest, including the ordinary types of ripple-mark due to winds and waves such as are so often preserved in older strata. The sloping part of the beach has an inclination as steep as 5°, and it is pointed out by the author that an ancient beach of similar slope, when exposed by denudation, might easily be mistaken for one limb of a fold. Under certain wind-conditions the beach sand is worked up into peculiar ridges called cusps by the author. They seem to be formed when the wind is straight on shore, and are destroyed by oblique surf-action. At times there are found in the sand numerous clots of asphalt; the origin of these is not yet understood, since they are apparently not connected with any local oil or bitumen occurrence, but appear to be washed up by the sea. Another feature mentioned is the occurrence of masses of a hard modern shell-limestone, called coquina; these are formed when a strong wind drives piles of shells into the hollows between the cusps; these accumulations are sometimes as much as a foot thick, and are soon hardened by cement deposited from percolating rain and sea-water. In course of time these will form small slabs and lenticles of limestone appearing abruptly in a coarse mechanical sediment, a puzzling feature when observed in the older rocks. Just below low-water mark the beach drops suddenly two or three feet and forms a distinct channel extending one or two hundred yards to the well-marked off-shore bar. This is the normal state of affairs, but occasionally under special weather conditions the bar moves inwards and coalesces with the beach, obliterating the channel. A description is also given of a very large shell-mound or kitchen-midden, showing layers of wood-ash and occasional bits of pottery. The mound is about 1,000 feet long, 50 feet wide, and 13 feet high in the middle. Other mounds larger than this are known in other parts of Florida, nevertheless this is impressive evidence of the activities of the earlier inhabitants of the region.

III.—Silver Spur Mine. Recent Development and Future Prospecting. By L. C. Ball. Queensland Geological Survey Publication No. 264. pp. 36, with 10 figures. Brisbane, 1918.

THIS mine, which is situated near the boundary between Queensland and New South Wales, on the Darling Downs, lies in metamorphosed sediments and tuffs of Permo-Carboniferous age. The ore bodies are found for the most part in crash zones in slate, and consist of masses and disseminations of mixed sulphides, with a gossan and oxidized zone at higher levels. The metals yielded are silver, lead, zinc, copper, with about 1 dwt. of gold per ton. The distribution and paragenesis of the ores is of interest, since a definite sequence is shown, with copper nearest the surface, followed by galena, blende, and arsenopyrite successively in depth. The whole thickness of the zone series is here unusually small, amounting to only about 500 feet, and it is an interesting subject for speculation as to what metal, if any, may be found at greater depths. The origin of the ores is here referred to an underlying igneous intrusion, probably connected with a dyke of diorite outcropping in the neighbourhood of the mine, though it has also been attributed to the influence of the Stanthorpe massif, which, however, appears to be at too great a distance.

IV.—On the Origin of Septarian Structure. By W. A. Richardson. Mineralogical Magazine, vol. xviii, pp. 327–38, 1919.

In spite of much discussion of the mechanism of septarian structure, the subject has hitherto remained obscure, largely for want of experimental evidence. It is here shown that the common description of radial cracks widening towards the centre is inaccurate and misleading, since the true structure is usually polygonal in section and the width of the cracks is independent of their position in the nodule. A section thus reproduces very closely the appearance of a film of clay allowed to dry on glass. The arrangement of the cracks is compared with the various types seen in drying timber, while experiments were also made with spheres of mud coated with Portland cement and immersed in salt solutions. This process produced a very good imitation of septarian structure, and it is concluded that the cracking of the nodules is due to chemical desiccation of a colloidal centre, while the nodules themselves originated by the rhythmic precipitation of solutions diffusing through a colloid according to the principles laid down by Liesegang: the material thus precipitated was probably formed by gradual accumulation of bicarbonates by the action of organic by-products on compounds of lime or iron in the rock. It is frequently stated that fossils are commonly found at the centres of septaria, but this occurs with comparative rarity; the majority of those examined contained no fossils at all, and when present they were rarely central. On the other hand many fossils occur in the immediate neighbourhood of barren concretions.

V.—The Keweenaw Fault. By A. C. Lane. Bull. Geol. Soc. Amer., vol. xxvii, pp. 93–100, 1916.

The great fault which forms the southernside of the copper-producing region is of considerable economic and structural interest. In this paper the author shows that it probably began as a block-fault and was also a line of volcanic activity. In the hollow bounded by the fault-scarp the Upper Keweenawan beds were deposited and appear to shade into the Eastern Sandstone of Upper

Cambrian age. After three more Palæozoic marine transgressions, thrust-faulting occurred at the time of the Appalachian Revolution, carrying Keweenawan beds over the Lower Palæozoic. The present land-surface is probably due for the most part to Cretaceous denudation, which has exposed the outcrops of both principal faults at different points.

VI.—Notes on the Placer Mines of Cariboo, British Columbia. By J. B. Tyrrell. Econ. Geol., vol. xiv, pp. 335–45, 1919.

THE importance of alluvial mining for gold in the valleys of the Cariboo district of British Columbia has led to a careful investigation and survey of the drainage system of this remote region, revealing features of considerable interest to the student of river development. An important feature of the region is the existence of auriferous gravels of pre-Glacial age, in some instances deposited by streams whose courses have been seriously modified at a later date. Many of these gravels are now deeply buried under boulder-clay and other glacial deposits. Some of the upper tributaries of the Willow River in the neighbourhood of Mount Agnes show very clear examples of capture and beheading, and in some cases the present creeks have cut narrow gorges in the floors of wide open valleys belonging to an earlier arrangement of the drainage. The present stream system in the neighbourhood of Barkerville, as shown in the small sketch-map given by Mr. Tyrrell, is a particularly striking case of diversion. Although some of the smaller changes seem to be due to the deposition of boulder-clay it would appear that the larger modifications have been brought about more by piracy in pre-Glacial times than by moraines or other barriers of Glacial age.

VII.—Platinum Metals in the Somabula Diamondiferous Gravels. By H. B. Maufe. Southern Rhodesia Geological Survey. Short Report No. 5, 1319.

THE Somabula Diamondiferous Gravels which contain the diamond and numerous gemstones are found almost on the main watershed of Southern Rhodesia close to Willoughby's Siding and about 12 miles south-west of Gwelo.

An examination of the pebbles composing the gravels revealed the presence of chromite and chromite-bearing rocks in appreciable quantity: and therefore the possibility that the rocks might contain platinum or metals of the platinum group (iridium, osmium, palladium, rhodium, and ruthenium).

The late Mr. Zealley, in writing of the occurrence of platinum in Southern Rhodesia, said: "The Somabula gravel for instance is a likely source, since it is known that much heavy material is concentrated therein, and that a considerable proportion of the pebbles are from ultra-basic rocks; thus pebbles of chromite rock are abundant, and many of the chalcedony pebbles can be recognized by the practised eye as silicified serpentines derived from the Great Dyke and from the ancient schists. The fine heavy black gold-bearing sands concentrated from the Somabula gravels apparently have not been examined for platinum. The finest material should preferably be tested."

A sample of the heaviest fine concentrate obtained in the washing for diamonds was sent to the Imperial Institute to be assayed for platinum metals, and the Director reports the following results:—

	Per ton of concentrate. oz.	dwt.
Platinum	3	12
Osmiridium	7	0

He also reports: "Palladium was probably present, but the quantity was too small to be definitely identified. The concentrate also contained a large amount of gold."

VIII.—The Tertiary Geology of Devon and Cornwall. By H. J. Lowe. Trans. Devon. Ass. Adv. Sci., etc., 1918, pp. 391–401.

The author reviews and discusses the conclusions reached by the Geological Survey and other authorities as to the Tertiary history of the Devono-Cornish peninsula, with special reference to the age and origin of the high-level plateaux and the courses of the Tertiary rivers. He criticizes the views put forward by others, but has little to offer in the way of alternatives. He does, however, suggest that the plateaux may in part be due to the peculiarly uniform and resistant character of the rocks composing them which renders them equably resistant to denudation over large areas: no evidence is brought forward in support of this hypothesis. It is estimated that the excavation of the Teign valley to its present depth occupied no less than 3½ million years, while a further argument concerning the age of the limestone caverns is not very clear, and its bearing on the point at issue is not obvious.

REPORTS AND PROCEEDINGS.

I.—Titles of Papers, etc., read at Meeting of British Association in Section C, Geology (and in other Sections bearing upon Geology), Bournemouth, September 9, 1919.

Presidential Address by *Dr. J. W. Evans, F.R.S.*

Dr. W. T. Ord.—The Tertiary Rocks of the Hampshire Basin.

Professor S. H. Reynolds.—The Lithological Succession in the Avonian of the Avon Section, Clifton.

Reports of Committees.

Excursion to Bournemouth Cliffs.—Leader, Dr. W. T. Ord.

Sir Aubrey Strahan, K.B.E., F.R.S.—The Mesozoic Rocks of the Bournemouth District.

Joint discussion with Section H (Anthropology) in the Rooms of Section C.—The Post-tertiary Geology of the District with special reference to the Flint Implements contained in them. *Mr. Reginald Smith* introduced the discussion, and his communication was illustrated by a collection of flint implements specially loaned for this occasion.

Mr. Henry Bury.—The Origin of the Bournemouth Chines.

Dr. W. E. Miller.—The Pre-Cambrian of Central Canada.

Dr. J. W. Evans, F.R.S.—The Correlation of the Marine Devonian of the United Kingdom with that of other Countries.
Dr. M. C. Stopes.—The Mesozoic Flora of the Bournemouth District.
Dr. W. T. Ord.—Bournemouth Bay and its Erosion.
Reports of Committees.
Excursion to Barton and Hordle Cliff.
Excursion to Swanage.—Leader, Sir Aubrey Strahan.
Excursion to Lulworth.—Leader, Sir Aubrey Strahan.
Excursion to Corfe.—Leader, Dr. W. T. Ord.
Excursion to Kimmeridge and Neighbourhood.—Leader, Mr. J. Pringle, H.M. Geological Survey.

PAPERS READ IN OTHER SECTIONS BEARING ON GEOLOGY.

SECTION D (ZOOLOGY).

Mr. C. Tate Regan, F.R.S.—The Geographical Distribution of Freshwater Fishes, with special reference to the past history of Continents.
Mr. D. M. S. Watson.—Palæontology and the Evolution Theory.
Joint meeting of Section C with Section D (Zoology) in the Rooms of Section C.
Excursion to Corfe.—Leader, Dr. W. T. Ord.

SECTION K (BOTANY).

Presidential Address by *Sir Daniel Morris, K.C.M.G.*
Dr. D. H. Scott, F.R.S.—The Relation of Seed Plants to the higher Cryptogams.
Dr. M. C. Stopes.—Plants in relation to the four parts of true Coal.
Mr. E. Heron-Allen, F.R.S., and *Mr. A. Earland.*—A Study of the Foraminiferal Species *Verneuilina polystropha* (Reuss), and some experiments in its cultivation in hypertonic sea-water and gem-sand.
Mr. H. Moncton.—The Flora of the District of the London Clay.

II.—ABSTRACTS OF PAPERS READ BEFORE THE BRITISH ASSOCIATION (SECTION C, GEOLOGY) AT BOURNEMOUTH, 1919.

1. THE POST-TERTIARY DEPOSITS OF THE BOURNEMOUTH AREA. BY REGINALD A. SMITH.

The temporary exhibition of palæoliths from the Bournemouth district suggests further inquiry into the age and character of the beds in which they are found. Gravel is widely distributed over the high ground between the Stour and the coast at about 100 feet O.D., and the implements are often found at the base of deep deposits in an unrolled condition, and therefore presumably in situ. The current view is that the gravels were laid down by a great river flowing eastward between the present coastline and a southern bank connecting the Needles with the Isle of Purbeck; but in view of similar discoveries on St. Catherine's Hill (between the Avon and Stour and close to their junction), it seems likely that the Bournemouth gravels were originally continuous with those of the New Forest, and that the implements were embedded in them before the present valleys of the Stour and Avon were deeply cut. Several implements have been found in high and low gravel-beds in the New Forest, and coast finds are abundant from Poole Harbour to Southampton Water. A section from Bramble Hill south-west to the coast is given in Proc. Geol. Assoc., xxvi (1915), 4, suggesting that the implement-bearing beds are part of a plateau deposit rather than the terrace-gravel of a Solent river.

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2. The Chines of Bournemouth. By Henry Bury, F.G.S.

The country round Bournemouth consists of an almost level plateau, intersected by numerous valleys, and some of the latter, running down to the sea, are of a precipitous character, and are distinguished under the name of "Chines". They are usually described as having started as small gullies in the face of the cliff and having worked back inland; but the evidence seems to be against this. Not only is there no sign of special activity at their heads, but each is found to consist of an older valley with a U-shaped section, and a newer one, shorter and narrower, shaped like a V. The older valleys probably joined the Frome–Solent River about 1–2 miles from the present shore-line; the newer ones owe their smaller size to reduction in water-supply, and their steepness to the rapid retreat of the shore-line under marine action. They are in fact growing shorter, and not longer, and the final obliteration of some of them may have helped to give rise to the belief that the cliffs themselves are growing steeper.

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3. The Lithological Succession in the Avonian of the Avon Section, Clifton. By S. H. Reynolds, Sc.D., F.G.S.

Several previous workers have dealt with the lithology of the Avon section, and in particular Mr. E. B. Wethered and the late Dr. A. Vaughan. The results of the present paper are based in part on field work, in part on the study of over 200 rock slices which have been cut with the aid of grants from the University of Bristol Colston Society.

The chief rock-types occurring are the following, the horizons being alluded to under the designation adopted in Vaughan's original paper.[1]

Calcareous Rocks.

Algal Limestones are abundant (*a*) in Km, (*b*) at the top of C_2, (*c*) in the lower part of S_1, (*d*) in the pisolitic beds of the lower part of S_2, (*e*) in the "Concretionary Beds" of the upper part of S_2: this is the most important development.

Mitcheldeania and *Solenopora* are the most persistent forms ranging from the base of K to the top of S_2. *Spongiostroma* is the prevalent form in the calcite-mudstones which are so abundant in C_2 and S.

Foraminiferal Limestones: Foraminifera first began to be fairly common in Z_2. They occur in great abundance in the upper part of S_2 and the lower part of D_1.

Coral Limestones: Zaphrentid corals play an appreciable part as limestone builders in Z_1, while bands full of *Lithostrotion martini* are

[1] Q.J.G.S., vol. lxi, 1905.

most characteristic of S. Corals attain their greatest importance in D.

CRINOIDAL LIMESTONES: Crinoids are abundant in K_1 and K_2, and are the greatest limestone builders throughout the whole of the Z beds.

BRACHIOPOD LIMESTONES are met with throughout nearly the whole section. *Spirifer*, *Orthotetes*, and *Chonetes* being the most abundant Tournaisian genera, *Seminula*, *Productus*, and *Chonetes* the commonest Viséan.

OSTRACODS are very plentiful wherever the rocks are shaly or of the calcite-mudstone type, viz.: throughout K, at the top of C_2, and in the lower part of S_1.

OOLITES occur at the following levels: (*a*) in the upper part of C_1, (*b*) in the middle of S_2, (*c*) throughout D.

Siliceous Rocks.

Grits are met with only in the D beds. Chert bands occur (*a*) near the middle of Z_1, (*b*) in S_2 below the oolite, (*c*) in S_2 between the oolite and the "Concretionary Beds".

Argillaceous Rocks.

Thick shales are met with (*a*) throughout K_1, (*b*) in upper C_2 and lower S_1, (*c*) in upper D_1 and upper D_2.

Changes which have affected certain of the rocks. Penecontemporaneous brecciation (desiccation breccias) are characteristic of all the shallow water (lagoon-phase, Dixon) rocks of C_2 and S.

Dolomitization proves to be considerably more widespread in the Avon rocks than had been previously supposed. The matrix of the *Petit Granit* of Z_1, Z_2, and γ is almost everywhere dolomitized. The almost complete dolomitization of C_1 and the upper part of C_2 has long been familiar. There has been considerable dolomitization in the calcite-mudstones of S_1 and lower S_2. All the chief dolomites are to be classed as contemporaneous according to the classification of Mr. L. M. Parsons.[1]

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4. THE PRE-CAMBRIAN OF CENTRAL CANADA. By WILLET G. MILLER.

Ten years ago, at the Winnipeg meeting of the British Association, the author presented a paper dealing with the age relations of the pre-Cambrian rocks of Canada. Since then much field work has been done in connexion with these rocks, not only in the province of Ontario, but to the eastward in Quebec and, to a lesser extent, to the westward in Manitoba and Saskatchewan. There has been great mining activity in the pre-Cambrian areas of Ontario, which has afforded special facilities for study to the geological staff of the Ontario Bureau of Mines. From time to time papers and reports have been published as our knowledge has increased, and the age classification has been revised.[2] The following classification is now employed by the Ontario Bureau[3]:—

[1] GEOL. MAG., Dec. VI, Vol. V, p. 246, 1918.
[2] *Ont. Bur. Mines*, vol. xix, pt. ii; vol. xxii, pt. ii.
[3] *Journal of Geology*, vol. xxiii, No. 7.

PRE-CAMBRIAN.

KEWEENAWAN *Unconformity*	
ANIMIKEAN	Under this heading are placed not only the rocks that have heretofore been called Animikie, but the so-called Huronian rocks of the "classic" Lake Huron area, and the Cobalt and Ramsay Lake series. Minor unconformities occur within the Animikean.
Great unconformity	
(ALGOMAN granite and gneiss) *Igneous contact*	Laurentian of some authors, and the Lorrain granite of Cobalt, the Killarney granite of Lake Huron, etc.
TIMISKAMIAN	In this group are placed sedimentary rocks of various localities that heretofore have been called Huronian, and the Sudbury series.
Great unconformity	There is no evidence that this unconformity is of lesser magnitude than that beneath the Animikean.
(LAURENTIAN granite and gneiss) *Igneous contact* LOGANIAN { Grenville (*Sedimentary*) / Keewatin *Igneous* }	The Grenville limestones, with more or less greywacke, quartzite, and iron formation or jaspilyte at the base, were deposited on the Keewatin lavas.

It will be noted that the historic name "Huronian" has been discarded. Much confusion has arisen through the employment of this name, especially with the prefixes Upper, Middle, and Lower, in different senses. The term "Lower Huronian", for example, has been applied indiscriminately to certain rocks that lie below one of the greatest known unconformities—that between the Timiskamian and Animikean in the table—as well as to some of those above it. When making use of the term "Huronian", in order to secure clearness, it has been necessary to say in what sense it is employed, whether in that of the United States Geological Survey or in that of various writers on the subject.

Logan first studied the rocks, to which he afterwards gave the name "Huronian", on the shores of Lake Timiskaming. There are two series of conglomerates and other fragmental rocks here, separated by a great unconformity, which was discovered only when the geology of the Cobalt area was worked out. The lower series belongs to the Timiskamian of the table and the other to the Animikean.

The age relations of another historic series, the Grenville, have also been determined only during recent years. Most authors had suggested that the Grenville belonged to the so-called Huronian group of sediments, but it has proved to be the oldest sedimentary series. The Keewatin rocks, essentially schists and greenstones, represent, for the most part, submarine lava-flows. On the surface of these flows were deposited the Grenville sediments. While the major part of the Grenville is later than the major part of the Keewatin, a minor part of one group is contemporaneous with a minor part of the other. It is remarkable that among the oldest series of Australia, India, Africa, and other countries are rocks that resemble very closely the Keewatin of Canada, with its associated iron formation or jaspilyte.

Among most of the workers on the pre-Cambrian of North America there is now general agreement as to the age relations of the rocks, but different classifications and nomenclatures are employed. Most authors make a dual subdivision of the pre-Cambrian which seems to the author to be purely arbitrary and based on a misconception. There is no proof that the unconformity at the base of the Timiskamian is of less magnitude than that at the base of the Animikean, or vice versa.

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5. The Plant-bearing Cherts at Rhynie, Aberdeenshire.—Report of the Committee, consisting of Dr. J. Horne (Chairman), Dr. W. Mackie (Secretary), and Drs. J. S. Flett, W. T. Gordon, G. Hickling, R. Kidston, B. N. Peach, and D. M. S. Watson, appointed to excavate Critical Sections therein.

The plant-bearing cherts discovered by Dr. Mackie in the Old Red Sandstone at Rhynie, Aberdeenshire, when examined under the microscope, showed fragments of Crustacea in certain sections. Some of the sections were submitted to Dr. W. T. Calman and Mr. D. I. Scourfield, who have furnished the following report: "The animal remains are, for the most part, very fragmentary and confused, but they are in an excellent state of preservation, even the fine feathering on small setæ being, in some cases, easily recognizable. All the remains examined appear to be referable to the class Crustacea, and to have belonged to animals comparable in size to the Copepoda of the present day. The most complete portions hitherto found have been tails, consisting each of a number of segments and ending in a furca. Both lateral and dorsal views have been seen, and the general arrangement of the parts fairly well made out. Two distinct species appear to be represented, belonging either to a primitive group of the Copepoda or to the very small Branchiopoda (? Anostraca). Fragments of appendages are numerous in nearly all the slides, but are extremely difficult to interpret. One slide, however, shows a series of about three pairs of biramous feet in their natural connexions. They are remarkably similar to the swimming feet of Copepods of the genus *Cyclops*, except that the branches are unjointed instead of being composed of the usual three segments. A considerable number of detached mandibles have also been seen, all of them most closely comparable to those of the Branchiopoda. It is evident that these remains are of extraordinary interest, and, although little progress has been made towards reconstructing any one of the several species that are represented in the material, enough has been done to show that, given a sufficient number of sections, the structure of the body and limbs could almost certainly be worked out, even if no entire specimens should be brought to light."

During 1918 Mr. D. Tait, H.M. Geological Survey, obtained additional specimens of chert from the Rhynie outcrop, to be examined by Dr. Calman and Mr. Scourfield. A grant from the Royal Society has been received to aid the investigation.

III.—Edinburgh Geological Society.

March 19, 1919.—Mr. John Mathieson, F.R.S.G.S., Vice-President, in the Chair.

1. "Acid Potassium Sulphate as a Petrochemical Test and Solvent." By Dr. Wm. Mackie, M.A., Elgin.

An abstract of this paper was given by Dr. Campbell. It is a record of a comprehensive research on the action of acid potassium sulphate as a petrochemical test and solvent, as applied to the study of residues of heavy minerals in Scottish granite, and sedimentary rocks. These residues when acted upon by this solvent, in a state of fusion, displayed certain changes in colour, characteristic etching marks, and other phenomena by which they could be readily distinguished under the microscope. Dr. Mackie describes certain methods of treating these mineral residues, and subsequently mounting them on microscopic slides for study and recognition.

2. "Chemical Analysis of the Dolerite and Hornfels of Auchinoon." By Mr. T. Cuthbert Day, F.C.S.

This paper gives a record of eight complete chemical analyses of the rocks of Auchinoon, including the intrusive dolerite and the overlying hornfels with which it is in contact. The differences in the appearance and composition of the dolerite as found about 10 feet below the junction, and at the junction itself, were pointed out, and also the variations in the analyses of the hornfels at the junction itself and at increasing distances from it. An analysis of the clay band overlying the hornfels was also given.

IV.—Liverpool Geological Society.

The annual meeting of this Society, inaugurating the Sixty-first Session, was held at the Royal Institution, Liverpool, on October 14, 1919. Mr. W. T. Walker, B.Sc., F.G.S., was elected President, and Professor P. G. H. Boswell, O.B.E., D.Sc., F.G.S., Vice-President.

The retiring President, Dr. J. C. M. Given, F.G.S., delivered an address on "The Divisions of the Pleistocene", which was devoted to a review and criticism of the results of recent work on this latest period of geological history. For the purpose of subdividing the epoch, palæontological methods might be employed, and the mammalian fauna enabled three distinct life zones to be defined, viz.: (1) that of a warm climate represented by *Elephas antiquus*; (2) that of a cold climate with *E. primigenius*, etc.; and finally (3) that of a more genial climate with *Rangifer tarandus* and *Cervus giganteus*. These faunal divisions are useful, but they overlap very much, and are not numerous or sharp enough to be of great scientific value. The four divisions of the glacial period established by Penck, supplemented by the additional two of James Geikie, were then considered, but the glacial age covered neither the beginning nor the end of Pleistocene time, for both were associated with mild climatic conditions.

The changes of level which occurred during the period were fully discussed, especially as they affected the British Isles and more particularly the Mersey district, and the remainder of the address was devoted to Palæolithic flint implements which might be regarded as zonal indices, and the different culture types from Strépyan to Azilian were briefly described and reference made to recent investigations for the purpose of correlating the various types found in this country with those occurring in the rest of Europe. The exact position of the different cultures in relation to the various phases of the glacial epoch is somewhat in dispute, and as regards the position in the British Isles the age of the Chalky Boulder-clay is critical, as the whole palæolithic series is subsequent to this deposit, as is proved by the occurrence of Chellean implements in the Biddenham gravels, near Bedford, and those of the St. Acheul type at Hoxne, in Suffolk.

V.—Wellington Philosophical Society (Geological Section).
Annual Report for 1918–19 (adopted August 20, 1919).

Since the presentation of the last annual report in August, 1918, six ordinary meetings have been held.

A number of exhibits have been brought and discussed by members, and ten papers have been read. The titles and authors of the papers are as follows: (August 21, 1918) "The post-Tertiary History of the Ohau River and of the Adjacent Coastal Plain," by G. L. Adkin; (September 18, 1918) "The Geology of the Southern Wairarapa District," by J. Allan Thomson; "Further Notes on the Horowhenua Coastal Plain and the Associated Physiographic Features," by G. L. Adkin; (October 16, 1918) "Tertiary Geology of the Waitaki Valley between Duntroon and Kurow," by G. Uttley; "The Significant Features of Reef-bordered Coasts," by W. M. Davis; (May 21, 1919) "The Tertiary Beds of Central Otago," by P. G. Morgan; "Glentunnel Coalfield, Malvern Hills, Canterbury," by P. G. Morgan; (June 18, 1919) "Road-making Stones of Wellington and Taranaki," by S. A. R. Mair; (July 16, 1919) "Brachiopod Genera," by J. Allan Thomson; "Some Conglomerates of East Marlborough," by J. Allan Thomson.

At the meeting held on July 16 it was resolved: "That, in the opinion of the Section, the preparation of a contoured topographical map of New Zealand on as large a scale as practicable (say, 1 . 125,000) is now an imperative necessity, as the map is required for agricultural, geological, geographical, and other purposes."

Election of officers for 1920.—Chairman, Mr. G. H. Uttley; Vice-Chairman, Mr. E. K. Lomas; Committee, Mr. R. W. Holmes, Dr. J. Henderson, Mr. P. G. Morgan, Mr. M. Ongley, Dr. J. A. Thomson; Hon. Secretary, C. A. Cotton.

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EDITED BY

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AND

R. H. RASTALL, M.A.

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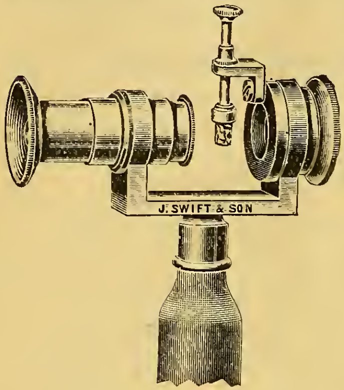

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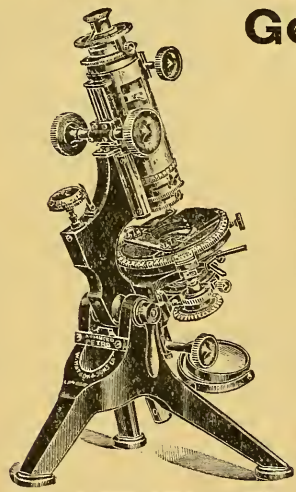

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GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. VI.

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No. XII.—DECEMBER, 1919.

EDITORIAL NOTES.

ALTHOUGH the situation with regard to the future of the Geological Magazine is still somewhat critical, it is satisfactory to be able to state that the worst anticipations have not been realized. At one time it was feared that the present number would have to be the last, but we are glad to be able to announce that it is proposed to carry on, for the present at any rate, in the hope of better times to come. But it cannot be too strongly emphasized that the future rests with our subscribers. Many promises of active support have already been secured, and the outlook is more promising than it was a few months ago. While still maintaining all the old features and the general traditions of the Magazine, every attempt will be made to move with the times and to give due weight to new developments. Geology has now become a science of the widest practical importance in all parts of the world: some of the apparently most abstruse and theoretical investigations of late years were primarily undertaken to subserve economic purposes and have proved to yield results of the highest value and importance in technical practice of all kinds. Unfortunately this fact is little realized in this country, and it is the duty of all modern geologists to keep in touch with such new developments wherever they are to be found, whether in America, Scandinavia, or Germany. Geology is necessarily an international science; it will be our desire and hope so far as in us lies to assist in making known its latest developments, of whatever nature they may be. Above all we shall endeavour to avoid that insidious blight of parochialism and narrowness of interest which has at times threatened to manifest itself in British geology, especially in isolated provincial circles, and to accommodate ourselves to the widening spirit of the times in which we live. Although our circulation is not large, it is wide: we have many contributors beyond the seas, and one of the pleasantest features of the Editorship is the opportunity that it gives for friendly personal communications with these distant workers on subjects connected with geology in all its branches.

* * * * *

At the Anniversary Meeting of the Mineralogical Society, held on November 4, the following Officers and Members of Council were elected: President, Sir William P. Beale, Bart., K.C.; Vice-Presidents, Professor H. L. Bowman, Mr. A. Hutchinson; Treasurer, Dr. J. W. Evans, F.R.S.; General Secretary, Dr. G. T. Prior, F.R.S.; Foreign Secretary, Professor W. W. Watts, F.R.S.; Editor of the Journal, Mr. L. J. Spencer; Ordinary Members of Council, Mr. H. F. Collins, Mr. J. P. De Castro, Professor H. Hilton, Mr. Arthur Russell, Dr. A. Holmes, Miss M. W. Porter, Mr. R. H. Rastall, Sir J. J. H. Teall, F.R.S., Mr. A. F. Hallimond, Dr. F. H. Hatch, Mr. J. A. Howe, and Mr. W. Campbell Smith, M.C.

* * * * *

The Committee appointed by the Board of Trade to consider and report on non-ferrous mining in the United Kingdom has apparently lost no time in getting to work. It was decided to deal with the tin-mining industry first, and a good deal of expert evidence has already been taken. The general opinion of mine-managers from Cornwall, with one or two notable exceptions, seems to be in favour of the policy of amalgamation and concerted development with a view to the reduction of costs and increased production. Several witnesses expressed the view that some form of Government subsidy was highly desirable, and the advance of £1,000,000 to the Anglo-Persian Oil Company was quoted as a precedent. Nevertheless, the idea of nationalization did not seem to receive much sympathy. The Cornish tin and wolfram mining industry rendered signal services to the country during the War, and this should make the Government and the nation all the more inclined to afford assistance towards the development of this important branch of our mineral resources. The geological evidence appears to be all in favour of the existence of rich deposits of tin at deep levels, both in hitherto unworked areas and in districts where many shallow mines have been abandoned: it is much to be wished that opportunity should be given to test the validity of the conclusions largely founded on scientific reasoning.

* * * * *

The Imperial Mineral Resources Bureau has issued a kind of interim Progress Report showing the steps that have already been taken. The Charter has now been received and numerous committees are already formed, consisting of experts in each branch together with representatives of technical and scientific societies dealing with that special subject. It is satisfactory to find that arrangements have been made with the Imperial Institute by which duplication and overlapping will be avoided and a harmonious co-operation assured. Similarly the Home Office has handed over to the Bureau certain duties hitherto performed by it in connexion with the Annual General Report of the Chief Inspector of Mines. The compilation of part iv of that Report, British Empire and Foreign, will in future be undertaken by the Bureau. Two lists are appended to the report showing the countries with which the Bureau is in active correspondence, either directly or through diplomatic and consular offices. The present writer is not aware of the geographical position of the state of Latvia, nor is it clear why information as to the Dutch East and West Indies and Guiana should be obtained from the Colonial Office, Copenhagen, or as to Nicaragua from the Central Statistical Office at Christiania.

ORIGINAL ARTICLES.

I.—*Bunaia Woodwardi*, a New Merostome from the Silurian Waterlimes of New York.

By John M. Clarke, LL.D., For. Corr. Geol. Soc. Lond., Director of the New York State Museum, Albany, N.Y., U.S.A.

(PLATE XIV.)

Prefatory remark by author.—Dr. Henry Woodward has asked me to prepare for the Geological Magazine a brief sketch of this new fossil. It seems to me most appropriate that the Magazine, the sturdy child of this eminent and venerable palæontologist, and the expositor of so many of his own observations on Palæozoic Crustacea, should carry the first printed account of this discovery, which I have taken pleasure in dedicating to Dr. Woodward, my colleague and friend of many years.

THE hydraulic limestone series which cap the Silurian rocks of the New York sections, and are commonly embraced under the name "Salina Group", are probably the richest known depository of remains of the Merostome Crustacea. During the past fifteen years we have been engaged upon the study of this fauna, and the results at which we arrived in our memoir on the Eurypterida of New York [1] could not have been safely attained without the previous labours of Dr. Woodward and the late Professor Rupert Jones, of Huxley, and Hugh Miller for the British species; of Friedrich Schmidt, Nieszkowski, and Holm for the species of the Baltic basin.

We now recognize in the Salina basin of New York over sixty species of the Eurypterida (*Eurypterus*, *Pterygotus*, *Dolichopterus*, *Stylonurus*, etc.), and to this large number are to be added two species of the rare genus *Pseudoniscus*, which had heretofore been found only in the Baltic beds. In the North European development of this shallow-water coastal bay fauna there are three genera of Merostomes which the New York deposits have never revealed; *Hemiaspis* and *Neolimulus*, from the Scottish Silurian, and *Bunodes* from the Island of Oesel. What we are now designating by the name *Bunaia* may be regarded as an alternative expression of *Bunodes*, which according to the descriptions by Eichwald, Schmidt, Nieszkowski, and more recently by Patten (*The Vertebrates and their Kin*) is a creature 2–3 inches long, with short semicircular head, a broad mesosoma of six segments, followed by three narrow segments of the post-abdomen and a long single telson-spine. The head is marked by five curved radial furrows diverging on each side from the central subtriangular glabellar elevation; and these divide the surface into corresponding radial ridges. Dr. Patten has called attention to the retention of this primitive structure in the *Limulus* embryo, a fact which certainly seems to bespeak the direct descent of the latter from this ancient primitive merostome.

The New York fossil is like *Bunodes* in these cephalic structures. Though of very much smaller size, the carapace shows on the upper surface the same arrangement of parts, and on the underside this

[1] Clarke & Ruedemann, Mem. 14, pts. 1, 2, N.Y. State Museum, 1912.

pentameral division is clearly accompanied by remains of the five pairs of legs, the mouth orifice, and, as it seems, the chelate first legs folded down close alongside the mouth.

We illustrate here in connexion with these features a head of *Bunodes lunula*, the Oesel species, showing a similar arrangement of the five pairs of legs and, in addition, what appear to be the lateral thickenings of the glabellar ridges. This is a specimen from which the very thin epidermal film has been removed. Further, the head-shield of *Bunaia* displays more than that of *Bunodes* in its thickened margins and extended cheek-spines. Patten believed that antennæ were present in *Bunodes*, and so restored it, but we find no evidence of these structures in *Bunaia.*

In our specimens the chief difference of *Bunaia* from *Bunodes* is in the structure of the abdomen. In the latter there are six broad segments followed behind by three narrow ones. In *Bunaia* this structure appears to be somewhat different. The cephalon or head-shield is followed behind by narrow segments of which seven or eight can be counted, with possibly one missing. These seem to be of somewhat unequal length and to be longitudinally ridged, but without lateral flanges. Our knowledge of this structure is restricted to a single example and is subject to modification. In one of the three specimens there is a broad detached smooth spine lying alongside the head, which may have been the telson, though apparently pretty large for the species.

The measurements are as follows: width of carapace, 8 mm.; estimated total length of animal, inclusive of telson, 23 mm.

The specimens of *Bunaia Woodwardi* are from the Bertie Waterlime of the Salina Group at East Buffalo, N.Y.

EXPLANATION OF PLATE XIV.

BUNAIA WOODWARDI, sp. nov., J. M. Clarke.

FIG. 1.—A weathered exterior of a head-shield showing the triangular central area or "glabella" and the five pairs of lateral lobes crenulating the surface and corresponding to the legs beneath. × 8.

FIG. 2.—The interior of a head-shield with five pairs of radial appendages and evidently a sixth pair at the central mouth. The light-coloured lines on the right-hand radial areas are elevated linear ridges which appear to be parts of the appendages themselves, and it is thought that the broad dark areas may include both legs and gills. × 8.

FIG. 3.—A crushed and defaced head-shield with a postabdomen of ridged segments. × 8.

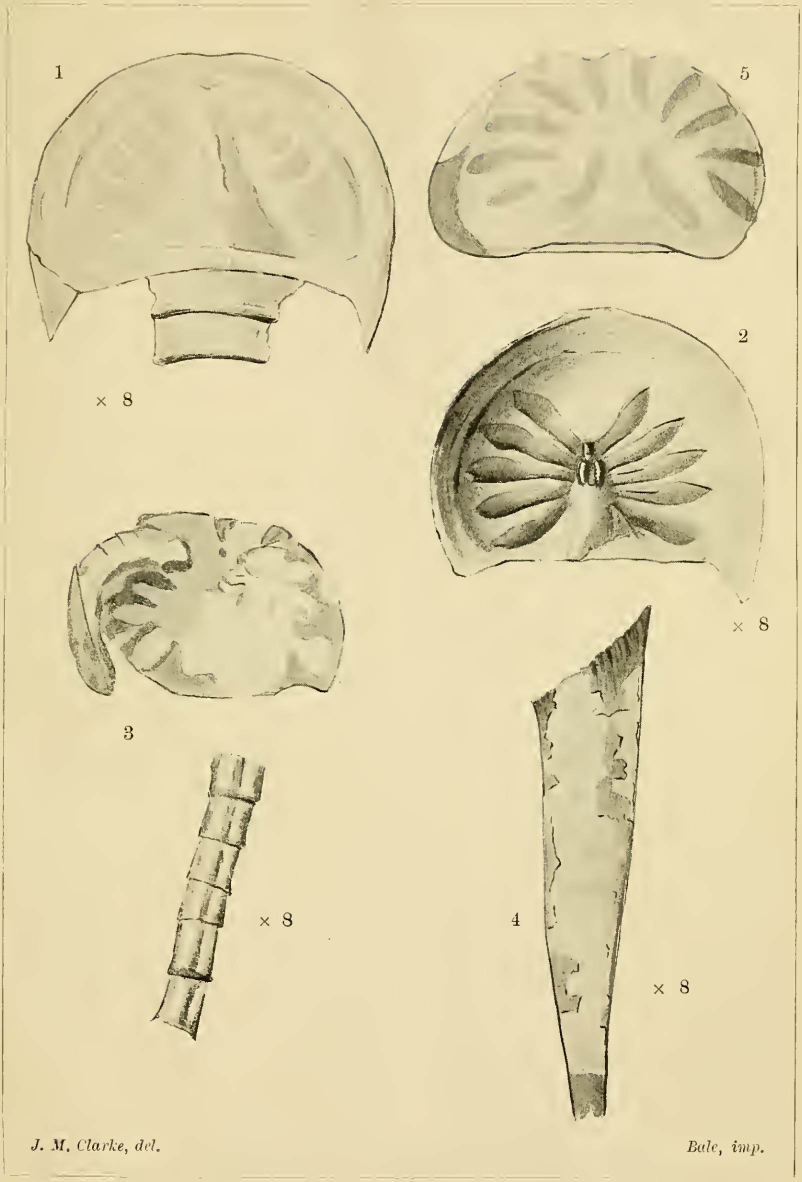
FIG. 4.—A telson spine which lies close to the specimen Fig. 1 and, it is thought, may belong to this species. × 8.

All the foregoing are from the Bertie Waterlime (Silurian) at the East Buffalo, N.Y., quarries.

BUNODES LUNULA, Eichwald.[1]

FIG. 5.—An exfoliated carapace from the Silurian of the Island of Oesel, showing the broad dark bands left by the six pairs of cephalic appendages and also the central divergent ridges which seem to be the interior projections of the ridges of the "glabella". × 3.

[1] Dr. d'Eichwald, Archiv für die Naturk. Liv.-Ehst.- und Kurlands, erste Serie, vol. ii, pl. ii, figs. 12–13, 15, pp. 378–82, Dorpat, 1859, 8vo.



FIGS. 1-4. BUNAIA WOODWARDI, *sp. nov.*, J. M. CLARKE.
FIG. 5. BUNODES LUNULA, EICHWALD, 1859.

II.—The Geology of the Isle of Purbeck.

Abstract of a lecture delivered to Section C, British Association, Bournemouth, by Sir Aubrey Strahan, K.B.E., Sc.D., F.R.S.

The "Isle" of Purbeck includes part of a heathy tract underlain by the Tertiary beds of the Hampshire Basin, a central ridge formed by the Chalk which rises abruptly from beneath those beds, and, in its southern part, a hilly region underlain by Wealden, Purbeck, Portland, and Kimmeridge strata, and terminated by bold cliffs. Each formation gives rise to characteristic features in the landscape, the Portland Stone especially forming a dominant escarpment and vertical sea-cliffs.

The emergence of the Chalk and underlying formations from beneath the Tertiary beds is due to an extremely sharp fold accompanied by overthrusting. The age of the movement is proved in the Isle of Wight to have been post-Oligocene, inasmuch as the Oligocene strata are there involved in it. On the other hand it was accomplished, and the uplifted strata were exposed to prolonged denudation, in pre-Pliocene times. The sagging of the strata which led to the formation of the Hampshire and London Basins and the arching-up of the intervening Wealden anticline are attributable to the same period and to the same earth-movement. So energetic a movement, coming into activity at so late a geological age, had a profound influence upon the physical geography of the south-east of England. The principal rivers, the Thames and Frome, each followed a syncline eastwards. On either side they received tributaries which rose upon the anticlines. The anticlines, however, have suffered severe denudation and no longer maintain their dominance of elevation, but the rivers have kept their courses, and now cross in narrow defiles the Chalk ridges which formed the foundations of the once continuous Chalk arch. Admirable examples of such defiles are shown at Corfe Castle.

The curve of the strata in the Isle of Purbeck may be compared to the figure 2. The lower limb of the 2 represents the horizontal beds of the Hampshire Basin, the middle limb shows the strata in a vertical or inverted position, while the upper limb illustrates the gentle curve by which they regain a more normal position. The strain, however, was too great to be relieved by folding alone, and overthrusting on a considerable scale came into play. The cliff-section of Ballard Down shows curving strata which belonged to the lower limb of the 2 resting upon the edges of vertical strata which belonged to the middle limb, a sharply defined slide-plane (the Isle of Purbeck fault) separating the two. Westwards from Lulworth Cove innumerable subsidiary thrust-planes can be detected in the Chalk, and less easily in the Wealden and Purbeck beds. Everywhere along the line of the Isle of Purbeck fault the Chalk is greatly hardened, while the flints are broken, pulverized, and even drawn out into streaks of flint powder. The Isle of Purbeck fault dies out under Weymouth Bay, but is replaced a mile or two to the north by the parallel and still more energetic Ridgeway overthrust.

As regards the regions which it was proposed to visit, in the neighbourhood of Swanage the whole sequence from the base of Upper Chalk to the Portland Stone is open to examination, but time would not admit of more than a brief inspection of the Purbeck and Portland cliff-sections. The Upper Purbeck with Paludina Limestones or "Marble-beds" and Unio beds form Peveril Point, and the Middle and Lower Purbeck beds are shown more or less continuously in Durlston Bay, a band composed of shells of *Ostrea distoria* (the "Cinder Bed") forming an easily recognized horizon. About 30 feet below it lies the Mammal bed, a thin earthy layer which has yielded the remains of several genera of marsupials. Below this again are the Lower Purbeck limestones and marls, some with gypsum, casts of crystals of rock-salt and insect remains, others yielding a brackish-water estuarine fauna. A double fault, with a downthrow of 100 feet to the south near the zigzag path, throws the Cinder Bed from the top of the cliff to below the beach. The junction with the Portland Stone is not well shown in Durlston Bay.

The cliffs near Kimmeridge give a continuous section from the lowest Purbeck (on the top of St. Albans Head) to a low horizon in the Kimmeridge Clay, more than 1,000 feet of strata in all. From the head westwards they show a descending section in gently inclined strata, and at rather more than 500 feet below the top of the Kimmeridge Clay the "Kimmeridge Coal" or "Brownstone" emerges from below the beach. This highly bituminous layer is about 2 ft. 10 in. thick and has been worked in the neighbourhood from time immemorial, firstly for the manufacture of ornaments or utensils, latterly as a fuel, and as a source of oil. During the War it attracted much attention as a possible source of oil and other products. Alum was also manufactured here. In Hobarrow Bay the main anticlinal axis is reached, and thence westwards the same strata are crossed in ascending order, until the beetling crag formed by the Portland Stone comes down to the beach and stops further progress.

Lulworth Cove illustrates the effect of attacks by the surf upon nearly vertical strata varying in their power of resistance. The Portland Stone has formed a natural breakwater, which, however, has been breached in places. Stair Hole shows the first effects of a breach; the waves have worn holes through the stone and are swilling the debris, the soft Upper Purbeck and Wealden strata, through them. In Lulworth Cove the breakwater has been completely broken through and a beautifully symmetrical natural harbour formed in the outcrops of the Purbeck, Wealden, and Gault formations. Everywhere the sea suffers a prolonged check on reaching the Chalk.

The coast east of Lulworth Cove shows all the formations below the Chalk except the Lower Greensand, but much attenuated as compared with Swanage. Here an unconformity below the Gault, which becomes most pronounced at White Nothe a few miles westwards, becomes manifest for the first time. The absence of Lower Greensand may be due in part to overstep by the Gault, and some of the uppermost Wealden beds may be absent for the same reason. The section at White Nothe shows the Gault resting on steeply upturned Wealden, Purbeck, and Kimmeridge strata, and proves that there had been produced in pre-Gault times a set of flexures wholly independent of those of post-Oligocene age, though parallel to them. These earlier flexures are ignored by the rivers.

Mupe Bay, east of Lulworth Cove, affords a clear view of the passage of the Purbeck beds up into the Wealden, and of the abrupt but conformable junction of the Lower Purbeck and Portland Stone. Half a mile east of Lulworth Cove a ledge of the cliff provides an unrivalled opportunity of examining the lower part of the Purbeck beds, including the junction with the Portland Stone, the thin layer of carbonaceous gravelly soil known as the dirt-bed, numerous stumps and prostrate trunks of coniferous trees silicified and enclosed in calcareous tufa, and the brecciated limestones associated with tufa, known as the "broken beds". Here the incoming of bands of tufa, among the sedimentary limestones, and the close association of such incoming with brecciation of the limestones, can be studied in detail. Westward from Lulworth Cove the cliffs illustrate the intense compression and supplementary overthrusting which all the formations have undergone in the neighbourhood of the Isle of Purbeck fault.

III.—The Origin of Cretaceous Flint.

By W. Alfred Richardson, M.Sc., B.Sc. (Eng.), F.G.S., A.M.I.Min.E.

1. Introduction.

It will be recalled that to the list of theories relating to the origin of flint Liesegang[1] has added another, namely, that the flint is due to the rhythmic precipitation of a silica solution diffusing through the Chalk. Cole[2] in an admirable essay has made this view accessible to English readers, and at the same time somewhat expanded the original suggestion. Yet little by way of evidence is offered beyond a certain plausibility in the idea, and its undoubted competence to explain better than any other hypothesis yet suggested the remarkably regular recurrence of flint lines. When reading over the chief Cretaceous literature with this problem in mind, there seemed to me to be a not inconsiderable body of fact lending support to this view. Accordingly the object of this paper is to examine existing data in the light of Liesegang's suggestion in order to see whether or not it may be regarded as a reasonable working hypothesis.

There are three outstanding questions connected with flint-origin which still await decisive answer. They are, namely:—

1. The age of formation relative to the Chalk.
2. The source of the silica.
3. The cause of the regular recurrence of flint bands.

This paper is only indirectly concerned with the first of these questions, and I shall, therefore, only summarize the position with regard to relative age and pass directly to a discussion of the remaining questions.

[1] R. Liesegang, *Geologische Diffusionen*, Dresden and Leipzig, 1913, p. 126.
[2] G. A. J. Cole, Geol. Mag., 1917, pp. 64–8.

2. The Relative Age of Formation.

The flint, relative to the Chalk, may have been formed either—

(*a*) *Contemporaneously* by original deposition, either organically as advocated by Bulman,[1] or chemically as held by Tarr.[2]

(*b*) *Penecontemporaneously* by segregation of silica disseminated in the ooze of the Cretaceous sea, as Van Tuyl[3] seems to think.

(*c*) *At the time of uplift* by diffusion, precipitation, and replacement, as advocated by Cole and Liesegang.

(*d*) *Subsequent to uplift and complete consolidation.* With regard to (*d*) there is no direct evidence. On the other hand there is something to be said for each of the other relative times. Setting aside for the moment the difficulties that arise when the regular vertical spacing of the bands is taken into account, the bearing of other field evidence may be mentioned.

The general mode of occurrence simulates bedding, but as W. Hill[4] and others have pointed out there is such a close correspondence between the grain, micro-structure, and faunal content of the flint and Chalk that these observers have expressed their belief that the flint is replacive in its attitude to the Chalk. This is quite consistent with penecontemporaneous formation.

On the other hand, the well-known occurrence of exactly similar flint in vertical or highly inclined planes[5] is difficult to reconcile with any other view except that according to which the flint was formed later than the complete deposition of the Chalk. There is no difference between the two types of flint. Sometimes the line of the crack can be seen running through the flint, but where the nodules bulge out they show the same replacive features as do the horizontal flints. This "vein" flint is most commonly observed in anticlinal areas, and the cracks conform in direction to the other tectonic features. They are thus directly related to uplift, and point to the formation of the flint at that time, so supporting Liesegang's contention. Moreover, there are certain puzzling types of nodule (paramoudras, pot-stones, flint rings) which are by no means easy to understand as original deposits. And it may be mentioned that although carefully sought for in both oceanic and shallow water, no flint either partially or completely formed has been dredged up.[6] On the other hand, in both the Upper and Middle Chalk masses of chalk of flint-like form have been found in all stages from white silicified chalk, with perhaps just a small central core of black flint, to the completely black nodule—facts strongly supporting a replacement hypothesis.

The evidence,[7] so far as it goes, seems to me to be decidedly in

[1] G. W. Bulman, Sci. Prog., No. 41, 1916, p. 154.

[2] W. A. Tarr, Amer. Journ. Sci., ser. IV, vol. xliv, p. 428, 1917.

[3] F. M. Van Tuyl, Amer. Journ. Sci., ser. IV, vol. xlv, p. 449, 1918.

[4] W. Hill, Proc. Geol. Assoc., vol. xxii, p. 62, 1911.

[5] A. D. Rowe and C. D. Sherborn, Proc. Geol. Assoc., vol. xvi, p. 170, 1900. W. J. Sollas, *The Age of the Earth*, London, 1905, p. 135.

[6] J. Murray and J. Hjort, *Depths of the Ocean*, London, 1912, pp. 183–5.

[7] See also E. Ray Lankester and others, discussion in *Nature*, 1917, reprinted in Trans. Geol. Physics Soc., 1917.

favour of the replacement of the chalk by silica at the time of uplift. Consideration of the remaining questions will be found to strengthen rather than oppose this conclusion.

3. The Source of the Silica.[1]

Some suggestions as to possible sources of the silica may be dismissed: such, for instance, that it was deposited by percolating sea-water. Magmatic sources are excluded at any rate from the English Chalk. Moore's[2] suggestion that the silicates of overlying strata decomposed by carbonated water furnished the supply has no geological evidence to support it.

Sollas,[3] among recent writers, treating the subject quantitatively, has maintained that the silica was derived from the tests and other remains of siliceous organisms scattered through the Chalk. Jukes-Browne always opposed this theory of disseminated silica, as he called it.[4] Tarr more recently favoured the direct chemical precipitation of silica from sea-water, and was impressed apparently by the immense amount of silica present as chert.

Jukes-Browne, as the result of analyses, stated definitely that "there is no inverse relation between the abundance of flint and the presence of disseminated silica". Since no later analyses seem to be available I have abstracted in Table No. 1 those given by Jukes-Browne himself. However, analyses of certain very siliceous beds in Wiltshire have been omitted. Three of these give respectively 39, 19, and 17 per cent of soluble silica, and inclusion of them would considerably raise the mean percentage of available soluble silica. The analyses in the table are plotted in one of the curves of Fig. 1—the percentage silica horizontally and the height of the sample above the base of the Chalk vertically. It will be noticed that there is a marked increase in soluble silica reported in all analyses below the Melbourn Rock.

Turning now for a moment to consider the amount of silica represented by the flint, I have made an estimate based on the Kent section, since details are available which give almost complete measurements for the whole of the Kent Chalk. The details of this estimate will be found in Table No. II. In this table some columns are devoted to a statement of the assumptions made when details are not available. Assumptions have sometimes to be made as to the number of bands present, their mean thickness, and the amount of flint in each band. In making these estimates I have been guided by actual statements available for the same zones in neighbouring districts, and by my own observations, chiefly in the London area. The mean results for each zone are plotted on the second curve in Fig. 1 to the same scales as the soluble silica.

[1] In what follows numerical data relating to the Chalk, unless otherwise stated, have been obtained from A. J. Jukes-Browne, *Cretaceous Rocks of Britain*, Mem. Geol. Surv.; and from the papers on the White Chalk of the English Coast in the Proc. Geol. Assoc. (1899–1903), by A. R. Rowe and C. D. Sherborn.

[2] B. Moore, Trans. Geol. Physics Soc., 1917, p. 1.

[3] W. J. Sollas, *The Age of the Earth*, London, 1905, pp. 132–65.

[4] A. J. Jukes-Browne, Geol. Mag., 1893, p. 541.

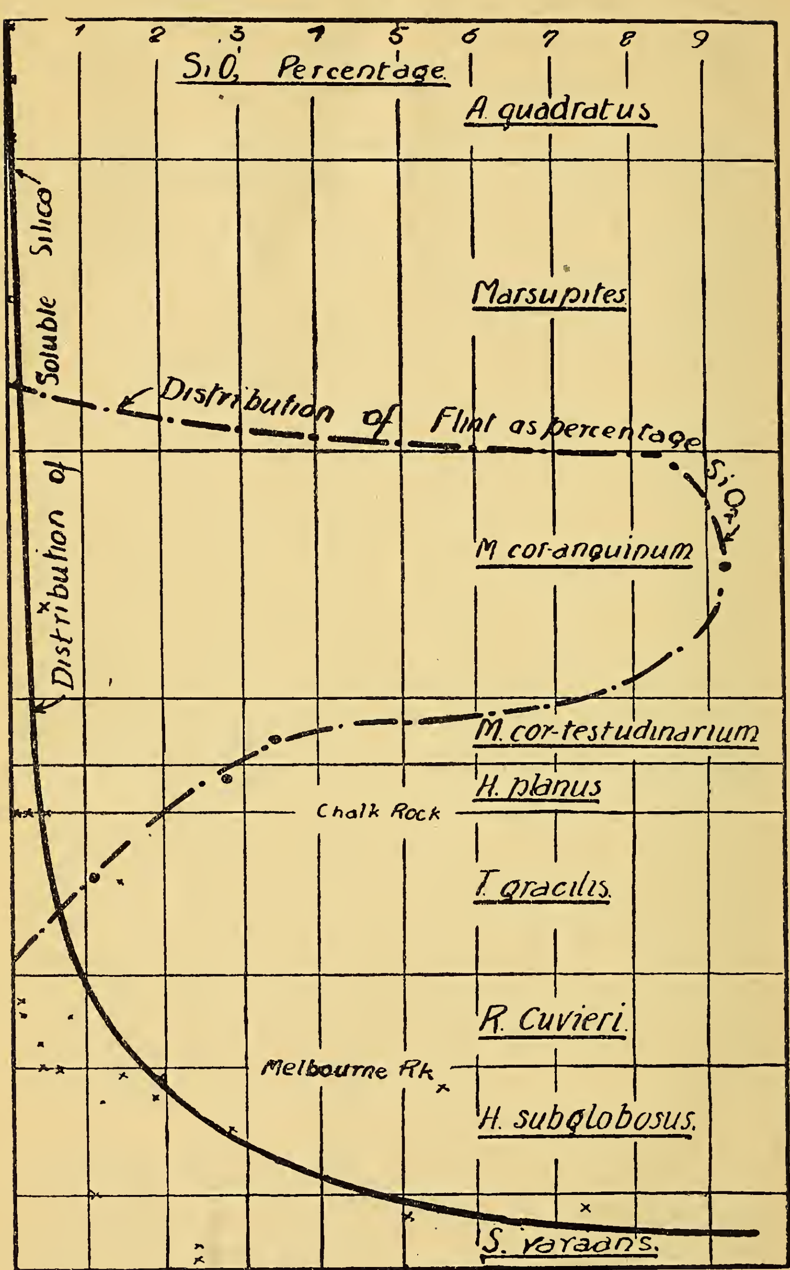


FIG. 1.—Comparison between the silica distributed in soluble form through the Chalk and that present as flint.

A comparison of these curves will bring out the following points:—

(*a*) The flinty chalk and the flintless chalk *above* it are both poor in soluble silica.

(*b*) Increased values in the Lower Chalk appear just where the flint is dying out.

The curves suggest that there *is* an "inverse relation" between the relative amounts of flint and soluble silica present, and that it is a very striking one. Jukes-Browne compared only flinty and flintless zones of the Upper Chalk, but it is obvious that the whole of the Chalk must be considered, because in this case the comparison suggests that the flint represents the silica once spread out in its own region and in the flintless beds above it.

If we now test quantitatively the hypothesis that the silica required for flint formation was obtained from that disseminated in the Chalk itself, it will be found that the analyses in Table No. 1 give the following averages:—

Below the Melbourn Rock, mean silica . .	2·9 per cent.
Above the ,, ,, ,, . .	0·3 ,, ,,

There is thus a balance of some 2·5 per cent in the lower part, which might reasonably be assumed to represent the minimum amount of silica originally available for the formation of flint. It may be noted that this amount is of the same order as the 2 per cent estimated by Mortimer[1] as available for the Chalk of Yorkshire, and as the observation of Sollas that the Upper Chalk may contain as much as 3 per cent of hollow casts of spicules.[2] The exceedingly siliceous beds of the Lower Chalk are here left out of account, but it must be remembered that such rich beds may originally have been present in the Upper Chalk. Indeed, the occasional occurrence of desilicified sponge beds rather points that way. Moreover, if modern oozes are any criterion as much as 10 per cent of silica in organic form is a not unreasonable figure for the original amount, and it might become necessary to account for the disappearance of a portion. In that case part of the original silica, instead of forming concretions, may easily have been carried off in solution, or have been partially dissolved on the sea-floor, as Murray has recorded for modern deposits.[3]

Taking, however, the 2½ per cent above as a conservative figure, my estimate for the 557 feet of flinty chalk in Kent gives a mean percentage flint content of 6 per cent. And, although there may be elsewhere a greater thickness of flinty beds, there is not, I think, a greater concentration of flint. The amount of flint to be accounted for is not, therefore, enormous, and if disseminated through the whole thickness of existing Chalk would be not much more than 2 per cent. It would, to put it in another way, require about 1,300 feet of Chalk to supply the Kent section, that is less than 700 feet above the flinty region. And if Sollas's figure of 5,000 feet for the minimum thickness of Chalk is correct there was ample for the purpose.[4]

[1] R. Mortimer, Proc. Geol. Assoc., vol. xxi, p. 96, 1910.
[2] W. J. Sollas, *The Age of the Earth*, London, 1905, p. 147.
[3] Ibid., p. 160.
[4] J. Murray and J. Hjort, loc. cit., pp. 183-5.

There yet remains one further matter which I think has not hitherto been discussed, namely, the history of the carbonate set free if the flint is a replacement of the Chalk. There are one or two interesting facts in this connexion, though no special emphasis should perhaps be laid on them. Jukes-Browne states that calcite is abundant in the *gracilis* and *planus* zones of Yorkshire, and that it is not uncommon in the Chalk Rock.[1] It has also been observed in the lower zones of the south. There are no quantitative observations, but it is significant that it should be several times reported in the lower zones. However, it is by no means necessary to suppose that the replaced carbonate is represented by calcite. It may in part be piesent as a cementing material in the Chalk, for there is usually about 30 per cent of pore space. It is therefore curious to note that whilst the Upper Chalk of the South is usually described as soft and friable, the bulk of the building stones are quarried in the Middle and Lower Chalk.[2]

4. The Rhythm of the Flint Bands.

The regularity of the recurrence of bands of flint in the Chalk attracted early attention. Many theories have been framed in the past to account for this periodicity of flint, and indeed no theory which neglects to take into account this obvious feature is likely to be generally accepted. Most of the earlier theories looked to periodic organic growth or to periodic precipitation from the sea. But there is no adequate external cause for this periodicity except a seasonal one, and Cole and others have shown the incompetence of this.[3] It is the simplicity of the Liesegang explanation of the rhythm that makes a re-examination of the evidence for possible support desirable. Before discussing the matter further, it is necessary to examine Liesegang's results and to summarize some recent work on precipitation in gels.[4]

If a gel, in which silver chromate has been precipitated rhythmically, or one of Liesegang's figures, be examined, it will be seen that near the entrance of the inward-diffusing solution the bands are so close together that they appear as a continuous precipitate, though they can usually be resolved by magnification. Passing outwards the banding is obvious to the naked eye. By measurement of one of Liesegang's[5] figures and plotting the amount separating the bands against their distance from the drop, as in Fig. 2*a*, a picture of the rhythm is obtained. It will be seen from this curve that the rhythm can be divided into two stages—

AB = near the origin. The bands so close as to appear continuous.

BC = Bands with the separation increasing approximately according to a linear law.

[1] A. R. Rowe and C. D. Sherborn, Proc. Geol. Assoc., vol. xvii, p. 229. A. J. Jukes-Browne, Geol. Mag., 1893, p. 317.

[2] J. A. Howe, *Geology of Building Stones*, London, 1910, p. 259.

[3] G. A. J. Cole, loc. cit.

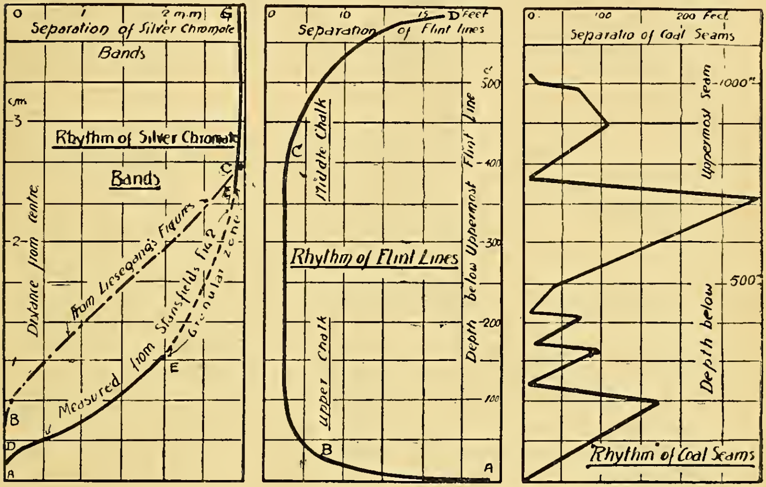
[4] For a simple and clear account of precipitation in gels see E. Hatschek, *Introduction to the Physics and Chemistry of Colloids*, 2nd ed., London, 1916.

[5] R. Liesegang, loc. cit., chap. x.

In a recent paper J. Stansfield, working with gels and solutions of different concentration, has added considerably to our knowledge of the rhythm. The following among his conclusions may be noted :—

(*a*) Increase in the distance between the bands is due to progressive dilution of the reagent, and the rate of diffusion is an important controlling factor. Under certain conditions the bands may be equally spaced, or spaced at decreasing distances.

(*b*) Banding may sometimes break down altogether, and be replaced by a granular zone. This, again, may be followed on further diffusion by a resumption of banded precipitation.



(*a*) Bichromate Gels. (*b*) Flint in Chalk. (*c*) Coal-seams.

Fig. 2.—Rhythm curves obtained by plotting distance separating bands against the position of bands measured from a chosen origin.

Now measuring up Stansfield's Fig. 2, and plotting the results besides those of Liesegang, the rhythm-curve given in Fig. 2*a* is obtained.[1] There is the closely banded stage AD as before ; a stage DE of increasing separation not quite linear; a granular zone EF where the precipitate is in spots scattered throughout the zone without linear or other arrangement; and a final region FG where the precipitate is in bands separated by constant intervals, but much greater than in the earlier banded stage DE.

We may now return to a consideration of the Chalk. In Fig. 3 I have constructed vertical sections for three coastal localities, putting in the position of the flint bands. Quantitative data are available for practically the whole of the Kent section, and in the others it is possible to fill satisfactorily the gaps in the measurements by qualitative statements, which are fortunately abundant. Now all of these show a sufficiently striking resemblance to the

[1] J. Stansfield, Amer. Journ. Sci., ser. iv, vol. xliii, p. 1.

precipitation of silver chromate bands in vertical tubes. Treating these measurements in the same way as those from the gels the rhythm-curve of Fig. 2*b* is obtained. Here the amount of separation of flint lines is plotted against their distance below the top flint line (since the curves of Fig. 1 suggest a downward diffusion). This curve is slightly generalized to show the characteristics of all the sections of Fig. 3. The rhythm may be analysed into three main stages, starting from the entry—

(*a*) AB, on the curve. Separation of the bands decreasing downwards.

(*b*) BC, dense banding. The bands separated by intervals nearly constant, but varying slightly between 2 and 3 feet.

(*c*) CD, the separation of the bands increasing downwards. There is also a marked tendency to the development of granular zones in stages 1 and 2.

This rhythm, therefore, differs from that which obtains in the gels by the addition of an earlier stage with *decreasing separation* of the bands. On the other hand, it is so definite that it can hardly be accidental. Moreover, the same rhythm will be repeated more or less perfectly, not only in the sections figured, but also in any other which is of sufficient length and where details are sufficient to apply the test. It is interesting to treat a coal-shaft section in the same way for comparison. In Fig. 2*c* the rhythm curve from a South Wales mine is given[1]—the intervals separating seams being plotted against their depth below the first seam. If the occurrence of long intervals separated by a series of short ones be taken as a kind of periodicity, it is obviously of a character vastly differing from that shown either in the Chalk or in the gels. At the same time this comparison brings out still more strikingly the close similarity of the phenomena in the last two cases.

It is not my purpose to speculate on the nature of the chemical reactions which took place. Liesegang supposes that at the time of uplift the Chalk was permeated by a solution of silica, which in the light of the results of the previous section we may suppose to be furnished by a partial solution of organic remains in the Chalk. The uplift caused a downward draining, and either the solution reached a supersaturated state or accumulated a precipitant. In either case the solution was precipitated rhythmically. In the early stage AB of the flint-rhythm (applying Stansfield's results) there was probably progressive increase in the concentration of the reacting solutions, accompanied by decreasing separation of the precipitation bands. There followed the zone of most favourable concentration and densest precipitation, and later progressive dilution of the solutions brought on a gradual lengthening of the separation interval. This sequence in the banding is curiously reflected in the character of the flints in the various zones. Where flints occur in the *mucronata* zone and the Chalk above they are generally small, often spongiform (as though "sowing" had caused the precipitation of a solution in the metastable state); and formed of immature flint. Scattered

[1] *South Wales Coalfield* (Mem. Geol. Surv.), pt. viii, p. 113, 1907.

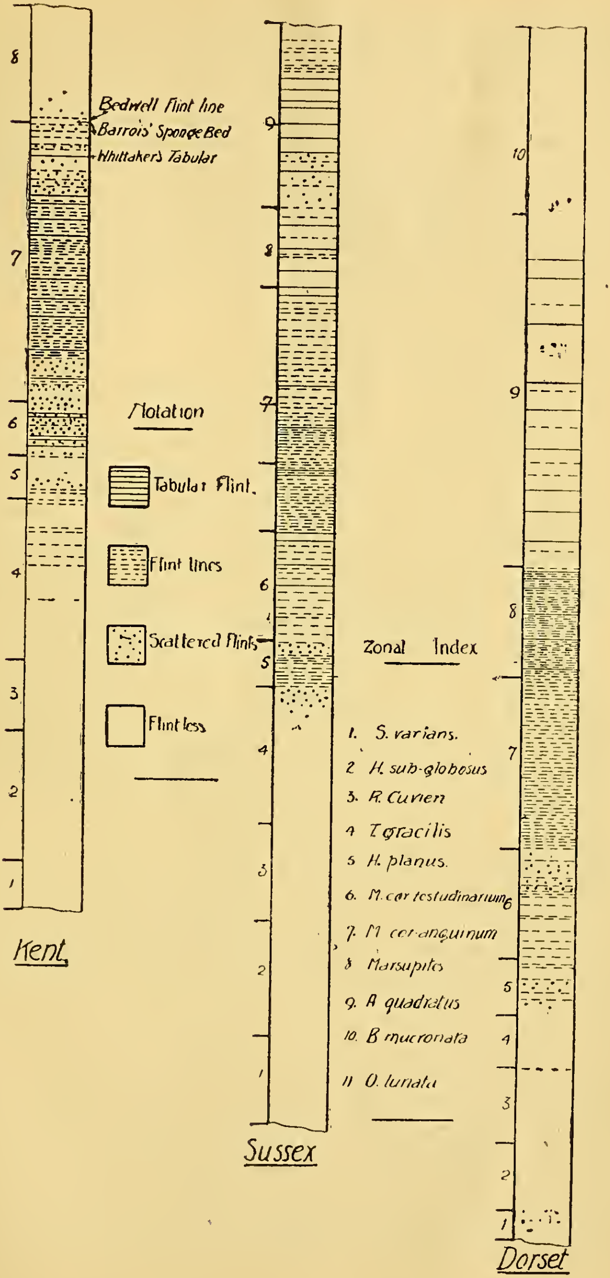


Fig. 3.—Vertical distribution of Flint in the Chalk.

flints corresponding to "granular zones" are common. In the *Marsupites* and *cor-anguinum* zones solid flints are the rule and continuous flint bands are common. In the lower parts of the latter zone carious flints become more common and prevail in the *gracilis* and *planus* zones, where the flints are also spongiform, often scattered, and immature. Thus the opening and closing phases of the sequence are characterized by enfeebled flint development as well as by a wide interval between the bands.

It may be mentioned that such types as banded flints, paramoudras, and flint rings present less difficulty when considered as rhythmic phenomena, and some of them have already been imitated in gels.

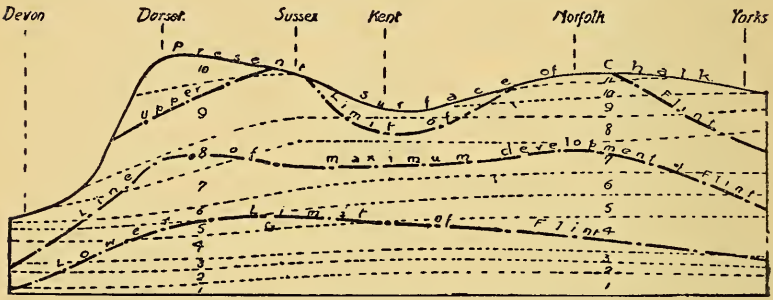


FIG. 4.—Horizontal distribution of Flint in the Chalk.
(The zonal numbers are the same as those used in Fig. 3.)

If the distribution of the flint be studied in a horizontal section, such as that given in Fig. 4, some rather interesting relations are brought to light. In drawing the section the Chalk has been reduced to a horizontal base. The zonal boundaries are shown in dotted lines. The chain-dotted lines represent the upper and lower limits of flint occurrence and the approximate line of its maximum development.

Now it will be apparent that the lines of flint development transgress the zonal boundaries. If the flint had been deposited contemporaneously with the Chalk, one would expect it to conform horizontally to the zones, and its failure so to do strongly supports the view that the flint is later in date than the deposition of the Chalk.

There is, moreover, a curious but rather striking tendency of the flint development lines to follow the present surface of the Chalk. If the flint bands are due to periodic organic growth, or to periodic chemical precipitation, there is no reason why its horizontal distribution should show such a characteristic. On the other hand, if we suppose the present surface to be related more or less remotely to the surface at the time of uplift, it would mean that the lines of flint development were also related to that surface. Such behaviour is not merely in conformity with the theory of rhythmic precipitation of solutions diffusing through the Chalk under draining actions due to uplift, but might be predicted as a result to be expected of such action.

TABLE No. 1.

Horizon.	Locality.	Soluble SiO_2 per cent.
Belemnitella mucronata	Corfe Castle	0·10
,, ,,	Studland, Dorset	0·11
Actinocamax quadratus	Otterburn, Hants	0·10
Marsupites testudinarius	Bishop's Down, Wilts	0·00
Micraster	Great Dunford, Wilts	0·50
Chalk Rock	Aston Rowant, Oxon	0·48
,,	Redburn Hills, Wilts	0·05
,,	Boxmoor, Herts	0·13
Terebratulina gracilis	Royston, Herts	1·48
Rhynchonella Cuvieri	300 feet above Gault, Wye	0·04
,, ,,	St. Catherine's Hill, Winchester	0·06
,, ,,	Hitchin	0·72
,, ,, 50 feet above Melbourn Rock	Hitchin	0·35
Melbourn Rock, upper part	Okeford Fitzpaine, Dorset	0·45
,, ,, lower part	,, ,,	0·65
Belemnite Marl, chalk between marls	Hitchin	1·53
Belemnite Marl, chalk between marls	Royston	1·90
Belemnite Marl (lower)	Hitchin	5·57
,, ,, (chalk just below)	Arlesey, Hitchin	1·81
20 feet below Melbourn Rock	Brimsdown, Wilts	1·15
50 feet below ,,	Belchalwell, Dorset	2·95
Totternhoe Stone	Arlesey, Hitchin	1·02
6 feet below Totternhoe Stone	,, ,,	1·41
20 feet below ,,	,, ,,	7·30
Schloenbachia varians	Warminster, Wilts	6·68
,, ,,	Upper Scudamore, Wilts	2·28
Chloritic Marl	Farnham, Surrey	2·16

5. Summary.

1. An examination of the amounts of silica disseminated through the Chalk and segregated as flint reveals a distinct and striking inverse relation between them.

2. The amount of silica present as flint is found to be of the same order as that disseminated, and confirms the conclusions at which Professor Sollas has already arrived. The silica, that is, might easily have been derived from the remains of siliceous organisms buried in the Chalk, and only requires a moderate thickness for the supply.

3. The rhythm found in the recurrence of flint lines presents a striking similarity to the Liesegang banding; and in general a study of flint distribution strongly supports the hypothesis that the flint originated by the rhythmic precipitation of solutions diffusing through the Chalk at the time of uplift.

Whether these conclusions apply to flint-like segregations in other formations it is impossible to say, since there is no such body of quantitative data available for their study as exists for that of the

TABLE No. 2.

Zone.	1	2	3	4	5	6	7	8
			Inches.	°/o	ft. in.	ft. in.	°/o	Feet.
Marsupites.	Few scattered several feet above base . . .	1	12	100	1 0			
	Bedwell Line. 4 inches. Flints scattered . .	—	—	50	2	1 2	—	60
Micraster cor-anguinum.	2 in. layer . . .	—	—	50	1			
	Layer	—	3	50	1½			
	Layer	—	3	50	1½			
	Whitaker's tabular, 3 in.	—	—	100	3			
	Few layers . . .	6	3	50	9			
	Columnar tabular . .	—	4	100	4			
	80 layers . . .	—	3	100	20 0			
	Irregular layers and scattered flints . .	4	3	50	6			
	Tabular, 2 inches . .	—	—	100	2			
	Scattered through 15 feet	3	3	50	5	22 9	9·3	246
Micraster cor-testudinarium.	Scattered through 26 feet	7	2	50	7			
	Tabular . . .	—	2	100	2			
	Scattered through 15 feet	3	3	50	5			
	Strong flint line . .	—	5	50	3			
	Two broken bands .	—	2	50	2			
	Strong flint line . .	—	5	50	3	1 10	3·3	56
Holaster planus.	Scattered through 15 feet	5	2	50	5			
	Layer, 4 inches thick .	—	—	50	2			
	,, ,, .	—	—	50	2			
	Flint line, 4 inches thick	—	—	50	2	11	2·7	34
T. gracilis.	Flint line . . .	—	4	50	2			
	Irregular lines . .	12	3	50	1 6			
	Flint line . . .	—	4	50	2	1 10		161
	Total for whole section					28 6	5·1	557

1. Remarks on character of flint bands with any actual measurements available.
2. Assumed number of bands present.
3. Assumed thickness of band.
4. Allowance for amount of flint in band.
5. Total thickness of flint if solid, calculated from previous columns.
6. Total thickness of solid flint in the zone.
7. Percentage flint per zone. (Plotted in Fig. 1.)
8. Thickness of zone. (Flinty *Marsupites* Chalk less than 60 feet.)

English Chalk. I have refrained from discussing in this paper theories recently advanced to account for the origin of chert, partly because of this lack of data as regards the formations in question, and partly because the authors make no attempt to account for any regularity in the recurrence of nodular lines. It may be that in the formations discussed in these papers such periodicity is not apparent. But so far as the English Chalk is concerned, this is one of the most obvious features and an explanation of it may reasonably be required of any hypothesis advanced as to flint origin.

My thanks are due to Professor H. H. Swinnerton, D.Sc., for critically reading this paper in MS.

IV.—The Correlation of the Devonian Rocks of North Devon with those of other Localities.

(Abstract of communication to Section C, British Association, 1919.)

By Dr. John W. Evans, F.R.S.

The Dartmouth Slates of South Devon and Cornwall, which correspond, it would seem, to the Schistes d'Oignies of the Ardennes, are not seen in North Devon, but may be concealed by later rocks and be represented in South Wales and the Welsh Border by the Red Marls of the Lower Old Red Sandstone. It is possible that the Foreland Grits are a local facies of the upper portion of the Dartmouth Slates, just as the arenaceous Cosheston Group is a local development of the upper part of the Red Marls. Both the Foreland Grits and the Cosheston Group appear to have yielded the typical Old Red Sandstone plant *Psilophyton*.[1]

The usual correlation of the Lynton Beds with the Meadfoots of South Devon seems well founded. The lower beds with *Pteraspis* may be compared with the Schistes de Saint Hubert of the Ardennes with *Spirifer primævus* and *Pteraspis dunensis* and the Schistes à *Pteraspis dunensis* in the Pas de Calais. The Senni Beds, which overlie the Red Marls on the north of the South Wales Coalfield and contain *Pteraspis* and *Cephalaspis*, may be of the same age. The two strata last mentioned have not, however, up to the present yielded any marine forms.

The Hangman Grits represent a great thickness of arenaceous beds of the Old Red Sandstone type overlying the Lynton Beds. Little is known of the lower portion, but the upper beds include lacustrine or fluviatile beds, with plant remains which are probably referable to the Middle Devonian plant *Ptilophyton*. These are succeeded by marine beds with several fossiliferous horizons, some of which have yielded *Stringocephalus*. The upper part at least of the Hangman Grits must therefore be considered to be of Givetian age, that is to say, Upper-Middle Devonian, instead of Upper-Lower Devonian, according to the usual correlation. This view is supported by the discovery near Combe Martin (after the reading of the paper) in the

[1] The author is not inclined to accept the view that the Foreland Grits are a repetition of the Hangman Grits, by faulting.

plant-bearing beds of a fish-plate referred by Dr. Smith Woodward to *Coccosteus*, a genus which is usually of Middle Old Red Sandstone and Middle Devonian age, though it has been found in the Upper Old Red Sandstone. The Staddon Grits of South Devon, on the other hand, which are usually considered to be the equivalent of the Hangman Grits, cannot extend upwards much above the base of the Eifelian or Lower-Middle Devonian, as they are succeeded by dark-grey slates and shaly limestones with *Calceola sandalina*. The succession in the Middle Devonian of North Devon may be paralleled in the Boulonnais, where micaceous sandstones with plant remains are overlaid by marine beds with *Stringocephalus burtini*.

The Hangman Grits are succeeded by the Combe Martin Beds, grits with occasional ferruginous crinoidal limestones, and these by the Ilfracombe Beds, shales and limestones with crinoids and corals. Except for an alleged occurrence of *Stringocephalus*, which cannot now be verified, no distinctive fossils have been found either in the Combe Martin or Lower Ilfracombe Beds, and they may be either Upper-Middle Devonian (Givetian) or Lower-Upper Devonian (Frasnian). Unfortunately no goniatites have been found in the Devonian of North Devon, so that exact correlation is difficult. In higher portions of the Ilfracombe Beds *Spirifer verneuili* and *Rhynchonella* (*Wilsonia*) *cuboides* are found, which are sufficient to establish the Upper Devonian (presumably Frasnian) age of the rocks. The highest Ilfracombe Beds are less calcareous, and there seems no reason to doubt that they pass upwards conformably into the Morte Slates, the Upper Devonian age of which is completely established by the occurrence of *Spirifer verneuili* (var. *hamlingi*), and they may well represent the Schistes de Matagne, which form the highest beds of the Frasnian in the Ardennes. Rocks of the same age appear to be met with in the Boulonnais and in the boring in Tottenham Court Road in London. The Morte Slates become more arenaceous at the summit and are succeeded probably conformably by the Pickwell Down Sandstones. The junction is usually faulted, but this is apt to be the case in strongly folded areas where successive beds differ considerably in physical characters and in the resistance they offer to the forces to which the rocks have been subjected. The Pickwell Down Sandstones have yielded the typical Upper Old Red Sandstone fish *Holoptychius* and *Bothriolepis*, and may be compared to the beds with the same forms reached by a boring at Southall, west of London, and to the Psammites de Condroz. They must therefore be referred to the terrestrial or Old Red Sandstone type of the Famennian. The Baggy and Marwood Beds that overlie the Pickwell Down Sandstones and the lower portion of the succeeding Pilton Beds represent a marine facies of the Upper Famennian, as well as the Calcaire d'Étroeungt, which forms a passage to the Carboniferous in the Ardennes. The Upper Devonian of the Turnford boring in the Lea Valley, north-east of London, and the marine beds of the Upper Old Red Sandstone of South Wales and the Coomhola Grits in South Ireland are probably at about the same horizon as the Baggy and Marwood Beds and the base of the Piltons. The Upper Pilton Beds have now been shown to be of Carboniferous and not Devonian age, and to extend upwards and include the basement beds of the *Zaphrentis* zone.

It will be seen that North Devon is characterized by a repeated alternation of the terrestrial or Old Red Sandstone facies formed of materials laid down by rivers or in lakes, or transported by the action of the wind, and the marine facies of the Devonian. This alternation is even more remarkable than that in the Eastern Baltic, with which all students of geology are familiar. There were, as we have seen in North Devon, three periods when the marine recession resulted in the deposition of the Old Red type of sediment with freshwater fossils, the first commencing in some areas towards the close of Silurian times and continuing through the Gedinnian, the second including the uppermost horizons of the Lower Devonian and apparently the whole of the Eifelian, and the third in the Famennian. Each recurrence of the terrestrial facies is characterized by a completely different fauna and flora. There were also three periods of marine transgression, one, which is missing in the Baltic area, about midway in the Lower Devonian, the second in the Givetian and Frasnian, and the third commencing near the close of the Famennian and reaching its maximum in the Carboniferous. In South Devon and Cornwall the conditions as a whole were more marine than in North Devon, and it was only during the deposition of the Dartmouth Slates in North Cornwall that entirely terrestrial (here freshwater) conditions prevailed. In South Wales, on the other hand, terrestrial conditions were more prevalent than in North Devon ; but a far more important difference between the north and south of the Bristol Channel lies in the complete omission, due either to non-deposition or erosion, of any representative of North Devon ; strata from at least low down in the Lynton Beds to the summit of the Morte Slates.

The variation of conditions of deposition which are so strongly marked in North Devon can be traced in most of the occurrences of Devonian rocks in other parts of the world, though they are nowhere else so striking and unambiguous. It is the deepening and transgression of the sea in Givetian and Frasnian times that is the most widely extended and most strongly marked of all these changes.

The Devonian period is not a natural division of the history of marine sedimentation characterized by a gradual deepening and subsequently a gradual shallowing of the ocean waters, but was determined solely by the interval between the last marine beds of the Silurian and the earliest marine beds of the Carboniferous Limestone on the Welsh Border, where these strata were first studied in the early days of stratigraphical research. It was in this way that the limits of the Old Red Sandstone were originally fixed, and as a consequence also those of the contemporaneous rocks of marine origin elsewhere deposited, which were a little later grouped together to form the Devonian.

V.—On the Discovery of Fossil Hydroid Remains of the Order Calyptoblastea in the Palæozoic of Victoria, Australia.

(PLATE XV.)

By Frederick Chapman, A.L.S., Palæontologist to the National Museum, Melbourne, and Professor Ernest W. Skeats, D.Sc., A.R.C.S., F.G.S., University of Melbourne.

SINCE no undoubted fossil remains of this group of hydroids have been previously recorded, with the exception of possible forms indicated by Ruedemann but placed by him with the Graptolites, it is thought that a few brief notes on a recent discovery in Victoria may be acceptable to readers of this Magazine. A description of the fossils by one of us (F. C.) will appear in the Proc. Roy. Soc. Victoria, while a description of the stratigraphy of the area will be given by the other author (E. W. S.)

Rocks in which the Fossils occur.

The fossils are found in a black shale about 2 miles north-east of North Monegetta and 2½ miles south-east of Romsey railway stations and about 40 miles north of Melbourne. The black shale occurs as vertical outcrops in Deep Creek, striking, N. 20° E., interbedded with black cherts and in conformable contact with Heathcotian (Cambrian) diabase which forms Hurst's Hill east of Deep Creek. The fossils are associated with a Brachiopod *Acrotreta antipodum*, Chapm., which suggests a horizon low down in the basal Ordovician, but somewhat similar branching forms occur with *Dinesusida* and other trilobite remains of probably Cambrian age near Heathcote, about 30 miles further north.

Condition of Fossils.

The remains of the hydrosome are seen as a silvery-white film on the dark slate. In the case of *Mastigograptus* this film is very tenuous and seems to disappear rapidly into the slaty surface, though under a lens the thecal growth can be seen extended for quite a distance. The shape of the aperture of the cups of both hydrothecæ and gonothecæ is distinct.

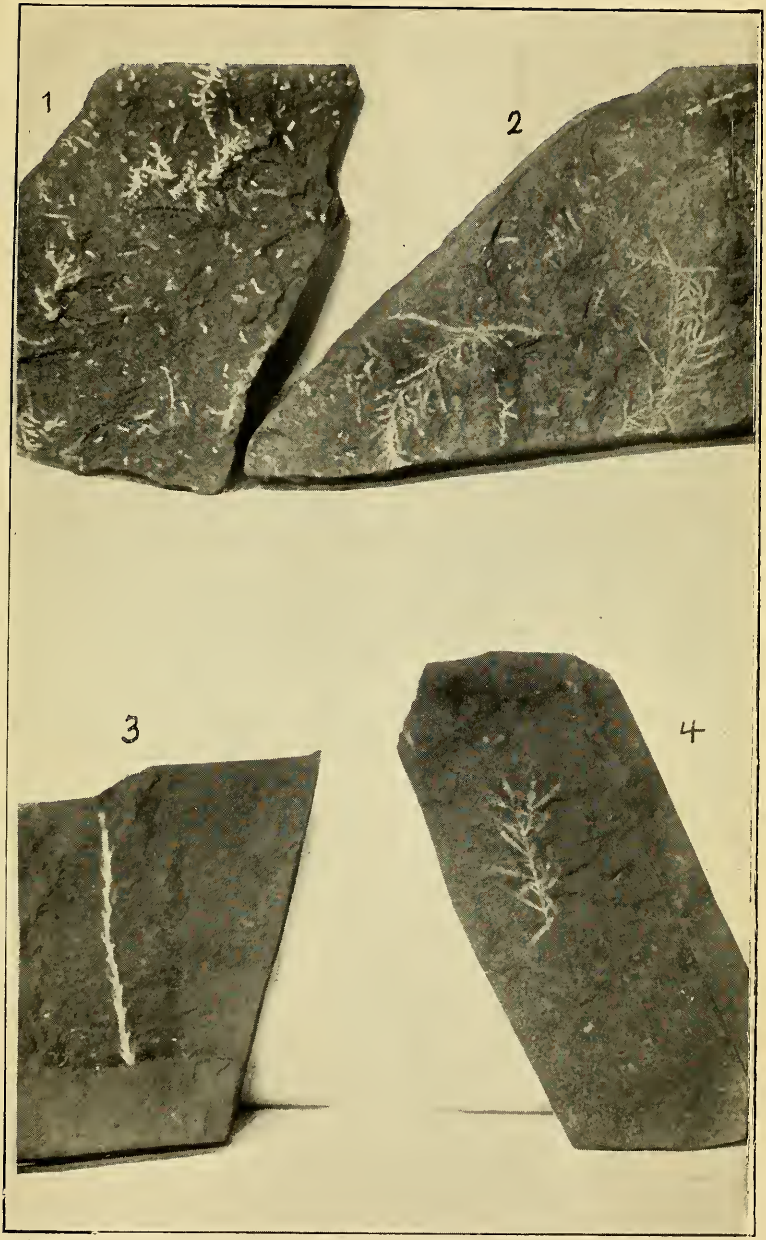
Definition and Relationships.

Comparing these Palæozoic fossils with living hydroids, two generic forms seem to be closely related to living genera, and are accordingly named *Archæocryptolaria* (*A. skeatsi*) and *Archæolafoëa* (*A. recta* and *A. longicornis*). *Archæocryptolaria* resembles in its long, cylindrical hydrothecæ *Cryptolaria angulata*, Bale, a living form found in the Great Australian Bight at 100 fathoms. *Archæolafoëa* is compared with the living *Lafoëa fruticosa*, Sars. *Mastigograptus* was described by Ruedemann from the Utica Slate of Trenton, New York (Middle Ordovician). *M. monegettæ* shows less tendency to branch than in *M. tenuiramosus* of Ruedemann.

EXPLANATION OF PLATE XV.

Fig. 1.—*Archæocryptolaria skeatsi*, Chapm.
,, 2.—*A. longicornis*, Ch.
,, 3.—*A. recta*, Ch.
,, 4.—*Mastigograptus monegettæ*, Ch.

From black shale in the basal Ordovician near North Monegetta, 40 miles north of Melbourne, Victoria. Figures slightly enlarged.



F. C. phot.

NEW FOSSIL HYDROIDS FROM THE PALÆOZOIC OF VICTORIA.

VI.—British Association for the Advancement of Science, Bournemouth, 1919.

Address to the Geological Section. By J. W. Evans, D.Sc., LL.B., F.R.S., President of the Section.

(*Concluded from p. 517.*)

ANOTHER direction in which the work of the Survey could with advantage be extended is in the execution of deep borings[1] on carefully thought-out schemes by which a maximum of information could be obtained. Both in Holland and Germany borings have been carried out to discover the nature of the older rocks beneath the Secondary and Tertiary strata, and Professor Watts, in his Presidental Address to the Geological Society in 1912 (Proc. Geol. Soc., pp. lxxx–xc), has dwelt on the importance of exploring systematically the region beneath the wide spread of the younger rocks that covers such a great extent of the East and South of England. Professor Boulton, my predecessor in this Chair, has endorsed this appeal, but nothing has been done or is apparently likely to be done in this direction. It seems extraordinary that no co-ordinated effort should have been made to ascertain the character and potentiality of this almost unknown land that lies close beneath our feet and is the continuation of the older rocks of the west and north to which we owe so much of our mineral wealth. It is true that borings have been put down by private enterprise, but, being directed only by the hope of private gain and by rival interests, they have been carried out on no settled plan, and the results and sometimes the very existence of the borings have been kept secret. The natural consequences of this procedure have been the maximum of expense and the minimum of useful information.

Unfortunately in recent years percussion or rope boring, which breaks up the rock into fine powder, has more and more, on account of its cheapness, replaced the use of a circular rotating drill which yields a substantial cylindrical core that affords far more information as to the nature of the rocks and the geological structure of the district. If private boring is still to be carried on, the adoption of the latter procedure should be insisted on, even if the difference of cost has to be defrayed by the Government. It is quite true that a considerable amount of useful information can be collected by means of a careful microscopic examination of the minute fragments which alone are available for study, so that the nature of the rocks traversed can be recognized; but the texture of the rock is destroyed, as well as any evidence which might have been available of its larger structures and stratigraphical relations, and almost all traces of fossils. It is, too, impossible to tell with certainty the exact depth at which any particular material was originally located, for fragments broken

[1] I have not space to deal here with the shallow borings in soft strata which have been so successfully conducted on the Flanders front during the War by Captain W. B. R. King, of the Geological Survey. Similar borings have been already carried out by the Survey on a limited scale, but in the light of the experience that has now been gained we may look for a widely extended use of the method both by private workers and by the Survey officers.

off from the sides of the bore may easily find their way to the bottom.

A good illustration, and one of many that might be cited, of the misdirected energy that is sometimes expended in prospecting operations, was afforded a few years ago by a company that put down a boring for oil through more than a thousand feet of granite without being aware of the nature of the rock that was being traversed. In this case a percussion drill was employed, but a few minutes' examination of the material should have enabled the engineer in charge, supposing he had even an elementary knowledge of geology, to save hundreds of pounds of needless expenditure. The sum-total of the funds which have been uselessly expended in this country alone in hopeless explorations for minerals, in complete disregard of the most obvious geological evidence, would have been sufficient to defray many times over the cost of a complete scientific underground survey.

If research is to be carried out economically and effectively, it must be organized systematically and directed primarily with the aim of advancing knowledge. If this aim be well and faithfully kept in view, material benefits will accrue which would never have been thought to be sufficiently probable to warrant the expenditure of money on prospecting.

It is, however, not only in the areas occupied by Secondary or Tertiary rocks that systematic boring is urgently needed. There are many other localities where important information as to the structure of the rocks could probably be obtained in this manner. Opinion is very much divided as to the relation of the Devonian to the older rocks in South Devon and Cornwall,[1] but there is little doubt that a series of judiciously placed borings would solve the problem without difficulty. In North Devon and West Somerset, the question as to whether the Foreland Grits are a repetition by faulting of the Hangman Grits could also be settled at once by borings in the Foreland Grits and in the Lynton Beds.

In the North of England, again, there are many points where the strata exposed at the surface are low down in the Carboniferous, and it would be comparatively easy to ascertain the nature of the earlier rocks beneath them, with regard to which we are much in need of information.[2]

[1] I have already referred to the economic importance of this area. The desirability of ascertaining its true geological structure is too obvious to need emphasis here.

[2] The recent borings for mineral oil in the Carboniferous rocks of Derbyshire were put down largely by means of public funds, and such success as they have attained has been due to the fact that they were directed by expert geologists; but there can be little doubt that, if they had been carried out as part of a carefully thought-out scheme of underground exploration wherever it was needed to elucidate the structure of the country, economies would have been effected and the sum-total of our knowledge even from the economic standpoint would have been far greater. It is a pity that these borings have been carried out by means of the percussion process. It is, however, usually employed in borings for oil—in America almost exclusively—and in war-time its greater speed was no doubt an important factor in the decision to resort to it.

It would be easy to cite other cases where information of considerable geological value could be obtained by boring at comparatively small expense, and would, in all probability, in the majority of cases lead ultimately to results of economic importance.

It is obviously only right that any commercial advantages resulting from investigations carried out at the public cost should accrue to the State, and, if this principle were adopted, expenditure by the Government or geological research on the lines I have suggested would be sooner or later recouped by the mineral wealth rendered available to the community.

It is not, however, on terra firma alone that such investigations may be usefully carried out. The floors of the shallow seas that separate these Islands from one another and from the continent of Europe are still almost unknown from the geological standpoint, although their investigation would present no serious difficulties. Joly [1] has described an electrically driven apparatus which, when lowered so as to rest on a hard sea-floor, will cut out and detach a cylindrical core of rock, and retain it till raised to the surface. Subsequently he invented a still more ingenious device,[2] in which the force of the sea-water entering an empty vessel is substituted for electrical power, but unfortunately neither the one or the other has actually been tried or even constructed.

Meantime, however, vertical sections up to 80 cm. (2 ft. 7½ in.) of the mud of the deep seas have actually been obtained in iron tubes attached to sounding apparatus employed in the course of the voyage of the *Gaussberg*. These reveal a succession of deposits of which the lower usually indicate colder water conditions than the upper, and have been referred for that reason to the last Glacial Period.[3]

In many places rock fragments are dredged up by fishing boats. These should, of course, be used with caution in drawing conclusions as to the distribution of rocks *in situ* on the sea-bottom, as such fragments may have been transported when embedded in ice-sheets or in icebergs or other forms of floating ice, or entangled in the roots of floating trees; but where the rock-fragments can be shown to have a definite distribution, as in those described by Grenville Cole and Crook from the Atlantic to the West of Ireland,[4] and by Worth from the western portion of the English Channel,[5] they may be regarded as affording trustworthy information as to the geology of the area.

There seems every reason to believe that advances in submarine

[1] "On the Geological Investigation of Submarine Rocks": Sci. Proc. Roy. Dublin Soc., vol. viii, pp. 509–24, 189.

[2] "On the Investigation of the Deep Sea Deposits": ibid., vol. xiv, pp. 256–67, 1914.

[3] Philippi, *Die Grundproben der deutschen Südpolar Expedition*, 1901–3, vol. ii, pp. 416–17, 591–8.

[4] *On Rock-specimens dredged off the Coast of Ireland and their Bearing on Submarine Geology*, Mem. Geol. Surv. Ireland, pp. 1–35, Dublin, 1910.

[5] "The Dredgings of the Marine Biological Association" (1895–1906) as a contribution to the knowledge of the geology of the English Channel: Journ. Marine Biol. Assoc., vol. viii, pp. 118–88, 1908.

geology will not be of only scientific interest, but will bring material benefits with them. Even at present the working of coal-seams and metalliferous veins has been extended outwards beyond low-water mark, and, if evidence should be forthcoming that valuable deposits underlie the shallower waters of the North Sea at any point, there is no reason to doubt that mining engineers would find means of exploiting them. It seems quite possible that off the shores of Northumberland and Durham there are in addition to extensions of the neighbouring coalfield, Permian rocks containing deposits of common salt, calcium sulphate (gypsum and anhydrite), and, above all, potash salts comparable to those at Stassfurt, which have proved such a source of wealth to Germany.

No less important than the work of the Geological Survey is that of our great national museums. I have already alluded to the need for local collections to illustrate the geology of the areas in which they are situated. The museums of our larger cities and our universities will naturally contain collections of a more general character, but it is to our national museums that we must chiefly look for the provision of specimens to which those engaged in research can refer for comparison, and it is imperative that they should be maintained in the highest state of efficiency, if the best results are to be obtained from scientific investigations in this country. The ability and industry of the staff of the Mineral and Geological Departments of the Natural History Museum are everywhere recognized, as well as their readiness to assist all those who go to them for information, but in point of numbers they are undeniably insufficient to perform their primary task of examining, describing, arranging, and cataloguing their ever-increasing collections so as to enable scientific workers to refer to them under the most favourable conditions.[1] Even if the staff were doubled, its time would be fully occupied in carrying out these duties, quite apart from any special researches to which its members would naturally wish to devote themselves. The additional expense incurred by the urgently needed increase of the Museum establishment would be more than repaid to the country in the increased facilities afforded for research.

There is room, too, for a considerable extension in the scope of the activity and usefulness of our museums in other directions, and more especially in the provision of typical lithological collections illustrating the geology of different parts of the British Empire and of foreign countries.

So far as the United Kingdom is concerned, this requirement has been admirably fulfilled in the museums attached to the Survey Headquarters in London, Edinburgh, and Dublin, and there is a smaller collection of the same nature, excellent in its way, at the Natural History Museum. But to obtain a broad outlook it is essential that the attention of geological workers should not be confined to one country, however diversified its rocks may be, and

[1] Even the number of skilled mechanics is quite insufficient, though their work is urgently needed. In the Geological Department provision is only made for two, and at present but one is actually at work.

it is impossible to assimilate effectively publications dealing with the geology of other parts of the world without being able to refer to collections of the rocks, minerals, and fossils described.

The rocks, for instance, of the Dominion of South Africa are of the greatest scientific and economic interest, and many important communications have been published with regard to them. They present at the same time many features which distinguish them from European types, but I am not aware of any museum in this country where they are adequately illustrated.[1]

Such collections should include not only rock specimens in the ordinary sense of the term, but also examples of metalliferous veins and other mineral deposits which present important distinctive features.

In the Imperial Institute there are at the present time collections from most of the different constituent parts of the British Empire, which fulfil to a certain extent these requirements, and they have been employed by myself and others in demonstrations to the Geologists' Association in illustration of the geology of Peninsular India and different parts of Africa; but they are very incomplete, having been collected with the view of exhibiting, not so much the character of the rocks and mode of occurrence of the minerals, as the economic resources of the British Empire.

This is, of course, a function of the very greatest importance, but collections of minerals of intrinsic economic significance gathered together to assist in the development of the resources of the Empire should be organized on a different plan. They should be arranged, not according to the areas in which they occur, but with reference to the products obtained from them. The object of such collections is to enable those who are in want of materials for commercial purposes to ascertain where they can be obtained, and of what quality and at what price. For this purpose different samples of the same or similar ores or other products should be placed together irrespective of their origin, and each specimen should be accompanied by an assay or analysis, and such information with regard to its source and mode of occurrence as will enable the inquirer to form an opinion as to whether it will be likely to satisfy his requirements.

The lithological and palæontological collections which I am now advocating should, on the other hand, be arranged so that each group of specimens illustrates an area possessing distinctive geological features. Little has, hitherto, yet been done in this direction. The Mineral Department of the Natural History Museum possesses a large and extensive collection of foreign and colonial lithological specimens arranged according to localities, which is too little known, but it is naturally very unequal and incomplete, some countries being comparatively well represented and others scarcely at all. The Geological Department of the Museum is well provided with palæontological specimens, but these are arranged according to their biological affinities, and they might well be supplemented by

[1] [There is a very complete collection of the rocks of South Africa in the Sedgwick Museum, Cambridge.—Ed. Geol. Mag.]

a series of typical collections illustrating the fauna and flora of the more distinctive horizons in different areas. This is all the more important, as the mode of preservation may be very different in different places. It is probable that the geological surveys of British Dominions and Dependencies and of foreign countries would in many cases be able to supply such collections of rocks, mineral deposits, and fossils as I have suggested. Where this is not possible, the only practicable means of obtaining really typical collections is to despatch a representative of the Museum, preferably one of its own officers, to make one himself. The provision of such facilities for the study of the geology of other lands is especially desirable in London, in view of the number of students of mining and economic geology who receive their training in this country and ultimately go out into the world to find themselves face to face with problems in which a true understanding of the local geology is absolutely essential.

I shall not discuss here the important subjects of the indexing of geological literature and the preparation of abstracts of current publications. The former is already being efficiently dealt with by the Geological Society, and the latter will, I trust, be provided for in some way in the immediate future.

I now proceed to indicate some lines along which it seems to me probable that there are opportunities for progress in geological research.

In the investigation of the sedimentary rocks attention has been usually directed mainly to the larger and more obvious features, and these have sufficed to afford considerable insight into the conditions which prevailed when they were laid down. The detailed study of the minor structures or texture of these rocks by lens and microscope has, on the other hand, been comparatively neglected, though it is capable of affording us valuable information that could be obtained in no other way. There are, however, I need hardly say, important exceptions, the classical researches of Sorby extending over more than half a century, the investigations of Hutchings on the argillaceous rocks, and much useful work in recent years on the mineral constituents and microzoa of the sedimentary rocks generally. But, although individual sediments have been carefully studied, few, if any, attempts have been made to carry out a detailed examination of the successive beds of a stratigraphical succession comparable to the systematic zoning by means of fossils which has yielded such valuable results.

Not only ought the texture and composition of the individual laminæ to be patiently studied to obtain information as to the exact manner of their deposition, but attention should be more especially directed to the character of the transition by which one layer gives place to another, so as to determine, if possible, the cases where there has been a gradual passage without a break, and those in which there has been a pause in the deposition of greater or less duration, or even a removal of material, although nothing in the nature of an unconformity, however slight, can be detected. Even in apparently uniform deposits, such as Chalk and clay, variations in texture and composition may be brought out by special treatment and reveal interesting details of the conditions under which they were deposited.

It is of special importance to recognize and examine in detail the occurrence of rhythmic repetitions of a similar succession of sedimentary materials and characters. A single cycle in such a succession may be only a twentieth of an inch in thickness, as in the case of ferruginous banding in the Lower Haugman Grits at Smith's Combe in the Quantocks, or may include 30 or 40 feet of strata, as in the Caithness Flags. Rhythms have been described from the pre-Cambrian of Finland, the Ordovician of North America,[1] the Permian of Stassfurt,[2] the Cretaceous of Arkansas,[3] and the Quaternary of Scandinavia and Palestine, and many more, no doubt, occur in the stratigraphical succession of different countries. It would probably be found that a similar repetition occurs in fine terrigenous deposits off the coast of tropical countries where there is a well-defined alteration of wet and dry seasons. In some places minor cycles may be superimposed on larger, as in the case of the Skerry Belts described by Bernard Smith[4] in the Upper Keuper of East Nottinghamshire. The general question of the significance of such rhythms of stratification must, however, be reserved for another occasion.

It is more difficult to arrive at the true interpretation of the phenomena presented by the endogenetic rocks[5] which have come into existence by the action of the forces of earth's interior, for the conditions of temperature and pressure under which they were formed, whether they are igneous rocks in the narrower sense, or mineral veins, or metamorphic in origin, were widely different from those with which we are familiar. Under such circumstances the ultimate physical principles are the same, but the so-called constants have to be determined afresh, and a new chemistry must be worked out. It is necessary, therefore, as far as possible, to reproduce the conditions that prevailed—a task which has been courageously undertaken and to a considerable extent accomplished by the Geophysical Laboratory of the Carnegie Institute at Washington.

By artificial means temperatures and pressures have been already produced far higher than those that were in all probability concerned in the evolution of any of the rocks that have been revealed to us at the surface by earth-movements and denudation, for it is unlikely that in any case they were formed at a greater depth than five or six miles, corresponding to a uniform (or, as it is sometimes termed, hydrostatic) pressure of 2,000 or 2,400 atmospheres, or at a greater temperature than 1,500° C. Indeed, it is probable that the vast majority of igneous and metamorphic rocks, as well as mineral veins, came into existence at considerably less depths and at more moderate temperatures. It is true that most of the rock-forming minerals crystallize from their own melts at temperatures between 1,100° C.

[1] Barrell, *Bull. Geol. Soc. Am.*, vol. xxviii, pp. 789–90, 1917.
[2] Ochsenius, *Zeitsch. für praktische Geologie*, vol. xiii, p. 168, 1905.
[3] Gilbert, *Journal of Geology*, vol. iii, pp. 121–7.
[4] Geol. Mag., 1910, pp. 303–5.
[5] Crook, *Min. Mag.*, vol. xvii, p. 87, 1914.

and 1,550° C., but they separate out from the complex magmas from which our igneous rocks were formed at lower temperatures, rarely much exceeding 1,200° C., and frequently considerably less.[1]

It has been found possible at the Geophysical Laboratory to maintain a temperature of 1,000° C. or more under a uniform pressure of 2,000 atmospheres for so long a time as may be desired, and, what is equally important, the temperature and pressure attained can be determined with satisfactory accuracy, the temperature within 2° C., and the pressure within 5 atmospheres.

It has been ascertained that such uniform pressure as would ordinarily be present at the depths mentioned does not directly affect the physical properties of minerals to anything like the same extent as the difference between the temperature prevailing at the earth's surface and even the lowest temperature at which igneous rocks can have been formed. It has, however, a most important indirect action in maintaining the concentration in the magma of a considerable proportion of water and other volatile constituents[2] which have a far-reaching influence in lowering the temperature at which the rock-forming minerals crystallize out, in other words, the temperature at which the rock consolidates, and in diminishing the molecular and molar viscosity of the magma, thus facilitating the growth of larger crystals and the formation of a rock of coarser grain. They must also be of profound significance in determining the minerals that separate out, the order of their formation, and the processes of differentiation in magmas.

It is, therefore, obvious that any conclusions derived from the early experiments which were carried out with dry melts at normal pressures must be received with very considerable caution. Nor does much advance appear to have been made, even at the Geophysical Laboratory, in experiments with melts containing large amounts of volatile fluxes, and yet, if we are to reproduce even approximately natural conditions, it is absolutely necessary to work with magmas containing a proportion of these constituents, and especially water, equal in weight to at least one-third or one-half of the silica present. This will obviously present considerable difficulties, but there is no reason to doubt that it will be found possible to surmount them.

A much more formidable obstacle in realizing the conditions under which rocks are formed is the small scale on which our operations can be carried on. There are important problems connected with the differentiation of magmas, whether in a completely fluid or partly crystallized state, under the action of gravitation, for the solution of which it would seem for this reason impossible to reproduce the conditions under which nature works. Instead of a reservoir many hundreds of feet in depth, we must content ourselves in our laboratory experiments with a vertical range of only a few inches.

[1] It is probable that the temperatures recorded in some lavas higher than the melting-point of copper, which is well over 1,200° C., are due to chemical reactions, such as the oxidation of hydrogen, carbon monoxide, ferrous oxide, and perhaps sulphur. See Day & Shepherd, *Bull. Geol. Soc. Am.*, vol. xxiv, pp. 599–601, 1913.

[2] Johnston, *Journ. Franklin Inst.*, January, 1917, pp. 14–19.

There are, however, other phenomena that require investigation and that involve a great difference of level in their operation, but do not take place at such elevated temperatures. Such are some of the processes of ore deposition or transference, especially secondary enrichment. Here, with the friendly assistance of mining engineers, but at the cost of considerable expenditure, it might even be possible to experiment with columns several thousand feet in vertical height.

In any attempt to reproduce the processes of metamorphism other than those of a purely thermal or pneumatolytic character, or to imitate the conditions that give rise to primary foliation, we must consider the effects of non-uniform or differential pressure involving stresses that operate in definite directions and result in deformation of the material on which they act. Unlike uniform pressure which usually raises the crystallization point, differential pressure may lower it considerably and thus give rise to local fusion and subsequent recrystallization of the rock.[1] At the same time it profoundly modifies the structure, resulting in folds and fractures of every degree of magnitude. One of the most pressing problems of geology at the present moment is to determine the effects of non-uniform pressure in its operation at different temperatures, and in the presence of different amounts of uniform pressure, a factor which has probably an important influnce on the result, which must also depend on the proportion and nature of the volatile constituents which are present, as well as on the time during which the stresses are in operation. There seems no reason why valuable information should not be obtained on all those points by properly conducted experiments.

The time element in the constructive or transforming operations of nature cannot, of course, be adequately reproduced within the short space of individual human activity, or, it may be, that of our race; but I am inclined to think that, even in the case of metamorphic action, the importance of extremely prolonged action has been exaggerated.

In attempting to imitate the natural processes involved in the formation and alteration of rocks and mineral veins, we require some means of ascertaining when we have approximately reproduced the conditions which actually prevailed. It is not sufficient to bring about artificially the formation of a mineral occurring in the rocks or mineral deposits under investigation, for the same mineral can be reproduced in many ways. It is, however, probable that a mineral produced under different conditions is never identical in all its characters. Its habit, or the extent to which its possible faces are developed (a function of the surface tension), the characters of the faces which are present, its twinning, its internal structure, inclusions, and impurities, all vary in different occurrences, and the more closely these can be reproduced, the greater the assurance we obtain that an

[1] See Johnston & Adams, *Journ. Am. Chem. Soc.*, vol. xxxiv, p. 563, 1912; *Am. Journ. Sci.*, vol. xxxx, p. 206, 1913; Harker, *Proc. Geol. Soc.*, vol. lxxiv, pp. 75–7, 1919. It is interesting to note that similar principles apply to the pseudo-fluidity induced in clay by non-uniform pressure. See Crosthwaite, *Proc. Inst. C.E.*, December 19, 1916, p. 149; *Journ. and Trans. Soc. Eng.*, vol. x, pp. 82–6, 92–4; Ackermann, ib., pp. 37–80, 102–7.

artificial mineral has been formed under the same conditions as the natural product.

For this purpose it is above all necessary that there should be in the first place a systematic comparative study of these characters and of the association in which they are found. The results thus obtained should be of the greatest value in indicating the directions along which experimental work would be most probably successful. They should, of course, be supplemented by laboratory studies of the relations of such subsidiary crystallographic characters to the environment in the case of crystals which can be formed under normal conditions of temperature and pressure, and therefore under the immediate observation of the experimenter. Some work has, in fact, already been done on the effects on these characters of the presence of other substances in the same solution.

In the study of the secondary alterations of metalliferous deposits, especially those which consist of the enrichment of mineral veins by the action of circulating solutions, either of atmospheric or intratelluric origin, the study of pseudomorphs gives, of course, valuable assistance in determining the nature of the chemical and physical changes that have taken place.

A successful solution of the problem of the exact conditions under which deposits of economic importance are found would be of incalculable value in facilitating their discovery and exploitation, and would be the means of saving a vast amount of unnecessary labour and expense.

The problem of the structure and nature of the earth's interior, inaccessible to us even by boring, would seem at first sight to be well-nigh insoluble, except as far as we can deduce from the dips and relations of the rocks at the surface their downward extension to considerable depths. We can, however, gain important information about the physical condition of the deeper portions from the reaction of the earth to the external forces to which it is subjected, and still more from a study of the "preliminary" earthquake tremors that traverse it, the time occupied in their passage, and the difference in intensity of those that follow different paths. These methods are, however, not applicable to the earth's crust. Its physical characters appear to be distinct from those of the interior, but very little is as yet definitely known about them, except of course in the neighbourhood of the surface, and for this reason they are usually ignored in calculating the paths of tremors traversing the earth. It seems to be separated from the deeper portions of the earth by a surface of discontinuity at which earthquake vibrations travelling upwards towards the surface may be reflected. Calculations based on the total time taken by these reflected waves to reach the surface after a second passage through the earth's interior appear to indicate that this surface of discontinuity, whatever its nature may be, is at a depth of about 20 miles, though there can be little doubt that this depth varies considerably from point to point.

The main earthquake vibrations appear to follow the curvature of the earth, and to be confined to its crust, instead of traversing the interior, as is the case with the preliminary tremors. In these vibrations a period of about 17 or 18 seconds is usually predominant, and is believed to be due to the natural period of vibration of the earth's crust. Wiechert[1] assumes that there is a node half-way down and a free movement above and below, so that the full wave-length would be twice the thickness of the earth's crust. Assuming a velocity of propagation of 3½ km. per second, he calculates the depth of the crust to be approximately 30 km. There seems, however, to be no warrant for supposing that the lower surface of the crust is capable of free vibration. The fact that not only waves of compression but waves of distortion can traverse it shows that it must possess very high rigidity so far as forces of brief duration are concerned. The lower surface should therefore be regarded as a node, and only the upper as capable of free movement, so that the whole would correspond to a quarter of a wave-length. On the other hand, the velocity of 3½ km. per second, which is that of the propagation of waves round the earth's crust, in all probability a complex process, is not the same as the true velocity of vibrations passing upwards and downward through the earth's crust. Those with a period of about 18 seconds appear to consist partly of horizontal vibrations and partly of vertical; the former would seem to correspond to waves of distortion and the latter to waves of compression. The velocity of the former would probably be about 4 km. and the latter 7 km. per second, corresponding to the thicknesses of 18 km. and 31½ km. (11 and 20 miles). There is some evidence in the case of a distant earthquake of a period approximating to 30 km. per second, which would correspond, with waves of distortion, to a thickness of 30 km. (19 miles). However, in the present state of our knowledge of these vibrations such calculations are only of speculative interest.

There must be numerous surfaces of discontinuity in the earth's crust in addition to that forming its lower limit. Such would be the boundaries between great tracts of granite or granitoid gneiss and the basic rocks that in all probability everywhere underlie them; the surface dividing gneisses and crystalline schists from unmetamorphosed sediments overlying them unconformably; that between hard Palæozoic rocks and softer strata of later age; and the surfaces of massive limestones or sills. Wiechert observed at Göttingen, at the time of the Indian earthquake of April 4, 1905, small horizontal vibrations, superimposed on the others, with a period of only 1½ seconds. He believed that these were due to horizontal distortional vibrations of the local sandstone formation with a node at its basal surface. He found the velocity of similar vibrations at the surface to be 250 m. per second, and thence calculated the depth of the sandstone stratum to be 90 m.[2] No doubt similar correlations of terrestrial vibrations and the structure of the earth's crust may be made in other cases.

It deserves consideration, however, as to how far it may be possible to add to our knowledge of the earth's crust by experimental work with a view of the determination of surfaces of discontinuity

[1] *Göttinger Nachrichten*, 1907, pp. 468–9.

[2] Ibid., pp. 467–8.

by their action in reflecting vibrations from artificial explosions, a procedure similar to that by means of which the presence of vessels at a distance can be detected by the reflection of submarine sound waves. The ordinary seismographs are not suited for this purpose; the scale of their record, both of amplitude and of time, is too small for the minute and rapid vibrations which would be expected to reach an instrument situated several miles from an explosion, or to distinguish between direct vibrations and those that may arrive a second or two later after reflexion at a surface of discontinuity. As the cylinder on which the record is made would be only in motion while the experiment was in progress, there would be no difficulty in arranging for a much more rapid movement. At the same time it would be desirable to dispense with any arrangement for damping the swing of the pendulum, which would be unnecessary with small and rapid vibrations, and would tend to suppress them. It is possible that it might be better to employ a seismograph which records, like that devised by Galitzin shortly before his death, variations of pressure expressing terrestrial acceleration, instead of one which records directly the movements of the ground. It would, however, probably be found desirable to substitute for the piezo-electric record of pressure employed by Galitzin a record founded on the effect of pressure in varying the resistance in an electric circuit. This is, in fact, the principle of the microphone and most modern telephone receivers, but quantitatively they are very unreliable. This would not matter so much for the present purpose, where the time of transmission is the most important feature in the evidence, but satisfactory results even in this respect appear to be given by Brown's liquid microphone, from which the record could be taken, if desired, by means of the reflection of a mirror, attached to the needle of the galvanometer.

Evidence of the structure of the earth's crust is also afforded by observations on the direction and magnitude of gravitation, which have been carried out in considerable detail in India and the United States—especially in the neighbourhood of great mountain ranges. At the present time the problem of correlating the variations observed with the underground structure is only in an embryonic stage. It is probable that our greatest hope of advancing researches with this object is by detailed work in areas which present no marked orographical features, and where the geological structure is already fairly well ascertained.

The same remarks apply to the results obtained by magnetic surveys. Apart from the marked effect of masses of magnetite in the immediate neighbourhood of the surface, local magnetic irregularities appear to be mainly determined by the presence of basic igneous rocks,[1] but there seems to be considerable room for research as to the relation between these phenomena and the form and composition of an igneous intrusion.

In this review of some of the possibilities of geological research I cannot claim to have done more than touch the fringe of the

[1] Cox, Abstracts of the Proceedings of the Geological Society of London, 1918, pp. 71–4.

subject. In every direction there is room for the development of fresh lines of investigation, as well as for renewed activity along paths already trodden. Whether my particular suggestions prove fruitful or not, they will have served their purpose if they have stimulated anyone to look for new fields of work.

Postscript.—Since this address was written, I have learnt that Professor Kendall has from time to time made valuable suggestions with regard to the association of the Survey with local workers, more especially the geological staff and students of our colleges.

REVIEWS.

I.—Shore Processes and Shoreline Development. By Douglas Wilson Johnson. 8vo; pp. xvii + 584, with 73 plates and 149 text-figures. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1919. Price 23*s*. net.

WHILE this book was in preparation Mr. Johnson was Associate Professor of Physiography in Columbia University. When he wrote the preface he was on his way to France, and he claims the indulgence of the reader for the lack of the final supervision which he had hoped to give the proofs. But it is only in details that indulgence is needed; in essentials the book seems to have suffered little from the circumstances under which it was produced.

It is the best and most complete exposition of its subject that has yet appeared. The style is lucid, though at times unnecessarily diffuse; the work of previous writers is discussed, with copious references to the original papers, but the author retains his own independent judgment, which is always thoughtful and never dogmatic. Even where the reader disagrees he will recognize that the author is making an honest attempt to discover the truth and is not endeavouring to enforce a preconceived opinion.

The general scheme of the work is clear and logical. The first three chapters deal with waves and currents, these being the chief agents, apart from changes of level, that tend to alter the shape and character of coasts. Questions of terminology and classification are next discussed, and having thus cleared the ground the author proceeds to consider the development of the shore, a subject which occupies nearly half the volume. In his treatment he separates the "shore profile", or the shape of the shore in section, from the "shoreline", the shape of its outer boundary in plan. Finally, there are two chapters on special features, such as beach ridges, ripple-marks, etc.

In the chapters on waves no attempt is made at a mathematical analysis of wave-motion, which would indeed be out of place in a work of this nature; but there is a summary of the results obtained by such analysis. On the vexed question of the depth at which wave-action is perceptible the author adopts the widely held opinion that 600 feet may be taken as the limit for ordinary wave-disturbances, though occasionally effective motion may descend beyond that depth.

In the section on terminology the author tries to avoid, as far as he can, the introduction of new terms; and by restricting the significance of common English words he hopes to make them serve his purpose. For him the "coast" is the sea-cliff and a zone of indeterminate width on its landward side; the "shore" is the belt between low-water mark and the cliff; "beach" is the actual material which moves along the shore, or on and off the shore. In his choice of words the author endeavours to do as little violence to the language as possible; but artificially to restrict the meaning of such widely used expressions may easily lead to misunderstanding. Indeed, because no vaguely limited term is left, the author himself is sometimes compelled to use one or other of these words in a wider sense than is contemplated by his own definition. The chapter on the development of the shore profile, for example, deals not only with the shore but with the whole width from the cliff to the edge of the continental shelf.

The classification of shores that the author follows is the simple and natural one into (1) shorelines of submergence, (2) shorelines of emergence, (3) neutral shorelines, which do not owe their characteristic features either to submergence or emergence, (4) compound shorelines, the essential features of which combine elements of at least two of the foregoing classes.

The account of the development of the shore profile suffers from the defect that it is almost exclusively deductive, and illustrative examples are too few. From a consideration of the agencies concerned in its production the author deduces the forms that the ideal profile should pass through; but whether real profiles assume these forms he makes little attempt to prove. The truth is that accurate profiles are not readily obtained. Even the large-scale maps of a Government Survey are not sufficiently minute with regard to altitudes on the land or depths in the sea, and in most cases a special survey would be needed. In consequence of this our knowledge of real profiles is far less complete than our knowledge of real shorelines.

It is no doubt for this reason that the chapters on the development of the shoreline are not open to the same criticism. Deduction is employed as freely, but there are frequent comparisons with actual examples. Probably this is the section of the book that will be found most generally attractive.

It would take too much space to follow the author further. The English geologist will be interested in the account of Dungeness; perhaps he may not be sorry to find that Chesil Bank is only incidentally referred to. The "fulls" of Orford Ness deserve more attention than they have received, either in this book or elsewhere.

An important general conclusion arrived at by the author is that marine denudation is more effective, compared with fluvial denudation, than the older school of geologists have usually been disposed to allow.

Illustrations, both in the text and in the form of plates, are numerous and, for the most part, good; but, except in a few instances, the maps are without a scale. This is the most serious of the omissions that call for the indulgence which the author claims.

A valuable feature of the book is the fullness of the references to previous literature, which appear at the end of each chapter, and again, in alphabetical list, at the end of the volume.

P. L.

II.—On the Inclination of the Thrust-plane or Reversed Fault between the Siwalik and Murree Line of Formations near Kotli, Jammu Province. By C. S. Middlemiss. Rec. Geol. Surv. India, vol. l, pp. 122–5, pl. xxviii, 1919.

IN the Geological Magazine for 1903 (pp. 305–6) Mr. Lake published a very short paper on "The Circular Form of Mountain Chains". In this paper Mr. Lake showed that if Suess' conception of mountain chains as the crumpled edges of flat-based earth-scales is true their intersection with the surface must always be an arc of a circle; furthermore, he pointed out that the angle which a plane makes at its outcrop with the surface of the sphere is equal to the angular distance measured on the surface of the sphere between the centre and circumference of the circle formed by the outcrop of the plane. Mr. Lake went on to say, "If I were to attempt, on this view, an ideal representation of the Himalayas, I should draw, some little distance below Middlemiss' Section VI" (referring to a paper in Mem. Geol. Surv. India, vol. xxiv, pt. ii), "a thrust-plane making an angle of 14° with the horizontal."

It has hitherto been customary in drawing ideal sections of the Himalayas to represent fold-faults of this category as having steep inclinations, usually something between 45° and 60° with the horizontal, and Mr. R. D. Oldham even speaks of the main boundary fault as being "a nearly vertical plane of separation" (Mem. Geol. Surv. India, vol. xlii, pt. ii, p. 4).

As described in the paper quoted at the head of this review, Mr. Middlemiss has plotted with great care on the new contoured 1 in. map of Jammu and Kashmir the plane of division between the younger zone of Siwalik rocks and the older Murree zone below. This plane can be traced with great accuracy owing to the strong colour-contrast between the two series. The course of the fault when thus plotted, as shown on the map accompanying the paper, makes two very distinct V-shaped upstream bends, and by using the data thus afforded Mr. Middlemiss has calculated that the actual angle of dip of the plane is from 12° to 15° with the horizontal. This affords a remarkable confirmation of the soundness of Mr. Lake's reasoning and is a valuable instance of the untrustworthiness of inferences drawn from field-observation without accurate mapping to scale.

III.—The Magnesite Deposits of Bulong. By F. R. Feldtmann. Bull. 82, Geol. Survey Western Australia. pp. 38, with 2 plates and 7 figures. Perth, 1919.

THIS Bulletin gives the results of a recent exploration, stimulated by war conditions, of deposits of magnesite in the North-East Coolgardie Goldfield, together with a general account of the occurrences of magnesite in other countries and its uses. The Bulong district lies in a complex of basic and ultrabasic greenstones, the most prominent members of which are serpentines and amphibolized gabbros, apparently local differentiations of a highly basic magma, intruded as one mass. These are traversed by a number of porphyrite dykes and are in contact with an area of sheared sediments, including slates and pebble beds. The magnesite occurs for the most part as irregular veins in the serpentine and is doubtless formed by the ordinary alteration-processes of that rock. It is comparatively free from lime, but contains moderate amounts of silica and iron. The amount of the mineral present is now wholly uncertain owing to the irregular nature of the deposit and the thick detrital covering, but it appears to be very large, and ranges in quality to 90 or even 95 per cent $MgCO_3$.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

November 5, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

A lecture was delivered by Hugh Hamshaw Thomas, M.A., F.G.S., "On some Features in the Topography and Geological History of Palestine," illustrated by aeroplane photographs taken during the War.

The lecturer observed that a perfectly new method of illustrating and investigating some branches of physical geology is afforded by aeroplane photography. It seems firstly to illustrate in a very striking and convincing form many geological phenomena, such as the structure of a volcano or the land-forms resulting from erosion, and may be of value in the teaching of the science. In the second place it may, in certain circumstances, become a valuable means of research, especially in connexion with river-development or denudation in a region which is somewhat inaccessible, or where the surface of the ground is very complicated and the main features are obscured by a mass of less important detail. The lecture dealt principally with the illustration of the physical features of Palestine, and owed its origin to the systematic photo survey made over Central Palestine during the War. The photographs were originally taken for the purpose of constructing detailed maps, and the examples shown had been selected from a large mass of similar material which still exists in the form of negatives, and these may eventually become available in this country for further study and research. The demarcation of the coastal plain from the foot-hills of the upland country is often well shown by oblique air-photographs, and the weathering-out of the flat alluvial ground by the winter rains to give characteristic wadis is clearly seen. In the central hill-country the terraced hills show the relation of the scenery to the underlying rock, but their general sculpture is regarded as belonging to a former period of great precipitation. In arid country, where the underlying rock is laid bare, the aeroplane camera often shows the general geological structure of the district.

The lacustrine deposits of the Jordan Valley and their weathering was shown, and also the form of the drainage-channels running down into the main valley. The depression of the Dead Sea with reference to the surrounding country has resulted in cañon formation in many places. Some evidences of faulting at different periods can be distinguished.

The Jordan at present forms an interesting study in river-development, and many of its main features were demonstrated. The relation of the Jordan to the Orontes has been considered, and an aeroplane photographic survey of the country between the two rivers indicates that the Jordan probably originated in Northern Syria in earlier times. The Syrian portion of the stream has been captured by the younger Orontes, and this has had a very important effect on the whole topography of the Jordan Valley.

A further study of the aeroplane photographs already taken, and of the maps made from them, may throw much new light on the questions of climatic changes and of topographical changes due to faulting in Palestine.

II.—Mineralogical Society.

Anniversary Meeting, *November* 4.—Sir William P. Beale, Bart., K.C., President, in the Chair.

Dr. W. R. Schoeller and A. R. Powell: "Villamaninite, a new mineral." The new mineral, which occurs, disseminated in black grains and plates, with a distinct cleavage, and in small nodules, with a radially fibrous structure, in a crystalline dolomite, near Villamanin, Cármenes district, León province, Spain, has probably a composition corresponding to $(Cu, Ni, Co, Fe) (S, Se)_2$. Its streak is sooty black, hardness 4·5, and specific gravity 4·4–4·5; it is opaque.

Arthur Russell: "On the Occurrence of Phenakite and Scheelite at Wheal Cock, St. Just, Cornwall." The author found good specimens of these minerals in 1914 at Wheal Cock, which is the locality whence came the crystal (undoubtedly phenakite) described by Sowerby in 1804 as argilla electrica or white tourmaline; phenakite was not known till 1833 as a distinct species.

L. J. Spencer: "New Crystal-forms on Pyrites, Calcite, and Epidote." On pyrites the dyakis-dodecahedron (641) occurs as large, well-developed faces on five specimens, one of them from Traversella, Piedmont, and the others from coal shales of unknown locality. On 424 crystallized specimens of pyrites in the British Museum collection 35 crystal-forms were noted. Faces of the cube are present on 76·6 per cent of the specimens, the octahedron on 62·7 per cent, the pentagonal dodecahedron (210) on 54·7 per cent, and the dyakis-dodecahedron (321) on 36·1 per cent. As simple forms, not in combination with other forms, they are represented by 12·2, 2·5, and 0·5 per cent respectively. The decomposition of specimens of pyrites in collections was discussed. Calcite, a clear scalenohedral crystal, probably from Iceland, consists of a combination of the two scalenohedra ($20\bar{1}$) and (12.0.7), both largely developed, and with an angle of 4½ degrees between corresponding faces. Epidote, a crystal, probably from Ala, Piedmont, closely resembling in appearance the yellow prismatic crystals of anatase, carries a minute face ($\bar{1}34$) (Dana's orientation) in addition to twenty other crystal-forms.

Dr. G. F. Herbert Smith: "A Curious Crystal from the Binnental." The crystal, which was found with a few loose sartorite crystals in the Trechmann Collection, is twinned and tabular in habit, and shows signs of corrosion. The symmetry is peculiar, since, although a face occurs at right angles to the prism edge, it is neither a plane nor a pole of symmetry, and the crystal appears to represent a new species of sulpharsenite.

CORRESPONDENCE.

THE TERTIARY GEOLOGY OF DEVON AND CORNWALL.

Sir,—Referring to your reviewer's remarks in the November number, p. 521, on an inquiry into the recent views relative to "The Tertiary Geology of Devon and Cornwall", may I be allowed a few lines to meet the objections that the "argument concerning the age of the limestone caverns is not very clear, and its bearing on the point at issue is not obvious".

The point at issue is the submergence of the peninsula during the Pliocene era as predicated by the platform theory. Of the seven standpoints from which the theory was considered, the caverns were taken as one contributing important controverting evidence. It was shown that caverns are almost entirely formed by solution of the rock, an immeasurably slow process, requiring geological ages to form these large subterranean hollows. It was also pointed out that the lowest deposits in the Devon caverns are glacial formations (surface material swept through the swallow-holes into the lowest depths during extraordinary climatic conditions) that determine the pre-Glacial existence of the cavern. It follows that the human and animal relics found in this deposit (the breccia) must have been of Pliocene origin. Now as the elevation of the caverns above the sea-level during their whole existence is unquestioned, and when the many ages taken in the formation of the similar Derby and Yorkshire caverns are put in comparison, it does not appear consistent with the character of the facts to assign the formation of the Devon caverns to the comparatively short geological period that must be implied to terminate the Pliocene era, as subsequent to the vast space of time drawn upon that era, which the enormous results embraced by the platform theory demand.

I submit the cavern phase of the argument to be one that is relevant, cogent, and obvious.

H. J. Lowe.

Torquay.

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