THE

SCIENTIFIC PROCEEDINGS

OF THE

ROYAL DUBLIN SOCIETY.

New Series.

VOLUME VI.

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
LONDON: WILLIAMS & NORGATE.
1888–1890.

THE SOCIETY *desires it to be understood that they are not answerable for any opinion, representation of facts, or train of reasoning that may appear in this Volume of their Proceedings. The Authors of the several Memoirs are alone responsible for their contents.*

Printed at THE UNIVERSITY PRESS, *Dublin.*

LIST OF THE CONTRIBUTORS

TO VOLUME SIX,

WITH

REFERENCES TO THE SEVERAL ARTICLES CONTRIBUTED BY EACH.

ADENEY, W. E., F.I.C. PAGE

On an Apparatus Applicable for Gas Analysis and other purposes (Plate XII.), ... 542

BARRETT, W. F.

Notes on a Remarkable Increase of Magnetic Susceptibility produced by Heating Manganese Steel Filings, . . 107

Notes from the Physical Laboratory of the Royal College of Science : On the Determination of the Absolute Expansion and the Densities of Liquids, ... 327

Note on the Magnetic Properties of Columnar Basalt, . . 382

On the Magnetic Moment and other Physical Constants of Steel containing from One to Twenty-one per cent. of Manganese, ... 460

CLARK, R.

See KINAHAN and CLARK.

DIXON, FRANCIS.

On the Arrangement of the Mesenteries in the Genus Sagartia, Gosse (Plates I. and II.), ... 136

DIXON, G. Y., M.A. PAGE

Remarks on *Sagartia venusta* and *Sagartia nivea*, . . . 111

DIXON, G. Y., and DIXON, F.

Notes on *Bunodes thallia*, *Bunodes verrucosa*, and *Tealia crassicornis* (Plates IV. and V.), ... 310

DRAPER, HARRY NAPIER, F.C.S.

On the Percentage Relating to Absolute Alcohol and Proof Spirit of the Alcoholic Beverages in Ordinary Use (Plate VIII.), ... 372

FITZGERALD, GEORGE F., M.A., F.R.S.

Note on the Origination of Turbulent Motion in Viscous Liquids, ... 289

FITZ GERALD, GEORGE F., M.A., F.R.S., and JOLY, J., M.A.

On the Measurement of Small Pressures, ... 128

GRUBB, SIR HOWARD, F.R.S.

On a Heliostat for the Smithsonian Institution, Washington (Plate XIII.), ... 598

HARTLEY, W. N., F.R.S.

On the Constitution of Electric Sparks (Plates VI. and VII.), 363

HULL, EDWARD, LL.D., F.R.S.

On the Temperature of the Water of Ballynoe Springs, near Queenstown, ... 307

HYLAND, J. SHEARSON, Ph.D., M.A.

On some Epi-Diorites of N.-W. Ireland, ... 405

On the Mesolite (Galactite) of Kenbane Head, Co. Antrim, 411

On some Spherulitic Rocks from Co. Down, . . . 420

On some specimens from Wady Halfa, Upper Egypt, . . 348

JOLY, J., M.A. PAGE

On a Method of Determining the Absolute Density of a Gas (Plate XI.), ... 534

On the Formation of Crystals of Calcium Oxide and Magnesium Oxide in the Oxyhydrogen Flame, ... 255

See also FITZ GERALD and JOLY.

KILROE, J. R.

The Discovery of two Carboniferous Outliers on Slieve League, Co. Donegal, ... 63

On Directions of Ice-flow in the North of Ireland, as determined by the Observations of the Geological Survey, . 259

KINAHAN, G. H.

On Irish Arenaceous Rocks (Supplement), ... 6

Granite, Elvan, Porphyry, Felstone, Whinstone, and Metamorphic Rocks of Ireland, ... 169

On Geological Unconformabilities, ... 283

On the Economic Geology of Ireland (Supplement), . . 343

KINAHAN, G. H., and CLARK, R.

Slates and Clays (Bricks, &c.). With Introduction and Building Notes. I., ... , . . 69

On the Slates and Clays of Ireland (Bricks, &c.). With Introduction and Building Notes. II., ... 143

KIRBY, W. F., F.Z.S.

On the Employment of the Names proposed for Genera of Orthoptera previously to 1840, ... 556

KIRKPATRICK, R.

Reports on the Zoological Collection made by Prof. Haddon in Torres Straits, Hydroida, and Polyzoa (Plates XIV. and XVII.), ... 603

MAXWELL, MAJOR SOMERSET, F.R.A.S. PAGE

Observations of the late Conjunction of Mars and Saturn, . 384

O'REILLY, J. P., C.E.

Note on some Ejecta of the Hot Springs of Tarawara, New Zealand, formed since the Earthquake of 23rd June, 1886, 67

Notes on some Assays for Gold of Rocks occurring in the Neighbourhood of Dublin, ... 450

RAMBAUT, A. A., M.A.

On the Lunar Eclipse of January 28, 1888, ... 43

On the Shape of the Earth's Shadow projected on the Moon's Disc during the Partial Phases of an Eclipse, . . . 51

Note on some Japanese Clocks lately purchased for the Science and Art Museum, ... 332

Note on the Conjunction of Saturn and Mars on 19th September, 1889, ... 379

REYNOLDS, J. EMERSON, M.D., F.R.S.

On Thiocamf—A New Disinfectant Material, . . . 360

SCHARFF, ROBERT F., Ph.D., B.Sc.

Review of Dohrn's Theories on the Origin of Vertebrates, . 14

On the Occurrence of Pallas's Sandgrouse (*Syrrhaptes paradoxus*) in Ireland, ... 278

Notes on a Sucking-Fish (*Liparis vulgaris*, Flem.) new to Ireland, ... 484

SMEETH, W. F., B.A., B.E.

An Apparatus for Separating the Mineral Constituents of Rocks, ... 58

On a Method of Determining the Specific Gravity of Substances in the form of Powder, ... 61

On the Dolomite of Howth (Plate III.), ... 272

SOLLAS, W. J., LL.D., F.R.S. PAGE

A Contribution to the History of Flints, ... 1

Preliminary Observations on the Granites of Wicklow and Down, ... 257

Preliminary Account of the Soda-Granites and Associated Dykes of Co. Wicklow, ... 263

On the Geodine Genera Synops, Vosm., and Sidonops. A Correction, ... 276

STONEY, G. JOHNSTONE, D.Sc., F.R.S.

Tables for the Easy Conversion of British into Metrical Measures, ... 355

Formulæ for the Easy Determination of Gaseous Volumes and Weights. 387

On Texture in Media, and on the Non-existence of Density in the Elemental Ether, ... 392

Studies in Ontology, from the Standpoint of the Scientific Student of Nature. I.—The First Step in which an attempt is made to find out in what way the Scientific Study of Nature is related to the actual Existences and Events of the Universe, ... 475

TROUTON, FREDERICK T., B.E.

On the Motion of a Body near Points of Unstable Equilibrium, and on the same when capable of Internal Vibration, ... 39

On a Convenient Method of obtaining any required Electrical Potential for use in Laboratory Teaching, . . . 110

On the Control Supply-pipes have on Reeds, . . . 132

WIGHAM, JOHN R.

An Improved Method of Using Annular Lenses for Lighthouse Illumination (Plates IX. and X.), ... 525

WYNNE, A. B., F.G.S.

On recent Physical Questions of Geological Interest—being a Presidential Address to the Royal Geological Society of Ireland, 1889, ... 290

DATES OF THE PUBLICATION OF THE SEVERAL PARTS OF VOLUME SIX.

Part 1.—Containing	pages	1 to 38.	(February, 1888.)
,, 2.	,,	,,	39 to 110.	(May, 1888.)
,, 3.	,,	,,	111 to 168.	(August, 1888.)
,, 4.	,,	,,	169 to 262.	(November, 1888.)
,, 5.	,,	,,	263 to 289.	(February, 1889.)
,, 6.	,,	,,	290 to 359,	(May, 1889.)
,, 7.	,,	,,	360 to 374.	(August, 1889.)
,, 8.	,,	,,	375 to 474.	(May, 1890.)
,, 9.	,,	,,	475 to 600.	(August, 1890.)
,, 10.	,,	,,	603 to 626.	(December, 1890.)

THE

SCIENTIFIC PROCEEDINGS

OF THE

ROYAL DUBLIN SOCIETY.

I.

A CONTRIBUTION TO THE HISTORY OF FLINTS. By Professor W. J. SOLLAS, D. Sc., LL.D.

[Read December 14, 1887.]

THAT the material of Flints has been derived from the silicious remains of Sponges can no longer be regarded as a mere hypothesis; it is a suggestive fact, and affords a basis for further investigations. In the present Paper I propose first to give the results of some investigations which I have lately made to determine the ratio between the weight of the silica (SiO_2) forming the skeleton of a given sponge and that of the whole sponge, including all internal cavities, supposing it to be converted into a solid mass of flint; and next to offer an estimate as to the length of time which would be required for the secretion of such a mass of flint.

The total volume of the sponge was first determined as follows:—A spirit specimen was transferred from alcohol to distilled water, which was repeatedly changed till all traces of alcohol were removed. It was then totally immersed in well-boiled distilled water contained in a weighing bottle, and the bottle and its contents were weighed: the sponge was then removed, and a second weighing of the bottle gave, by difference, the weight of the sponge and of the water contained within it and coating its surface. In later experiments the process was slightly modified : the sponge was transferred from a beaker of distilled water to a dry weighing bottle, and its weight obtained direct. In the case of sponges hirsute with hispidating spicules, the results thus obtained would, from capillarity, be too high: these sponges were therefore touched for an instant with a piece of filter paper before being placed in the weighing bottle. The sponge was next dried in the water oven, and again weighed.

The specific gravity of the dried sponge being taken as 2—and this is a very close approximation—one-half its weight was deducted from the first weighing; the remainder is the weight of a volume of water equal to the total volume of the sponge. The specific gravity of flint varies from 2·5 to 2·6. Taking the higher number, we multiply that just obtained by it, and this gives the weight of the total sponge supposed to be converted into flint.

The sponge was next boiled in strong nitric acid till all traces of organic matter were destroyed, and the spicules remaining separated by filtration: after well washing they were transferred to a platinum crucible, and the ashes of the ignited filter paper added: after again drying, they were weighed (this weighing was only made use of in the calculation when the weight of the dried sponge was not obtained). Since the spicules contain about 7 per cent. of water, they were ignited to eliminate this—first over a Bunsen, and finally with a Herepath. The weight of the ignited spicules gives the weight of the silica present in the sponge. By dividing the number representing this by that representing the weight of a mass of flint equal in volume to the whole sponge, we obtain as a percentage the ratio of the silica present in the sponge to that required to totally convert it into solid flint. An example will render the process clearer.

SPONGE TAKEN—*Anthastra pyriformis*, Sollas.

Weight of the sponge full of water, 1·9203 grammes,
Weight of the sponge when dried, 0·788 grammes,

$$1{\cdot}9203 - (0{\cdot}788 \div 2) = 1{\cdot}5263 \text{ grammes,}$$

which is the weight of a volume of water equal to that of the sponge; this multiplied by 2·6, the specific gravity of flint, is

3·96838 grammes, the weight of a volume of flint equal to that of the sponge. Weight of the ignited spicules, 0·6658 grammes :

$$0·6658 \div 3·96838 = 16·77 \text{ per cent.}$$

Anthastra pyriformis thus contains 16·77 per cent. of the quantity of silica required to convert it into solid flint. Expressed as a common fraction, this is the $\frac{1}{6}$, so that it would require six equal and similar sponges to furnish sufficient silica for the conversion of one of them into flint.

The percentages in the following Table have been obtained by the method just described, from such sponges as resemble those of which skeletal remains are actually found associated with flint.

Table *showing the percentage of Silica present in various species of Sponges, the weight of a volume of Flint equal to that of the Sponge being taken as* 100 :—

Anthastra communis, Sollas, . .	5·05	
Anthastra pyriformis, Sollas, . .	16·77	
Pachastrella abyssi, O. Schmidt, .	3·9	(mean of 3 determinations).
Cydonium hirsutus, Sollas, . . .	17·5	
Cydonium pachydermata, Sollas, .	9·9	
Tethya maza, Selenka, ...	7·4	
Cinachyra barbata, Sollas, . . .	5·5	(mean of 3 determinations).
Azorica pfeifferae, Carter, . . .	6·44	
Corallistes masoni, Bowerbank, .	14·6	
Vetulina stalactites, O. Schmidt, .	25·0	(taken from a skeleton).
Theonella swinhoei, Gray, . . .	12·4	(from a skeleton).

The mean of these results is 12·22 per cent.

And since 100 ÷ 12·22 = 8·18, we may say that it would on an average require 8·18 sponges to produce sufficient silica to make a flint of the size of one of them.

We may now attempt to form a rough estimate of the period of time required to produce the material of a bed of flints. The experiments made on sponge culture in the Adriatic and the Florida Gulf showed that it takes from five to seven years for a bath sponge to grow from about one cubic inch to a saleable size. Now the size of a saleable sponge is not very different to that of an average-sized flint nodule; and assuming that the rate of growth of siliceous sponges is not very different to that of bath sponges, we may make the following calculation:—The average of from five to seven is 6. It takes 8·18 sponges to produce one flint; and supposing these to grow one after another, end on, it will take $8{\cdot}18 \times 6 = 49{\cdot}08$ years for the formation of the material of a flint of the size of a saleable bath sponge; and a bed of such flints would be formed in the same time, which is considerably less than the lifetime of a healthy man.

It is very probably true that the rate of growth is not the same for bath sponges and silicious sponges; but a number of considerations show that if the silicious grow less rapidly than the others, yet, as far as the formation of silica is concerned, this may be compensated for in a variety of ways. We have supposed the successive sponges to grow in a linear series, one after the other, and have taken no account of the swarms of young sponges which they produce at each breeding season; no doubt most of these are prematurely destroyed, since every sponge must have sufficient space about it for, so to speak, breathing purposes; but the exterminated young forms leave their quota of silica behind, since they commence its secretion even from the planula stage. Again, the total quantity of silica found at any one time in an adult sponge is not necessarily all that it has produced during its lifetime; for, as I have elsewhere shown, some silicious sponges, if not all, are constantly extricating some of the spicules they have secreted; and these dead spicules, discharged around them over the sea floor, may bear a not inconsiderable ratio to those remaining in the sponge. In one case (*Cydonium neptuni*) they accumulate within certain cavities of the interior of the sponge, completely filling them up, so that they look as if stuffed with cotton wool: the quantity of spicules so preserved must, I should imagine, amount to at least one-fifth of the total quantity present in the sponge; but these are only what, by an accident of structural character, are preserved and can be seen. How many others have been extruded at the surface, fallen on the sea floor, and left no trace of their previous connection with the sponge behind, we do not know, and have no means of knowing. But it is a very suggestive fact that at one of the stations from which the "Challenger" obtained sponges in great numbers (Station 149, off Kerguelen), the mud of the sea floor from which the sponges were dredged is crammed full of sponge spicules; and though the majority of these may have been derived from dead sponges, yet a goodly proportion may quite fairly be regarded as having been cast out from the living sponges.

It is obvious that experiments are required to determine the rate of production of silica by silicious sponges. Some Geodine sponge, with hispidating spicules (if it could be induced to grow in a tank), would be admirably adapted for investigation: it should be kept in a basin which would admit of clearing out at intervals, so that the quantity of cast-out spicules could be obtained and weighed.

Although it is clear that the material of flint owes its origin chiefly to silicious sponges, it does not follow that other organisms have not assisted. Schulze notices the comparatively rich development of Hexactinellid sponges in association with diatomaceous ooze, and I have observed something similar in the case of the Tetractinellida. If, then, the contributions of these organisms and of Radiolaria be taken into account, the time required for the formation of a bed of flints may be still further shortened.

So far as the evidence goes, it tends to show that a bed of average-sized flints may be formed in a period of about fifty years, more or less—a much shorter period than would, I fancy, have been expected; and though this case is a single and special one, it possesses also a special value, since it tends, along with the arguments of Wallace, to bring the estimates of geologic time, independently calculated by the physicist and the geologist, into harmony.

II.

ON IRISH ARENACEOUS ROCKS. By G. H. KINAHAN, M. R. I. A., Etc.

[In this Supplement information is given which was either omitted in my previous Paper[1] on this subject, or has been obtained since that Paper was written. A classification of paving setts has not as yet appeared, which omission is now rectified, while the subject of mosaic pavement is also referred to. I also give some information as to the durability and selection of stones, taken from the valuable Papers of Dr. Julien of New York.]

[Read November 16, 1887.]

The durability of building-stones and their selection is most important; therefore it may be allowable to refer to Papers by Dr. Alexis A. Julien "On the Decay of the Building Stones of New York City," abstracts of which appeared in the *Trans. New York Acad. Sci.*, 1883, pp. 67, &c., as in them there is interesting and valuable information applicable more or less to the Irish stones. The stones used in New York are principally sandstone, marble, granite, and gneiss—over 80 per cent. being sandstones. In consequence of the frequent fires in that city, stone buildings are preferred to frame-houses; but, on account of the friable nature of the stone generally used, brick and stucco have been much in request—frame-houses being 42·5, brick and stucco 47·9, stone 9·1, and iron 0·5 per cent. of the whole.

Although in New York there are some excellent stone structures, the severe competition has caused great quantities of most inferior sandstone to be employed in building. Some of the coarse sandstones in use last only from 5 to 15 years, but the best fine stones have lasted from 100 to 200; the coarse limestones last from 20 to 40 years, but some of the fine marbles have lasted 200; the granites have lasted from 75 to 200 years; while the gneiss appears to be more durable. In the great majority of the buildings, however, sandstones of bad quality have been used.

The durability of a stone depends partly upon the chemical composition of its constituents and of their cement. "This in-

---

[1] *Scientific Proceedings*, R. D. S., vol. iv., p. 507.

volves a consideration of their solubility in atmospheric waters; *e.g.* the calcium (carbonates of a marble or limestone), the ferric oxide of certain sandstones, &c.; their tendency to oxidation, hydration, and decomposition, *e.g.* of the sulphides (especially marcasite), in roofing-slates, limestones, &c.; the biotite and ferruginous orthoclase in a granite or sandstone, &c.; the enclosure of fluid and moisture, *e.g.* as 'quarry sap' in chemical combination—as hydrated silicates (chlorite, kaolin, &c.) and iron oxides, and as fluid-cavities locked up in quartz," &c. The durability of a stone depends also upon its physical structure in regard to the following, viz.: the size, form, and disposition of its constituents. For instance, an excess of mica plates in parallel position may be an element of weakness; the porosity of the rock permitting the percolation of water through its interstices; the hardness and toughness; the crystalline structure; the tension of the grains (which appears especially to explain the disruption of many crystalline marbles); the contiguity of the grains, and the proportion of cement in their interstices, and the homogeneity of the rock. "Again, the durability of a rock may depend on the character of its surface, whether polished, smoothly dressed, or rough hewn; since upon these circumstances may depend the rapidity with which atmospheric waters are shed, or with which the disposition of soot, street-dust, &c., may be promoted; also on the inclination and position of the surface, as affecting the retention of rain-water and moisture, exposure to northerly gales and to burning suns," &c.

The agencies concerned in the process of destruction belong to three classes, viz. chemical, physical, and organic. The chemical agents are sulphurous and sulphuric acids, discharged in vast quantities into the air of a city from the combustion of coal and gas, sewer gas, the decomposition of street refuse, &c.; carbonic, nitric, and hydrochloric acids; carbolic, hippuric, and many other acids, derived from smoke, street-dust, sewer exhalations, &c.; oxygen, ozone, ammonia, and sea-salt.

The more prominent *mechanical* and *physical* agencies are: extreme variations in temperature, wind and rain (to which some faces of a building are more exposed than others), crystallization by efflorescence, pressure of superincumbent masonry, friction, and fire.

The natural method of ascertaining the durability of stone, suggested by the author, is the examination of the outcrop of the beds, "where the exposure of the surface of the rock during ages may give some indication of its power of resistance to decomposition; and the examination of stones in old structures." He specially points out the examination of stones in monoliths and tombstones: "There could hardly be devised a better method for thoroughly testing, by natural means, the durability of the stone, than by its erection in this way, with partial insertion in the moist earth, complete exposure to the wind, rain, and sun, on every side, its bedding-lamination standing on edge, and several of its surfaces smoothed and polished, and sharply incised with dates, inscriptions, and carvings, by which to detect and to measure the character and extent of the decay."

As to the *seasoning* of stones, it is recorded that Vitruvius recommended it 2000 years ago, and that it has "been observed at times down to the days of Sir Christopher Wren, who would not accept the stone which he proposed to use in St. Paul's cathedral, in London, until it had lain for three years seasoning on the sea-shore. Since then little or no attention appears to have been paid to this important requirement by modern architects, in the heedless haste of the energy of the times. Building-stone, even for many notable edifices, is hurried from the quarries into its position in masonry long before the 'quarry sap' has been permitted, by its evaporation, to produce solid cementation in the interstices of the stone."

The pernicious effect of placing stones on their edges, and not on their bed-surfaces, is also mentioned, and the carelessness with which stones are selected and used.

While pointing out the effect of the different denudants on stone, it is mentioned by Dr. Julien that no material differences were remarked by him in graveyards near *the sea* and in those away from it. It seems, however, to be otherwise in Ireland, as the sandstones, slates, limestones, granite, &c., on the coasts of Cork, Kerry, Clare, and Galway, are recorded as having weathered more and differently from those inland (G. S. M.). *Heat* has a considerable effect, as stones exposed to the sun are more weathered than those which are constantly in the shade. *Lichens* do not seem to have much effect, as, "on their removal, the surface of the stone beneath is not found corroded; it only retains a fresh colour." *Imperfect pointing* is most deleterious, as it exposes the stones, as it were, in flank, to freezing, solution by rain, hydration, &c.

[In Ireland, although there are no very sudden changes between great heat and cold, yet the frequent alternations during winter of freezing and thawing cause a considerable amount of denudation, as can be seen in walls and natural rock-faces exposed to the mid-day sun: the sudden changes from wet to dry in summer have also a marked effect. Wind, not only in this but also in other climates, has more power as a denudant than it is generally given credit for. Strong winds in dry weather, carrying gritty particles, will act similarly to "sand-blasts," especially in eddies round corners, under-cutting the joints in buildings, and eroding grooves along the bedding and other lines in natural surfaces. Wind after rain dries the saturated surfaces and enters the minute shrinkage fissures, thus cutting out the particles, to carry them away and use them as "sand blasts" elsewhere. If wind and rain are combined, the latter is driven into the faces of walls, so that they have to be protected by weather-slating, cement, or some such appliances. The effects of wind, combined either with carried particles of sand or rain, may be observed in all exposed places—on buildings, monoliths, tombs, surface-blocks, and cliffs, especially at the earth-line, where they are more or less under-cut. In our climate some stones, such as granite and allied rocks, sandstone and slate, seem nearly always to be protected from weathering by those lichens that grow in sheets; but those that grow in branching tufts from a small root seem to promote decay. But all lichens seem to induce weathering in limestone, and even in slightly calcareous rocks: the decay being apparently due to the acids generated by those plants.

In former publications I have shown that in all classes of rocks there are some that are chemically hard, although physically soft; while there are others which are physically hard, although they may be chemically soft. These characteristics must be taken into consideration in selecting stones for different purposes. Chemically hard stones may be most suitable for building purposes, while unsuitable for places where they are subject to wear and tear; while the opposite may be the case with physically hard materials.

In sea works, that are exposed when the tide is out, as also in those above high water which are wetted during storms, or such like, some stones weather peculiarly; irregular holes wearing out; or, if they are cleaved rocks, the cleavage planes becoming developed. Cement, which is an artificially-formed calcareous rock, is in some places curiously licked out by sea or brackish water. This I have specially remarked at New Ross, on the Barrow, Co. Wexford, where the walls were pinned with wooden pegs, these being more durable than cement; and also in a wall at the north end of the Esplanade, Bray, Co. Wicklow. This action of sea-water seems to be in part the mechanical result of the sudden wetting and drying of the rocks; and in part the chemical result of the action of acids, and the formation of salts that are easily dissolved.]

PAVING-SETTS.—Paving must have been in vogue at a very early date, as it is found in prehistoric structures, such as the large crannog in Lough Rea, Co. Galway, where the stones were well selected. In early times the stones principally used were the naturally-rounded ones procured from the drift, or the beaches of rivers, lakes, and the sea, or some other natural accumulations. Sometimes they were well selected, both as to hardness and size; but often this was not so, as is at present the case in parts of the city of Glasgow and elsewhere; and consequently the surface after a time became rough and uneven. This appears to be one of the great reasons why, at the beginning of this century, Macadam's plan of making roads with broken stone was received with such great favour.

The early artificial paving-stones, or setts, seem to have been principally made of soft materials, that split readily; and in this country they were generally of limestone, or other soft materials, that are now universally condemned. The setts in the market seem to be generally classed by the trade as *black setts* and *white setts*. The first formerly included both the limestone and the whinstone, although the term is now more generally appropriated to the latter; while "white setts" include the granite and the grits. Limestones are classed by themselves.

The stone for paving-setts should split easily, thus requiring little or no after-dressing. It should be durable, that is, capable of resisting crushing and surface wear; and when subjected to traffic its surface should not become soapy or glassy. It is, however, very difficult to find a stone having all these qualities combined. Many of the *limestones* split easily, and are cheaply wrought; but in general they are friable or soft; while those that are tough or silicious, especially the first, receive a more or less soapy polish. Limestone-setts are suitable only for places where there is very little traffic; but on account of their cheapness they can very profitably be used for pathways. The *whinstones* almost always are hard, durable, and capable of resisting crushing and wear; but they have to be selected with great care, as many, especially some of those that are tough and hard, readily acquire a soapy-polished surface, which makes them unsuitable for a good pavement. *Granites* perhaps make the most comfortable road; but they are generally less durable than whinstones; while the hardest or quartzose varieties are liable to take a glassy polish. *Grits* are very variable in character, from open to compact and quartzose. Some of the hard quartzose grits split, or rather break up naturally into sizes suitable for setts, and consequently can be very cheaply wrought; but unfortunately they are often liable to receive a glassy polish. A quartozse felspathic grit, however, if it splits easily, is a cheap and good stone.

Some localities where good grit setts can be procured have been mentioned in my previous Paper.[1] The Irish localities from which granite and whinstone setts are now sent into the market will be mentioned hereafter in the section treating on those rocks.

Mosaic Pavement has lately been more or less in demand. The ancient Romans used principally fragments of marble, introducing, however, pieces of glass and terra cotta to give tints. The modern Italians also use principally marble fragments. Messrs. Sibthorpe and Son, of Dublin, are trying to start a new Irish industry by bringing over Italians to teach Irish workmen the art. Mosaic pavement, consisting entirely of terra cotta, seems to be a modern invention.

A sort of rough mosaic work is seen in some of the English towns, pieces of flags placed on edge being used for pavement. For similar work there is plenty of materials in Ireland at the various flag quarries, especially those of Kilkenny and Clare, where the detritus might readily and cheaply be dressed into setts suitable for pathways and such like. These, if cut, would make a beautiful floor, permanent in character, and unique in appearance.

ANTRIM.

Portrush.—Church of the Holy Trinity, Portrush, Mr. Christie's quarry, Dunmurry, Draperstown, Co. Londonderry. The stone, when raised from the quarry, deep red, but when dressed, pale pink, and some beds whiteish. Dresses very fine, and especially suitable for fine inside work. The blocks should be laid on their quarry beds. All the columns and part of the windows are of this stone. New Wesleyan Church; from Altmore, Dungiven, Co. Londonderry, and Gortnaglosh, Dungannon, Co. Tyrone. The Altmore stone—yellowish, coarse-grained, and rather hard; used for quoins and courses without mouldings. The Gortnaglosh stone is of a buff colour, fine-grained, and especially suitable for mouldings and dressed windows; the large windows and porch of this stone. In places it shows slight iron stains. (*R. G. Symes.*)

---

[1] *Scientific Proceedings*, R.D.S., vol. v., pp. 543, 563, &c.

CORK.

Glanmire Quarry.—Good, rich, red, capital building-stone, even when set on edge. In many fine buildings this stone has been used, such as the following in the city of Cork:—SS. Peter and Paul's Church and Convent; Roman Catholic Cathedral; St. Vincent's Church and Convent, Sunday's Well; Dominican Convent, Pope's-quay; St. Mary-of-the-Isle Convent New Orphanage; the Incurable Hospital, and others. All these buildings have limestone dressings. Most of the brown stone flags used in Cork have been procured here, while the bottom bed, a greenish-grey hard stone, is used for macadamizing. Smaller quarries to the northward of the city with the same class of stone. St. Luke's Church, lately burnt down, was built of a duller stone from the quarry north of the Police Barracks. The Police Court, and many other buildings, are built of sandstone, with limestone dressings. (*R. W. Johnson.*)

Rostellan, near Midleton. Good sand, formerly used in the glasshouses, Cork.

DONEGAL.

Dromkeelan, near Mount Charles.—This stone, lately brought prominently forward, has a good character if set on its natural bed; but if set on edge it is friable and peels off.

Glenalla, a little north of the church-green.—The stone rises in large blocks; punches well. Used in the foundation and lower courses of the church and Glebe House. (*F. M'Fadden.*)

Creeve, north-west of Rathmullen.—Good scythe-stones.

At different places in the tracts of quartzite and sandstone that extend from Lough Swilly, near Rathmullen, to and beyond Ramelton, there are beds of a sound stone which rises in large, squarish blocks; very suitable for rough walling, as also for sea-walls, foundations, and coping of bridges.

Margining Ballymastocker Bay, Lough Swilly, there are dunes of æolian drift: these are principally composed of highly *calcareous sand*, very valuable as a manure. It ought to be much more utilised than it is at present, as it could be easily carried by boat to great distances.

Associated with the sand dunes, and at times within them, are peculiar thin-bedded horizontal friable calcareous *sandstones*, suitable for farm walls. The mode of formation of these horizontal sandstones is hard to conjecture, as they seem to have been originally æolian drift, which is not horizontally bedded. They seem to have been cemented from the outside inwards, as in places the middle parts of the beds are uncemented: on these the wind acts, and consequently the sandstone is very much tumbled about.

TYRONE.

Douglas Bridge, eight miles south of Strabane.—The stone here has been extensively used for cut-stone purposes in Strabane, and in Letterkenny, Co. Donegal (twenty-seven miles distant); easily worked; stones all dressed in the quarry.

WEXFORD.

With reference to the epitome of the geology of this county, we may take this opportunity of adding the following, which is of special interest.

Baginbun, N.N.W. of Baginbun Point, on the coast S.E. of Fethard, are conglomerates which dip N.N.W., and appear to lie unconformably on greyish and blackish slates and grits, which dip S.S.E. at high angles. In one bed graptolites were found; but further south are conglomeritic slaty rocks, unlike any of the Ordovicians of the county, but very similar to some of the Cambrians, especially those at Ferrycarrig, N.W. of Wexford town (G. S. M.). Some of the early explorers considered the Fethard conglomerate to be the base of the Ordovician; but the graptolites in the beds below it were considered fatal to such a conclusion. What has now been ascertained in the Co. Donegal may suggest a solution, as these dark beds with graptolites, between the Fethard conglomerate and the Baginbun beds, may belong to a portion of the ARENIGS. If the existence of Arenigs can be proved here, it would, perhaps, also suggest that farther north a band of similar rocks may have extended obliquely north-eastward from Killurin and Ferrycarrig to the sea, having to the northward and southward the typical Oldhamia-bearing Cambrians. The beds in the neighbourhood of Ferrycarrig are very similar to those at Baginbun.

III.

REVIEW OF DOHRN'S THEORIES ON THE ORIGIN OF VERTEBRATES.

By ROBERT F. SCHARFF, B. Sc., Ph. D., Curator, Natural History Department, Museum of Science and Art, Dublin.

[Read December 14, 1887].

The only account, in English, of some of these "Studien zur Urgeschichte des Wirbelthierkörpers" was published by Cunningham in the *Quarterly Journal of Microscopical Science*, 1886. I herewith propose to give a full *resumé* of the subject, including the most recent Paper, which was only issued a few months ago. Those who have not seriously considered these new theories will, no doubt, welcome an additional exposition before tackling the original German version, of which twelve parts have now been published in the Journal issued by the Zoological Station at Naples.[1]

In 1875, Dohrn wrote a small pamphlet "On the Origin of Vertebrates, and the Principle of Change of Function." He, in this Paper, drew attention to the fact, that in three chief points his views differed from the current ideas. These were, the derivation of vertebrates from worm-like ancestors, that the principle of change of function was the best guide in tracing morphological histories, and that degeneration might proceed to an unlimited extent.

The fundamental idea contained in the above-mentioned Paper was that the ancestral vertebrate possessed an "œsophageal nerve ring," similar to what we find at present in most of the

[1] *Mittheilungen d. Zool. Station Neapel:* "Studien zur Urgeschichte d. Wirbelthierkörpers," by Anton Dohrn. Part I. vol. iii. 1882, pp. 252–263. Part II. vol. iii. 1882, pp. 264–279. Part III. vol. iv. 1883, pp. 172–189. Part IV. vol. v. 1884, pp. 102–151. Part V. vol. v. 1884, pp. 151–160. Part VI. vol. v. 1884, 161–195. Part VII. vol. vi. 1885, pp. 1–48. Part VIII. vol. vi. 1885, pp. 49–92. Part IX. vol. vi. 1885, pp. 399–431. Part X. vol. vi. 1885, pp. 432–480. Part XI. vol. vii. 1886, pp. 128–176. Part XII. vol. vii. 1887, pp. 301–337.

invertebrates. He located the ancestral mouth in the fourth ventricle, and supposed that the crura cerebelli were the homologues of the lateral commissures. However, in the first part of his "Studies," published seven years after this pamphlet, Dohrn acknowledges that he had committed a fault in enunciating such an untenable supposition. Two investigators especially drew his attention to it, viz. Professor Fritsch and Mr. Sanders. According to Dohrn's original view, several cerebral nerves would have been included in the supra-œsophageal ganglion. This induced the author to abandon, for the present, the investigation as to the position of the ancestral mouth, and to take up another problem, namely, that of the development of the actual mouth.

I.—*The Origin of the Mouth.*[1]

The results of researches made on embryos of bony fishes have confirmed a view Dohrn arrived at, as far back as 1871. This view was that the mouth of living vertebrates had originated from a union of two gill-clefts. He observed in several teleostean embryos that there was no stomodaeum or ectodermal oral invagination. The mouth opened to the exterior, first on the sides, the middle part being still closed. Hence there were two ready-formed openings at first, which had an endodermal origin, before the ultimate rupture of the part between had taken place.

This concludes Dohrn's first Paper.

II.—*The Origin and Significance of the Hypophysis in Teleosteans.*[2]

Several of the more recent investigators on the development of elasmobranch fishes, amphibia, and the higher vertebrates, agree that the hypophysis is strictly ectodermal in its origin, being a derivative of the stomodaeum. Dohrn having denied the existence of a stomodaeum in teleosteans, it would evidently have been difficult for him to derive the hypophysis from it. But actual observation favoured his view in this case again. The hypophysis makes its first appearance at the same time as the endodermal

---

[1] *Ibid.*, vol. iii. 1882, pp. 252–263. [2] *Ibid.*, vol. iii. pp. 264–279.

evaginations of the gill and mouth-clefts. It arises in form of a pair of more or less distinct endodermal evaginations, considerably in front of those forming the mouth.

Various suppositions have been advanced by zoologists as to what the hypophysis represented. The primary idea was to connect it in some way with the ciliated pit in tunicates, and it was for some time looked upon as a sensory organ. Another supposition was that it was a glandular structure. Dohrn is opposed to either of these views. He regards the hypophysis as a pair of praeoral gill-clefts, arrested in their development in such a manner as not to reach the surface of the skin.

In concluding his second Paper Dohrn makes reference to Hatschek's results on the development of Amphioxus. According to that author, the hypophysis owes its origin to two endodermal evaginations lying in front of the mouth. One of these is constricted off completely from the endoderm, and breaking through the ectoderm forms a ciliated pouch, which to all appearances might be supposed to be ectodermal in its origin. The second evagination remains for a longer time connected with the endoderm, but its ultimate fate had then not been made known. Dohrn suggests that these two evaginations might be homologous with the ciliated pit of tunicates on the one hand, and the hypophysis of vertebrates on the other.

III.—*The Hypophysis in Petromyzon.*[1]

One of the great features in the development of Petromyzon is the presence of a stomodaeum, as has already been pointed out by Scott; but Dohrn leaves the consideration of this structure for a later study. In front of the stomodaeum (mo.), and close to it, we find another invagination (hy.), which is preceded by a third (na.). The latter is the nasal organ, between which and the mouth lies the second, the rudimentary hypophysial invagination. (See fig. 1.)

However, instead of being drawn within the mouth, as in other vertebrates, the powerful development of the upper lip (ul.) not only causes the hypophysis to be removed close to the nasal organ, but the latter itself is pushed along until it reaches the dorsal surface.

---

[1] *Ibid.*, vol. iv. 1883, pp. 172–189.

We thus find at a later stage that the so-called nasal organ of Petromyzon is in reality almost wholly formed by the hypophysis, only the external part belonging to the former. (See figs. II. and III.)

The hypophysis ends blindly, underneath the part of the brain known as the infundibulum (in.).

In closing this chapter on the development of the hypophysis in Petromyzon, Dohrn alludes again to his view, that this organ was originally a pair of gill-clefts in front of the mouth. When the coalition of the two gill-clefts in the ancestral vertebrate took

I

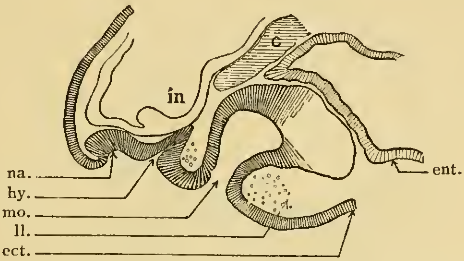


Figure I., longitudinal section through the head of an embryonic Petromyzon (after Dohrn).

in. = infundibulum.
c. = chorda dorsalis.
ll. = lower lip.
mo. = mouth, or stomodacum.
na. = nasal invagination.
hy. = hypophysial invagination.
ect. = ectoderm.
ent. = entoderm.

place in order to form the mouth, the anterior hypophysial gill-clefts also lost their independent character, and in one group of vertebrates they were drawn within the mouth and in the other, owing to the enormous development of the upper lip, they united within the nasal organ.

In Petromyzon the so-called nasal organ probably still retains to some extent, the function of a gill.

IV.—*The Visceral Arches of Elasmobranchs.*[1]

Balfour was opposed to Dohrn's theories about the origin of the mouth. He held the view, that the present mouth of verte-

[1] *Ibid.*, vol. v. 1884, pp. 102–151.

brates was also the ancestral mouth which, in the vertebral ancestors, had a suctorial function. Balfour's chief argument lay in his opinion of the homology of the so-called external gill-arches in elasmobranchs with the branchial skeleton in the lamprey.

In order to disprove this view, Dohrn commences his fourth study with a consideration of the development of the visceral arches. He choses the arches lying between the second and fourth clefts, being more typical in their form than the others.

In speaking of the branchial veins, Dohrn alters the current

II

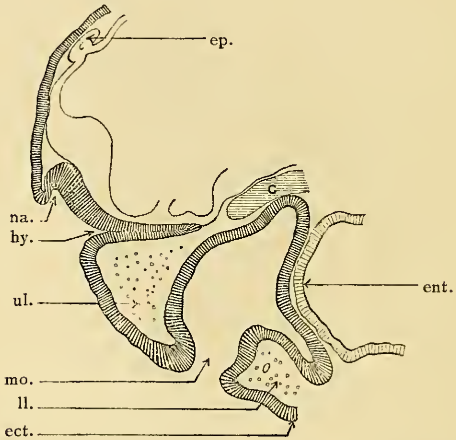


Figure II., longitudinal section through the head of an embryonic Petromyzon (after Dohrn).

ep. = epiphysis.
na. = nasal invagination.
hy. = hypophysial invagination.
ul. = upper lip.
mo. = mouth, or stomodacum.
ll. = lower lip.
ect. = ectoderm.
ent. = entoderm.

terminology by calling them the anterior and posterior vein of a certain arch, while formerly they were spoken of as the anterior and posterior vein of a gill-pouch, which, of course, is exactly the reverse of the former. (See fig. IV.)

The original root of the aorta is identical with the original branchial artery whose dorsal part is called aortic root. As development proceeds, branchial veins originate from subsidiary streams, which at first open into the dorsal part of the artery. The anterior vein now develops more strongly, and the posterior vein, along with the artery, shed their blood into the former. The artery then loses all connexion with the anterior vein, which alone represents the aortic arch. The posterior vein also becomes independent, and joins the aortic arch of the next gill-arch, so that ultimately each aortic arch receives its blood from two very unequally large veins of two different gill-arches.

On that part of the visceral arch which is nearest the intestine (the proximal part) the mesoderm cells condense to form the rudimentary cartilaginous arch. From the distal parts of the

III

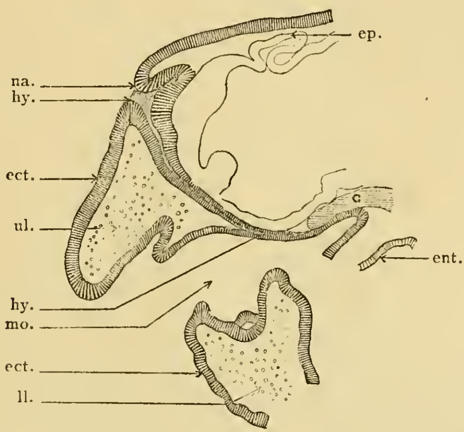


Figure III., longitudinal section through the head of an embryonic Petromyzon (after Dohrn)

ep. = epiphysis.
na. = nasal invagination.
hy. = hypophysial invagination.
ect. = ectoderm.

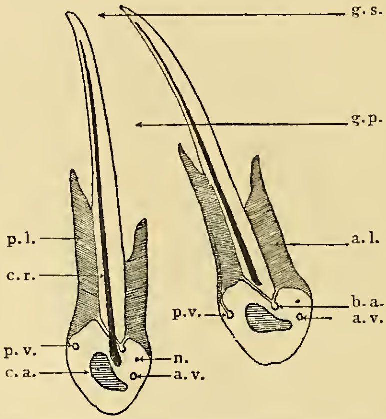
ul. = upper lip.
mo. = mouth, or stomodacum.
ll. = lower lip.
ent. = entoderm.

mesoblastic somite in the interior of each arch, the musculi interbranchiales are developed; the dorsal parts of the same form the constrictor superficialis. The musculi interarcuales arise from the dorsal proximal parts of the mesoblastic somite. The muscle which quite at the beginning was constricted off from the proximal portion of the mesoblastic somite by the venous commissures and the cartilaginous arch is the adductor arcus visceralis. (See fig. v.)

The two middle portions of the cartilaginous arch are formed from the original cartilaginous piece. They are articulated to one another. The "basale" (pharyngo-branchial) is constricted off from the dorsal, and the "copulare" (hypo-branchial) from the ventral piece. (See fig. VI.)

The branchial cartilaginous rays are formed considerably later than the arches. They arise as condensations of mesoderm cells between the branchial artery and the posterior vein close to the cartilaginous arch. Later on the rays approach the arch still more, without, however, becoming anchylosed with it. These rays, except the two external ones, are in connexion with the two middle

IV.



Diagrammatic figure of a cross section of two Branchial Arches (Elasmobranch).

g. s. = ext. gill-slit.	a. v. = ant. vein.
g. p. = gill-pouch.	c. a. = cartil. arch.
p. l. = post. gill-lamella.	c. r. = cartil. ray.
a. l. = ant. gill-lamella.	n. = nerve.
p. v. = post. vein.	b. a. = branchial art.

pieces of the arch. While all other rays grow straight out, these two external ones (one dorsal and the other ventral) receive from their very beginning a curvature. As they grow longer they curve still more—in fact they grow towards one another. This extraordinary growth is probably due to the gradual diminution in size of the branchial clefts. These dorsal and ventral external rays constitute the so-called external cartilages. By all previous observers, including Balfour and Gegenbaur, these cartilages were looked upon as being equivalent with the arches in Petromyzon. Most of their speculations were based upon that fact. Dohrn, however, proves that the external cartilages have nothing to do with the arches of Petromyzon, which are true arches. (See fig. VI.)

The commencement of the real gill-formation takes place as soon as the first four clefts and the mouth have been formed. The branchial lamellae originate as semicircular evaginations of the external epithelial layer.

As they are further differentiated, however, a great difference appears between the anterior and posterior rows of lamellae of each arch. While those of the anterior rows gradually assume the form of true lamellae, those of the posterior rows elongate considerably and project through the gill-clefts. The latter constitute the so-called branchial filaments of the embryonic elasmobranch. As regards their function, Dohrn suggests that they absorb yolk from the surrounding medium. He found that the filaments as well as the veins were filled with an emulsion of yolk, but he never met with any in the branchial arteries or the heart.

Dohrn next goes on to the consideration of the thymus in elasmobranchs, discussing its origin and function.

Some time previous to the differentiation of the branchial rays, five buds appear one after another in the upper angle of the five gill-clefts. The last of these soon disappears again. They are epithelial in their origin, only the lower layer of the epithelium taking part in their growth; but from the very commencement, mesodermic cells as well, seem to enter into the formation of the buds. After having increased considerably in size, the buds sink into the mesoderm. The cause of their disappearance from the surface is to be sought in the reduction in size of the visceral clefts referred to above.

That these buds represent the thymus of elasmobranchs is evident from their position. Dohrn concludes this article by referring to the function attributed to the thymus by the various authors.

V.—*The Origin and Differentiation of the Visceral Arches in Petromyzon.*[1]

We know, from the researches of Scott and Balfour, that the visceral arches arise in the shape of head-cavities, lying

---

[1] *Ibid.*, vol. v. 1884, pp. 151–160.

between the diverticula of the alimentary tract, from which the gill-clefts are formed. Balfour has already pointed out that the original gill-arches in Petromyzon do not lie near the distal end, as in selachians, but are in close proximity to the proximal end or inner border of the visceral arches. The muscle-tube, which is originally round, elongates, causing the component cells to group themselves into two rows, which will be spoken of as the visceral and parietal respectively. At the same time the cartilaginous arch is differentiated from the mesoderm tissue on that side, lying externally to the parietal row just mentioned. The visceral wall of the muscle-tube now becomes thickened more strongly than the parietal, and a proximal portion separates off from a distal part of the mesoblastic somite, the cartilaginous arch appearing between the two.

While the arch undergoes a series of curvatures in various directions, a histological differentiation of a peculiar kind is noticed in the two muscular layers. The visceral muscle shows a most perfect striation, while the cells of the parietal become drawn out into long tubes, persisting in their embryonic form and exhibiting only an external striation.

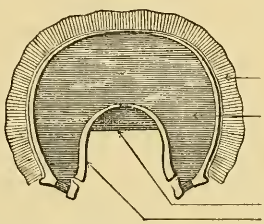
All muscles belonging to the visceral arches spread along the whole circumference of the branchial cavity. They are inserted dorsally to the chorda dorsalis; but, both dorsally and ventrally, the arches of each side unite with one another. The muscles are inserted comparatively late in various regions of the cartilaginous rods. At first they pass by the rods and unite dorsally and ventrally with one another. This is of great importance, as will be shown later on, when Myxine comes to be considered. In the latter, indeed, where the rods have disappeared, this condition of the muscles still remains. The great difference of the branchial apparatus of elasmobranchs, and that of Petromyzon, consists in the gill-lamellae of the former being directed outwards, and inwards in the latter.

The external clefts are probably opened by the action of the adductor muscles. On the other hand, the long muscles of the distal parts—the constrictor muscles—are perhaps expiratory in function.

We thus find that the gill-arches in Petromyzon are completely homologous with the inner arches of elasmobranchs. This is confirmed by their early appearance, their primitive position between the distal and proximal portions of the visceral muscles, their insertion, and the appearance of secondary cartilages. The latter are homologous with the cartilaginous rays, but on account of their appearing very late they have not yet been described.

If we compare the elasmobranch arch with that of Petromyzon, the main difference is exhibited in the separation of the former into four pieces. But supposing, says Dohrn, this reduction did not take place—in fact, if the arch remained as a single piece—and if we further supposed that the constrictor and inter-branchial muscles which are parts of the distal and the adductors, inter-

V.



Cartilaginous arch of an Elasmobranch, showing the principal muscles.

c. a. = cartilaginous arch.
a. m. = adductor muscle.
m. i. = musculi interbranchialis.
c. m. = constrictor muscle.

arcuales and coracobranchiales which are parts of the proximal portion, remained all in connexion with one another, we should have exactly what we find in Ammocoetes, the young of Petromyzon.

No one will doubt that the separation into four parts of the gill-arches is one of the later modifications, and that originally there was only one cartilaginous rod. Hence we may reasonably suppose that both the elasmobranchs and the cyclostomata are derived from such an ancestor whose hypophysis discharged the duties of an independent cleft.

In his previous pamphlet Dohrn drew attention to the fact, that in almost all animals the gills were protected by special contrivances. This necessity of protecting the gills must have arisen when the present habits of cyclostomata (burrowing in mud or attaching themselves to other animals) were acquired. The displacement of the branchial lamellae to the interior explains also the position of the branchial artery internally, instead of externally, to the cartilaginous arch.

With regard to the comparison which has been drawn by previous authors between the external or extra-branchial arches in selachians, and the branchial arches of cyclostomata, Dohrn has clearly proved that they are not homologous. The branchial arches of the cyclostomata, however, are strictly homologous with the inner or chief arches of selachians, the extra-branchial ones of the latter being merely terminal cartilaginous rays belonging to the inner arches. In describing the cyclostomata, remarks Dohrn, we should, therefore, not follow Gegenbaur and others by saying that they have no jaws because the true inner arches are wanting, but that they possess inner arches, and have lost their jaws, probably on account of the change of the mouth from a biting to a sucking one.

Gegenbaur argues further that the cyclostomata could not have had limbs, because limbs were transformed gills, and the archipterygium could be reduced to branchial rays. This argument likewise falls to the ground, apart from the invalidity of the archipterygium theory, and we shall presently see that there are still rudiments of the pelvic fin in Petromyzon.

VI.—*The Fins of Elasmobranchs.*[1]

The first stage of the limb formation is recognizable by a skin-fold which, beginning immediately behind the branchial apparatus, reaches as far as the anus. A quantity of mesoderm elements grows into the anterior part of this fold, which at first consists only of ectoderm cells. The same takes place near the anus a little later, and these two projections are the rudimentary pectoral and pelvic fins.

The mesoblastic somites, or myotomes, lying near the fins, produce two buds each—an anterior and a posterior. These buds, after becoming constricted off from the myotomes, divide again. Hence each myotome produces four separate muscle-masses, which

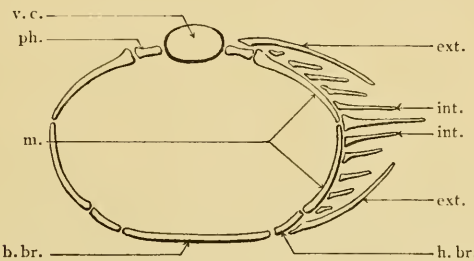
[1] *Ibid.*, vol. v. 1884, pp. 161–195.

are the bases of the whole system of muscles in connexion with the limbs.

The first traces of cartilage in the pectoral fin appear at its base in the mesoderm tissue, between the two pairs of buds. The spinal nerves supplying the fin are equal in number to the myotomes which are concerned in the formation of its muscles.

As regards the myotomes lying between the pectoral and pelvic fins, they also develop buds; but these soon disappear again. The ventral unpaired fin makes its appearance in the same manner as the fins just described, and Dohrn supposes that it also must originally have been a paired fin. Just as in the paired fins, the skeleton consists of a series of simple cartilaginous rays. The dorsal fin also appears to originate in a similar way, the muscle-

VI.



Diagrammatic figure of Skeleton of a Branchial Arch in an Elasmobranch.

v. c. = vertebral column.
ph. = basale or pharyngobranchial.
ext. = external rays.
int. = internal rays.
m. = middle pieces.
b. br. = basibranchial.
h. br. = hypobranchial or copulare.

buds arising from the dorsal end of the myotomes, but with the difference that there is no separation into outer and inner buds. Hence the dorsal fin is apparently unpaired from its very beginning; however, Dohrn proposes to try and solve this problem presently. In conclusion, he deals with a few phylogenetic questions regarding the origin of the fins. The cause of the ventral union of the paired post-anal fins lies in the non-existence of the intestine in that part. But the history of development tells us that there existed a post-anal portion of the alimentary tract. In the ancestral vertebrate this tract extended to the end of the body, the present anus being a more recent formation. We can understand, therefore, says Dohrn, that by means of a reduction of that part, a coalescence of the paired fins must have taken place.

The medullary canal must originally have been an open plate. The formation of an unpaired dorsal fin may have followed the closing of the plate to form a tube, the dorsal fin having most probably been paired like the ventral.

We have every reason to look upon vertebrates as segmented animals; and as we see the muscles, nerves, and the skeleton appear metamerically, we may also look upon the fins as having originally been metamerical. Hence we have arrived at the conclusion that the ancestral vertebrate possessed two dorsal and two ventral metamerically separate folds, an alimentary tract (continuous through the whole body), and a medullary plate. If we compare this with an annelid, the striking similarity becomes evident, the dorsal and ventral parapodia in the latter corresponding to the ventral and dorsal of the former respectively.

VII.—*The Origin of the Hyoid and Mandibular Arches of Elasmobranchs.*[1]

There is hardly a subject in animal morphology which has been so much discussed as this, and to make matters worse, almost every author has invented his own terminology.

The arteries of the hyoid arches form the terminal bifurcation of the conus arteriosus, just in front of the arteries belonging to the first true branchial arch. The small thyroid or mandibular arteries take their origin at the base of the first-mentioned arteries. The hyoid arteries supply only the posterior row of branchial lamellae. There is, likewise, only one hyoid vein, and consequently only one commissure instead of two, as in the posterior arches, and thus it sheds its blood into the commencement of the spiracular artery which is the continuation of the thyroid artery. (See fig. VII.)

The hyoid vein divides into two branches, one of which runs backward joining the aortic system, while the other is directed towards the hypophysial invagination, where it unites with the branch from the opposite side. They soon separate again, however,

---

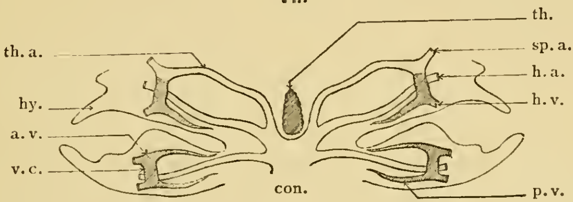
[1] *Ibid.*, vol. vi. 1885, pp. 1–48.

and each unites with a vessel coming from the spiracle. (See fig. VIII.)

One of the most characteristic differences between the muscular system of the hyoid arch and that of the branchial arches lies in the absence of the proximal piece from which, in the latter, the adductor takes its origin. The musculi interarcuales are likewise wanting; but instead of these muscles we find a complicated arrangement of ligaments, fixing the so-called hyomandibular. The ventral muscles, however, are present, and are like those of the posterior arches.

The venous commissure in the hyoid arch indicates the position where the primitive cartilage is formed—in fact it lies in the

VII.



Anterior portion of arterial circulatory system in an embryo of Pristiurus (after Dohrn).

th. = thyroid.
sp. a. = spiracular artery.
h. a. = hyoid artery.
h. v. = hyoid vein.
hy. = hyoid arch.
p. v. = post. vein.
v. c. = venous commissure.
a. v. = ant. vein.
con. = conus arteriosus.
th. a. = thyroid artery.

middle of the hyoid cartilage. In the sharks we recognize the hyomandibular as the upper middle piece of the hyoid arch by its supporting a number of cartilaginous rays. A dorsal ray homodynamous with the extra-branchial rays is also present. Hence it follows that the hyomandibular likewise contains the "basale" (pharyngobranchial) of the hyoid arch.

The first rudiment of the mandibular arch in sharks appears on the same level where the rudimentary hyoid cartilage is formed. The difference, however, in this formation is made apparent by the circumstance that the mandibular cartilages arise from two centres, one of which becomes the lower jaw, and the other the upper jaw, the so-called palato-quadrate. A segmentation of the cartilage into "middle piece," "basale," and "copulare" does not take place. No venous commissure is formed, and no adductor. As the cartilaginous rays are also wanting in the mandibular arch, the doctrine which represents the upper and lower jaw as one visceral arch, homodynamous with the branchial arches, becomes considerably shaken, to say the least of it.

The development of the cartilaginous parts of the hyoid arch in the rays differs from that in the sharks. We find two cartilage-centres in the arch—one close to the posterior margin, the other near the spiracle. We equally have two muscular centres in connexion with the two cartilaginous centres. The first cartilage bears cartilaginous rays, four of which are dorsal, and four ventral of the venous commissure. The latter divides the arch into a dorsal and a ventral part, as in other arches. We have, therefore, in this arch a complete system of muscles, except the adductors and musculi interarcuales dorsalis. We further have an artery, a posterior vein, and a posterior complete row of branchial lamellae. Only the anterior row of lamellae and the anterior vein are wanting, while the venous commissure is present. But, nevertheless, according to the current opinion, especially held by Gegenbaur, this arch is only said to correspond to the ventral portion of the hyoid arch, while the dorsal—the hyomandibular—has been differentiated from it.

The second cartilage mentioned above represents the hyomandibular. It possesses its own strong muscular system which, however, lies only dorsally. If the fact is taken into consideration, says Dohrn, that in the rays we have two cartilaginous centres, and two muscular systems in the hyoid arch, we must come to the conclusion that we are dealing here with two segments united into one visceral arch. The posterior segment is represented by the true hyoid arch. Dohrn concludes from this, contrary to Gegenbaur, that in the rays the hyoid arch is in a more primitive condition than in the sharks. According to Gegenbaur, the hyomandibular in the rays represents only the mandibular process of the hyomandibular in the sharks; however, the former possess cartilaginous rays in the dorsal part of the hyoid in considerable number, dorsal to the venous commissure, which fact contradicts Gegenbaur's statement.

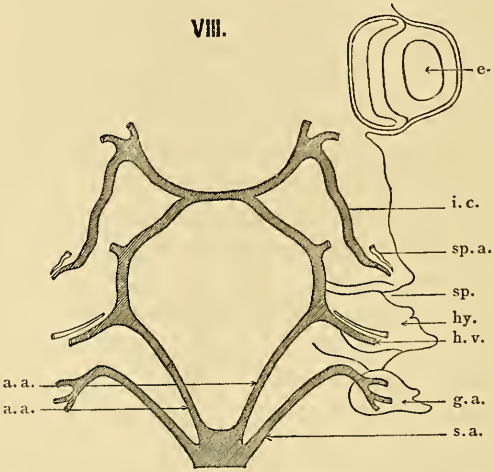
The spiracular cartilage in the elasmobranchs used for investigation is originally always a single cartilage. It is invariably situated in front of the spiracular system of blood-vessels. In this respect it is distinguished very materially from the rays of other arches. This mode of origin, indeed, gives us no cause to suppose that the spiracular cartilage consists of a fusion of rays. The cartilage, on the contrary, is much more likely a portion of a visceral arch. Which arch, however, it may have belonged to remains all the more doubtful, as the changes of the anterior arches have been so extraordinary. The adductor mandibulae has been looked upon by comparative anatomists as homodynamous with the adductors of the visceral arches. It is developed from the whole of the walls of the mandibular head-cavities, no portion being separated off as an adductor. The portion lying next the spiracle is differentiated from the other part, and forms the levator maxillae superioris. All the rest goes to form the adductor mandibulae. Hence this adductor cannot be taken as a homologue of the visceral arches. The difficulties connected in deriving the upper and lower jaw from visceral arches are much augmented by the nature of the muscular system—not lessened, as Gegenbaur thinks.

Dohrn concludes his seventh study with a consideration of the origin of the thyroid gland (see fig. vii.). It makes its appearance early. It arises in the median line just behind the mouth as a solid outgrowth from the endoderm. In time this outgrowth grows towards the heart and obtains the shape of a flask. A formation of follicles then takes place connected with an ingrowth of mesoderm into the body of the gland. Along with the mesoderm, small vessels appear which have been mentioned before. The gland ultimately moves from its original position, travelling more and more backwards until it occupies the place where we find it in the adult. No doubt, says Dohrn, we have here the last remains of a branchial cleft lying between the hyoid and hyomandibular arches. It might be argued, that as the thyroid arises as a single outgrowth, it cannot represent a pair of gill-clefts. However, as Dohrn pointed out before, bilateral organs often come into such close contact—either vertically or dorsally—as to become apparently unpaired organs. Later on he proposes to discuss the general processes leading to such fusions of originally bilateral formations. The thyroid artery also points to the fact of a well-developed gill-cleft having once existed in that position. It is also known that during the later stages of development the thyroid gland in many animals becomes paired. According to M. Müller the thyroid gland is probably equivalent to the hypobranchial groove in tunicates and Amphioxus. Dohrn discusses whether this theory is correct or not in the next study.

VIII.—*The Thyroid in Petromyzon, Amphioxus, and the Tunicates.*[1]

In Ammocoetes—the larval form of Petromyzon—the first trace of the thyroid appears at the time when the most anterior branchial diverticula of the endoderm grow out. Immediately beneath the first of these diverticula an invagination is formed, which is directed downwards and somewhat forwards. This invagination is

VIII.



Anterior portion of venous circulatory system in an embryo of Pristiurus (after Dohrn).

e. = eye.
i. c. = internal ant. carotid.
sp. a. = spiracular artery.
sp. = spiracle.
hy. = hyoid arch.
h. v. = hyoid vein.
g. a. = first gill arch.
s. a. = second aortic arch.
a. a. = first aortic arch.

the first rudiment of the thyroid. Two parallel branches of the conus arteriosus first pass round this invagination and then run along a mesoderm fold—the velum—which has been formed between the stomodaeum and the endoderm. These arteries are the most anterior branchial arteries and as such are homologous

[1] *Ibid.*, vol. vi. 1885, pp. 49-92.

with the spiracular artery of elasmobranchs. As there are two cephalic aortae in Petromyzon, one on each side of the notochord, each of these two arteries opens into the aorta of its own side. The backward growth of the mesodermic velum causes the original opening of the thyroid to be pushed back, so that it comes to lie at the level of the second pair of branchial diverticula.

An ingrowing lamella of connective tissue now divides the thyroid into two parts. Subsequently another lamella breaks into the anterior part of the thyroid on each side and in so doing pushes in the outer wall. Dohrn now calls the invaginated part "the glandular lamella" and the uninvaginated "the opercular lamella." In the glandular-lamella, a differentiation of the cells takes place into masses of long, conical gland-cells and shorter ciliated cells.

At a later stage, says Dohrn, we find two ciliated grooves running along the floor of the pharynx, and converging on the median ventral line. They meet at the opening of the thyroid.

Developmental history shows that these grooves are the last remains of the most anterior gill-pouches, which are homologous with the spiracular clefts of elasmobranchs.

If we compare the fully developed endostyle or hypobranchial groove of an ascidian—say *Ciona intestinalis*—with the thyroid of Ammocoetes, we find, in spite of a series of minor dissimilarities, the same characteristic fundamental structure in both. Both organs are on the ventral side of the pharynx and in the same position, and have a similar length. Two primary branches of the main branchial artery pass along the sides of the thyroid; similar blood-vessels accompany the endostyle. However, it is chiefly the part of the glandular cells and that of the ciliated cells in the thyroid which corresponds very closely with what we find in the tunicate endostyle, except that the former is somewhat more complicated. No one can doubt, however, that these are homologous organs, especially if we add that the ascidian possesses a pair of ciliated grooves immediately behind the mouth, which converge ventrally towards the endostyle. Dohrn pointed out before that the two grooves in Ammocoetes arose from a transformation of the spiracular clefts. If therefore these are identical with the ciliated grooves of tunicates, it follows that the latter also represent spiracular clefts.

Tunicates must therefore be derived from fishes, not *vice versâ*.

Dohrn suggests that the ciliated grooves in Ammocoetes are mucus-excreting glands. The mucus, in enveloping food, is supposed to protect the delicate walls of the intestine, and also to act on it chemically.

The endostyle of Amphioxus is not a groove, but a raised ridge. Histologically, however, this difference between tunicates and Amphioxus disappears entirely, and the homology of the organ with the thyroid of Ammocoetes and the hypobranchial groove of tunicates becomes evident.

IX.—*The Signification of the Unpaired Fin, &c.*[1]

In a previous chapter Dohrn explained that he had not succeeded in demonstrating the derivation of the muscular system in the unpaired caudal fin of elasmobranchs. In teleosteans, however, this is easily shown. On a row of myotomes or mesoblastic somites, lying immediately behind the anus, muscle-buds grow out, which form the muscular-system of the so-called anal fin. If we can demonstrate, says Dohrn, that the unpaired fin has been produced by coalescence of paired rudiments, and that these paired rudiments are found in cyclostomes, we likewise prove that these must have possessed pectoral and pelvic fins like other fishes. Indeed, if Ammocoetes is examined with regard to the origin of its muscles, muscle-buds are found both dorsally and ventrally, but they remain as indifferent cells during the Ammocoetes stage. During the later stages the buds are differentiated into the fin-muscles. These buds in Petromyzon are therefore homologous with the dorsal and ventral muscle-buds, which in elâsmobranchs and teleosteans produce the paired and unpaired fins. As they develop, especially on the posterior part of the back, into muscles of the unpaired dorsal fin, it follows that the present ventral ones must also at one time have formed muscles of paired fins. No doubt they have become lost during the general process of degeneration and reduction which the cyclostomes have undergone. Dohrn found no trace of the pectoral fin, except the muscle-buds; however, the longitudinal folds bordering the anus in Petromyzon may be

[1] *Ibid.*, vol. vi. 1885, pp. 399–431.

looked upon as rudiments of pelvic fins. Moreover, Dohrn advances the hypothesis that the so-called anal fin-muscles in the lampreys may be homologous with the muscles of the pelvic fin of fishes.

X.—*The Origin of the Vertebrate Eye.*[1]

According to Dohrn's theory of descent, the tunicate eye must either be looked upon as an entirely new formation, or it must have degenerated from the vertebrate eye to its present condition. It would be difficult, however, to harmonize the first view with the principle of change of function. The solution, then, must be looked for in the second hypothesis.

In order to find the phylogenetic path of changes from the paired and highly differentiated vertebrate eye to the unpaired and apparently very primitive organ of vision in the tunicates, such complications arose as to compel Dohrn to put off his detailed publication. He proposes, therefore, at present only to give a general outline of his hypothesis.

The starting-point of Dohrn's inquiry is the development of the eye-muscles. Balfour indicated that the various muscles of the eye (rectus externus and internus, sup. and inf., obliquus, sup. and inf.) took their origin from the anterior head-cavities. Marshall completed these investigations and ascertained that the rectus int., sup., and inf., and the obliquus inf. arose from the most anterior head cavity, which had been called praemandibular by Balfour. He also found that the obliq. sup. was formed from the dorsal piece of the second or mandibular cavity, and the rectus ext. even from the third or hyoid cavity.

During the change of these anterior head-cavities into real muscles, Dohrn ascertained that there was a general agreement with the transformation of the ventral parts of the posterior head-cavities, and not with that of the myotomes. There is no difference observable in the formation of the eye-muscles and the other muscles formed by the most anterior head-cavity.

If we can prove with certainty, says Dohrn, that the eye-muscles are not body-muscles, and do not therefore correspond to

---

[1] *Ibid.*, vol. vi. 1885, pp. 432–480.

myotomes, it follows that Marshall's theory as to the division of the mesoderm head-segments into ventral and dorsal portions falls to the ground. Only ventral mesoderm formations remain.

In considering the phylogenetic history of the eye, it is of the utmost importance that the muscles moving it should belong to the same category, as the muscles of the visceral arches, viz. the branchial and mandibular muscles.

The great revolution produced by the removal of the mouth in the ancestral vertebrate to the dorsal surface (the ventral in living forms) must likewise have had a considerable effect on the structure of the eye. We must suppose, says Dohrn, that the medullary canal began to close, and that the eye, on account of the above-mentioned great changes, was somewhat removed from its former position. In thus changing its position, it approached in all probability the gill-clefts surrounding the new mouth. We may further suppose that rays of light now fell through one or more of these clefts into the eye, one of which may already have lost its function, and had therefore discontinued its endodermal connexion. The ectodermal invagination or pit of this gill-cleft is then supposed to have formed the lens of the eye, whose peculiar mode of formation would thus be explained. This hypothesis is strengthened by the occurrence of the choroid gland in the teleostean eye, which receives its blood supply from the pseudo-branchial vein. The choroid gland may be looked upon as a rest of a former gill, which, having lost its ecto and endodermal connexion, is merely represented by a network of blood-vessels.

The arteria opthalmica is probably the artery which supplied this ancestral gill with blood. This hypothesis likewise explains the meaning of the pecten in the eye of reptiles and birds, as well as the embryonic vessels in the mammalian eye, and a number of other anomalous formations. All of them may be regarded as remnants of the gill now represented by the lens.

Dohrn then leaves the consideration of the muscles and nerves supplying the eye for the present, in order to get additional support from other facts.

In a previous study he enunciated the view, that the tail of the vertebrate animals represented mostly dorsal parts of its original composition, and that the head, on the other hand, exhibited principally ventral parts, the brain being the only remnant of the dorsum. As Dohrn attempted to prove in previous chapters, no trace of myotomes were to be found in the head, and the apparently dorsal optic muscles were branchial muscles. In this case also it is very natural to look upon the cartilaginous parts which the muscles are inserted on as transformed visceral arches, whichever portions of the primordial cranium they may belong to. As to the cranial nerves, Dohrn has not yet come to a definite conclusion. His opinion, at present, is that they have lost those branches which innervated the myotomes and their derivatives. In consequence, however, of the extraordinary enlargement and complication of the ventral region of the head, the cranial nerves have gained all the more. They have become greatly complicated in their course, due to the manifold changes of position among the branchial arches. The spinal nerves, as a whole, have been less modified than the cranial nerves. In the caudal region, however, they have been deprived of their entire visceral parts, and, consequently, they are here least complicated.

The above hypothesis will enable us, continues Dohrn, to draw other conclusions, viz. that the dorsal roots of the cranial nerves have become lost along with the corresponding muscles, and that the attempts of Van Wijhe and others to diagnose dorsal branches are founded in mistaken views.

XI.—*The Spiracle and the Pseudobranch.*[1]

After having reviewed passages from a number of authorities on the spiracle, Dohrn explains the course of blood-vessels of the same organ in elasmobranchs. This has, however, been considered before in the seventh study.

It is a most peculiar fact, says Dohrn, that the aërated blood from the hyoid gill finds its way directly, by means of the cross commissure, into the spiracular artery. It then circulates once more through the lamellae of the spiracular gill, before entering the cephalic circle. It is evident that this condition cannot have obtained originally, and it must be presumed that the spiracle once upon a time received blood directly from the conus arteriosus. In

---

[1] *Ibid.*, vol. vii. 1886, pp. 128–176.

the seventh study a small vessel was mentioned, which takes its origin from the anterior side of the hyoid artery. Dohrn now considers this artery as the original ventral portion of the spiracular artery. (See fig. VII.)

The question now arises, what were the functional motives which led to the change of condition which we perceive at present? The answer to this must be sought in the formation of the mouth. The relative enlargement of the oral aperture in elasmobranchs must have constituted the most important cause in forcing back the gills, lying posteriorly to the mouth. A fusion of gills and vessels was the result of this pressure. Probably the ventral portion of the posterior spiracular vein and the anterior hyoid vein became fused. On that account a direct communication of the posterior hyoid vein with the spiracular artery resulted, and after the ventral part of the posterior spiracular vein and the anterior hyoid vein had disappeared, the passage of the blood from the posterior hyoid vein to the spiracular artery remained by means of the hyoid commissure. (See fig. VII.)

The connexion of vessels of the teleostean pseudobranch and that of the selachian spiracle with the conus arteriosus are identical. Dohrn concludes, therefore, that the pseudobranch of teleosteans is homologous with the selachian spiracle. The efferent vessels of the teleostean pseudobranch, likewise, arise exactly as in elasmobranchs. The main vessel opens directly into the posterior carotid, a branch is connected with the ganglion oculomotorii, just as in elasmobranchs, and then runs on to the posterior side of the bulb. Gradually, networks of vessels are produced, which increase in number, forming the peculiar body known as choroidal gland. Later on, the vessel going to this gland becomes the more powerful, while the main vessel to the posterior carotid grows smaller, and at last it loses all connexion with it.

The pseudobranchia of teleosteans is formed from the anterior wall of the original spiracular cleft, and is separated from the hyomandibular by the remaining lumen of the spiracular pouch. If the spiracular cleft had not disappeared, says Dohrn, no one would have thought of taking the pseudobranchia for anything but the spiracular gill of teleosteans.

Dohrn concludes the last study but one, by making a few remarks on the opercular gill of ganoids, which he studied from embryos of Accipenser. As a result of these studies, he feels inclined to regard the branchiostegal membrane of teleosteans as the homologue of the opercular gill of ganoids.

XII.—*Criticism of Recent Memoirs.*[1]

In the most recent of Dohrn's studies a preliminary notice on the morphology of tunicates by Van Beneden and Julin is discussed by the author. According to their researches, the whole body of a fully-grown ascidian is only homologous with the two most anterior segments of Amphioxus. The gill-clefts of Amphioxus and tunicates are therefore not homologous either with Petromyzon, or with those of fishes. The heart of an ascidian, they say, and the heart of vertebrates are completely different formations, for one is endodermal, while the other is a mesodermal formation. The same authors not only attack Dohrn's theories in general, but throw doubt on some of the facts ascertained by him.

It will be remembered that Dohrn laid particular stress on the homology of the thyroid in fishes, and the hypobranchial groove in tunicates and Amphioxus. His views were based especially on the existence of a pseudobranchial groove, which he compared with the ciliated œsophageal groove of tunicates.

Van Beneden and Julin doubt the identity of the ciliated apparatus in tunicates with that in Ammocoetes on account of the apparent difference in their constitution. This difference, however, according to Dohrn, only lies in a misconception on the part of the author's of Schneider's description of the pseudobranchial groove in Ammocoetes.

Along with a full Paper on this subject, Van Beneden and Julin also propose to publish shortly their researches on the innervation of the branchial apparatus of elasmobranchs and cyclostomes. According to Dohrn's opinion, which, by the way, differs from Van Beneden and Julin's, there is not the slightest doubt, as proved by the position of the nerves, that the gill-pouch which forms the pseudobranchial groove in Ammocoetes is homologous with the spiracle of elasmobranchs. It is further proved by the

---

[1] *Ibid.*, vol. vii. 1887, pp. 301–337.

position of the nerves, that the first definite gill-cleft in Ammocoetes is identical with the hyoid cleft in elasmobranchs.

In conclusion, Dohrn refers to Shipley's recent paper on some points in the development of *Petromyzon fluviatilis.*

The description given by this investigator confirms Dohrn's views that the pseudobranchial groove is homologous with the spiracle. The objection raised by the Belgian authors, therefore, falls to the ground, so far as that point is concerned, at any rate.

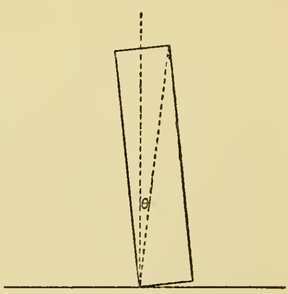
IV.

ON THE MOTION OF A BODY NEAR POINTS OF UNSTABLE EQUILIBRIUM, AND ON THE SAME WHEN CAPABLE OF INTERNAL VIBRATION. By FREDERICK T. TROUTON, B.E.

[Read January 18, 1888.]

Probably everyone will recollect often having heard such things as forms or stools, after getting a tilt insufficient to overset them, vibrating from side to side, and gradually settling down, all the while getting *faster and faster* until stopping. Sometimes plates and dishes will be heard to do the same, also coins after spinning, and such like.

The nature of the motion may be best seen by considering the simple case of a tall rectangular block, which has been tilted over one edge into the position shown in the diagram. From this position the block rotates back round the edge until it regains the vertical, then, owing to its momentum, it tilts up on the other side, rotating round the opposite edge, and so on each time, tilting up a little less than before, until at length it comes to rest. From the following considerations, it will be seen to what a great extent the time of returning to the vertical depends on the amount of the arc through which the body has been tilted. If θ be the angle made with the vertical by the line joining the centre of gravity to the edge about which the block is tilted, and if θ be small, i.e. if the block be tall as compared to its width, we have



$$I\frac{d^2\theta}{dt^2} = Wgl\theta,$$

where I is the moment of inertia round the edge, and l is the distance of the centre of gravity from it, and W the weight of the block, and g the acceleration of gravity. If β is the value of θ when the body began to fall,

$$\frac{d\theta}{dt} = \sqrt{\frac{Wgl}{I}}\sqrt{\theta^2 - \beta^2},$$

and if the time is reckoned from the moment the block began to fall,

$$t = \sqrt{\frac{I}{Wgl}} \log \frac{\theta + \sqrt{\theta^2 - \beta^2}}{\beta},$$

and the time to fall to the vertical is

$$T = \sqrt{\frac{I}{Wgl}} \log \frac{a + \sqrt{a^2 - \beta^2}}{\beta},$$

where a is the value of θ in that position. From this expression for T it will be easily seen that if the arc of tilting, i. e. $(a - \beta)$ is small, T also is small, tending to the limiting value of 0 when β equals a, and that if the arc be large, that is, if β be small, T is much greater, tending to the limiting value of infinity when $\beta = 0$: that is to say, it would take an infinite time to fall from the position of unstable equilibrium which the body is in when the centre of gravity is vertically over the edge.

At Professor FitzGerald's suggestion, who pointed out to me the nature of the motion, experiments were undertaken with the view of verifying the above expression for the time. Owing to the difficulty of making observations with the ordinary bodies to be met with on account of their coming to rest so soon, a heavy iron wheel was fixed on a square iron axle, each end of which rested on an iron table. The wheel rocked between these supports, first on one edge of the axle, then back and on to the other edge. This arrangement was highly satisfactory, as it could keep rocking without much decrement at any required arc, thus permitting the time to be observed. The following table exhibits some of the results of the observations made with it. In the first column is the arc fallen through as read off a scale; in the second is the time in seconds taken to do so; in the third column is $\log\frac{a + \sqrt{a^2 - \beta^2}}{\beta}$; in the fourth the ratio of the time to this, which is seen to be very nearly constant from 20 down to 4, and perhaps fairly so for the rest, considering the difficulties of the experiments at very short periods.

$(\alpha - \beta)$.	T	$\log \frac{\alpha + \sqrt{\alpha^2 - \beta^2}}{\beta}$.	$\frac{T}{\log \frac{\alpha + \sqrt{\alpha^2 - \beta^2}}{\beta}}$.
20	2·20	1·3522	1·63
17	1·47	·8926	1·65
15	1·26	·7562	1·66
10	·87	·6150	1·66
7	·66	·3959	1·67
4	·45	·2993	1·61
3	·37	·2364	1·58
2	·29	·1892	1·52
1	·20	·1312	1·52
·5	·131	·0918	1·42
·25	·087	·0647	1·35

A very interesting suggestion was made by Prof. Fitz Gerald as to the cause of the observed time in the cases at the end of the table being shorter than would be expected. It was to the effect, that the acceleration of the wheel might be due to the period of oscillation being then comparable with the period of internal vibration of the wheel about the axle as fixed, and to the tendency to isocronism in vibrations, of approximately the same period as in the explanations of Anomalous Dispersion. To test this, the rim of a smaller wheel, its spokes being removed, was connected by spring spokes to the axle, so as to present an artificial internal vibration not so extremely fast as that of the wheel itself, thus giving opportunity to observe the effect on the wheel at more manageable periods. With this apparatus, the first thing noticed is that the wheel refuses to vibrate through those arcs which have their time of swing nearly the same as the time of the artificial internal vibration, and again through those arcs which have a period about three times this, and also to a slight degree at five times. So that if the wheel be tilted and left to itself, as it gradually settles down, instead of the arcs getting systematically less each time, the wheel is noticed to skip one or two swings at five, several more at the "three period," and likewise again on coming to accordance with the period of the "spring rim," leaving a whole number of swings unperformed. Experiments were made to see if the time of swing previous to absorption or skipping of the swings was altered; but no alteration was detected: this, so far as the experiments go, not bearing out the suggestion as to the cause of the discrepancy.

After the "five period absorption," and again markedly so after "three period absorption," there is a recurrence of swings of about the same length and slightly less than the absorbed ones. When the wheel comes to any of these periods of accordance, the "spring rim" is greatly disturbed and vibrates violently. In the case where the periods are the same, the energy is never given back to the wheel, which quickly stops; but in the other two cases the rim rapidly quiets down, giving back its energy to the wheel, which is the cause of the persistence of the swings after each absorption.

The analogy is very interesting between the absorption of certain light vibrations by the molecules of some substances and the absorption of certain vibrations by this apparatus. Also the analogy with fluorescence perhaps would make the apparatus a suitable mechanical model of fluorescence. The energy absorbed at one period by the internal vibration is given out at another period, as in fluorescence; but it must be borne in mind that, unlike the case of light, the energy is given out at a faster period than it was absorbed at.

V.

ON THE LUNAR ECLIPSE OF JANUARY 28, 1888. By A. A. RAMBAUT, M.A.

[Read February 14, 1888.]

Previous to the total lunar eclipse of October 4th, 1884, very little attention was paid to such phenomena. Consequently eclipse after eclipse was allowed to pass by without any unusual stir in the observatories. There were, of course, accounts in the astronomical Papers from a few observers, noting the colour of the moon, and giving a general description of its appearance in the various phases, but up till the year 1884, astronomers never made a combined effort to utilise the occasion, because the phenomenon did not appear capable of being turned to any practical use.

On the occasion of the eclipse of October 4th, 1884, however, it was proposed by Professor Otto Struve, of the Poulkova Observatory, to employ the interval during which the moon was obscured in observing occultations of a number of stars, with the object of obtaining a more correct value of the moon's parallax and semidiameter.

Although the method by which the moon's parallax is derived from occultations of stars is necessarily of a complicated nature, it will be seen from the following simple considerations that a number of such observations, made at different stations on the globe, will furnish data for its determination.

If ϖ is the moon's equatorial horizontal parallax, and

θ its hour angle at the moment of observation,
δ its declination, and
ϕ the latitude of the observatory,

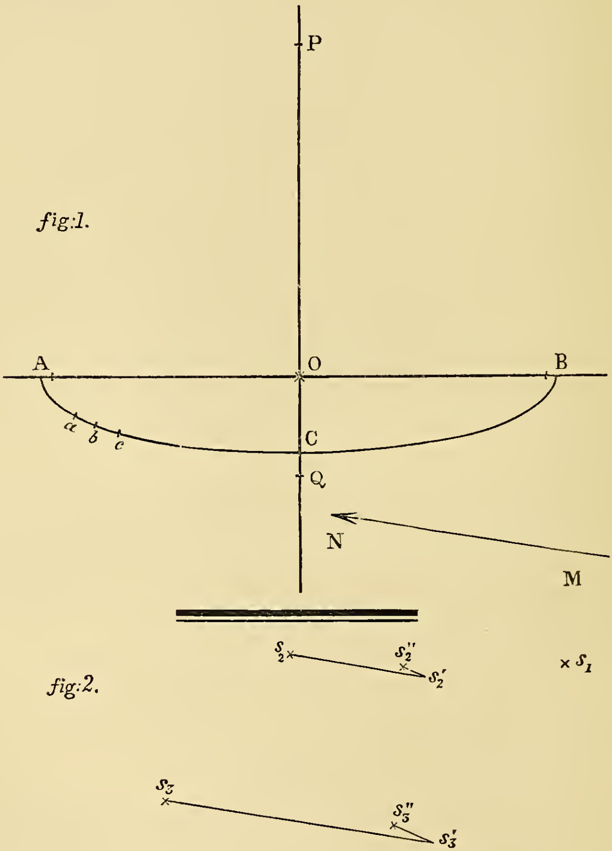
then the displacements in R. A. and declination due to parallax are given by the equations

$$\Delta\alpha = \varpi \cos \phi \sin \theta, \text{ and}$$

$$\Delta\delta = \varpi [\sin \phi \cos \delta + \cos \phi \sin \delta \cos \theta],$$

or the moon appears to describe an ellipse round a point south of its true position by the amount $\varpi \sin \phi \cos \delta$, the axes of the ellipse being $\varpi \cos \phi$ and $\varpi \cos \phi \sin \delta$, and the hour angle ($\theta$) being the complement of the eccentric angle of the ellipse.

If the true position of the moon's centre be represented by P in Fig. 1, then the parallactic displacement will be Pa if $\theta = 4^h$, half an hour later it will be Pb, and an hour later Pc; so that ab, ac, are the apparent motions of the moon due to this cause in the two intervals.



The whole parallax is represented on the same scale (that of 1 mm. to 1 minute of arc) by the line PQ, and the ratios of Pa, Pb, Pc to PQ are accurately known, so that any small error in the assumed value of PQ will have a very small effect on those of ab and ac.

Suppose s_1, s_2, and s_3 (Fig. 2) to be three stars occulted in the order named, the first being a re-appearance, and the two others disappearances, and suppose the hour angle of the moon when these occultations take place to be 4^h, $3\frac{1}{2}^h$, and 3^h respectively; then if we suppose the moon to become stationary just when it occults s_1, and if we move the star s_2 through a space equal and parallel to the motion of the moon's centre in the interval which has elapsed between the occultations of s_1 and s_2, but in the opposite direction, it is obvious that the moon and s_2 will be in the same *relative* position as at the moment when s_2 was occulted. That is to say, s_2 will lie on the circumference of the moon's disc. If we treat s_3 in the same way, we will get all three on the circle representing the circumference of the moon at the moment when it occulted s_1.

Now, the apparent motion of the moon is composed of two parts—its own motion and the displacement due to parallax. Let the hourly motion of the centre be represented by MN; then we must bring s_2 back to s_2' through a distance equal to half MN, and parallel to it; and, again, to s_2'' where $s_2'\, s_2''$ is parallel and equal to ba. Similarly s_3 is to be brought to s_3' through a distance equal and parallel to MN and to s_3'' where $s_3'\, s_3''$ is parallel and equal to ca. Then the three points s_1, s_2'', s_3'', all lie on the circumference of the circle, which represents the position of the moon at the moment when s_1 was occulted. This gives the direction in which the moon appeared at the observatory under consideration, and if similar observations are made at another observatory, their distances apart, and these two positions of the moon would furnish data from which the moon's parallax or distance might be found.

Under ordinary circumstances the occultations of only the brighter stars can be observed, owing to the intensity of the moon's light, and a further disadvantage is, that observations at the bright and dark limbs are not quite comparable, being made under very different circumstances. A bright star, such as Aldebaran or Regulus, for instance, when passing behind the bright limb, is very often seen as if it were interposed between the moon and the earth, or as if the moon were partly transparent; and when it has appeared for a few seconds projected on the disc, it is extinguished. This effect is due to irradiation, which causes the disc to appear of larger dimensions than it really is. The occultations at the dark limb are, on the contrary, so sudden as almost to take the observer's breath away, if he is not accustomed to such work.

During a total eclipse the effect of irradiation is almost wholly absent, and the moon's light is so much reduced, that very faint stars can be observed as they disappear, or emerge from, behind the body of the moon.

Very extensive preparations were made for the eclipses which took place on October 4, 1884, and on January 28th of this year. In view of the latter, Dr. Döllen prepared a list of 300 stars which would be occulted during the eclipse, and computed the times for 120 observatories. A large number prepared to co-operate in the work; but as far as the accounts received up to the present go, it would seem that the weather, at a great many of them, was very unfavourable. At Greenwich, nine telescopes were provided with observers; but clouds interfered greatly with the observations. Only four of the larger instruments were able to see the faint stars occulted, and altogether they obtained only seven observations of disappearance and fifteen of reappearance.

At Poulkova, where three instruments were employed, the atmosphere was clear, and fifty occultations were observed.

At Leipzig, Dresden, Vienna, and Kasan, it was quite cloudy; at Berlin, Paris, and Gotha, partially so, and only a few observations were made. At Bothkamp thirty occultations were observed in a clear sky, and at Moscow the night was fine; but the number of occultations is not recorded.

At Dunsink we were exceptionally favoured. In the early part of the week the weather had been very bad; but it cleared up, as if for the occasion, giving us a splendid night for observing on the 28th.

I was observing with the "South" Equatorial of $11\frac{3}{4}$ inches aperture, which was connected with the chronograph described in the Sixth Part of the "Dunsink Observations," which has just been published, and in which a copy of one of our chronograph sheets is given.

The occultations allotted to Dunsink—73 in number—followed each other so rapidly that it would have been impossible to set the micrometer for each star to the required position angle. Accordingly, I set the single wire in the parallel, and had on the chair beside me a graduated card-board circle, by the aid of which I was able to estimate the position angles with sufficient accuracy for the purpose. For a short time, however, about the middle of totality I was not able to see the wires, which I had omitted to illuminate, and I had to determine the direction of the parallel by unclamping the telescope and moving it in R. A.

Ten minutes before the total phase, I was unable to find a star of the 11th magnitude, owing to the brightness of the moon; but at five minutes before this commenced the occultation of a 10th magnitude star was well seen. In the interval of an hour and three quarters, during which the moon was dark enough for this kind of observation, I obtained 35 occultations—17 disappearances, and 18 reappearances, including both phases for 11 stars. As the eastern limb brightened, the difficulty due to irradiation became more and more marked, and so much as 18^m before the end of totality, a star, whose magnitude is $9\frac{1}{2}$, appeared for a few seconds projected on the disc.

The following is a list of the occultations observed, in which the numbers of the stars refer to Dr. Döllen's list:—

GREENWICH MEAN TIME.							
Star.	Disappearance.			Reappearance.			Mag.
153	10^h	26^m	$33^s{\cdot}3$	11^h	33^m	$53^s{\cdot}9$	10
157	10	29	28·5	11	23	29·9	9·4
164	10	32	13·2	11	45	16·5	8·0
166	10	32	22·5	11	42	30·5	9·5
165	10	33	25·5	11	45	49·8	9·4
141	10	39	43·7	11	3	51·9	11
136	..	..	..	10	44	3·4	9·5
180	10	45	21·1	11	54	26·2	9·5
172	10	48	16·2	11	46	59·6	11
181	10	56	17·6	11	47	53·2	10
128	..	..	..	10	58	7·6	9·5
198	11	9	19·5	..	..	..	9·5
194	11	13	15·0	11	59	10·5	11
142	..	..	..	11	16	43·8	10
148	..	..	..	11	19	42·8	10
190	11	21	43·2	12	3	59·1	11
155	..	..	..	11	27	20·7	11
150	..	..	..	11	30	15·8	10
216	11	35	13·7	..	..	..	10
225	11	37	28·9	..	..	..	10
224	11	38	31·1	..	..	..	11
236	11	51	13·8	..	..	..	9·5
201	..	..	..	12	7	41·2	8·7
247	12	10	4·7	..	..	..	9·2

The following notes, referring to the character of the observations, were made at the time :—

Star.	Disappearance.	Reappearance.
153		Good.
157	Very well seen.	Good.
164	Good.	Good.
166	Good.	Good.
165	Good.	Good.
141	Very bad. Limb still very bright.	Perhaps half a second late.
136		Perhaps a quarter of a second late.
180	Beautiful.	Subtract half a second.
172	Difficult.	
181	Good.	Perhaps a few tenths of a second late.
128		Fair.
198	Beautiful. Instantaneous.	
194	Good.	Good.
142		Fair.
148		Excellent.
190	Seemed to be extinguished momentarily several seconds before final disappearance.	Good.
155		Clear of limb when first seen. Very faint. Observation worthless.
150		Good.
216	Limb brightening.	
224	Difficult, owing to brightening of limb.	
236	Projected on the disc a few seconds before final disappearance.	
201		Good, although limb very bright.
247	Appeared in contact with the limb 2^s before final disappearance.	

No diminution of light was noticed till 9^h 10^m (throughout I give Greenwich mean time). Up to that hour I had been watching the moon with the naked eye, but, on looking through the telescope, I then observed that the penumbra extended over a considerable portion of the disc. This was only $20\frac{1}{2}$ mins. before the time calculated for the contact with the shadow. On the occasion, of what may be called the same eclipse occurring eighteen years previously, on January 17th, 1870, which was observed at Windsor, New South Wales, the first defalcation of light was noticed 20^m before the first contact with the shadow. This is, probably, a mere coincidence. At 9^h 23^m the whole surface appeared of a sandy-brown colour, except the western limb, which was of a silvery hue. At 9^h 31^m the first trace of the shadow appeared, but the contact with the geometrical cone must have occurred a little before the shadow became visible.

At 9^h 35^m the obscured portion began to show a copper tinge. This was more marked at the darkened limb than at the edge of the shadow, which was almost black. About this time Aristarchus, which was involved in the shadow, was distinctly brighter than the surrounding region, and remained so throughout the whole eclipse, whenever my attention was directed to it.

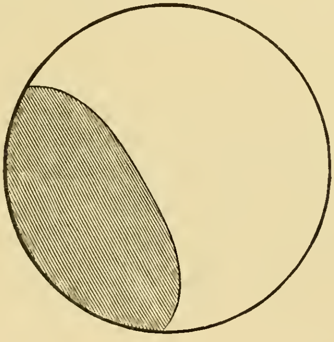


Fig. 3.

At 9^h 55^m the obscured portion was first noticed with the naked eye. At this time the obscured limb was much brighter than the parts nearer to the edge of the shadow, the shaded portion appearing almost as if it were bounded by a bright circular line, while the illuminated part appeared to belong to a larger circle in consequence of irradiation.

About this time the shadow appeared somewhat the shape shown in figure 3, the curvature of its edge increasing as it approached the moon's limb; but no irregularity could be detected in the telescope.

As the eclipse advanced the redness increased, and during the total phase the surface appeared more like red-hot iron than copper. At the middle of the eclipse the illumination appeared nearly uniform, or darkening slightly towards the centre, except over the dark plains, where the colour was deeper.

At 11^h 6^m 25^s a meteor crossed the disc of the moon a little to the south of Plato, the position angle of its path being about 250°.

As the shadow passed off the moon, its appearance and that of the surface were very similar to what they had been in the corresponding phase before totality. While this was taking place I paid particular attention to the outline of the shadow, with a view to noting any irregularities which might occur in it.

Once or twice an appearance very like a protuberance presented itself, but always where the shadow crossed the grey plains, chiefly at the Mare Serenetatis and the Mare Tranquilitatis. At these spots the darkening of the surface, in immediate proximity to the edge of the shadow, had the effect of making the latter appear to project beyond the regular curve bounding it. But, as the shadow passed on, the protuberance vanished, or reappeared in another place, according to the nature of the surface where it happened to fall.

Throughout the eclipse the redness was very marked, and in striking contrast to the grey colour which the surface presented in the eclipse of 1884. During totality, too, the illumination was much more intense than on the former occasion, and at no time did the obscured limb disappear wholly from view in the telescope, as was the case, except during the total phase, in the eclipse of 1884.

VI.

ON THE SHAPE OF THE EARTH'S SHADOW PROJECTED ON THE MOON'S DISC DURING THE PARTIAL PHASES OF AN ECLIPSE. By A. A. RAMBAUT, M.A.

[Read February 14, 1888.]

HAVING observed during the partial lunar eclipse of August 3rd, 1887, and during the partial phases of the eclipse of January 28th, 1888, that the outline of the shadow appeared to the naked eye to diverge from the circular form, and to be more deeply curved where it approached the limb of the moon, whereas in the telescope no such divergence could be detected, it occurred to me that this effect might possibly be due to parallax.

Although on further consideration it appeared that the parallactic displacement is much too small to account for the abnormal shape of the shadow observed, I thought it might be of interest to ascertain how far the outline of the shadow could be affected by this cause.

The investigation of this question is the object of the present Paper.

If we take as origin of rectangular co-ordinates a point on the earth's surface in the plane containing the centres of the sun, earth, and moon, the plane of xy coinciding with this plane, and the axis of x passing through the moon's centre, and if the co-ordinates of the earth's centre referred to these axes are ξ, η, 0, the equation of its surface will be

$$(x-\xi)^2 + (y-\eta)^2 + z^2 = R^2,$$

the surface being taken, with sufficient accuracy for the purposes of this investigation, to be a sphere of radius R.

If α, β, 0 are the co-ordinates of the vertex of the shadow-cone, the equation of its surface is

$$[(x-\xi)^2 + (y-\eta)^2 + z^2 - R^2] \times [(\alpha-\xi)^2 + (\beta-\eta)^2 - R^2]$$
$$= [(x-\xi)(\alpha-\xi) + (y-\eta)(\beta-\eta) - R^2]^2,$$

which may be written

$$[(\beta-\eta)^2-R^2]x^2+[(\alpha-\xi)^2-R^2]y^2+[(\alpha-\xi)^2+(\beta-\eta)^2-R^2]z^2$$
$$-2(\alpha-\xi)(\beta-\eta)xy+2[-\xi\{(\beta-\eta)^2-R^2\}+\eta\{\alpha-\xi\}\{\beta-\eta\}+(\alpha-\xi)R^2]x$$
$$+2[\xi(\alpha-\xi)(\beta-\eta)-\eta\{(\alpha-\xi)^2-R^2\}+(\beta-\eta)R^2]y+[\{(\beta-\eta)^2-R^2\}\xi^2$$
$$+\{(\alpha-\xi)^2-R^2\}\eta^2-2(\alpha-\xi)(\beta-\eta)\xi\eta-2(\alpha-\xi)R^2\xi-2(\beta-\eta)R^2\eta$$
$$-R^2\{(\alpha-\xi)^2+\beta-\eta)^2\}]=0. \quad (1)$$

If u denote the distance of the moon's centre, and r its radius, the equation of its surface is

$$(x-u)^2+y^2+z^2=r^2. \quad (2)$$

Writing the equations (1) and (2) for convenience thus—

$$ax^2+by^2+cz^2+2hxy+2lx+2my+d=0, \quad (3)$$

and

$$x^2+y^2+z^2+2l'x+d'=0, \quad (4)$$

and eliminating x between the equations (3) and (4), we get as the equation of the projected curve

$$[a(y^2+z^2+d')-(by^2+cz^2+2my+d)]^2+4[hy+l-al']\times$$
$$[(hy+l)(y^2+z^2+d')-l'(by^2+cz^2+2my+l)]=0,$$

which may be written

$$[(a-b)^2+4h^2]y^4+(a-c)^2z^4+2[(a-b)(a-c)+2h^2]y^2z^2$$
$$+4[h(l-al'+l-bl')-m(a-b)]y^3+4[h(l-al'+l-cl')-m(a-c)]yz^2$$
$$+2[(a-b)(ad'-d)+2h(hd'-2ml')+2(l-al')(l-bl')+2m^2]y^2$$
$$+2[(a-c)(ad'-d)+2(l-al')(l-cl')]z^2$$
$$+4[h(ld'-l'd)+(l-al')(hd'-2ml')-m(ad'-d)]y$$
$$+(ad'-d)^2+4(l-al')(ld'-l'd)=0 \quad \ldots\ldots \quad \text{A.}$$

Let p = the sun's parallax,

s = the sun's angular semidiameter,

ϖ = the moon's parallax,

ρ = the moon's angular semidiameter,

σ = the angle of the cone,

and θ = the angle between the axis of x and the axis of the cone.

Then
$$\sigma = s - p,$$
and
$$\sqrt{(a-\xi)^2 + (\beta-\eta)^2} = \frac{R}{\sin\sigma};$$
therefore
$$a - \xi = \frac{R\cos\theta}{\sin\sigma}, \text{ and } \beta - \eta = -\frac{R\sin\theta}{\sin\sigma}.$$

Also if ζ denotes the zenith distance of the moon, we have
$$\xi = -R\cos\zeta, \text{ and } \eta = R\sin\zeta.$$
Therefore
$$a = \frac{R^2}{\sin^2\sigma}(\sin^2\theta - \sin^2\sigma),\ b = \frac{R^2}{\sin^2\sigma}(\cos^2\theta - \sin^2\sigma),\quad c = \frac{R^2}{\sin^2\sigma}(\cos^2\sigma),$$
$$h = \frac{R^2}{\sin^2\sigma}(\sin\theta\cos\theta),$$
$$l = \frac{R^3}{\sin^2\sigma}\left[(\sin^2\theta - \sin^2\sigma)\cos\zeta - \sin\theta\cos\theta\sin\zeta + \cos\theta\sin\sigma\right],$$
$$m = \frac{R^3}{\sin^2\sigma}\left[\sin\theta\cos\theta\cos\zeta - (\cos^2\theta - \sin^2\sigma)\sin\zeta - \sin\theta\sin\sigma\right],$$
$$d = \frac{R^4}{\sin^2\sigma}\left[(\sin^2\theta - \sin^2\sigma)\cos^2\zeta + (\cos^2\theta - \sin^2\sigma)\sin^2\zeta - 2\sin\theta\cos\theta\sin\zeta\cos\zeta + 2\sin\sigma\cos\theta\cos\zeta + 2\sin\sigma\sin\theta\sin\zeta - 1\right].$$

Also
$$u = \frac{R(1 - \sin\varpi\cos\zeta)}{\sin\varpi}, \text{ and } r = \frac{R\sin\rho}{\sin\varpi}.$$
Hence
$$l' = -\frac{R(1-\sin\varpi\cos\zeta)}{\sin\varpi}, \text{ and } d' = R^2\left[(1-\sin\varpi\cos\zeta)^2 - \sin^2\rho\right]\frac{1}{\sin^2\varpi}.$$

If we take the moon on the horizon, in which case the effect of parallax will be greatest, we have
$$\cos\zeta = 0, \text{ and } \sin\zeta = 1.$$

Also, if $180° - \phi$ be the angle between the directions of the sun and moon as seen from the earth's centre; then
$$\theta = \phi + \varpi.$$

Now ϕ is a small angle, at its greatest about equal to ϖ. Hence θ can never exceed 2°. We may therefore put
$$\sin\theta = \phi + \varpi, \text{ and } \cos\theta = 1.$$

We may also put

$$\sin\sigma = \sigma,\quad \sin\rho = \rho,\quad \text{and}\quad \sin\varpi = \varpi.$$

If in equation A we write yR for y and zR for z, so that the new y and z may be expressed in parts of R, and if we substitute the above values of a, b, c, &c., we shall have $\frac{R^8}{\sin^4\sigma}$ multiplying every term in equation A.

It is therefore only necessary to consider the factors of a, b, c, &c., within the brackets. We thus obtain

$$a = (\phi + \varpi)^2 - \sigma^2,\quad b = 1 - \sigma^2,\quad c = 1 - \sigma^2,$$

$$h = \phi + \varpi,\quad l = \sigma - (\phi + \varpi),\quad m = -1 + \sigma^2 - (\phi + \varpi)\sigma,$$

$$d = -[(\phi + \varpi) - \sigma]^2,$$

$$l' = -\frac{1}{\varpi},\quad d' = \frac{\cos^2\rho}{\sin^2\varpi} = \frac{1}{\varpi^2}.$$

We thus obtain

$$a - b = (\phi + \varpi)^2 - 1,\quad a - c = (\phi + \varpi)^2 - 1,$$

$$l - al' = \frac{(\phi + \varpi)^2}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi + \varpi),$$

$$l - bl' = \frac{1}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi + \varpi),$$

$$l - cl' = \frac{1}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi + \varpi),$$

$$ad' - d = \frac{(\phi + \varpi)^2}{\varpi^2} - \frac{\sigma^2}{\varpi^2} + [(\phi + \varpi) - \sigma]^2,$$

$$hd' - 2ml' = \frac{(\phi + \varpi)}{\varpi^2} - \frac{2}{\varpi} + \frac{2\sigma^2}{\varpi} - \frac{(\phi + \varpi)\sigma}{\varpi},$$

$$ld' - l'd = \frac{\sigma}{\varpi^2} - \frac{\phi + \varpi}{\varpi^2} - \frac{((\phi + \varpi) - \sigma)^2}{\varpi}.$$

Whence

$$(a - b)^2 + 4h^2 = 1 + \text{terms of the second degree in } \phi, \varpi, \&c.,$$

$$(a - c)^2 = 1 + \text{terms of the second degree},$$

$$(a-b)(a-c)+2h^2 = 1 + \text{terms of the second degree,}$$

$$h(l-al'+l-bl') = \frac{\phi+\varpi}{\varpi} + \text{terms of the second degree,}$$

$$m(a-b) = 1 + \text{terms of the second degree,}$$

$$h(l-al'+l-cl') = \frac{\phi+\varpi}{\varpi} + \text{terms of the second degree,}$$

$$m(a-c) = 1 + \text{terms of the second degree,}$$

$$(a-b)(ad'-d) = -\frac{(\phi+\varpi)^2}{\varpi^2} + \frac{\sigma^2}{\varpi^2} + \text{terms of the second degree,}$$

$$2h(hd'-2ml') = 2(\phi+\varpi)\left(\frac{\phi+\varpi}{\varpi^2} - \frac{2}{\varpi}\right) + \text{terms of the second degree,}$$

$$2(l-al')(l-bl') = 2\left[\frac{(\phi+\varpi)^2}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi+\varpi)\right]\frac{1}{\varpi} + \text{terms of the second degree,}$$

$$2m^2 = 2 + \text{terms of the second degree,}$$

$$(a-c)(ad'-d) = -\frac{(\phi+\varpi)^2}{\varpi^2} + \frac{\sigma^2}{\varpi^2} + \text{terms of the second degree,}$$

$$2(l-al')(l-cl') = 2\left[\frac{(\phi+\varpi)^2}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi+\varpi)\right]\frac{1}{\varpi} + \text{terms of the second degree,}$$

$$h(ld'-l'd) = (\phi+\varpi)\left(\frac{\sigma}{\varpi^2} - \frac{(\phi+\varpi)}{\varpi^2}\right) + \text{terms of the second degree,}$$

$$(l-al')(hd'-2ml') = \left\{\frac{(\phi+\varpi)^2}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi+\varpi)\right\}\left\{\frac{(\phi+\varpi)}{\varpi^2} - \frac{2}{\varpi}\right\} + \text{terms of the second degree,}$$

$$m(ad'-d) = -\frac{(\phi+\varpi)^2}{\varpi^2} + \frac{\sigma^2}{\varpi^2} + \text{terms of the second degree.}$$

$$(ad'-d)^2 = \left\{\frac{(\phi+\varpi)^2}{\varpi^2} - \frac{\sigma^2}{\varpi^2}\right\}^2 + \text{terms of the second degree.}$$

$$4(l-al')(ld'-l'd) = 4\left\{\frac{(\phi+\varpi)^2}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi+\varpi)\right\}\left\{\frac{\sigma}{\varpi^2} - \frac{(\phi+\varpi)}{\varpi^2}\right\} + \text{terms of the second degree.}$$

If we neglect the terms of the second degree in $\phi\varpi$ and σ, which will be quite inappreciable, the equation A becomes

$$y^4 + z^4 + 2y^2z^2 + 4\left\{\frac{\phi+\varpi}{\varpi} - 1\right\}y^3 + 4\left\{\frac{\phi+\varpi}{\varpi} - 1\right\}yz^2$$

$$+ 2\left[-\frac{(\phi+\varpi)^2}{\varpi^2} + \frac{\sigma^2}{\varpi^2} + 2(\phi+\varpi)\left(\frac{\phi+\varpi}{\varpi^2} - \frac{2}{\varpi}\right)\right.$$

$$\left. + \frac{2}{\varpi}\left(\frac{(\phi+\varpi)^2}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi+\varpi)\right) + 2\right]y^2$$

$$+ 2\left[-\frac{(\phi+\varpi)^2}{\varpi^2} + \frac{\sigma^2}{\varpi^2} + \frac{2}{\varpi}\left\{\frac{(\phi+\varpi)^2}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi+\varpi)\right\}\right]z^2$$

$$+ 4\left[(\phi+\varpi)\left(\frac{\sigma}{\varpi^2} - \frac{(\phi+\varpi)}{\varpi^2}\right) + \left\{\frac{(\phi+\varpi)^2}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi+\varpi)\right\}\right.$$

$$\left.\left\{\frac{\phi+\varpi}{\varpi^2} - \frac{2}{\varpi}\right\} + \frac{(\phi+\varpi)^2}{\varpi^2} - \frac{\sigma^2}{\varpi^2}\right]y$$

$$+ \left[\left\{\frac{(\phi+\varpi)^2}{\varpi^2} - \frac{\sigma^2}{\varpi^2}\right\}^2 + 4\left\{\frac{(\phi+\varpi)^2}{\varpi} - \frac{\sigma^2}{\varpi} + \sigma - (\phi+\varpi)\right\}\left\{\frac{\sigma}{\varpi^2} - \frac{\phi+\varpi}{\varpi^2}\right\}\right] = 0.$$

This, after some reduction, becomes

$$y^4 + z^4 + 2y^2z^2 + 4\frac{\phi}{\varpi}y^3 + 4\frac{\phi}{\varpi}yz^2 + 2\left[3\frac{\phi^2}{\varpi^2} - \left(1 - \frac{\sigma}{\varpi}\right)^2\right]y^2$$

$$+ 2\left[\frac{\phi^2}{\varpi^2} - \left(1 - \frac{\sigma}{\varpi}\right)^2\right]z^2 + 4\frac{\phi}{\varpi}\left[\frac{\phi^2}{\varpi^2} - \left(1 - \frac{\sigma}{\varpi}\right)^2\right]y$$

$$+ \left[\frac{\phi^2}{\varpi^2} - \left(1 - \frac{\sigma}{\varpi}\right)^{22}\right] = 0,$$

or

$$\left[\left(y + \frac{\phi}{\varpi}\right)^2 + z^2 - \left(1 - \frac{\sigma}{\varpi}\right)^2\right]^2 = 0.$$

This is the equation of a circle, and represents the section of the shadow-cone by the plane at right angles to its axis at the distance of the moon.

The effect of parallax is therefore to this degree of approximation imperceptible.

I have computed the equation of the curve from the complete formulæ given on page 53, for the time at which the abnormal shape was noticed, namely, when about four-tenths of the moon's diameter was obscured. At that time we have on Jan. 28, 1888,

$$\phi = 45',$$

$$\varpi = 58',$$

$$\rho = \sigma = 16',$$

and I find for the equation of the curve,

$$y^4 + 0{\cdot}9982\,z^4 + 1{\cdot}9982\,y^2z^2 + 3{\cdot}1035\,y^3 + 3{\cdot}1063\,yz^2 + 2{\cdot}5949\,y^2 + 0{\cdot}1887\,z^2 + 0{\cdot}2886\,y + 0{\cdot}0089 = 0.$$

This curve coincides so nearly with the circle whose equation is given above, that it would be quite impossible to distinguish, in the case of an ill-defined object like the edge of the shadow, whether it were bounded by this curve or were accurately circular in form.

VII.

AN APPARATUS FOR SEPARATING THE MINERAL CONSTITUENTS OF ROCKS. By W. F. SMEETH (Petrological Laboratory, Trinity College, Dublin).

[Communicated by Professor Sollas.]

[Read February 14, 1888.]

There are several weighty objections to the apparatus which is at present employed for separating the mineral constituents of rocks. Briefly, it consists of a funnel-shaped vessel, the stem of which is considerably prolonged, and is capable of being closed at various points of its length by glass stopcocks. These stopcocks offer the first objection. They are difficult to make, and cannot have a bore greater than from two to three millimetres in diameter; consequently there is more or less hindrance to the passage of the mineral particles up and down the tube. Again, the liquid, when poured in above, will not pass these narrow apertures, owing to the air in the lower part of the tube. This involves passing a capillary stirring-rod down to pump out the air; and there is always the risk of this rod breaking in the tube, which would necessitate emptying everything out and starting afresh. Lastly, the vessel will not stand of itself, but must be supported. The piece of apparatus to be described claims to have obviated these difficulties satisfactorily.

It consists of an urn-shaped vessel *v* (Fig. 1), closed at the top by a large stopper. The lower part of this vessel is drawn out into a neck, *n*, which is ground so as to fit accurately into the top of the bottle, *b*, of which the sides are vertical, and which has a projecting lip, *l*. The bottle is attached to a glass foot, which forms a firm support for the whole. The essentially new feature in the apparatus is the stopper, *s* (Fig. 2), with a long handle, so that it can be passed through the upper opening, and completely close the orifice of the neck, *n*.

To make a separation, join the parts together, as shown in

Fig. 1, pour in the heavy liquid, and then the powdered rock; now close the opening at the top, and shake up the contents thoroughly; then allow settlement to take place, and the heaviest particles will subside to the bottom of the bottle, *b*. When this is accomplished, pass the stopper, *s*, through the top opening, and, after giving it a few turns in the liquid, to cleanse it, press it into the neck, *n*, and disconnect the parts of the apparatus, as shown in Fig. 3. For rapidity, it is convenient to have a second bottle similar to *b*, into

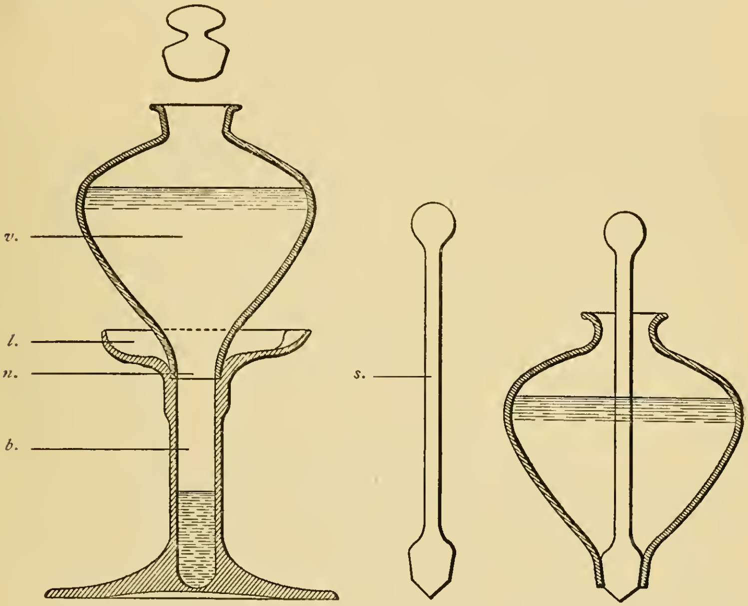


FIG. 1. FIG. 2. FIG. 3.

which *v* may now be fitted. The stopper, *s*, should then be removed, and sufficient water to bring down the next mineral shaken up with the contents. While this is proceeding the specific gravity of the first separation (or more generally of any one but the first) may be very approximately estimated by immersing the plummet of a Westphal's balance in the liquid in *b*; because for any separation the specific gravity of the mineral in *b* will be just between that of the liquid in *b* and that of the liquid just before the mineral sank. The bottle may now be relieved of its contents, and prepared to receive another separation.

A rough and ready form of the apparatus may be set up in any laboratory in the following way :—Take an ordinary funnel, and cut off all but half an inch of the stem. Over this stretch a piece of India-rubber tubing, so as to connect it with a piece of glass tubing, to serve for a bottle. Another piece of tubing, or an India-rubber cork on the end of a glass rod, to serve for a stopper, completes the apparatus.

VIII.

ON A METHOD OF DETERMINING THE SPECIFIC GRAVITY OF SUBSTANCES IN THE FORM OF POWDER. By W. F. SMEETH (Petrological Laboratory, Trinity College, Dublin).

[Communicated by PROFESSOR SOLLAS.]

[Read February 14, 1888.]

THE great difficulty in determining the specific gravity of a powdered substance is owing to the tendency which the finer particles have to float on the surface of the water. This difficulty has been avoided in various ways by using other liquids, such as paraffin, to sink the powder in. All these methods, so far as I know, involve the determination of the specific gravity of the liquid so used. In the method which I am about to describe, the specific gravity of the vehicle used (which is ordinary vaseline) need not be determined.

All that is necessary for the operation is a little pan, which may be most conveniently made with a light watch-glass, into which a handle of fine platinum wire may easily be fused. The process of making an experiment is as follows:—

Place the pan on the top of an oven, and put into it, with the point of a knife, a little vaseline. This quickly melts to a clear liquid, and any air-bubbles which remain floating on the surface may be removed by touching them with a piece of filter paper. Now transfer the pan to a dessicator, to keep it free from dust, &c., and allow it to cool. When cold, take it out, and suspend in a beaker of water, by a fine wire, from the arm of a balance. The weight in water, w_1, of the pan and the vaseline is thus determined. Now take it out of the beaker, holding it up sideways, so as to let the water run off. If any drops remain, they may be removed with a little filter paper, care being taken not to disturb the vaseline. Now place the pan on the oven again, and when the vaseline has melted, sprinkle over its surface some of the powder whose specific gravity is required. The vaseline completely encloses all of the powder. The pan and its contents may now be cooled, and again weighed in water. Let this weight, viz. of the pan and the vaseline and the powder, be w_2; then $w_2 - w_1$ is the weight in water of the quantity of powder used. If the weight of the powder used be W, then $W - (w_2 - w_1)$ is the weight of water displaced by the powder, therefore its specific gravity $= \frac{W}{W - (w_2 - w_1)}$.

Evidently the specific gravity of the vaseline does not come into the result. As regards the accuracy of the method, I add the results of some of the determinations which I have made with it.

The first column gives the weight in grammes of the substance used. In the second are the values which I have found, and in the third the corresponding values given by Naumann.

	W.	Sp. gr.	Sp. gr. (Naumann).	
Labradorite, . . .	0·5904	2·723	2·728	
Manganese—mica, .	0·1386	2·919	. . . .	1st determination.
	0·1870	2·922	. . . .	2nd ,,
Quartz, ...	0·2122	2·63*	2·65	
Oligoclase, ...	0·289	2·658	2·659	1st determination.
	0·3706	2·661		2nd ,,

* This specific gravity is apparently low for quartz, but the powder, when examined under the microscope, was seen to be very full of air bubbles.

IX.

THE DISCOVERY OF TWO CARBONIFEROUS OUTLIERS ON SLIEVE LEAGUE, CO. DONEGAL. By J. R. KILROE, H. M. Geological Survey.

[Read February 14, 1888.]

I AM not aware that any notice has been published of the existence of Carboniferous rocks in the Glencolombkille district; and as their discovery there possesses considerable geological interest, I am permitted, through the courtesy of the Director-General and Director of H. M. Geological Survey, to describe two outliers which repose unconformably on the rocks forming the mass of Slieve League. This mountain is already well known to those who have paid a holiday visit to the village of Carrick, situated at the base of the hill. Few visit the place without making an ascent, which may be easily done by a good bridle path, through a glen on its east side; or along the more circuitous route by Bunglass, where the tedium of the climb will be compensated by an impressive view of Slieve League Cliff, the finest sea-face in the British Isles. For any not acquainted with the locality, it may be further stated that Slieve League forms a bold feature in the mountain scenery of West Donegal. Rising upward from Teelin Harbour on the east to a height of 1972 feet, it overlooks the hilly tract forming the promontory which stretches westward between Donegal Bay on the south, and Loughros Bay on the north, and stands on the southern shore of this promontory. The cliff is thus washed at its base by the Atlantic breakers, and rises almost sheer to the trigonometrical station on the summit of the hill.

Two fine corries, with embosomed loughlets, divide Slieve League into separate limbs, connected with a central mass by colls. The western limb attains the greatest elevation and overlooks the central mass by some eighty feet. Two of these colls are narrow edges, where the sea-face meets the steep wall of either corry—each being known as "The One-man's-pass." A third coll overlooks the corries north-west and south-east. Seen from some distance eastward, it may be noticed that the hill is flat-topped—a feature with which one becomes familiar in a Carboniferous country, such as that forming the opposite shore of Donegal Bay, and illustrated on so grand a scale in Benbulben, and other Leitrim and Sligo hills. This feature is but just noticeable in Slieve League, and might pass unobserved by one not acquainted with its geological history.

During the progress of my Survey work in the vicinity of Carrick, I noticed that these beds consisted of white compact sandstone, not easily distinguishable at first sight from partially-formed quartzite; associated with conglomerate and breccia, which contain pebbles of quartzite, and pink and white quartz. I did not then suspect what Formation they represented, and merely noted them as constituting a peculiar band in the quartzite series of Slieve League. Neither did the occurrence of conglomerate strike me as surprising; for it may be mentioned that at various horizons in the quartzite series occur pebble-beds, and notably in the Glencolombkille district. One of these I had observed in the cliff forming the south wall of the western corry of Slieve League. Similar pebble-beds are to be seen along the base of the sea-cliff, and in striking development on the shore of Malin Bay, where the quartzite area spreads out westward, beyond the adjoining hill (Leahan.) The pebbles in these beds consist chiefly of red and gray granite, up to 9″ in diameter, and quartzite, with a few of mica schist and fine-grained gray gneiss: all embedded in graywhacke, quartzite, or calcareous matrix. The occurrence of these pebbles indicate the former existence of Archœan land at no great distance, while a portion at least of the supposed Silurian Formation of the locality was in process of deposition.

During a recent visit of Dr. Geikie to the county of Donegal, he arranged to ascend Slieve League, being especially desirous of seeing the conglomerates referred to. This he did on the 24th October, accompanied by two of my colleagues and myself. We reached the summit of the central mass, after a climb along the brow of the cliff by Bunglass, and, arriving there, had little difficulty in deciding that the majority of the pebbles consisted of quartzite. The similarity to a Carboniferous pebbly deposit was very apparent—indeed this was suggested and accepted as we proceeded, but more as a general than as a decisive fact. Thus the true age of the beds remained enveloped in a haze of obscurity, until Mr. Wilkinson, one of the party, placed the end of his walking-stick upon a very fine impression of *Stigmaria.* At the same instant, Dr. Geikie, judging from the other evidence mentioned, had arrived at the conviction that the beds were of Carboniferous age. We had been traversing the beds north-westward, and had reached a point at which their thickness seems greatest, the basal character of the deposit here giving place to white fine-grained grit. I had previously traversed the beds south-westward, though not through this point, and had thus missed the decisive evidence as to their age. With very little trouble we succeeded in finding several impressions similar to that first met with; and being satisfied that the beds constitute a Carboniferous outlier on the summit of the central mass of Slieve League, we crossed "The One-man's-pass" to the north-western limb, and found the beds there exactly similar to those crowning the central mass, though somewhat coarser. The strata lie almost horizontally on flaggy quartzite, which dips at 50°; and on tracing the boundaries, the western outlier was found to occupy an area of some twenty, and the eastern some sixty acres.

The occurrence of *Stigmaria* would suggest that these beds, though littoral, represent an elevated horizon in the Carboniferous Formation—perhaps that of Millstone Grit. It may, however, be questioned whether such evidence is determinative upon the point, this fossil having been found at all horizons in the formation, and even in Upper Old Red Sandstone. A very fine specimen of this fossil was sent to the museum some thirty years ago by Sir Richard Griffith, from the shore of M'Swyne's Bay, near Killybegs, Co. Donegal; and Dr. Haughton, in a Paper read in December, 1860, mentions *Stigmaria* as one of several plants sent him by Mr. Harte, from Yellow Sandstone of Darney, near Dunkineely. Both these specimens were from lower Carboniferous beds.

It is suggestive, also, that Millstone Grit caps several of the Leitrim and Cavan hills on the opposite shore of Donegal Bay. Cuilcagh, forty-eight miles distant, is especially conspicuous from Slieve League, the Millstone Grit there occurring at an elevation of 2180 feet above datum. But at Truskmore, near Benbulben, twenty-two miles off, Upper Limestone reaches the 2000 feet

[1] See Explanation to accompany Sheet 44, *Memoirs of the Geological Survey.*

contour. This would, according to Mr. Wilkinson's estimate of the thickness of the Yoredale Series in that area, place the Millstone Grit some 850 feet higher. Thus no substantial argument can be deduced from such considerations in favour of the beds being representative of Millstone Grit; nor yet from their lithological similarity to this member; for, derived as they obviously have been from quartzite, which once spread out widely over the adjoining area, they might be expected to consist of white sandstone, &c.

Passing by the Yoredale Series, which comes next in succession below the Millstone Grit, there is a possibility that the Slieve League beds may represent the Calp or Middle Limestone Series, which shows a considerable thickness of sandstone, and conglomerates at Mount Charles and Lough Easke, near Donegal. But it is more probable, from the considerations following, that they represent the lowest member of the Formation; and it is strong corroborative evidence towards such a conclusion, that it was Lower Carboniferous Sandstone, near Killybegs, which yielded Sir R. Griffith and Dr. Haughton the specimens of *Stigmaria* already referred to.

If the denuded portions of the Lower Carboniferous Sandstone and conglomerate were restored, near Largy, six miles east of Slieve League, this member would reach an elevation of 1000 feet above datum, or some 700 feet lower than the point at which the conglomerate beds repose on the older rocks of the hill. This may be lessened by, perhaps, 600 feet at least, due to the occurrence of two western up-throws along lines of post-Carboniferous faults, which run south-westward between Slieve League and Largy. The 100 feet difference of level which remain distributed over the six miles would give an inappreciable slope, compared with that which is observable in passing from the basal bed on the north-western limb of the hill to that on the central mass. This amounts to 200 feet in less than a mile.

It may be added that the occurrence of these beds at so high an elevation in South Donegal implies a former extension of Carboniferous strata, not only throughout the county, but westward, over ground now covered by waters of the Atlantic ocean. With this conclusion may also be inferred the vast extent to which denudation has obtained since the Carboniferous epoch.

X.

NOTE ON SOME EJECTA OF THE HOT SPRINGS OF TARAWARA, NEW ZEALAND, FORMED SINCE THE EARTHQUAKE OF 23RD JUNE, 1886. BY J. P. O'REILLY, C.E., V.-P., R.I.A.

[Read November 16, 1887.]

The following letter, with a sample of the ejecta referred to therein, was received by me, in August last, from Wm. Ferguson, Esq., C.E., formerly of Trinity College, and of the Royal College of Science, who, knowing the interest I took in all the phenomena connected with the great eruption and earthquake of Tarawara (23rd June, 1886), has had the goodness to send me the specimens submitted. The quantity thereof is very small, but, under the circumstances mentioned in his letter, of value: since, at least, the exact chemical nature of these globules can be examined. As, however, the form and surface appearance must also be of interest, I have enlarged (about $\frac{6}{1}$) a portion of one of the globules, so as

to show what struck me as being noteworthy characters. The surfaces, exteriorly, are smooth, and nearly jet black; more or less globular and dimpled here and there, as shown in the enlarged drawing: these dimples being seemingly the vesicules resulting from the interior pressure of the heated gases or steam, which, after explosion of the contained gas or steam, contract to the surface, and present the dimple or ring-forms indicated.

It is possible, if not probable, that under certain conditions such globules should attain an extreme degree of thinness, and thus, if the contained gas have sufficient buoyancy, be caused to float in the air as minute balloons or bubbles. It is to be remarked that these globules are thrown up by hot springs, and are so far to a certain degree of the nature of the oolites, formed so frequently by hot springs. What would be interesting to know is the nature of the gases emitted, as also the temperature at which emitted at present.

WELLINGTON, 27*th July*, 1887.

MY DEAR PROFESSOR,

Just a line, before the mail closes, to forward you with this some specimens of ejecta from the hot springs at the Tarawara site, handed to me by Sir James Hector for you. He says they are quite a new departure, and to him novel. They are thrown up in immense numbers, and burst on cooling inwards, as may be seen by some which have not burst having depressions on them.

He has had them analysed as follows:—

Amorphous	Sulphur, . . .	88·81
,,	Carbon, . . .	0·34
,,	Ash, . . .	1·88
,,	Water, . . .	9·46
,,	Loss, . . .	1·39
		101·88

Sir J. Hector says this is interesting, as being the first recorded natural occurrence of sulphur in this form.

Yours, WILLIAM FERGUSON.

J. P. O'REILLY, ESQ.,
ROYAL COLLEGE OF SCIENCE, DUBLIN.

XI.

SLATES AND CLAYS (BRICKS, ETC.). BY G. H. KINAHAN, M. R. I. A. WITH INTRODUCTION AND BUILDING NOTES BY R. CLARK.

[Read January 18, 1888.]

[The order followed is, first, to give a general description of the slates and clays, and then to treat of the *slates*, both for roofing and general purposes, according to the counties arranged in alphabetical order, and to conclude with the *clays*, similarly arranged. As to the latter, the uses to which they can be put will be mentioned, especially brick-making. The prices of bricks vary very much, and very rapidly. From inquiries made, and the Records, it would appear that the prices before 1850 and at the present time are very similar. Between 1850 and 1860 they fell to a minimum, in fact they then scarcely exceeded expenses; after 1860 they gradually rose to a maximum, between 1870 and 1880; while now they are very low. The average sizes and weights of bricks in country places are those given by Wilkinson, as they do not seem to have changed; but in the vicinity of Dublin, Belfast, and a few other places new sizes and weight have been introduced.]

INTRODUCTION.

THIS Paper, which is in continuation of the series of Papers on Irish Economic Geology, commencing with "Irish Metal Mining,"[1] proposes to review former efforts at working the slates and clays of Ireland, and also to point out such localities as the writers believe to offer favourable prospects for the opening of new works, or the extension of those already in existence; and for developing the abundant resources available to us for the manufacture of Slates, and for the numerous branches of the brick and potter trades.

The working of Irish slate formations, and the manufacture of pottery, earthenware, and bricks have been carried on from very remote periods, and more or less successfully at times, though none of those industries ever attained such a reputation as might have been expected from the abundance and excellence of the material, and the readiness with which cheap labour, suitable for carrying on the necessary works, is procurable in Ireland.

---

[1] *Vide* these *Proceedings*, vol. v., p. 200.

Careful inquiries on the subject of the decay of the Irish slate and brick trades make it apparent that the Irish manufacturers are themselves in no small degree accountable for the low state to which they have been, for years past, reduced. The improvements and changes necessitated by the requirements of modern architecture were, in great part, neglected, and some of the goods, though excellent in quality, so far as durability was concerned, were unable to compete with the more highly finished articles placed on our markets by our neighbours, who have accordingly, for the past thirty or forty years, maintained a monopoly of the supply of the better descriptions of building materials required in this country. This is by no means a satisfactory state of affairs in a country which, from advantages before referred to, should not alone be able to supply its own wants, but have been an extensive exporter of the goods it has so long imported.

Like most other industries, the production of building materials in many districts succumbed to the shock of the disastrous period preceding the year 1850. The abundant labour available in the country at that time fled to other fields, and the enterprises being almost exclusively in the hands of small capitalists who were unable to stem the tide of adversity which had set against them. The recurrence of better times, and the consequent revival of trade in general, found the Irish brick and slate trade in many cases either annihilated, or in such a depressed condition as to afford an opportunity for importation from elsewhere, which eventually, with but few exceptions, drove the native production out of its natural market. As the foreign article was, in general, very superior in appearance and finish to the Irish then procurable, the latter was soon relegated to work of secondary character, and from that position it did not recover until within the past few years, when some works have been started which bid fair to successfully compete with their rivals across the Channel.

The Irish Slate Trade has never been attempted to be developed with the energy or perseverance which the material at command undoubtedly deserves. With a few exceptions in the vast number of so-called slate quarries, the workings merely consist of surface-grubbing, where nothing but the more or less weathered upper part of the slate-rock is met with, and in many instances the dressing of the slate is done in such a crude style as to be almost ludicrous. Again, even in quarries where a better state of things exists, and the slates are extracted from a moderate depth, where also some regard is paid to their trimming, the workings will often be found choked with the *debris* which has been allowed to accumulate from no provision having been made for its removal. Of course there are quarries where the arrangements are nearly perfect; but in general the Irish slate quarries have been worked in a more or less primitive fashion.

The rocks of Ireland offer a promising field for a great extension of the existing slate trade, as will appear hereafter. There is no apparent reason why the project should not be carried to a successful issue, if it were energetically and properly taken in hand and followed out, it being but a question of time and money to produce as good an article as the Welsh slate, which has, in a great measure, excluded the home article for many years past.

It should, however, be borne in mind that the principal obstacle to the development of the Irish slate trade has been the small capitals with which most of the enterprises were started, the capital in many cases not being more than sufficient to clear the off-baring from the quarries; so that long before the proper depth was reached the capital was exhausted, while inferior slates from the weathered portions of the rock were put on the market in the anxiety to earn a dividend, thereby giving the slate a bad reputation, and ruining the undertaking. The oft-repeated failures of the Irish slate quarries are therefore in general to be attributed to the lack of the two essentials—time and money—but, as already mentioned, there is every reason to hope that a fair expenditure of these necessaries would result in the production of a good article, always in demand, and thereby bring back to this country the advantage of a flourishing remunerative trade.

IRISH CLAYS have been, from pre-historic times, applied to various uses by the inhabitants of the country, though almost entirely to the making of articles of pottery, until more recent periods. In the kitchen-middens, so abundant in the sandhills on the coast of Co. Antrim, are found numerous specimens of rudely-baked and ornamented pottery, associated with flint and bone implements, and probably formed from the Lias clay of the vicinity. These, from various indications, would appear to have been used for cooking purposes. The funeral urns, which have been so often exhumed from the ancient places of sepulture, are often of very finished workmanship as compared with the utensils just referred to, some of them being ornamented with designs of no small artistic merits.

The manufacture of bricks in Ireland does not date back to anything like the antiquity of that of pottery—a fact borne out by the entire absence of any trace of such in the ancient structures so numerous throughout the greater part of this country.

As late as the year 1641 Gerrard Boate wrote as follows:—" In every part of Ireland there is found a kind of clay fit for to make bricks and all sorts of potters' ware, although the Irish never had the wit or industry to make use of it for either of these ends; yea, they have ever been so far from making any earthen vessels, that even the use thereof hath been very rare amongst them, and to the most part unknown, not only before the coming in of the English, but also since, yea, even until these very last times, although a great number of English potters, in several parts of the land, had set up their trade, so as all kind of earthenware was very common, and was to be had at very easy rates.

" And as for the bricks, they have been little used in Ireland, even among the English themselves, for a great while; but of late years they began to be very common, as well in the country as in the cities, especially Dublin, where all the new buildings (the which not only in handsomeness, but also in number, do surpass the old) are all made of brick. But that which is made in Ireland, for the most part, is not so good as that of other countries, not so much for any unfitness in the clay itself, as for want of handling and preparing it aright—as may easily be conceived by the following description of the manner they use to make it."

Boate then gives a lengthened account of the manufacture of bricks, as then carried on; but, as the information he gives of the manufacture of potters' ware is rather inaccurate, it is perhaps unnecessary to recapitulate his version of brickmaking further than to state that he estimates the value of the brick at six to eight shillings per thousand. As regards the manufacture of pottery, it is strange that a writer of Boate's abilities as an investigator should have been unaware that pottery had been extensively made by the ancient Irish; whilst as to brick, the early English structures in this country rarely contain more traces of brick work than do those of the Irish. Boate also mentions that "tiles are imported from Holland for covering houses," and comments on the great abundance of slates which could be raised with little "charge and labour." It is, however, worthy of note that about this period tiled houses were the prevalent fashion in England, and it is quite possible that the custom was introduced by the English settlers.

It would be impossible, in a Paper of this description, to enumerate all the various places throughout Ireland in which bricks have been burnt formerly, because as now a kiln might be burnt, solely for local use, and little or no record of it left. Nor are the prices which are mentioned in general an indication of the quality of the article. Local causes, such as the paucity of fuel in the neighbourhood in which the bricks are burnt, or the distance same have to be carted to a railway or shipping port, are often an important factor in determining the price, as really inferior bricks in one place, on account of local circumstances, will fetch a much larger price than that obtainable for good bricks in other places.

It may be generally stated that so far as the inferior or "Place" brick is concerned, the demand has been always supplied from home sources, but it is when the "Facing" brick is in question that the lamentable want of enterprise on the part of Irish manufacturers becomes apparent. Indeed we need not pass the City of Dublin to see how our brickmaking industries have decayed in late years. Formerly the best streets were built exclusively of brick, burnt in close proximity to the city; and many bricklayers remember when no foreign brick was imported. Whilst, on the other hand, the houses in the more modern townships which have sprung up around Dublin during the past 30 years are almost exclusively faced with Bridgwater bricks, roofed with Welsh slates, and floored with Baltic deals; whilst the blue or white ornamental brick which generally plays an important part, as well as the coarse flue lining, and glazed sewage pipe, are imported from Scotland or Cheshire. After this unpleasant retrospect, it is agreeable to find that there are some exceptions in Ireland: the most important one being in Belfast, where bricks of a very superior class have long been made and used in the erection of most of the magnificent buildings, largely or entirely composed of brick, which are a prominent feature of that town.

Within the past few years, however, a great improvement has taken place in the Irish-made bricks put on the Dublin market; and it is gratifying to state that the manufacturers' efforts have not been unappreciated, most of the brick buildings erected of late having been built of them. Comparing most favourably, both as to solidity and appearance, with the imported article heretofore employed, it is to be hoped that the enterprises now being so energetically carried on at Kingscourt, Kill-o'-the-Grange, Harold's-cross, and other places, will lead to the opening of works of a similar nature in many districts hereinafter referred to, where material of a likely character exists, and that ere long, at least, the Irish demand for the various descriptions of brick will be supplied from home sources.

Much will, of course, depend upon causes more or less apart from control of either the manufacturer or the buyer, foremost amongst which may be mentioned the rates of carriage, where it may be necessary to either transport the bricks from a distance to a good market, or to bring the fuel necessary to the fields. The railway rates are undoubtedly in many instances prohibitory to the development of the brick and slate trade, amongst many others; and it is to be hoped that steps will be taken to remove such a detrimental obstacle to the progress of a revival of Irish trade—a change which could not but be beneficial to the railway companies equally with the manufacturers.

A perusal of the evidence on this subject, given before the Parliamentary Committee on Irish Industries during the Session of 1885, would be interesting and instructive.

Pottery, Fire-clay Goods, etc.—As with the slates and bricks, so also with this very important class of goods, an abundance of suitable material lies in this country, but, with few exceptions, it remains undeveloped; and the goods of Stafford, Chester, and Glasgow supply the wants of even the most remote districts in Ireland.

As previously mentioned, the manufacture of pottery dates in Ireland from a very early period, and must have been extensively carried on judging by the abundance of the remains of sepulchral urns, cooking utensils, &c., met with.

The potters' trade, if it did not die out all together, at all events did not flourish or improve with the times, as already pointed out. Gerrard Boate mentions that "a great number of English potters in several parts of the land had set up their trade, so as all kind of earthenware was very common, and was to be had at very easy rates." But in recent times the principal use of the Irish clays was to export them to England for manufacture into the various descriptions of pottery, some of which, it is probable, found its way back to the locality from which the raw material was derived.

The manufacture of tobacco-pipes was, some forty years ago, a familiar industry in numerous places throughout this country, but is now confined to a few localities only. In and about the city of Dublin a very common article are the small pipes, popularly known as "Dane's pipes," which are often found in abundance during the progress of excavations. It is questionable where they were manufactured. From the immense quantities of their remains which occur in some localities it would at first appear probable that they had been made in the district; but Dr. William Frazer, than whom there is no better authority on matters of antiquarian research relative to Dublin, having taken much trouble to investigate the matter, is of opinion that they were imported from England and that the large quantities of them often met with occur near the sites of former fairs, taverns, or similar places of public resort. In connexion, however, with this opinion, it may be of interest to note that during the cutting of the Waterloo and other roads in Baggotrath, near Dublin, an immense number of those pipes were found in heaps, as well as spread over a large area, and which, from their unfinished and damaged appearance, strongly resembled the *debris* to be met with in connexion with modern pipe-kilns.

It is encouraging to be able to state that during the past few years some improvement has taken place in the prospects of the Irish delf trade. Excellent work has been turned out from the few manufactories which now exist. It is unnecessary to speak here of the reputation which has been obtained by one firm in particular, viz. the Belleek Company, whose goods have established themselves so well on the Continental and American markets. Suffice it to say that a large percentage of their output of the finer descriptions of pottery is bought up for the markets just referred to. The success of this enterprise, which labours under many disadvantages on account of position and other causes, should encourage the promotion of pottery-making in many other districts where it would be likely to prove remunerative, as even the supplying of a small portion of the home trade would necessitate a very large make.

The manufacture of the common red ware, such as flower-pots, tiles, and similar articles, is of very general occurrence throughout the country. About the year 1850 this trade received a great impetus, and many new works were started to supply the existing demand for drainage-pipes, in consequence of the active drainage operations which were then carried on.

Fireclay ware comes principally from abroad, few manufactories for its production being now in existence in this country. This is much to be regretted, as there is a large supply of excellent material available, the utilization of which is very desirable, and would be likely to prove remunerative.

Many of the localities mentioned hereafter offer every inducement to industrial enterprize. It is true, indeed, that the present time does not seem to be an encouraging one in face of existing prices; but it is probable that these have reached their lowest ebb. However, the immense amount of goods for building purposes yearly imported suggests the natural inquiry as to why native materials, perfectly suitable for such purposes, have been so long allowed to lie unused; and it is for those within whose province it lies to make some effort to infuse a more active spirit of trade, always, however, bearing in mind that no mere sentimental support will carry them through to a successful end; but that the work must be prosecuted on a sound commercial basis, of a pecuniary return on the capital invested; and against the attainment of such result, should the subject be properly taken up, there appears to be no hindrance. (*R. Clark.*)

PART I.—SLATES.

From the argillaceous rocks are procured *Roofing slates* and *Slates suitable for walling purposes* Some of the latter are eminently adapted for the uses to which they have been put, as mentioned hereafter; some of the structures built with them being both elegant and durable.

Most of the roofing slates are heavier than the English slates in the market—this being due, in some measure, to the comparative shallowness of the Irish quarries. It is well known that the deeper the working the better the slate. For roofs in exposed places heavy slates are better than light ones, as the latter would be carried away by the wind. For this reason, in many places in Donegal, Mayo, Galway, &c., thin flags are preferred on account of their weight (vol. v., page 565).

The best Irish slates occur principally in the "Slate Series," or Upper division of the *Ordovicians;* nevertheless very good slates have been worked in the *Cambrians,* other parts of the *Silurians, Devonians, Carboniferous slates;* inferior ones have been obtained from the *Coal-measures.*

The Irish slate quarries have been usually more or less injured by their being injudiciously laid out and opened; the waste is often allowed to accumulate at the mouth of the working on the vein; and as the quarry is extended the heaps have to be removed at great cost. Moreover, during the working, the waste is often thrown into the worked portion of the quarry, from which it has to be removed afterwards, if the vein is followad in depth. In many cases landlords have prevented quarries from being worked by asking too high royalties.

The following seem to be the principal slate-quarries which have been, or are now being, worked:—

CLARE, ...	*Broadford,* a good slate, once largely worked; quarries north of *Killaloe,* to the west of Lough Derg, p. 78.
CORK, ...	*Glentane,* near Mallow; *Audley Cove,* near Ballydehob; *Sherkin Island,* Baltimore Harbour; *Benduff,* near Rosscarbery, p. 79.
DONEGAL, . . .	*Glentown,* near St. Johnstown, p. 81.
DOWN, ...	*Tullyeavan,* near Newtownards, p. 83.
KERRY, ...	*Valentia,* famous for its large slabs, p. 84.
KILKENNY, . . .	"*Ormond Quarry,*" *Valley of the Lingaun,* near Carrick-on-Suir, p. 86.

LIMERICK, . . .	*Ahaphuca*, S.S.W. of Ballylanders.
TIPPERARY, . . .	*Victoria Quarries, Valley of the Lingaun*, near Carrick-on-Suir; *Vale of Aherlow*, near Caher; *Corbally* and *neighbouring quarries*, near Killaloe, to the east of Lough Derg, p. 88.
WATERFORD, . .	*Ross*, near Kilmacthomas; *Glenpatrick*, near Clonmel and Carrick; *Clashmore*, near Youghal, p. 91.
WEXFORD, . . .	*Newtownbarry*, p. 92.
WICKLOW, . . .	*Ashford*, p. 93.

ROOFING SLATE.

CLARE.

To the west of the south arm of Lough Derg there is a tract of the upper division of the *Ordovicians*, similar to those in which the Killaloe (*Corbally*) slate quarry is situated; but the slates in general do not appear to be comparable either as to quantity or quality.

At Trough, about four miles north of Limerick, slate was quarried to a slight extent, but as it was coarse and heavy, the works were abandoned, as were also others in this range of hills.

To the N. E., in Slieve Bernagh, or the group of hills about Broadford and Killaloe, slate veins have been opened in several places between *Huddlestown* and *Broadford*, and at *Knockprise*. The slate was good; but as it was greatly ruptured by faults, no large working could be carried on, the slate occurring in small patches, locally called "pockets."

In the hills south of Glenomra, the valley between Broadford and Killaloe, various trials were made without good success, although for a time a coarse slate was worked a mile S. W. of Kilbane.

To the east of Broadford there is an apparently good vein, which at one time was rather extensively worked; but the long and expensive land carriage to a market seems to have stopped the work. Farther eastward, north of Glenomra, and near Lough

Derg, in *Craglee*, trials have been made, and in a few places slate has been worked to a slight extent.

In the west part of the county the shales in the *Coal-measures* between Kilkee and Miltown Malbay are cleaved, and in places have been worked for roofing slate.

CORK.

In this county good slates occur in the *Silurian* (?), the *Devonian*, the *Yellow Sandstone*, and the *Carboniferous slate*. Lewis mentions the following quarries in 1835 :—

Prohust and *Glentane*, respectively, N.W. and S.W. of Mallow, "the latter producing slate of superior quality" ; *Ringabella* (Cork Harbour), "a slate quarry badly worked"; *Enniscarra*, S. W. of Cork ; *Kilbrittan*, S. E. of Bandon, "a good slate quarry" ; *Bracknagh*, about eight miles W. S. W. of Bandon, "good slate quarries" ; *Enniskeen*, west of Bandon ; *Mohanagh*, near Dunmanway ; *Rooska*, north shore of Bantry Bay, about sixteen miles from Berehaven, "an extensive quarry" ; *Audley Cove* and *Tilemuck*, Ballydehob, " opened by the West Cork Mining Co., who, in 1834, had 500 hands employed. The slate was of good quality, hard, compact, durable, and had a ready sale in London and other English markets" ; *Sherkin Island*, Baltimore Harbour, "an excellent reddish, hard, and durable slate"; in 1835 there were 100 hands employed, and many cargoes were shipped to England, where they had a ready sale"; near *Clonakilty Bay*, blue slate ; *Templeomalus*, Clonakilty Bay, "good slate" ; *Forkhill*, N. E. of Clonakilty, "excellent slate"; *Donaghmore*, seven miles S. S. E. of Clonakilty, "quarry of excellent slate"; W. S. W. of *Kinsale*, "some quarries of excellent slate" ; *Robert's Cove*, parish of Ballyfoil, ten miles N.E. of Kinsale, "valuable slate quarry; the slates were formerly exported in the ships that brought coal to the bay" ; *Trabolgan*, about six miles S.W. of Cloyne ; in 1835 there was "a valuable and extensive quarry of good, durable, and well-coloured slate, employing a good number of workmen" ; *Carrigduff*, southward of Mallow, rough slates ; *Derrygool.*

In some of those places mentioned by Lewis the slates are undoubtedly good, and might be easily and cheaply worked, while there are great facilities for shipping them to any market; yet since his time very little has been done. The Devonian slates of green and red colours, that ought to be valuable for ornamental purposes, have been very little used. These usually occur on a well-marked horizon, at the junction of the Yellow and Old Red Sandstones. At *Browhead mine*, and between Horseshoe Harbour and Barrackpoint, they were worked for local purposes. The slate at the S. E. corner of *Sherkin Island*, Baltimore Harbour, has been highly approved of, and sometime since a Company was formed to work this vein; but for some unknown reason the enterprise was abandoned. At Cappoge, west shore of Roaring Water Bay, there is a purplish blue slate well suited for slabs. In different other places the slate veins have been opened for local purposes; but more often to obtain slabs than roofing slates.

The Carboniferous dark-grey and blackish slates have been more worked of late years than the others. One quarry is at *Rossmore*, about a mile W. S. W. of Fourmile Water; farther south westward, near Kilcrohane, there are quarries in the townlands of *Gortakilly*, *Gouladoo*, and *Foilakilly*, the slate being of better quality than at Rossmore, besides being near a harbour; these slates have been worked only for local purposes. Grey slate has also been worked N. W. of *Dromdaleague*, *Curraghlicky*, *Enniskeen*, *Bandon*, and *Clonakilty;* but the most extensive quarry from which slates are exported is at *Benduff*, two miles N. W. of Rosscarbery, on the road to Leap. Here the vein is about seventy yards wide, and of a very dark-grey colour. In places in the slate there are small specks and veins of pyrites (rucks), nodules (bulls' eyes), and a curled structure in lines called *cullheads;* all of which, when they occur, deteriorate the slate. Slabs for flagging have also been raised here, and were used in Skibbereen and elsewhere.

DONEGAL.

In this county there have been many trials for slate, but only in a very few places is the quality and quantity sufficient to make it worth while opening a quarry. The following is a list of the principal places:—

Dunwiley, a mile and a-half from Stranorlar; half a mile from *Letterkenny*, and about the same distance from Lough Swilly;

Thorn, eastward of Letterkenny; between Dunfanaghy and Falcarragh (Cross-roads), a heavy slate, quarried in different places for local purposes; near *Milford; Strawbridge*, four miles from Carndonagh; *Carrickmacroly*, nine miles from Carndonagh; *Dunmore*, nine miles from Carndonagh; *Buncrana; Fahan Point*. In all these places there have only been trials made, or very small quarries opened.

On the shore of Lough Swilly, at Saltpans, to the north of Rathmullen, there is a vein of good-looking slate.

In the country west of Lough Swilly there are numerous bedded sheets of whinstone, which have baked the associated shales; and some of these baked rocks are good novaculites or honestones. A good vein occurs west of Oughterlinn R. C. Church, north of Lough Swilly.

Glentown quarry, about two miles west of St. Johnstown. In this neighbourhood there appears to be two or more veins of slate, which have been holed in places. Tradition has it that slates have been procured here for about 100 years, the oldest working being about a quarter of a mile N.E. of the present quarry. They are mentioned by Dr. McFarlane, who wrote in the beginning of the century. The main vein is from twenty to thirty feet wide, and ranges about N. 60° E., dipping northward at from 50° to 70°, the cleavage striking N. 20° W., and hading E. at about 55°. For a length of over a quarter of a mile there are old openings along its out-crop; while to the eastward, at the margin of the drift slope, a deep quarry was opened some fifty or sixty years ago by a Mr. Alexander, who raised the stuff, waste, and water by an engine. About forty years ago (say 1845) it fell into the hands of the landlord, the Marquess (afterwards Duke) of Abercorn, who, at a cost of £2000, ran in a tunnel, from the valley on the east, 380 yards long, which cut the vein eighty-four feet below the surface. This tunnel drained the workings, besides being used as a tramway, by which the stuff and rubbish was removed. Subsequently the vein was wrought for about 400 yards to the level of the tunnel, while at the eastern end it was further worked for a depth of forty feet below that level. The works were continued to the year 1879, when, on account of the depression in trade, they ceased to pay, and had to be abandoned. At that time from twenty to thirty hands were employed making the slates, all of whom were from the neighbourhood, and had learned the trade when children.

The slate is very good "metal," of a darkish-grey colour, which is permanent, as can be seen in the roofs of the neighbouring houses. The slate seems to be durable, and as it is light, the roofs require timber of but small scantling. As in other slate veins, the stuff improves in quality in depth, but at the same time it is remarkable what good metal can be procured close to the surface. The vein, however, is crossed by numerous joints, which prevent the slates being raised of large dimensions, the slate, as seen in the roofs of the houses, being about 18 to 24 inches long, and from 4 to 12 inches wide; but the better and larger slates were exported to Glasgow, and their dimensions could not be satisfactorily ascertained. The joints in the upper portion are said to have continued down as deep as the slate was followed. Only roofing slates appear to have been wrought. They were brought to a yard at the mouth of the tunnel, and there sold, either for local use, or to be shipped to Derry, Strabane, or Glasgow, from St. Johnstown.

The work does not seem to have been very judiciously planned, as the waste, instead of being run out of the quarry by the tunnel, was run into the deep working, and when operations are resumed, it will have to be lifted and removed at considerable expense. An apparently advantageous method of using this quarry would be to remove all the *debris* of the ancient working, and any bad stuff on the back of the vein, into the valley to the westward, and from the brow at the west to carry a-breast eastward. This would leave the vein clear, so that all that would afterwards have to be carried through the tunnel would be the workable stuff, and a small percentage of waste. The removal of the back of the vein would not be altogether unprofitable, on account of the good quality of some of the surface-stone, which could be wrought into slates.

DOWN.

Prior to 1837, as mentioned by Lewis in his *Topographical Dictionary of Ireland*, there were many trials made, or small quarries opened, for roofing slate, none of which have since become of importance. He states that the Co. Down slates "are inferior to those of Bangor (in Wales) in colour and lightness, but superior in durability." They are of *Ordovician* age.

Aghaderg parish (Scarva), quarries in places worked prior to 1837; *Cloontogh* (parish of Annahilt), E. S. E. of Hillsborough, "fine slate quarry"; *Bangor; Donaghadee*, vein wrought only on the surface where the slates are inferior, though better in depth"; *Tullycavan* (parish of Grey Abbey), S. E. of Newtownards, "an excellent slate, but the quarry is worked injudiciously"; *Loughinisk*, west of Downpatrick; *Ballynacrag*, near Strangford Lough; near *Ballinahinch;* Ballyloe; *Ballyahwood*, between Bangor and Ballywalter; *Carngarva*, S.W. of Conbiggs Hill; *Mourne Mountains*, small quarries in different places on the lower slopes.

DUBLIN.

The slates that occur in this county (page 98) seem not suitable for roofing purposes.

[QUOTATION.—*Killaloe*, 16″ × 8″ – 16″ × 10″ – 20″ × 10″ – 22″ × 11″ – 24″ × 12″ – Prices about 20 per cent. less than the Welsh; but they have not a great demand, in consequence of being so heavy. A good wearing slate; freight about 5*s*. per ton.

Present (December, 1887) prices Welsh slates—best blue *Bangor*, Queens, 85*s*. per ton; 24″ × 14″, £13 10*s*. per 1200; 24″ × 12″, £11 5*s*. per 1200; 22″ × 12″, £9 5*s*. per 1200. *Port Madoc*, 24″ × 14″; first quality, £11 10*s*. per 1200; second quality, £10 5*s*. per 1200.

American and Italian slates were in the market some five years ago, and were in use, but are now quite gone out, in consequence of the Welsh men lowering their prices. Both kinds changed colour on the roof, the Italians becoming quite white.]

FERMANAGH.

In the *Ordovician* rocks, north of Lisbellaw, there is a slate vein that has been worked a little; the slate, however, is of poor quality.

GALWAY.

As yet no vein of good roofing slate has been proved in this county. In the *Silurians*, at Gowlane, north of Letterfrack, there is a kind slate, but it is, unfortunately, so full of joints that it splits up into small pieces. To the north-east, north of Lough Muck, a green slate has been worked; but it is too heavy, except as slabs for flagging purposes. Still further north, at Salrock farmyard, there is an untried, good-looking vein of reddish-purple slate. There are also in the valley, between Leenaun and Maum, and in the hills to the eastward, fair-looking red and bluish-grey slates.

KERRY.

In Valentia Island, on the eastern slope of Geokaun, a quarry was opened by the Knight of Kerry in 1816, and he continued to work it, principally for roofing slates, till 1825, when it was taken by the Irish Mining Company, who worked it for only about six years. It was then taken up again by the Knight of Kerry and worked by him till 1839, in which year it was taken by the *Valentia Flag Company*, and worked till about 1877, when it again fell into the hands of the Knight of Kerry (Sir Peter Fitzgerald, Bart.), who wrought it till his death in 1880.

The slate is not good for roofing purposes, as it is hard to split. The best roofing slates in the immediate neighbourhood are in a vein in the townland of Coole, and in another below high-water mark on the west side of Beginish, in Valentia Harbour. The latter can be worked only during low tides.

The roofing slates made at Geokaun had a good local sale, but could not compete in the open market with other slates. This, however, could not be said of the slabs, which are not to be excelled for beauty, strength, or size, and were largely exported to London, as also to America. The largest sizes for London averaged 14 feet by 6 feet but; some required of extra length were procured over 20 feet long. The Flag Company developed the trade, and for some years carried it on very successfully, until the Welsh slabs came into the market, which could be sold at lower prices, being an inferior softer slab, more easily sawn and planed, besides which for many purposes the small Welsh slabs answered as well as the larger from Valentia. The Valentia slabs sold for prices varying from 35*s.* to 55*s.* a ton, according to sizes; about 150 superficial feet an inch thick going to a ton.

In the quarry there are three slate-beds. The upper bed, which gives the best slabs, is about nine feet thick, and yields blocks 14 feet long, by various widths, the latter being due to vertical joints, which bear N. and S. (magnetic.) The middle bed is about 16 feet thick. It is of a softer nature, and is crossed by diagonal joints, which prevents the material being wrought economically into slabs; but it splits more easily than either of the others into roofing slates, and it is from it most of these were made. The lowest bed is about 14 feet thick. It is not as good for slabs as the upper one; but is better than the middle one, having fewer diagonal joints, so that in places good-sized blocks can be procured; whilst from the waste roofing slates were made. The quarry is a great cave in the face of the hill. It is remarkable that in the good veins of these *Silurian* slate the angle of the cleavage is always low, while in the best slate of *Ordovician* age the inclination is high, often vertical.

In Coole, which lies westward of the Geokaun quarry, there is a very good vein of slate, both for slabs and roofing purposes; it has been very little worked.

The vein of slate on Beginish has already been described.

On the mainland, near Cahirciveen, to the west of Ballycarbery Castle, some slates have been raised from a purple vein, while in the county to the eastward slate has been raised in the Lough Carra district, but not extensively. Small workings for local use are mentioned at page 96 when describing the slates used for walling purposes.

KILKENNY.

In the *Ordovician* rocks in the valley of the Lingaun, at the junction of Tipperary and Kilkenny, the Ormond quarries have been opened on slate veins. The slate is of excellent quality; but unfortunately near the river, where the quarries are situated, the strata are very much cut up and shifted by faults, which adds considerably to the working expenses, as the slate vein may be cut out when a quarry is in full working order. Farther away from the vein, in the hills, the veins seem to be much more continuous, and therefore more suitable for the site of a quarry; besides, on the hills the veins could be worked by a tunnel and level without the expense of the present lifting and pumping. These quarries used to supply a large quantity of slates.

The *Ormond Slate Quarries* are in the townlands of Knockroe and Mealoughmore, barony of Kells, Co. Kilkenny. The veins are similar, and similarly circumstanced to those in the Co. Tipperary. (See *Victoria Slate Quarries*, under Tipperary, p. 88). But the quarries have not been so continuously or systematically worked, as they have passed through the hands of different companies and individuals.

Between Kilmaganny and Ballygowan a slate-vein was, at one time, worked; but the slates were considered too soft. At this place there is an excellent novaculite or honestone; it is soft, but capable of giving a fine and finished edge to tools; it is much used in the neighbourhood.—(G. S. M.)

Blessington, about a mile and a-half eastward of Thomastown; an untried vein of slate.

In the south-east of the county various trials have been made, but no satisfactory vein was discovered.

KING'S COUNTY.

The *Ordovician* slates appear only in the south-east of the county, to the southward of Kinnity; and various small openings have been made in different places; but none of any great extent. In general, the good veins appear to be of small dimensions and not worth quarrying.

LIMERICK.

Ordovician slates are found to the south of the county in the neighbourhoods of Kilfinane and Ballylanders, where there are several small quarries. Four miles S. S. W. of Ballylanders, in the Ahaphuca valley, on a vein of greenish-grey good slate, an extensive quarry has been opened; and a second on a similar slate to the east of Ballylanders, just outside the mearing of the county, in county Tipperary (page 88). These slates were at one time extensively used in all the neighbouring country; but now they are considered two heavy for ordinary roofing purposes.

Lewis mentions a "slate of good quality quarried in the immediate neighbourhood of *Kilmallock*; a vein south-east of *Houndscourt*, parish of Kilflynn; an inferior slate at Towerlegan; and a slate quarry at Darragh, south-east of Kilfinane."

LONDONDERRY.

In the parish of *Muff*, and in other places, there are green, chloritic, coarse slates (*Ordovician?*), which are used locally for roofing purposes.

LONGFORD.

Derrycrois, west of Granard, a good-looking slate; as yet untried.

LOUTH.

The greater portion of this county is occupied by *Ordovician* rocks, in which are different slate veins; but the products of these seem not to have been favourably received as roofing slate, although excellent for general building purposes (p. 102).

Near Mellifont the slates can be raised in large slabs, and some of them have also been used as roofing slates; but these are not much approved of, being too heavy; however, some of the veins in this neighbourhood, if worked on in depth, would doubtless improve greatly.

Creggan, W.N.W. of Dundalk, a coarse and heavy, but durable slate.

MAYO.

At *Lanmore*, between five and six miles south-east of Westport, there are dark-grey *Ordovician* slates, which have been quarried along the outcrop to supply roofing slates in Westport and that neighbourhood.

At *Derrygarve*, about six miles southward of Louisburg, there is a thin vein of a good bluish-grey slate of a fair quality, but of too small dimensions to be worth much. The slate is used in Louisburg.

Along the north shore of Killary Harbour there are also *Ordovician* slates to the east of Bundorragha. Some of them have a good appearance; but as yet no trials have been made.

Parish of *Kilfian*, west of Killala; in different places small quarries produce a coarse slate.

MEATH.

In this county there is a considerable area of *Ordovician* rocks; but in general the slates are hard and intractable, and not suitable even for ordinary building purposes, as in the neighbouring county of Louth.

MONAGHAN.

In *Crieve Mountain* there are small slate quarries. Over the greater part of this county the rocks belong to the *Ordovicians*; but, as in Meath, the slates are hard and intractable.

QUEEN'S COUNTY.

S.W. of Mountrath, in Offerlane parish, there is a slate quarry, as also at Cappard, west of Mountmellick (L. D.).

SLIGO.

Trials for slate have been made at Kilmacshalgan, near Dromore West, but without success.

TIPPERARY.

In the south-eastern part of the county, in the valley of the Lingaun River, are the Victoria, or Clashnasmut quarries (Kilkenny, *ante*, p. 85).

The *Victoria Slate Quarries* are situated in the townland of Clashnasmut, barony of Slieveardagh, Co. Tipperary; they are six miles from the town of Carrick-on-Suir, and fourteen miles from Waterford.

The district in which these quarries are situated is thus described by the late Mr. Du Noyer:—" On the eastern side of Slievenaman Mountain, in the counties of Tipperary and Kilkenny, there is an elevated plateau formed of the Lower Palæozoic or Lower Silurian slates, with a few associated trappean beds, occupying a space of twelve miles from east to west, with an average width of three to five miles. This is completely surrounded by a barrier higher than itself, formed of Old Red Sandstone, the beds of which are unconformable to the Silurian slates, and dip away from them on all sides, usually at high angles.

"The greater part of this plateau is drained from east to west by the river Lingaun, which joins the river Suir, close to the town of Carrick. Near the central portion of this plateau, between the villages of Windgap and Tinnakelly, the river Lingaun has cut a deep glen in the slate rocks, and here extensive quarrying for roofing slates has been carried on for many years, which include the open quarries of Clashnasmut and others.

"The average strike or direction of the slate veins in the Victoria Quarries is north-east and south-west, with rolling-dips at 60° to 70°, and as the general direction of the slaty cleavage which invariably pervades these rocks is 30° to 40° north of east, and south of west, vertical, the relation of the planes of dip and cleavage is most favourable for the development of the required slaty structure.

"The slates raised from this quarry are of a pale-grey colour, free from any iron pyrites; they are remarkable for their size, soundness and evenness of the cleavage, and for the ease and thinness with which they split. The quality of the slate is second to none in Ireland, and the quantity is practically inexhaustible."

The present Company was incorporated in 1864, with a capital of £50,000, of which £40,000 has been already spent in developing the resources of the quarries; various causes have delayed the full opening of this property, the present annual raisings from which are of the value of from £6000 to £7000. The slates are in steady demand.

On one portion of the property, where the slate rock comes into contact with the Old Red Sandstone, the slate is of a greenish hue—a colour in great request for ornamental roofing. This slate was awarded a gold medal at the last Dublin Exhibition (1882), and a large bronze medal "for its colour, strength, grain, and texture" at the Cork Exhibition (1883). The rock is cut and dressed by machinery, the motive power being supplied by the river Lingaun.

In the Galtymore range, in the south-west of the county, and near the mearing of the Co. Limerick, is the already mentioned (Limerick, *ante*, p. 86) large quarry in the southern side of the Glen of Aherlow, one and a-half miles south of Ballynacourty, or New

Forest House. The slate is of a greenish colour, and very good, but heavy. It has been extensively used for the roofing of the neighbouring mansions, farm-houses, and buildings. The slate has been tried again of late years, but only a narrow portion of the vein formerly worked was found capable of producing slates light enough for the present market. To the south of the quarry there is a vein of good appearance not as yet tried.

About seven miles or so N.N.E. of Killaloe are the quarries called after that town.

Killaloe Slate Quarry.—The quarry to which this name is now almost solely applied is at *Corbally*, near the village of Portroe. In the vein there appears to be here a nearly inexhaustible supply of excellent slate; but the quarry was badly laid out originally, and is too confined to be worked to the best advantage; and a great deal that ought to be profit is spent in raising the slate, rubbish, and water out of the quarry, which is large and deep.

This quarry was first opened, about the year 1826, by the Mining Company of Ireland, who worked it till about 1841, when it was bought by the Imperial Mining Company, who were working quarries in the vicinity. Besides roofing slates, the latter Company manufactured slabs for flooring, steps, window-sills, &c. Under these Companies the quarry does not appear to have been very profitable. It eventually, however, fell into the hands of Mr. Headach, who was very successful, and in the end sold it to the Killaloe Slate Company, who are now working it. There is a ready sale for all the slates that can be made, but, unfortunately, on account of the peculiar contracted condition of the quarry, the output is much less than it ought to be.

To put the quarry into a condition so that it could be worked to the best advantage would require a considerable immediate outlay; but this would be vastly more than compensated for hereafter by the saving of working expenses and the much larger annual sales.

The width of the slate vein is over 400 feet. It is divided into sub-veins, some with a ribbon (*cleaved shale*), and some without (*cleaved clay-rock*), which average in width from fifteen to twenty feet. The latter are the more profitable, as they split more easily; besides which they have horizontal joints (*soles*), which facilitate the working of the veins. The soles are greatly prized by the quarry men, as without them there would be a considerable loss from the waste of good material in getting out the blocks.

Other quarries in this vicinity are—that at *Laghtea*, about two miles S.W. of Portroe, in which there appears to be a good small vein; two small quarries, north of Tountinna, near the "graves of the Leinster men"; *The Gap*, which lies a little east of the last; *Derry Castle*, a large quarry worked by the "Imperial Company:" there is said to be in these slates a "wind," in consequence of which they are liable to cast up; it was for this reason that the Company purchased the Corbally quarry; a quarry one mile south of Derry Castle; and a quarry half a mile N.W. of Ballina. In the last the slate is of a very superior quality, but it has an off-baring of twenty feet in thickness, of a massive green grit, which made the slate very expensive to work. Other small openings were made in this vicinity; but the slate was not of much value, as regards either quantity or quality.

TYRONE.

North-east of Pomeroy, at the village of *Slate Quarry*, roofing slates were formerly obtained, but they were poor, being small, heavy, and rough.

WATERFORD.

Four and a-half miles east of Kilmacthomas are the *Ross quarries*, which were worked up to 1863; the slate is good, of a dark-grey colour.

In *Glenpatrick*, six miles from both Carrick and Clonmel, there were, before 1850, rather extensive quarries on veins of *Ordovician* slate. The largest are *Toor*, to the north, and a quarry 300 yards to the south of Glenpatrick bridge. In the former the slate is fine-grained, of a bright bluish-grey, and in the latter of a lighter grey. The veins in both are of a good width.

A third quarry is situated in Clondonnell, at the base of the Reeks of Glenpatrick, on a vein of finely-cleaved, earthy, grey slate.

The slates in this glen seem well worthy of being re-worked, more especially on account of the nearness of the river Suir, which is there navigable for boats; but they ought to be worked on better principles than formerly.

Ordovician slates was also worked in the south-west part of Lisnadill parish.

In the *Devonians* a red bed was considerably worked near *Clashmore*, in the valley of the Lickey. In places in the vicinity of *Lismore* slates of this age were also worked, the quarries being more fully described hereafter; also in *Glenribbon*, north of the Blackwater, and on the slopes of *Knockmealdown;* the slate was of good quality, but the veins of small dimensions.

WEXFORD.

In the *Cambrians* of the Forth Mountains, about a mile east of Trinity cross-roads, a nice-looking blueish-grey slate is recorded; but it is as yet untried.—(G. S. M.)

In the *Ordovicians*, a mile and a-half S. S. W. of Bunclody, or Newtownbarry, in the townland of *Ballyprecas* (Hall-Dare), and *Glaslacken* (Digby), north and south of a glen, slates are found. The veins are peculiar; because, although the quarries are opposite one another, and seem to strike one at the other, the slabs are quite different; those to the north, in the Hall-Dare quarry, being blue and ribboned, while those to the south, in the Digby quarry, are grey or greenish grey; a grey vein in the latter is of excellent quality.

At the present time these quarries are smothered up, and are only worked in a very small way; yet there are great facilities for opening a good quarry—that is if a deep cutting was made up the glen from the westward, by means of which the veins would be drained to a considerable depth, while the waste could be run out into the valley to the westward and the veins both to the north and south economically worked.

In Slievebawn, the hill about five miles north-west of Gorey, and immediately westward of Hollyford, there are considerable veins of slate. To the westward, near *Monaseed*, there are various small workings; and although none of them are deep or of great extent, yet a very fair slate has been procured, with every prospect of a superior slate in depth. The veins could be easily driven on, either from the eastward or westward, and the opening and working of a quarry ought not to be expensive.

A fair slate was worked a little at Killybeg, four miles from Enniscorthy; while trials were made on the eastern slopes of Mount Leinster.

WICKLOW.

In the north-west of this county, a few miles north of *Blessington*, near the mearing of county Kildare, a slate vein was worked in the *Ordovicians* about the middle of the eighteenth century. Jukes states:—"The cleavage is often as fine and complete as in any slate whatever; and it only fails to make good roofing slates from the want of firmness in the materials." It was formerly much worked for small slates, but to no great depth; and it is possible that if it were sunk on, in depth, the size and quality of the slate would improve.—(G. S. M.)

Near *Ashford*, in the Devil's Glen, a slate was being worked in the year 1845, both for roofing slate and slabs. Both Kane and Wilkinson write approving of it, and state that it has a very strong resemblance to the Welsh slate, both in colour and in texture, being about intermediate in character between those of Bangor and Llanberis; while, like those veins, it is of *Cambrian* age. This quarry appears to have been worked for a few years with every prospect of success, turning out good work in roofing slates and slabs; but the proprietor, like many others, suffered from the great depression in trade of 1850 and subsequent years, during which the works were abandoned.

In different places south and south-east of Rathdrum there have been trials, or small workings, on *Ordovician* slates; those in *Kilmacrea* Hills, north of Redcross, were the most extensive, and good slate was procured near the north part of the Pass; but the veins are narrow, so that there is no opportunity for a large quarry.

At *Clanwilliam*, a little south of Wooden Bridge, in the *Ordovicians*, there is a small quarry which was lately worked principally for the manufacture of "school slates," as the slate is not very good for roofing purposes. In the opposite brow, to the east of the valley, there appears to be a better vein of roofing slate. The colour varies, the slate being greyish green, bright green and purplish. These veins have not as yet got a fair trial, as the works were injudiciously laid out.

Westward of Wooden Bridge, both north and south of the Darragh Water, or Aughrim River, there is a vein easily wrought into large slabs. This has been worked a little for tombstones.

In the southern part of the county, a little north of Carnew, are the *Kilcavan slate quarries.* Here the veins are peculiar, as they swell out and contract suddenly; while in the vein a mass of grit may appear cutting out the slate. The slate is of a dark colour and fair quality; but the quarry has been greatly injured by allowing the rubbish to accumulate in it, and at its mouth; and now before it could be worked this would have to be cleared away at considerable expense.

About two miles from Rathdrum there is a slaty flag that has been used in the town.

Lewis mentions "quarries of good slate at *Crehelp,* three or four miles east of Dunlavin, and a slate quarry, opened about the year 1830, at *Gibbet Hill,* near Clonegal.

SLATES USED AS BUILDING-STONE.

ANTRIM.

In the north-east of this county there is a small tract of more or less metamorphosed rocks, probably the equivalents of either the *Ordovician* or *Arenig.* The schists and slates are locally used for common walling purposes.

ARMAGH.

In Armagh, extending north-eastward and south-westward into the adjoining counties of Down and Monaghan, respectively, is a large area occupied by *Ordovician* rocks, in which slates largely occur. Here, as in the rest of these Ordovicians, they are the general building-stone of the country, being preferred to the associated grits; but they are not suited for cut-stone purposes. At Carricklane there is a quarry of good stone that was used for walling in the building of Gosford Castle.

CARLOW.

The slate rocks of this county are of very little importance. *Ordovicians* occur only in the south-east of the county in the neighbourhood of Clonegall and Kildavin, where they are more or less metamorphosed; the slates and schists are locally used for common walling purposes. In the south-west of the county, in the *Coal-measures*, there are shales, but they are usually too friable or soft to be much used, except for road-mending.

CAVAN.

The south-western end of the tract of *Ordovicians*, mentioned under Armagh, occupies a considerable portion of this county; and in the towns situated thereon, as Cootehill, Ballyhaise, Bailieborough, Virginia, Ballyjamesduff, and others, slate is principally used for ordinary walling, sandstones usually being used for quoins and dressings; some few of the slate rocks, however, from deep quarries, can be turned out as quoins. The slates vary very much from gritty to fine and soft; some of the best class occur near Cootehill. In the north-west of the county there are *Coal-measure* shales; these are usually soft, and not much used, the associated grits and flags being preferred.

CLARE.

In the east of the county are more or less small isolated exposures of *Ordovicians*. In these and in the marginal tracts of *Lower Carboniferous*, and in the *Coal-measures*, in the west of the county, are slates and shales, which are locally used for building purposes, such as bridges, farm-houses, and fences. In the *Coal-measures*, between Kilkee and Miltown Malbay, the slate is better than ordinary, and splits easily, so much so that it has been used in places for roofing slate (*ante*, p. 79).

CORK.

For building purposes, both in old and modern times, slate-rocks have been more used in the Co. Cork than perhaps any other county in Ireland—as in Bantry, Skibbereen, Dunmanway, Bandon, and Kinsale.

At *Bantry* is the Seskin quarry, where most of the stones used in building the town were procured. Usually it is a greyish gritty stone; but there are subordinate beds of purer slate which are wrought into window-sills, steps, quoins, &c., and appear durable if set on edge. When the Union Workhouse was being erected, about 1830, they came on a peculiar arch in this quarry, which has been figured and described by Wilkinson. It had a distinct arched form among the vertical strata, both above and below it. The face of the arch to the east, when first met with, was smooth from springing to springing, being about thirty-four feet wide, and narrowing gradually as it was followed westward to about twenty feet in a length of 120 feet. The vertical strata "abutting close under its soffit, and forming abutments to the springing of the arch . . . . The greater number of the ring-stones of the arches of the building (Union Workhouse) were procured from this vein, as also many fine quoins, &c. Many of the stones taken from the rings were used in arched portions, in the state already prepared by the hand of Nature."

At *Rushnacara*, north-west of Dunmanus Bay, and sixteen miles from Bantry, a green and grey slate-rock was used in the building of the National Schools. It is very durable, and can be raised in large scantlings; but is only fit for rubble work.

In the neighbourhood of *Skibbereen* the slate is greyish and reddish brown. It is often mixed with a scaly quartzose rock, which adds to the cost of quarrying.

Near *Dunmanway*, the stone which seems to be most preferred is a hard, gritty slate, but abounding in good natural joints, which make it easily quarried in suitable sizes; the more slaty, or argillaceous, rocks are less used.

In the vicinity of *Enniskeen* is Kinneigh round tower, a good example of slate work. The stone used in this tower, which abounds in the neighbourhood "is well worked and is closely dressed on the edges of the beds, both in the circular work of the upper walls and in the splayed angles of the lower portions of the tower. The stones used vary in length from one to nearly five feet, and in thickness from three to twelve inches, and the material appears durable." (*Wilkinson.*)

The Abbey of Timoleague is also a good example of slate building. It is of Early English architecture, and illustrates the good quality of the slate rock of the locality, "and the simple and proper mode of using it; the design and constructive arrangements being suited to the materials employed." (*Wilkinson.*)

In the neighbourhood of *Bandon* the slate rock is a good building stone; for, although finely cleaved, some veins being wrought into roofing slate, it can be worked freely across the edges. It seems to have been more used in old times than at present, as now limestone is often preferred.

In the *Kinsale* district the slates are of a bad description; but at a few miles' distance there are greenish slaty rocks, suitable for rubble work, while sandstone or limestone are used for the dressings.

DONEGAL.

More or less metamorphosed rocks of the *Cambrian*, *Arenig*, *Ordovician*, and *Llandovery* formations occupy the greater part of this county.[1]

In the less altered parts the slates and schists are used for local building purposes; but none of them are suitable for cut-stone. From some beds margining the gneiss on the southward, between Lough Salt, to the eastward, and *Glendowan*, to the westward, good purple micalyte flags of fair sizes can be procured in the strip margining the foliated Granite and Gneiss. A little S.W. of *Kindrum* (Fanad-Within-the-Waters) are good felspathic schist flags, which can be raised of large dimensions. Thin-bedded flags occur to the eastward in several places in the neighbourhood of Lough Swilly, a very good vein occurring at *Saltpans*, which has been quarried a little for eave courses and quoins. As already mentioned, in different places in the county trials have been made for roofing slates.

DOWN.

Occupying a considerable part of this county is the north-east portion of the large area of *Ordovicians*, already mentioned in connexion with the counties of Armagh and Cavan. Here, as there, are different varieties, which are very generally used for rubble work and ordinary walling, while granite in the south portion of the county, and freestone in the north part, are used for cut work and dressings.

---

[1] *Vide* these *Proceedings*, vol. v., p. 548.

DUBLIN.

The slate rocks, when they occur in the north portion of the county, at *Howth*, and to the southward, bordering Wicklow, are employed for common building purposes; but in general they are not used as they might be, bricks being greatly run after in many places. Bricks are more economical for finer kinds of work; as although the slate may be easily and cheaply procured, the mortar working and setting, which is necessary to make neat masonry of it renders it more expensive than brick.

FERMANAGH.

Metamorphosed *Ordovician*, *Arenig* (?), or *Cambrian* (?) rocks occupy a small area near Pettigoe and Belleek, at the north-west of the county, and a smaller one to the north-east, at Lack; and the slates and schists in these are locally used for common walling purposes.

In the *Slievebeagh Series* (Carboniferous, *vide* Sands and Sandstones, page 524, vol. v.), in the south-east of the county, in the different tracts of *Calp* and *Coal-measures*, there are shales; but these are only very locally used.

GALWAY.

In Yar Connaught, or the country west of Loughs Mask and Corrib, many of the rocks are of slaty character, but usually metamorphosed into micalyte or allied schists. The probable ages (*Ordovician*, *Arenig*, and *Cambrian* (?)) of these rocks have already been discussed (Sands and Sandstones, page 517, vol. v.). Over these, to the north, and extending into the county Mayo, are slaty rocks of *Silurian* age, while margining these and the older metamorphic rocks are the *Lower Carboniferous*. The slate rocks that occur in these different geological groups are more or less locally used for common walling purposes; but there is no very great demand for them anywhere, the villages and hamlets being few and far between; and the stones required are procured on the surface of the ground, or any place where they will cost least in the getting. In building Kylemore Castle, in the north of the county, the stone for general walling purposes was blasted out of the site to be occupied by the castle. It constitutes good and apparently durable work, the dressings and facings being of granite from Bullock, Co. Dublin. This seems to be the only large modern structure in which slate rock has been extensively used, and the result shows that it is very suitable for such work.

KERRY.

The slate rocks of this county are of good and durable material. They nearly always dress well on the bedding surfaces, and if sawn across the grain, and moulded by planing, they would be capable of being used for nearly any purpose, as exemplified in the slate quarries of the Knight of Kerry, Valentia. In different places, on account of the low dip of the strata, and the water-power nearly everywhere available, there would be great facilities for cutting the rocks *in situ* into any scantlings, by machinery, in the quarries. This, however, has not as yet been adopted in Ireland; although, as previously pointed out (MARBLES and LIMESTONES, page 492, and SAND and SANDSTONES, page 514, vol. v.), it might in places be advantageously introduced.

The slate rocks are eminently suitable for dry masonry, as exemplified in many of the modern, and in the ancient erections, such as the forts at Ballycarbery, near Cahirciveen, and those of Derrynane and Staigue, as also the forts and bee-hive houses (*cloughauns*) of the ancient settlement, called by DuNoyer the "city of Faha," in the Dingle promontory.

In the *Devonian* and *Silurian* areas the slate rocks are preferred to any others for general building purposes; at *Tarbert* and *Killarney* gritty varieties being principally used.

[The slate and slab quarries at *Valentia* have been described (*ante* p. 84), but besides these there are many local openings into the slate veins, the stones from which are principally used merely for walling; but some of them are wrought into slate, the stone usually being carried from the quarry to the building in the rough state, and there split into slates by the slaters. On this account all through this district there are many places known as "slate quarries," although a slate was never split in them.]

KILDARE.

In the east of this county, where slate rocks occur, they are commonly used for general walling purposes. They are often of a gritty character. The walling of the Round Tower at Kilcullen is of the slate rock of the locality, the doorway being of granite. In the upper portion of the Round Tower at Kildare slate rock is used indiscriminately with granite, sandstone, and limestone.

KILKENNY.

Extending across the south portion of this county, from Tipperary into Wexford, there is an area of slate rocks. They principally belong to the *Ordovicians*, only a few occurring in the *Lower Carboniferous*. They are good for walling, and are found in many of the ancient buildings, sandstone (sometimes Caen (?)), having been used in the dressings.

In the north of the county the *Coal-measure* shales yield bad building stones. Some of the shales, raised when the coals were being worked, after they had disintegrated or "melted," were found to be an excellent top-dressing for the land, while others were injurious, burning off the herbage. The bad qualities of the latter seem to have died out in time by exposure, as all the stacks of them that existed a quarter of a century ago have been apparently used up. Good roofing slate can be procured, as mentioned, *ante* p. 85.

KING'S COUNTY.

Slate rocks occur only on the south-east, in the small portion of Slievebloom that extends into this county. They are very little used.

LEITRIM.

Schists, slates, and shales occur in the *metamorphic rocks* and the *Coal-measures*, and some of them are locally employed for walling purposes.

LIMERICK.

In the exposures of *Ordovicians*, in their marginal tracts of *Lower Carboniferous* rocks, and also in the *Coal-measures*, slates and shales occur. Here and there some of these are extensively quarried for general building purposes. Near Glin there is a hard, compact *Coal-measure* shale, very suitable for walling.

LONDONDERRY.

Here, as in the neighbouring counties of Donegal and Tyrone, there is a large tract of more or less altered rock, probably equivalents of the *Ordovician*, and perhaps partly of the *Llandovery* strata. In the less altered rocks the slates and schists range from fine and argillaceous to coarse and arenaceous. Some of the latter, which perhaps are more properly sandstones than schists, and have already been mentioned in the paper on sandstones (*vide*, p. 581, vol. v.), are largely used for all common walling purposes in Derry and its neighbourhood. The principal quarry is at *Prehen*, where there is a bluish stone, of a slaty structure; but there are several others, the stones varying slightly in colour and texture. Elsewhere, within the district, the schists and slates are the materials generally used for building purposes; but they are nearly always unfit for dressed work or quoins. Some contain iron, which soon oxidises and gives a dirty, burnt appearance to the walls. Some of the fine varieties split into coarse slates, and are occasionally used for roofing purposes.

LONGFORD.

In the north of this county, in the *Ordovicians*, at the south-western end of the already-mentioned large tract of these rocks in Cavan, &c., as also in a few small outlying patches, and in the associated *Lower Carboniferous*, slate rocks occur. These are locally used for walling, similarly as in the adjoining county of Cavan.

LOUTH.

Here, as in the adjoining counties—Cavan, Monaghan, and Armagh—there is a considerable area of *Ordovicians*; and in them, as elsewhere, there are a number of varieties of slate rock, more or less suitable for ordinary building purposes. In this area slate was used by the old people, as exemplified in the ruins of the ecclesiastical buildings at Monasterboice, which are constructed almost wholly of them. "The old round tower is a good example of the working of this material, the stones being shaped to the curvature of the circular surface." (*Wilkinson.*)

The stones used in Monasterboice seem to have been procured in the immediate vicinity. Near the old gateway at Mellifont, and in other places in that part of the county, there is a dark-grey compact slate, with a tendency to split into laminæ. "This, if properly worked, would be a very useful and good material for many purposes, as it admits of division to any moderate thickness required." (*Wilkinson.*)

MAYO.

As in the adjoining county of Galway, the slate rocks in the *Arenigs*, *Ordovicians*, and *Silurians* of Mayo are often more or less metamorphosed into schists. Slate rocks also occur in the *Lower Carboniferous* and the *Coal-measures.*

In the areas in which they are found the older slates and schists are very generally used for ordinary building purposes, sandstone and limestone being used for the cut work. They are very varied in character. "West of Swineford the slate rocks have vertical cleavage and joints, and subdivide, when much exposed, into large, flat-bedded masses, standing on edge. A peculiar mass of rock of this kind appears above the surface, a few miles north-west of Swineford, and, from the large square-shaped and moderately thick beds of the rock, presents such inviting and ready-prepared materials for walls of great magnitude as almost to cause a wish that the available powers of the present day should make some bold use of them." (*Wilkinson.*) According to Symes, the splitting into these cyclopean slabs have been produced by water freezing in the cleavage divisions. Slates that have been used for roofing purposes occur in places previously mentioned.

MEATH.

The slate rocks occur principally in the northern part of this county, and have been extensively used in *Kells*, both in ancient and modern times, the stone generally used being more or less gritty. St. Columbkille's house, at *Kells*, as also the round castle there, are built of a hard, durable rock, that does not admit of much working. A similar stone is found in the old church and round tower at that place, but mixed with limestone, the cut-work being of sandstone. In the quarry to the east of *Kells* the stone is exceedingly hard and brittle, rising in angular and wedge-shaped masses, while in the quarry to the west it is much kinder, laminated, and compact.

Elsewhere in the slate areas it is very generally used for walling.

MONAGHAN.

A considerable area of this county is occupied by part of the great *Ordovician* tract, so frequently mentioned already, the slate rocks of which have been described under Cavan. In the towns of Monaghan and Clones these rocks are used, along with limestone, for general building purposes, but elsewhere by themselves.

In the north part of the county, in the *Slievebeagh Series* (Carboniferous, *vide* SANDS and SANDSTONES, p. 593, vol. v.) there are shales locally used for rough walling.

QUEEN'S COUNTY.

In this area, as in other parts of the central plains of Ireland, there are slate rocks in the *Ordovicians* and in the *Lower Carboniferous* strata, while to the south-east there are *Coal-measure* shales.

The general characters of the last are given in the description of the Kilkenny rocks. The slates and shales of earlier formations seem to be only sparingly utilised, the associated grits and sandstones being preferred.

ROSCOMMON.

In this county the slate rocks seem to be of little account, except for farm purposes.

SLIGO.

The slate rocks, except in the *Coal-measures*, have been more or less metamorphosed into schist and gneiss. The schists are used locally for walling and such like. The *Coal-measure* slates do not appear to be much used, as they are nearly always associated with thin-bedded, nicely-jointed sandstones.

TIPPERARY.

Slate rocks occur in the *Ordovician* and in the marginal *Lower Carboniferous* strata of this county, and also in the *Coal-measures* as shales.

The slate rocks are not very generally used for building, on account of the proximity of the limestone or sandstone, which are often more suitable for that purpose; but some of them can be wrought into good slates (*ante*, p. 88).

TYRONE.

In the northern part of the county there are slate rocks more or less metamorphosed into schists, in the strata which are probably the equivalents of the *Ordovician*, *Arenig*, and possibly *Cambrian*. Near Pomeroy they also occur in a small tract of *Llandovery* (?) and in *Silurian*, that extend from Pomeroy westward into the county Fermanagh.

In the metamorphic area, especially in the neighbourhood of Strabane and Castlederg, the slates and schists are largely used for common building purposes. In the *Lower Carboniferous*, the *Calp*, and the *Coal-measures* there are shales used for local purposes.

WATERFORD.

The slate rocks of the *Ordovician*, *Devonian*, and *Carboniferous* districts of this county are used for walling purposes, the dressings being limestone, sandstone, or granite. Near Waterford very gritty slates, already described among the sandstones (*vide*, p. 611, vol. v.), are quarried at Grange Hill, south of the river; while north of the river more argillaceous rocks are also quarried for walling and general building purposes. The stones in the north quarry can be raised in large, flat-bedded rough blocks, suitable for foundations or heavy work.

There are good veins of roofing slates (*see* p. 92).

WESTMEATH.

Slaty rocks are nearly quite absent; they occur only as subordinate beds in the *Carboniferous* strata.

WEXFORD.

Slaty rocks occur very generally throughout this county. In some places, however, they have been metamorphosed into schists, or even gneiss (?) They vary greatly, from roofing slates to gritty slates—the latter passing into grits and quartzite. They are very extensively used for walling and rubble in all the towns and in the ancient buildings, as in the castles and churches of Ferns, Enniscorthy, &c.

In places there are veins of roofing slates, mentioned at p. 92.

WICKLOW.

This county, like Wexford, is largely occupied by slaty or allied rocks, which have been used extensively for common building purposes in Bray, Newtownmountkennedy, Wicklow, Rathdrum, Arklow, Tinahely, Carnew, Shillelagh, &c. Many of them are more or less metamorphosed; but in general all give good flat-bedded tones, often of large sizes, capable of producing good work. They very seldom dress well on the edges. Many, however, might be sawn; but this is not practised, as granite is generally used for dressings and quoins.

In Saint Kevin's Kitchen, *Glendalough*, there is a high-pitched roof, built in horizontal courses, partly supported by a cylindrical vault made with voussoirs, both of micalyte. Anciently, and up to the middle of this century, the majority of the monuments at the Seven Churches were slabs of micalyte, some of the ancient ones being elaborately carved. But nearly all the more modern ones in the large graveyard were some years ago replaced by limestone ones, while subsequently many of the latter have been in their turn replaced by sandstone or Bath stone, thus depriving the place of its ancient look and character, and giving it the appearance of a modern cemetery.

PART II.—CLAYS (BRICKS, ETC.),

Will appear in the next Number of these *Proceedings*.

XII.

NOTE ON A REMARKABLE INCREASE OF MAGNETIC SUSCEPTIBILITY PRODUCED BY HEATING MANGANESE STEEL FILINGS. By Professor W. F. BARRETT.

[Read March 21, 1888.]

The remarkable physical properties of manganese steel formed the subject of a Paper I read before the Royal Dublin Society, in December, 1886.[1] In that Paper it was shown that a steel containing from 12 to 15 per cent. of manganese, manufactured by Messrs. Hadfield & Co., of Sheffield, is almost devoid of magnetic properties, its magnetic susceptibility being almost insensible even in the most powerful magnetic fields. Unlike ordinary steel, manganese steel is annealed by heating to redness and plunging in cold water, and made hard and brittle by slow cooling. By careful annealing, I obtained wire of this steel, and found it had an enormous tenacity, the hard manganese steel wire exceeding the tenacity of steel wire, and being only surpassed by the best pianoforte steel wire. It had a low modulus of elasticity, and a very high elastic resistance, three and a-half times that of iron wire.

I have now to bring before the Society another curious property possessed by this alloy. When visiting Messrs. Hadfield's steel works, at Sheffield, last Christmas, Mr. Hadfield drew my attention to the fact, that filings of manganese steel were feebly attracted to a magnet, though the casting from which they were bored was non-magnetic; and, further, that heating the filings to redness caused them to be strongly attracted to a magnet, after cooling down again. My explanation of the phenomenon, at first sight, was, that particles of the steel-boring tool had become abraded, and, mingling with the non-magnetic filings, caused the quasi-magnetic character of the filings of the alloy. Mr. Hadfield, however, supplied me with some of the filings for further investigation. Experiment showed that the filings of any given alloy

---

[1] *Vide* these *Proceedings*, vol. v., p. 360.

of manganese steel are, before heating, undoubtedly considerably more magnetic than the bar from which they are bored. This cannot be wholly due to abrasion; for, whilst filings of a 12 or even 16 per cent. alloy are feebly magnetic, filings of 36 per cent. are more magnetic. Heating the feebly magnetic filings of the 18 per cent. alloy to redness in an open platinum crucible, they became black with oxide, and when cold were strongly magnetic, being readily attracted by a small permanent magnet.[1] Believing the attraction to be due to the formation of an oxide of manganese, thus leaving the steel in its ordinary unalloyed state, I covered fresh filings with a deep layer of powdered charcoal, and heated them to redness in a crucible: strong attraction still ensued on cooling; the filings became of a gray colour, showing less oxidation than before. I then tried heating the filings in an atmosphere of hydrogen. They were enclosed in a hard glass tube, and after hydrogen had passed over for some time the tube was sealed, and the filings heated to redness. Even here a slight change of colour occurred, and a powerful attraction ensued when the filings were cool. Numerous experiments were made to exclude every trace of oxygen, and at last scarcely any discolouration of the filings was obtained: nevertheless, a magnetic character was conferred by the heating. These results were confirmed by the experiments of Professor O'Shea, of Firth College, Sheffield, who very carefully weighed the filings, before and after they had been heated in hydrogen, and ultimately obtained a result where no gain in weight arose on heating; nevertheless, a higher magnetic state was found on cooling.

Experiments with a 36 per cent. alloy of manganese, 3 per cent. carbon, and 60 per cent. iron, gave even more striking results. There was no sensible attraction with a permanent magnet before heating, but a powerful attraction after heating.

I now compared the behaviour of manganese wire and foil with that of the filings.

Suspending a fragment of manganese steel foil over and very near the pole of a powerful electro magnet, I obtained an attrac-

---

[1] The magnetic property of iron and steel, as is well known, is destroyed at a bright red heat, but is recovered on cooling; but a magnetized body loses its magnetized state, without recovery on cooling, when heated to redness.

tion represented by 1 gramme before heating. Upon heating to redness, after cooling, an attraction represented by 2 grammes was obtained; but no attraction was sensible by a permanent magnet either before or after heating. Precisely similar results were obtained with a bit of thin manganese wire. In all cases the surface was, of course, discoloured by oxidation through heating. Placing some 36 per cent. manganese steel filings in a hard glass tube, an attraction represented by 5 centigrams was obtained before heating; after heating to redness, in an atmosphere of coal-gas passing through all the time, upon cooling the attraction had increased to 20 centigrams, the electro-magnet being employed. This is a far higher increase than with the wire or foil, as was obvious by the fact that a permanent magnet readily attracted the filings.

I now wrapped some filings very tightly in platinum foil and heated them to redness, as before; now the attraction after heating was only double the attraction before heating; about the same, in fact, as the wire or foil exhibited: no attraction with a permanent magnet was found after the compressed filings had been heated.

The difference in behaviour of manganese steel when in loose filings and when in wire, foil, or compressed filings, may furnish a clue leading to an explanation of the curious phenomena described in the preceding note, but at present I am unable to suggest any explanation. As regards the temperature at which the increased magnetic property is conferred, I find no alteration is produced by the temperature of 100° C. or 250° C.: a slight increase occurs at a black heat; but the change sets in at a low red heat.

I hope before long to make another communication on this subject to the Society.

XIII.

ON A CONVENIENT METHOD OF OBTAINING ANY REQUIRED ELECTRICAL POTENTIAL FOR USE IN LABORATORY TEACHING. By F. T. TROUTON, B.E.

[Read March 21, 1888.]

It would be an obvious advantage in the experimental teaching of Electrostatics to be able conveniently to charge bodies to any required potential. Although it does not enable us to do this, yet by the following method, two or more bodies can be charged to potentials, the ratio of which to each other can be determined and varied as required.

To the poles of an electrical machine, say a Holtz, a length of about five feet is connected of a poorly-conducting substance—an ordinary cord, if smooth, does fairly well. It is, however, of considerable importance, to prevent discharge into the air as much as possible from the little points and roughnesses on the cord, by having it smooth. Neglecting any discharge which may occur, we can consider the potential as falling proportionately to the distance along the cord, when the machine is working uniformly. By touching the bodies to be charged to the proper points along the cord, the desired potentials are obtained. The difference of potential at each point touched from that at either pole is proportional to the length measured along the cord.

By this method the capacity of two bodies can be very simply compared. First, connect one pole of the machine to earth; then, if the bodies be touched to the cord, at distances from the pole to earth, that are in the inverse ratio of the capacities, equal quantities of electricity are obtained on the bodies. This equality is best tested by the null method described in Maxwell's *Elementary Treatise on Electricity*, Experiment VII. After a few trials the correct distances are easily found; then the inverse ratio of the distances, measured along the cord, is the ratio of the capacities of the bodies.

XIV.

REMARKS ON *SAGARTIA VENUSTA* AND *SAGARTIA NIVEA*. By G. Y. DIXON, M. A.

[Communicated by Professor A. C. Haddon.]

[Read March 21, 1888.]

Sagartia venusta, Gosse.

Bibliography.

1854.	*Actinia venusta*, .	P. H. Gosse, *Ann. and Mag. of Nat. Hist.*, ser. 2, vol. xiv., p. 281.
1855.	*Sagartia venusta*, .	P. H. Gosse, *Trans. Linn. Soc.*, vol. xxi., pp. 272 and 274.
,,	,, ,, .	P. H. Gosse, *Proc. Linn. Soc.*, vol. ii., pp. 372 and 374.
,,	,, ,, .	P. H. Gosse, *Ann. and Mag. of Nat. Hist.*, ser. 2, vol. xvi., p. 294.
,,	,, ,, .	P. H. Gosse, *Manual of Marine Zoology*, vol. i., p. 28.
1856.	,, ,, .	P. H. Gosse, *Tenby: A Seaside Holiday*, pp. 39, 60, 97, 358–361, 367, 375, 387, 390, and 393. Pl. xxiii., figs. *a* and *b*.
,,	*Actinia venusta*, .	G. Tugwell, *Manual of Sea Anemones*, pp. 56 and 98.
1857.	*Cereus venusta*, .	Milne-Edwards, *Histoire Naturelle des Coralliaires*, vol. i., p. 273.
1858.	*Sagartia venusta*, .	J. R. Greene, *Nat. Hist. Rev.*, vol. v., p. 36.
,,	,, ,, .	P. H. Gosse, *Ann. and Mag. of Nat. Hist.*, ser. 3, vol. i., p. 415.
,,	,, ,, .	E. P. Wright and J. R. Greene, *Report of British Association*, 1858, p. 178.
,,	,, ,, .	George Henry Lewes, *Seaside Studies*, pp. 19, 79, 142, and 239.

1859. *Sagartia venusta*, . E. P. Wright, *Proc. Zool. and Bot. Assoc. of Dublin*, vol. i., pp. 179 and 187; *Nat. Hist. Rev.*, vol. vi., pp. 117 and 124.

1860. ,, ,, . P. H. Gosse, *Actinologia Britannica*, pp. 42, 53, 55, 60–66, 72, 87, 122, and Pl. i., fig. 7.

1861. ,, ,, . T. Hincks, *Ann. and Mag. of Nat. Hist.* ser. 3, vol. viii., p. 361.

,, ,, ,, . F. J. Foot, *Proc. Nat. Hist. Soc. of Dublin*, vol. iii., p. 65.

1870. ,, ,, . William Andrews, *Proc. Nat. Hist. Soc. Dub.*, vol. vi., p. 17.

1874. ,, ,, . P. Fischer, *Comptes rendus*, vol. lxxix., p. 1207: transl. *Ann. and Mag. of Nat. Hist.*, ser. 4, vol. xv., p. 373.

,, ,, ,, . P. Fischer, *Nouv. Arch. du Museum*, vol. x., pp. 212 and 239.

1876. ,, ,, . J. E. Taylor, *Half-Hours at the Seaside*, p. 130.

,, ,, ,, . H. W. Mackintosh, *Guide to City and County of Dublin*, part ii., Fauna, p. 6.

1880. ,, ,, . E. Jourdan, *Ann. des Sci. Nat.* (*Zool.*), ser. 6, vol. x., p. 33; *Revue Scientifique*, ser. 2, vol. x., p. 381.

,, ,, ,, . G. Y. Dixon, *Rathmines School News*, vol. viii., No. 3, p. 1.

,, *Heliactis venusta*, . A. Andres, *Le Attinie*, vol. i. (*Fauna und Flora des Golfes von Neapel*, vol. ix.), p. 143.

,, ,, ,, . A. S. Pennington, *British Zoophytes*, p. 151, Pl. xii., fig. 3.

1886. ,, ,, . A. C. Haddon, *Proc. Roy. Irish Acad.*, ser. 2, vol. iv. (Science), p. 527.

,, ,, ,, . A. C. Haddon, *Zoologist*, ser. 3, vol. x., p. 6.

Description.

Form

Base—Adherent, slightly exceeding the column.

Column—Cylindrical, sometimes pillar-like; in height generally exceeding the diameter; smooth, or slightly corrugated; studded on the upper half with suckers, which form more or less distinct warts; and on the upper third perforated by cinclides; marked with numerous longitudinal lines corresponding to the insertions of the mesenteries, which shine through the body-wall. Substance fleshy.

Disk—Sometimes flat, but in large specimens generally concave and expanded, so as to exceed and overhang the column; margin more or less undulate; outline either oval or circular; radii inconspicuous, forty-eight in number, of which twenty-four run from the mouth to the feet of the tentacles of the first row, and the remaining twenty-four, which alternate with those just mentioned, are subdivided by the insertion of secondary and tertiary radii, which run to the feet of the tentacles in the second and third rows, respectively, but do not reach the mouth.

Tentacles—In number, 192; set in four rows, of which the first and second contain each twenty-four, the third forty-eight, and the fourth, which is marginal, ninety-six. This would appear to be the usual arrangement, though slight deviations are not infrequent. Those of the first row, when extended, are about as long as the diameter of the disk, and are generally turned upwards and outwards: the tentacles in the other rows diminish gradually, and are bent back further; those in the outer row are frequently extended horizontally to the disk: they are small, and sometimes contracted to the condition of mere papillæ, so as to form a fringe to the margin.

Mouth—Generally swollen and gaping, frequently thrown into lobes, sometimes raised on a cone, furnished with either one or two œsophageal grooves; lip tumid, and marked with ridges, which terminate the radii; a pair of œsophageal tubercles mark the juncture of the œsophageal groove with its corresponding radius; specimens with two grooves having, of course, two such pairs of tubercles; throat ridged; acontia emitted freely and copiously through the cinclides and the mouth.

Colour.

Column—Upper half varying from buff to an orange-brown; lower half paler, and sometimes marked with whitish longitudinal lines, which fade away as they ascend; suckers whitish.

Disk—Pellucid orange, without markings.

Tentacles—Pure, opaque, white; without markings, except that the colour is sometimes pellucid at the foot and at the tip. The tentacles of the outer row have sometimes an orange core.

Mouth—Buff to brick-red; ridges of throat white.

Dimensions.

Diameter of column may reach one inch.

Diameter of expanded disk and tentacles may reach one inch and a-half; the total height may reach two inches.

Distribution.

Sagartia venusta has been recorded as found in the following localities:—

South-west Coast of England:—

Torquay, ...	P. H. Gosse.
Clovelly, ...	Charles Kingsley (on oysters from deep water).
Morte stone, ...	George Tugwell.
Lundy, ...	George Tugwell.

Coast of Wales:—

Tenby, ...	P. H. Gosse.
St. Gowan's Head, . . .	P. H. Gosse.
Puffin Island, ...	E. L. Williams.

East Coast of Ireland:—

Belfast, ...	C. Bosanquet.
Monkstown, Co. Dublin, .	H. W. Mackintosh.
Dalkey Island, ...	G. Y. Dixon (under sides of loosely-piled granite boulders).

South Coast of Ireland:—

Youghal, ...	J. R. Greene.

South-west Coast of Ireland :—

Bantry Bay, ...	E. P. Wright.
Valentia, ...	A. C. Haddon.
Dingle Bay, ...	W. Andrews.

Channel Islands :—

Guernsey, ...	J. D. Hilton (on *Laminariæ*, washed up); Miss Guille.

North-coast of France :—

Saint Malo, ...	Vaillant (au Petit Bey).

South Coast of France :—

Gulf of Marseilles, . .	E. Jourdan (at 100 fathoms).

Sagartia nivea, Gosse.

Bibliography.

1853.	*Actinia nivea*, . .	P. H. Gosse, *Devonshire Coast*, pp. 93 and 435; Pl. i., fig. 8.
1855.	*Sagartia nivea*, .	P. H. Gosse, *Trans. Linn. Soc.*, vol. xxi., p. 274.
,,	,, ,, .	P. H. Gosse, *Proc. Linn. Soc.*, vol. ii., p. 374.
,,	,, ,, .	P. H. Gosse, *Ann. and Mag. of Nat. Hist.*, ser. 2, vol. xvi., p. 294.
,,	,, ,, .	P. H. Gosse, *Manual of Marine Zoology*, vol. i., p. 28.
1856.	,, ,, .	P. H. Gosse, *Tenby: A Seaside Holiday*, pp. 26, 32, 60, 97, 130, 360, 367, 368, 369, 375, 390, and Frontispiece.
1858.	,, ,, .	P. H. Gosse, *Ann. and Mag. of Nat. Hist.*, ser. 3, vol. i., p. 415.
,,	,, ,, .	E. P. Wright, and J. R. Greene, *Report of British Association*, 1858, p. 178.
,,	,, ,, .	George Henry Lewes, *Seaside Studies*, p. 240.

1859.	*Sagartia nivea*, .	E. P. Wright, *Proc. Zool. and Bot. Ass. of Dublin*, vol. i., pp. 179 and 187; *Nat. Hist. Review*, vol. vi., pp. 117 and 124.
1860.	,, ,, .	P. H. Gosse, *Actinologia Britannica*, pp. 55, 62, 66, 67–72, 77, 122; Pl. ii., figs. 1 and 8.
,,	,, ,, .	F. J. Foot, *Nat. Hist. Rev.*, vol. vii., p. 392.
1861.	,, ,, .	T. Hincks, *Ann. and Mag. of Nat. Hist.*, ser. 3, vol. viii., p. 361.
,,	,, ,, .	F. J. Foot, *Proc. Nat. Hist. Soc. of Dublin*, vol. iii., p. 65.
1874.	,, ,, .	P. Fischer, *Comptes rendus*, vol. lxxix., p. 1207, transl. *Ann. and Mag. of Nat. Hist.*, ser. 4, vol. xv., p. 373.
,,	,, ,, .	P. Fischer, *Nouv. Arch. du Museum*, vol. x., pp. 212, 239, and 240.
1880.	,, ,, .	G. Y. Dixon, *Rathmines School News*, vol. viii., No. 3, p. 1.
,,	*Heliactis venusta*, .	A. Andres, *Le Attinie*, vol. i. (*Fauna und Flora des Golfes von Neapel*, vol. ix.), p. 143.
,,	,, ,, .	A. S. Pennington, *British Zoophytes*, p. 151, Pl. xii., fig. 3.
1886.	,, ,, .	A. C. Haddon, *Proc. Roy. Irish Academy*, ser. 2, vol. iv. (Science), p. 527.
,,	,, ,, .	A. C. Haddon, *Zoologist*, ser. 3, vol. x., p. 6.

Description.

Form.

Base—Adherent, slightly exceeding the column.

Column—Cylindrical, sometimes columnar; in height slightly exceeding the diameter; smooth, or slightly corrugated; studded on the upper half with suckers, which form more or less distinct warts, and perforated on the upper third with cinclides; marked with numerous longitudinal lines corresponding to the insertions of the septa, which shine through the body-wall. Substance fleshy.

Disk—Flat, or very slightly concave; the margin scarcely undulate, and rarely expanded so as to overhang the column; outline circular; radii conspicuous, forty-eight in number, of which twenty-four run from the mouth to the feet of the tentacles of the first row; and the remaining twenty-four, which alternate with those just mentioned, are subdivided by the insertion of secondary and tertiary radii, which run to the feet of the tentacles in the second and third rows, respectively, but do not reach the mouth.

Tentacles—In number, 192, set in four rows, of which the first and second contain each twenty-four, the third forty-eight, and the fourth, which is marginal, ninety-six. This would appear to be the usual arrangement, though slight deviations are not infrequent. Those of the first row, when extended, are about as long as the diameter of the disk, and are generally turned upwards and outwards; the tentacles in the other rows diminish gradually, and are bent back further; those in the outer row are frequently extended horizontally to the disk: they are small, and are sometimes contracted to the condition of mere papillæ, so as to form a fringe.

Mouth—Generally swollen and gaping, frequently thrown into lobes, sometimes raised on a cone, furnished with either one or two œsophageal grooves; lip tumid, and marked with ridges which terminate the radii; a pair of œsophageal tubercles mark the juncture of the œsophageal groove with its corresponding radius, specimens with two grooves having, of course, two such pairs of tubercles; throat ridged; acontia emitted freely and copiously through the cinclides and the mouth.

Colour.

Column—A very pale olive-drab to orange-brown; slightly varying in intensity, becoming paler towards the base, which is often marked by longitudinal lines of white, which fade as they ascend. The lines showing the insertion of the mesenteries are conspicuous throughout; suckers white.

Disk—Opaque-white to greyish-olive, without markings other than the radii, and pellucid spots, which in some cases may be seen, when the animal is well expanded, at the foot of each of the tentacles in the inner row. Occasionally a faint tinge of yellow surrounds the mouth, and a shade of smoke-grey the tentacular region.

Tentacles—Those of the first, second, and third rows are always opaque snow-white, except at the back and tip; and even there only pellucid when much extended; those of the fourth row are sometimes similar to the others and sometimes furnished with an orange core above; and below, just at the base, with a pellucid round spot, which is conspicuous when the light shines through.

Mouth—Lip and throat ashy-white, with denser white spots on the tops of the ridges on the lip.

Dimensions.

Height—One inch.

Diameter—Of column, three-quarters of an inch; of disk, sometimes rather more.

Distribution.

Sagartia nivea has been recorded as found in the following localities:—

South-west Coast of England:—

Torquay, ...	P. H. Gosse.
Dartmouth, ...	E. W. H. Holdsworth.
Clovelly, ...	Charles Kingsley (on oysters trawled).
Morte stone, ...	George Tugwell.
Ilfracombe, ...	P. H. Gosse.
Lundy, ...	George Tugwell.

Coast of Wales:—

Tenby, ...	P. H. Gosse.
St. Gowan's Head, . . .	P. H. Gosse.

East Coast of Ireland:—

Dalkey Island, ...	G. Y. Dixon.

South Coast of Ireland:—

Crookhaven, ...	E. P. Wright.

West Coast of Ireland:—

Miltown Malbay, . . .	F. J. Foot.

Channel Islands:—

Guernsey, ...	E. W. H. Holdsworth.

It will be seen at once that the above description of *Sagartia nivea* and *Sagartia venusta* agrees in the main with Gosse's account of these forms. In three points, however, some difference will be detected in the two accounts. First, in describing the colour of the tentacles, I have mentioned that in both species sometimes the tentacles of the outer row are possessed of an orange core.[1] This is, however, a matter of no great importance. In *Sagartia miniata* it is by no means uncommon to find individuals without the characteristic cored tentacles, so their occasional presence in *S. venusta* and *S. nivea* need not excite surprise. Secondly, in describing the dimensions of *S. venusta,* I have ventured to differ from Gosse. He (Actin. Brit., pp. 60 and 61) says: "A full-sized specimen, well expanded, is about three-fourths of an inch in diameter of disk; but the extended tentacles may increase this to an inch and a-half, or rather more. The height rarely exceeds three-fourths of an inch." M. Jourdan agrees with Gosse in making the height and diameter of the column about equal, but the measurement he gives for both, 0^{mm}, 007, shows that the two specimens on which he bases his description must have been immature. In the Irish specimens that I have seen the height was generally twice the diameter of the disk; and further, the average height was considerably in excess of the limit which Gosse assigns. I have seen many individuals, when expanded, attain a height of two inches, measuring from the base to the margin of the disk; but I have never seen the disk expanded beyond a diameter of one inch, measuring from margin to margin. Gosse's illustrations of *S. venusta* (Actin. Brit., Pl. i., fig. 7; Tenby, Pl. xxiii., figs. *a* and *b*, represent shorter and more thick-set specimens than any I have seen. Those which Professor Haddon kindly sent me from Valentia, as well as those which I found at Dalkey Island, were larger, and more pillar-like. Coupling this with the occurrence of the orange-cored tentacles mentioned above, one is inclined to believe that the *S. venusta* of our Irish coasts is, perhaps, more robust than its English relations. The proportions of Gosse's illustration of *S. nivea* (Actin. Brit., Pl. ii., fig. 8) are very

---

[1] F. J. Foot (*Nat. Hist. Rev.*, 1860, vol. vii., p. 392) describes a variety of *S. nivea* with the outer tentacles orange. From the description he gives of the specimen, I am inclined to think that it ought, perhaps, to be referred to *S. miniata.*

similar to those of the specimens of this species which I have seen both in Devonshire and at Dalkey Island.

The third point in which my description differs with that given by Gosse of both these forms raises considerations of much greater importance. Gosse seems to have thought (Actin. Brit., p. 4) that in all the sea-anemones, except Actinoloba (Actin. Brit., p. 11) and Peachia (Actin. Brit., p. 234), there are always present two œsophageal grooves. In the case of the genus *Sagartia*, he definitely states (Actin. Brit., p. 25) that the mouth is "furnished with two gonidial grooves, each with its pair of tubercles." Hollard had previously (Annales des Sciences Naturelles, Zoologie, 3 sér., t. xv., p. 274), and the brothers Oscar and Richard Hertwig, have subsequently (die Actinien, p. 57) stated that two œsophageal grooves are to be found in all sea-anemones. In his Report on the Actiniaria dredged by H. M. S. "Challenger" (p. 10), Professor Richard Hertwig lays great stress on the existence of the two œsophageal grooves, which he states are found in all Actiniæ except the Zoantheæ and the Ilyanthidæ, the former of which (he states) have only one groove, and the latter none worth mentioning. Thus it seems to have been, on all hands, an admitted fact, that with the exception, possibly, of *Actinoloba dianthus*,[1] and the two families mentioned by Professor Richard Hertwig, all Actiniæ are characterized by the possession of two œsophageal grooves.

I believe that this is not so, and that in the case of *Sagartia miniata*, *S. venusta*, and *S. nivea*, specimens may frequently be met with in which there is present only one groove. Last June I found several specimens of *S. miniata* and *S. venusta* at Dalkey Island; all the specimens of *S. miniata* had two grooves, and all the specimens of *S. venusta* only one. Subsequently Professor Haddon sent me two more *S. venusta*, from Valentia, and they also had but one groove. A transverse section was cut off one of these, and it exhibited but a single pair of directive mesenteries, and they correspond in position with the groove.

At the end of last December I made another visit to Dalkey Island, and secured one specimen of *S. nivea*, and several examples of *S. miniata* and *S. venusta*. The specimen of *S. nivea* proved to

---

[1] As to whether *Actinoloba dianthus* invariably has two œsophageal grooves, see F. J. Foot, 1861: *Proceedings*, Natural History Society of Dublin, vol. iii., p. 64.

have only one groove, while only one *S. venusta* expanded sufficiently to let me examine its mouth and œsophagus, and it had two œsophageal grooves. I examined carefully seven of the specimens of *S. miniata*, and of these four had two grooves, and three one groove. In all these species great care must be exercised in examining the mouth when counting the number of the grooves, for the lip is so frequently thrown into lobes and puckers, that if it alone be examined it will be very likely to mislead, and a cursory observation might even induce one to believe there were three or more grooves. But when, as is frequently the case in all three species, the mouth gapes, or the œsophagus is protruded, we can easily discover the position of the grooves, and recognize their number. I feel sure that the fact that there is sometimes only one groove present in the œsophagus in these three Actiniæ has escaped notice hitherto, owing to the varying and irregular configuration of the mouth.

As to the cinclides, I have been able to satisfy myself of their existence in all three forms—*Sagartia nivea*, *S. venusta*, and *S. miniata*. Gosse's account of these openings (Actin. Brit., pp. xxv–xxix) is, I believe, quite accurate. In one point only I have not been able to verify his observations—that is, I have never seen the cinclides overspread by a film of mucous such as he describes. In each of the three species just mentioned, when the animal is fully expanded, there generally may be seen, on the upper third of its column, fifty to one hundred open cinclides arranged in three encircling belts, each cinclis being invariably situated midway between two of the longitudinal lines which mark the column, and therefore probably communicating with one of the spaces between the mesenteries. When open, these pores seem to be surrounded by a ring of tissue, more densely coloured than the adjoining region. In *Sagartia miniata* the warmer and richer colour of the column renders this densely-coloured ring and the cinclides more conspicuous than they are in *S. nivea* and *S. venusta*. Perhaps I should state that I have never observed the cinclides "anatomically by transverse and horizontal sections," and that for the account I have just given of them I am indebted entirely to "observation with the naked eye." My reason for having thus gone at length into the appearance presented in the living animal by these minute pores is to be found in the way Professor R. Hertwig has seen fit to deal with the matter. From working exclusively at spirit-preserved specimens, this author has been led to reject, as unsatisfactory, Gosse's observations and conclusions, and even to look on the existence of cinclides as "questionable in most cases."—Report on the Actiniaria, pp. 6, 17, and 72.

In all three forms (*Sagartia miniata*, *S. nivea*, and *S. venusta*) I have witnessed acontia being discharged through these perforations as well as through the mouth. I am inclined to think, however, that the supplying of a means of exit for these weapons is not the only function which the cinclides perform. From the fact that the cinclides may be observed open when the animal is at rest and fully expanded, and when they are not being used as loop-holes for the shooting out of acontia, and also from the apparently haphazard way in which, as Gosse himself observed, the acontia, when emitted, issue forth from them, I believe that Louis Agassiz (Comptes rendus, vol. xxv., p. 678) is right in assigning to these perforations a part in the work of providing communication between the interior of the animal and the surrounding water. Writing of the Actiniæ, in general, though his conclusions would appear to be based on observations made in one species, *Rhodactinia dævisii*, L. Agassiz (Comptes rendus, vol. xxv., p. 678) says: "La cavite générale du corps est remplie d'eau, qui y entre par la bouche et l'estomac aussi bien qui par de nombreux pores microscopiques, rangés par series verticales, dans les parois: elle en est expulsée par les tentacules, et par ces mêmes pores." Milne-Edwards (1857, Histoire Naturelle des Coralliaires, vol. i., p. 17) attributes to the cinclides the function of providing means of escape both for the water contained in the animal and for the acontia: "Chez plusieurs Coralliaires on y aperçoit des pores qui établissent une communication directe avec l'extérieur et servent à la sortie de l'eau dont le corps de l'animal est rempli. Le plus ordinairement ces pores sont placés à l'extrémité libre des tentacules, et chez quelques Actinies on voit souvent des petit jets d'eau être lancés par ces ouvertures quand l'animal se contracte. D'autres fois, des orifices analogues sont pratiqués sur les côtés de la cavité viscérale, et traversent de part en part les parois du corps, de façon à livrer passage, non seulement à des liquides, mais aussi aux cordons à nématocystes, qui flottent dans cette cavité."

The occurrence of similar perforations in the physa of Peachia and Halcampa, neither of which possesses acontia, points to the same conclusion. Professor R. Hertwig definitely attributes the function of allowing water to pass in and out to the openings in *Halcampa clavus* (Report on the Actiniaria, p. 97); but, so far as I can discover, he does not identify these openings with the cinclides.

The white spots on the upper portion of the column in *Sagartia miniata*, *S. nivea*, and *S. venusta*, are undoubtedly suckers. I have seen a specimen of *S. nivea* relinquish its hold with its base, and, while fully expanded, attach itself to the glass side of the tank by means of three of these spots; subsequently it contracted, and remained hanging by the three suckers for a considerable time. The weight of the animal thereupon drew the suckers up into sharply-raised and finely-pointed conical papillæ. I have seen Peachia adhere to the glass in a precisely similar way by conical papillæ, which were raised just close under the tentacles; but when Peachia has relinquished its hold, the portion by which it held is externally not distinguishable, to the eye at least, from the rest of the body-wall. In *Sagartia miniata*, *S. nivea*, and *S. venusta*, however, the white spots on the column are the only portions of the body which I have observed exercising this power of adherence. The suckers are scattered irregularly all over the surface of the upper third of the column, being of less size the more nearly they approach to the margin of the disk.[1] They are not, like the cinclides, confined to the spaces between the lines made on the body wall by the insertion of the mesenteries, but may be situated immediately over these lines as well as in the spaces between them. This account of the suckers I have given at the risk of stating again something that is already well known. I have been induced to do so by reading in Professor R. Hertwig's Report on the Actiniaria, &c., p. 16, the following two rather concise sentences: "I have entirely omitted the sucking papillæ in the general description of the anatomy of the Actiniæ, even in forms which are capable of incrusting themselves with foreign bodies. I am the more justified

---

[1] Milne-Edwards (*Histoire Naturelle des Coralliaires*, 1857, vol. i., p. 272) places *Cereus* (= *Sagartia*) *venusta*, under a group, in which "les tubercles verruciformes occupant seulement la région inférieure des parois latérales du corps." But there is no doubt the suckers are in all our Irish specimens much more conspicuous, at least, on the upper portion of the column.

in doubting their existence, as Gosse has given no proof verifying his assertions." Perhaps repeated reiteration may convince Professor Hertwig.

Though Gosse gives *S. miniata*, *S. venusta*, and *S. nivea* as distinct species, nevertheless he twice (Actin. Brit., pp. 42 and 66) admits that they very closely approach one another. Besides those points of similarity mentioned by him, the following may be noticed:—(1). Orange-cored tentacles, which Gosse describes as characteristic of *S. miniata*, may be present also in a specimen of either of the other forms. I have found them in all the Irish specimens of *S. venusta* and of *S. nivea* that I have seen. (2). The same arrangement of the lines which mark the mesenteries on the body-wall is to be found in all three forms, that is, the lines which mark the mesenteries belonging to the outer row of tentacles are continued but a short way down the column from the margin not longer than these tentacles themselves, while those relating to the mesenteries, corresponding to the other rows of tentacles, may be traced throughout the entire length of the column.

On the whole, however, Gosse is, I think, right in keeping the three species distinct. There is less difficulty in keeping *Sagartia miniata* separate from the other two than in keeping them separate from each other. A *Sagartia miniata* has larger tentacles, and those but half as many as a *S. venusta*, or a *S. nivea* of equal size. Its disk is more undulated and generally more overhanging than that of either of the others; so that it comes nearer *Sagartia bellis*, in its form, than they do: it resembles rule, may readily be seen to be arranged twelve in the first and *S. bellis*, too, in the arrangement of its tentacles, which, as a second rows, twenty-four in the third, forty-eight in the fourth, and so on.

In distinguishing *S. nivea* from *S. venusta* the most salient point of difference is undoubtedly to be found in the colours of their respective disks. On this point I can fully confirm what Gosse says (Actin. Brit., p. 66) as to the constancy of the colouring in *S. venusta*. This constancy is the more remarkable, as while specimens of *S. nivea* exhibit on their disks every shade from snow-white to greyish-olive (which constitute the distinguishing colours of Gosse's two varieties, *immaculata* and *obscurata*), yet I have never observed a specimen with anything even approaching to any intermediate tint between these shades and the bright orange of *S. venusta.* The absence of any intermediate condition is especially noteworthy, when we consider that both forms, in many places, grow together in profusion.

In addition to the colour, the dimensions of the two forms will help us in distinguishing them. The height of *S. venusta* is greater than that of *S. nivea*, considered relatively to the diameters of their columns respectively. Moreover, in *S. venusta* the disk is more inclined to be undulate in its outline, and more prone to overspread the column than it is in *S. nivea.* From this it follows, that when the animal is only partially expanded the disk is more concave and cup-shaped in *S. venusta* than in *S. nivea*, under similar conditions.

Dr. Andres' treatment of these forms is indeed remarkable; he keeps the species *miniata* apart, giving it to the genus *Heliactis;* on the other hand, he groups *S. nivea*, *S. venusta*, *S. rosea*, and *S. aurora* (Gosse) together as *Heliactis venusta*, assigning as one of his reasons for so doing the difficulty of finding specific points whereby to keep them separate. Now, on this ground, I could understand either all four forms, *S. miniata*, *S. rosea*, *S. nivea*, and *S. venusta* (the true place of *S. aurora* we shall presently see) being placed together, or *S. miniata* and *S. rosea* being made to constitute one species, for they undoubtedly have close affinities (Gosse, Actin. Brit., pp. 43 and 50), while *S. nivea* and *S. venusta* were relegated to another; but as *S. rosea* has far less in common with *S. nivea* and *S. venusta* than *S. miniata* has, it certainly should not be placed with them, while *S. miniata* is kept distinct. Dr. Andres assigns as his second reason for so grouping these forms the statement made by Mr. George Henry Lewes (Seaside Studies, p. 142), that he saw *S. venusta* change into *S. aurora.* Let us see what are the circumstances on which this rather astounding statement is based.

In the year 1854 Gosse published a Paper (Ann. and Mag. of Natural History, series 2, vol. xiv., page 281) describing three new species of Actinia, with two of which only we are now concerned. They are *Actinia aurora*, which he also named "the orange-tentacled anemone," and *Actinia venusta*, which he called "the orange-disked anemone." Gosse subsequently saw that *Actinia aurora* was only a variety of *Sagartia troglodytes*, and accordingly in his subsequent works so placed it (Actin. Brit., pp. 88 and 90). I have found in the submerged peat at Torquay specimens exactly corresponding to his description of this variety, so that I have no doubt on my own mind that I am speaking of the same form which Gosse so described; and I am perfectly sure it must be placed as Gosse has placed it. Now just before Gosse published his Actinologia Britannica, Mr. Lewes' interesting work, Seaside Studies, which contains the statement we are now considering, appeared. At p. 142 (or p. 150, in the second edition) we find the following passage:—"*Apropos* of this peculiarity of colour [a dark-brown smooth anemone (*Actinia equina* = *A. mesembryanthemum*) giving birth to one faintly striped with green], I may remark on the great variations of colour observable in the colour of anemones, and the impropriety of making colour the distinguishing mark of a species. Thus, to select a striking example, Mr. Gosse makes two distinct species of the orange-disked and orange-tentacled anemones, naming them *Venusta* and *Aurora*; but as if to prove the indifference of all such characteristics, I brought with me from Tenby an orange-disked—and only one—which, before it had been home a fortnight, I discovered, with great surprise, was changed into an orange-tentacled, disk and tentacles being of a rich orange hue, the only traces of white remaining just at the tips. If there had been any other species in the vase I might have doubted; but having only one, in company with a white daisy (*Sagartia bellis*) and a smooth anemone, there was no avoiding the conclusion."

Now what Mr. Lewes observed here was an "orange-disked" turn into an "orange-tentacled anemone," that is, the tentacles of a *Sagartia venusta* lost their characteristic opaque white colour, and assumed the orange colour of the disk. His description of the transformation, as well as the context into which it is introduced, preclude us from believing that the change amounted to anything more than this. But a great deal more than this slight change would have been necessary to turn a *Sagartia venusta* into a *Sagartia troglodytes*, var. *aurora*, as anyone may see by referring either to An. and Mag. of Natural Hist., ser. 2, 1854, vol. xiv., p. 281, where Gosse first described this form, or to the Actin. Brit., p. 90, where he places it in its proper position. I am inclined, therefore, to believe that the reasons given by Dr. Andres for placing *S. aurora* along with *S. venusta* must be considered insufficient. Pennington (British Zoophytes, 1880, p. 151) blindly follows Dr. Andres; but as he adduces no fresh grounds for the classification which he adopts, his arrangement calls for no further remarks. Professor Haddon, to whom I am indebted for many valuable hints in this Paper, has authorized me to say that notwithstanding what he has previously written (Proc. Roy. Irish Acad., ser. 2, vol. iv. (Science), p. 527; Zoologist, ser. 3, vol. x., p. 6), he believes it may be better, for the present, to retain *S. venusta* and *S. nivea* as separate species, and inclines to think that the genus Heliactis cannot stand.

XV.

ON THE MEASUREMENT OF SMALL PRESSURES. By PROFESSOR GEORGE FRANCIS FITZGERALD, M.A., F.R.S., F.T.C.D.; and J. JOLY, M.A.

[Read April 18, 1888.]

The difficulty in measuring small pressures is not on account of the smallness of the forces concerned: a pressure of the millionth of an atmosphere is about the weight of a milligram per sq. cm., and this on any considerable area is quite a large force compared with the weights measured every day in balances. The difficulty arises from its being so hard to make the surface pressed on freely movable. We may use fluids in tubes—in horizontal or nearly horizontal tubes, for instance—but the sticking of the surface of the liquid and the tube, due to capillarity, which becomes serious on account of the necessity for using small tubes, if the liquid is to stand with free surfaces nearly at right angles to the tube, when it is nearly horizontal, has seriously interfered with this method of observation. Herr Toppler has recently used a liquid in the bend of a tube bent at a very obtuse angle, and has observed the motion of the surface by means of a microscope. This method seems capable of considerable accuracy. The capillary sticking might be entirely obviated by making the tube large. To whatever extent it exists it would generally diminish the effect of pressure, and its irregularity of action would introduce an unnecessary uncertainty into the measurement. In the case of water, the difference of level due to a pressure of the millionth of an atmosphere is the hundredth of a mm., an amount that can be easily measured by means of a microscope. A float on the surface with a fine mark attached would be a convenient object to observe with the microscope. The difficulty in this case is to keep the float steady, but it could probably be anchored at the junction of two crossed spider lines, or by suspending part of its weight by a stretched spider line. With a pretty large float—and there is no reason in many cases why it should not be large—there would be plenty of force to turn a light mirror; and so a spot of light, instead of a microscope, might be used to observe changes in the level of the liquid. A method depending on changes in the position of Newton's rings might also be used. In all methods when liquids are used the vapour pressure of the liquid is one of the great difficulties in measuring the pressure of the rest of the gas, and can only be reduced by using liquids that have a very small vapour pressure. In some cases we can practically get rid of it by only opening temporary communication between our measuring apparatus and the gas, whose pressure we wish to determine, and not allowing time for any serious amount of diffusion to take place. At very low pressures, as the flow of gas through even relatively large tubes is of the nature of diffusion, a great additional difficulty is introduced.

Another method of measuring very small pressures is to observe the position of the centre of a flat elastic membrane when subject to a difference of pressure at its opposite surfaces. A flat film of indiarubber, such as is used in toy balloons, stretched across a circle 5 cm. in diameter, can easily show, when observed by a microscope, a difference of pressure of the millionth of an atmosphere. The very smallest difference of pressure will move a flat film, and thin flat films of glass can be made which can be moved by very small pressures. There is an objection to using inextensible films like glass because of the uncertainty as to what point moves most, but there is a great advantage in their non-liability to diffusion or evaporation, both of which faults exist in indiarubber films. We have not made sufficient experiments on glass films to speak with any degree of confidence as to their being capable of measuring such small pressures as the millionth of an atmosphere. If a lens were placed near them, and displacements of Newton's rings observed, it seems most likely that a very much less pressure could be detected. Of course soap-bubble films might in some cases be employed, though they are liable to all the faults of indiarubber films and to others of their own, such as the difficulty of attaching a suitable pointer to be viewed through the microscope, their want of permanence, especially if vertical, and the danger of dust, liquid, &c., deflecting them if they are horizontal. An aneroid barometer is practically a film such as we are suggesting, and one on a large scale observed with a powerful microscope would probably be a very efficient measurer of small changes of pressure. A film of this kind which had sufficiently little rigidity to be deflected by a very small change of pressure would not in general be strong enough to support high pressures, and if a column of liquid be added on top of it to assist it the surface may not be in stable equilibrium. For instance, if it is attempted to get over the difficulty of the evolution of hydrocarbons by indiarubber, and the facility it offers for diffusion by pouring a liquid on top of the film and increasing the air pressure below, so as to keep the film flat, it will be found that the film is no longer stable, but buckles up in some places and down in others. If the pressure below be not sufficient, the liquid gradually extends the indiarubber until it bursts it. By choosing the right pressure for the air below it would be possible to have the film just near the point of neutral equilibrium, and then any very small change in the pressure would make a considerable one in the position of the film. Stretched films of indiarubber are, however, a nuisance to work with, they tire so rapidly.

A third method of measuring small pressures accurately is by a plan which is practically the same as the balanced barometer tube. If a bell glass be turned over into a liquid, any small change of pressure in the air inside produces a corresponding force on the glass, and if it be attached to a balance this change in pressure may be readily weighed. As this pressure varies as the area of the surface of liquid enclosed, and the capillarity only varies as its perimeter by making the vessel large, the relative effect of capillarity may be made very small. The only difficulty in this method arises from the very small range of motion of the suspended vessel. In the case of water being the liquid, the motion of the suspended vessel would only be the hundredth of a millimeter for the millionth of an atmosphere; but this should be quite easily detected by means of a microscope, or a movable mirror, or Newton's rings. This method is liable to the objection that a liquid with a possible, though perhaps small, vapour pressure is present. Another objection to liquids which have necessarily horizontal surfaces is the danger of their absorbing gases superficially, and so changing in density. The only one of these methods that is quite free from all these objections is the one depending on the use of large, flat, thin glass or metal films.

There are several uses to which these methods of measuring small pressures may be put. One of the most important is the determination of the densities of gases by balancing columns of them against one another. This method of measuring the density is quite independent of condensation of the gas upon surfaces which introduce such difficulties into balloon and displacement methods. Mr. Joly has suggested it as a method of measuring high temperatures by measuring the density of a known column of air heated to the high temperature. For these purposes, the indiarubber film, we believe, can be got to work satisfactorily. It need only be used as an indicator, to show when the pressures on its two faces are equal. The change in pressure can be measured by a known small compression of the air at one of its faces. Mr. Joly has made some experiments on the possibility of using a horizontal column of dusty air as an indicator to show whether two columns of gas balance one another, but his results were not very encouraging. This method, or one depending on the blowing about of fine fibres, such as silk, cobwebs, &c., is, however, we believe, capable of being used to determine when the pressures in two vessels are exactly equal.

One of the most desired measuring instruments at present is one by which it may be possible to measure very small pressures accurately when the total pressure is very small. The M'Cleod gauge is almost the only apparatus at present in use for this purpose. It has obvious objections. It is doubtful what exactly its indications mean. To what extent is there condensation of gas on the surfaces? To what extent does the mercury vapour condense? The presence of other condensible gases is fatal to its indications.

Some apparatus such as we have sketched out might be used instead of the M'Cleod gauge; but, of course, none of them can ever tell us when we have attained to a perfect vacuum. We must be content to compare pressures with that in some standard vacuum: it is evidently impossible by any methods such as we have been proposing ever to measure absolute pressure; we can only by these means measure differences of pressure, and so we can only compare one vacuum with some standard vacuum, such as a potash vacuum, which we provisionally take as a standard.

Note.—During the discussion on this Paper, Mr. Vereker suggested mica as suitable substance of which to construct films.

XVI.

ON THE CONTROL SUPPLY-PIPES HAVE ON REEDS.

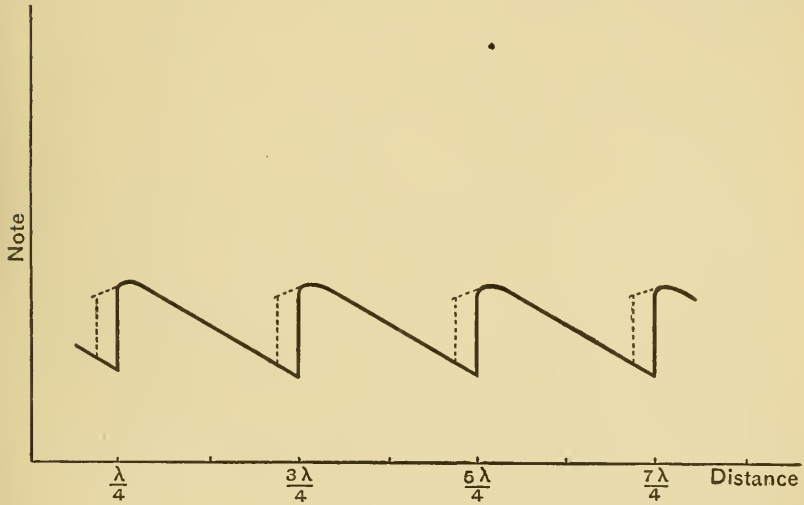
By FREDERICK T. TROUTON, B.E.

[Read April 18, 1888.]

If a free reed be supplied with air through a long tube it will in most cases be found difficult, often impossible, to get it to sound, especially if the pitch be low. The introduction of a bulb on the tube just before the reed generally prevents this effect to a large extent, and allows the reed to sound more or less freely. It is equally efficacious to have the bulb connected at right angles on one side of the tube where the current of air does not pass through it. The first explanation which suggested itself was, that to keep up the supply a reservoir of air near the reed was necessary, such as the mouth presents when the reed is blown directly, or the air chamber of the various musical instruments in which reeds are employed. This idea was next found to be untenable, for a tube of much larger volume than the bulb was attached to one side without preventing the effect of the long tube.

It was then suspected that the vibration period of the mass of air attached in this way was important. To test this, close to the reed a glass tube was attached at right angles, the effective length of which could be varied by means of a piston. It was then found that this tube had control over the vibrations of the reed; for as the piston was moved up and down the glass tube, at definite places, of equal distances apart, the reed sounded quite freely, and at places half-way between these it would not sound, while in intermediate positions the note was more or less lowered according to the position of the piston. The distance between these recurrent positions was found to be always about half the wave length of the note of the reed employed; there was, however, some difficulty in determining the exact position of these points, for it was found that any point within certain limits had pretty much the same effect. The position of the piston when the reed first sounded freely was about one quarter of a wave length from the reed.

With reeds of different pitch slightly different results were obtained. When the note of the reed employed was low, the piston in the control tube required to be much nearer to the definite positions, in order that the reed might sound, than for higher notes. When a reed of moderate pitch (about 650) was used it was observed to act as follows:—When the piston was in the whole way, the control tube, of course, had no effect, but when drawn out some little distance the reed commenced to sound a lower note than when free. As the piston receded the note suddenly rose to nearly that of the free reed, which it attained a little further at a point a



little short of a quarter of the wave length from the reed. From that on the note fell, until, when half a wave length from the last place, it suddenly rose again, and, as before, when the piston was slightly short of three quarters of the wave length, the reed sounded freely, and so on in order to the end of the tube. The diagram is intended to roughly represent this. The distance along the control tube is here marked in quarter wave lengths, beginning at a point a little outside the reed. The ordinates represent the number of vibrations per second. When the piston was moved in the opposite direction, as might be expected, the sudden fall in pitch occurred at points nearer to the reed than where the rise had taken place on going outwards. This is represented by the dotted part. The diagram for a lower reed would consist of only short portions of the higher parts of the curve, the reed only sounding at the corresponding positions of the piston in the tube.

On putting cork dust into the side tube, Kundt's figures formed themselves, and made it plainly visible to the eye what was occurring as the piston was pulled out. The dust was seen to keep collected in a heap behind the piston until the pitch of the reed rose for the second time, when, of course, there were two heaps formed, and so on as the piston was withdrawn. At first, when the lower note was sounding, evidently the half wave was situated partly in the control tube and partly in the supply tube, the reed being between the loop in the supply tube and the node in the control tube. When sounding freely the reed was practically at a loop, and remained so as the piston was drawn out, the distance to the first node in the control tube varying.

One of the advantages in using resonating side tubes, in studying vibrations in tubes carrying air currents, is, that Kundt's figures can be employed to show to the eye what is going on, the dust not being blown away, as it would be if put into the main tube.

Experiments were next made as to how the length of the supply tube affected the reed. The reed was fixed to the end of a glass tube, and this in turn to a narrower rubber tube. It was found that there was always a tendency for a node to form at this point. When the glass tube was a quarter of a wave length long, or shorter, the reed sounded freely, but if longer, the pitch of the reed was diminished, or ceased altogether; but when a tube of three-quarters of a wave length was used, the reed vibrated freely again, and so on.

From all these experiments it would appear that a reed vibrates most freely near a loop; but the fact that Helmholtz,[1] in his theory of reeds, deduced that they ought to be found at a node, made it of importance that a more careful examination of the case should be made. So to further test the position of the reed with respect to the nearest node when sounding freely, the control tube was inserted at right angles as before in the supply pipe, but at a dis-

[1] Jamin, *Cours de Physique*, tome iii., fas. i., p. 56.

tance of one quarter of a wave length from the reed. Now when the piston was placed at one quarter of a wave length along the tube the reed would not sound, but when it came near a half wave length the reed sounded freely, as it had done at one quarter of a wave length in the previous experiment, when the control tube was inserted at the reed, thus showing that when the reed sounded freely the point at one quarter of a wave length from the reed was a node, and that the reed must be at, or at least nearly at, a loop, as was before determined.

Experiments were made with a beating reed (the one used was a bassoon reed) to see if it were at a node under similar circumstances, the theory perhaps referring more especially to them; but as far as the experiments went it appeared always to be at least as near to a loop as a node, generally much nearer. However, these experiments were open to considerable uncertainty as to their meaning, as Professor FitzGerald pointed out, for in this case it is probably insufficient to consider only the vibrations taking place in one dimension. From these experiments it is obvious how a long supply tube often can prevent a reed from sounding freely. For the tube must be of such a length as to break up into the right number of vibrating segments, so as to agree in period with what the reed can sound, and also so as to have the reed near to a loop. It is easy to see that with a long tube of given length these conditions are not so likely to be fulfilled in the case of a reed of low pitch as in that of one of higher pitch; for when the length of the tube is many times that of the half wave length—even if there should be the maximum discrepancy between the nearest number of half wave lengths and the tube—a small percentage lengthening in the half wave length, to which a reed can always alter itself, will allow of the reed sounding, the note, of course, being slightly lower. The corresponding change in pitch required in the case of a low-pitched reed might easily be so great that the reed could not possibly sound a note so much lower than its own. Besides this, in the case of low notes, even when the pitch is such as to admit of the necessary agreement between the wave length and the tube, the tendency of long narrow tubes when sounding low notes to break up into harmonics makes it often almost impossible to get the reed to sound.

XVII.

ON THE ARRANGEMENT OF THE MESENTERIES IN THE GENUS *SAGARTIA*, GOSSE. BY FRANCIS DIXON. (PLATES I. and II.)

[Communicated by PROFESSOR A. C. HADDON.]

[Read April 18, 1888.]

THE following investigations were undertaken to try to explain a fact which had been observed by my brother (*antea*, p. 111), that some species of Gosse's genus *Sagartia* possessed sometimes but a single œsophageal groove.

When considered in connexion with the current opinion that a hexamerous arrangement of mesenteries prevails in all the more common Actiniæ, the results arrived at were more surprising even than might have been expected from the variability in the number of œsophageal grooves. For it was found that not only the number of pairs of directive mesenteries varied as the number of grooves, but that the number of perfect mesenteries reaching the œsophagus varied in each case, apparently with the size of the specimen examined, a completely hexamerous arrangement being, in most cases, not recognizable. The only regularity common to all the specimens examined was that just mentioned, viz. that the number of pairs of directive mesenteries corresponded to the number of œsophageal grooves. In most cases the number of mesenteries reaching the œsophagus near the oral disk was considerably greater than lower down near the base of the œsophagus. In all the larger specimens, at all events, the œsophageal ridges corresponded to the lines of insertion of the mesenteries; and, as my brother has pointed out that the œsophageal ridges correspond to the radii on the disk, it would seem that the radii on the disk mark the position of the mesenteries. Whether the arrangement of the mesenteries is at first regular, and if so, how it afterwards becomes irregular, it is impossible to say at present, owing to an insufficient number of specimens of different ages having been examined.

This is merely a preliminary notice; and I hope to be able, at a future date, to lay before the Society an account of the arrangement of the mesenteries in these Actiniæ at different ages, and thereby possibly to throw some light upon the apparently anomalous facts here recorded.

I am indebted to Professor Haddon for much valuable assistance in making these investigations, which, by his kind permission, were carried on in the Zoological Laboratory of the Royal College of Science, Dublin.

Sagartia venusta, Gosse.

The arrangement of the mesenteries was examined in three specimens of *Sagartia venusta*, two of which were collected by Professor Haddon, at Valentia, county Kerry, while the third was obtained by myself at Dalkey Island, county Dublin.

Specimen *α* (Valentia).—This specimen had but a single œsophageal groove and a single pair of directive mesenteries. The groove was much more marked in this than in either of the two following specimens. Near the oral disk twenty-five, or perhaps only twenty-four pairs of mesenteries reached the œsophagus. Alternating with these were twenty-five pairs of very minute mesenteries. Lower down the number of mesenteries reaching the œsophagus was reduced to twelve pairs, these twelve remaining perfect to the base of the œsophagus.

Specimen *β* (Valentia).—This was the only specimen in which the arrangement of the mesenteries was quite regular. There were two œsophageal grooves, and two pairs of directive mesenteries. In the neighbourhood of the oral disk twenty-four pairs of mesenteries reached the œsophagus, in the spaces between which were developed twenty-four pairs of small mesenteries, and alternating with these and those reaching the œsophagus were forty-eight pairs of still smaller ones. Lower down, the number of mesenteries reaching the œsophagus was reduced to twelve pairs. These remained perfect throughout the whole length of the œsophagus. In this specimen the œsophageal ridges plainly corresponded to the points of insertion of the mesenteries.

Specimen γ (Dalkey Island).—This specimen had two œsophageal grooves and two pairs of directive mesenteries. Near the oral disk twenty-nine pairs of mesenteries reached the œsophagus —thirteen pairs on one side, between the œsophageal grooves, and fourteen on the other. Alternating with these were twenty-nine pairs of small mesenteries. Lower down, the number of mesenteries reaching the œsophagus was reduced to sixteen pairs. These remained perfect the whole way down to the base of the œsophagus. In this specimen also the œsophageal ribs corresponded to the points of insertion of the mesenteries.

Sagartia miniata, Gosse.

The arrangement of the mesenteries was also made out in three specimens of *S. miniata*, all obtained at Dalkey Island. Of these three, two were rather small, while the third was an average-sized specimen.

Specimen *a* (Dalkey Island).—This specimen had no well-marked grooves, but two pairs of directive mesenteries were plainly visible. Altogether, six pairs and one odd mesentery reached the œsophagus. The odd mesentery was situated next one of the pairs of directives, with its longitudinal muscle turned in the same direction as those of the mesenteries on each side of it. In each intermesenteric chamber, except in that one in which the odd mesentery was, a pair of very small mesenteries was present. Here also the œsophageal ridges corresponded to the mesenteries reaching the œsophagus.

Specimen β (Dalkey Island).—This small specimen had a single œsophageal groove and a single pair of directive mesenteries. Seven pairs of mesenteries in all reached the œsophagus.

Specimen γ (Dalkey Island).—This specimen had a single œsophageal groove, and a single pair of directive mesenteries. Near the oral disk fourteen pairs of mesenteries joined the œsophagus ; lower down the number was reduced to ten pairs. It was only quite close to the oral disk that the œsophageal ridges were well marked. There were a good many small mesenteries apparently irregularly developed in the intermesenteric chambers.

Sagartia nivea, Gosse.

In two specimens of *S. nivea*, obtained at Dalkey Island, although the exact arrangement of the mesenteries was not made out, it was certain that in one, at least, sixteen pairs were perfect throughout the whole length of the œsophagus, and in the other twelve pairs. Each had but a single pair of directive mesenteries.

In a third specimen from Dalkey Island, which also possessed a single groove and a single pair of directive mesenteries, twenty-five pairs of mesenteries reached the œsophagus near the oral disk; alternating with these were twenty-five pairs of small mesenteries. The arrangement of the mesenteries in this specimen was quite similar to that in the first specimen of *S. venusta*, described above.

Sagartia rosea, Gosse.

I have had an opportunity of examining a single specimen of this Actinia, which was kindly sent to me from Valentia by Mr. W. De V. Kane. It had but a single œsophageal groove, and a single pair of directive mesenteries. In it twelve pairs of mesenteries were perfect throughout the whole length of the œsophagus.

Professor R. Hertwig [(1882) "Challenger" Report on Actiniaria, p. 70] states of the *Sagartidæ*, that they all possess acontia, and that in all of them six pairs of principal mesenteries alone are perfect, none of the others reaching the œsophagus. He goes on to say that in no instance where acontia are present is the differentiation of mesenteries wanting. The only exception to his definition of the family of which he takes any notice is *S. troglodytes*, which, he says, Heider had described as having forty-eight pairs of perfect mesenteries. This exception he explains away by attributing it to Heider's having mistaken sections through the oral disk for sections through the œsophagus. Having thus got rid of the only exception which he knew where the mesenteries did not conform to what he called the typical Sagartid arrangement, Professor Hertwig confirmed himself in his opinion by remarking that the family *Sagartidæ*, as he had defined it, would correspond, on the whole, with Gosse's *Sagartidæ*.

From the foregoing account it will be seen that four species belonging to this family, and even to the genus from which it gets its name, possess more than six pairs of perfect mesenteries.

Heider (Sitzungsb. d. k. Akad. d. W., Math. Nat., Cl. lxxv., Bd. i., Abth. 1887) describes and figures sections both through the oral disk and through the œsophagus of *S. troglodytes.* He classifies the mesenteries into seven orders, the first of which is composed of twelve pairs, the second of twelve, the third of twenty-four, and so on. In his description and figure of a section through the œsophageal region, he makes the mesenteries of the first, second, and third orders — forty-eight pairs in all — join the œsophagus. Although he figures neither œsophageal grooves nor directive mesenteries, yet it is certain that the section has passed through the œsophagus, and not through the oral disk, as Professor Hertwig suggests, both from the presence of the œsophageal ridges, and from the character of the epithelium. Further, in two small specimens of this Actinia, obtained at South Devon, the arrangement of the mesenteries was found to be as follows:—both possessed two pairs of directive mesenteries; in the smaller specimen, near the oral disk, eight pairs of mesenteries reached the œsophagus; lower down, however, the number was reduced to six pairs; in the larger specimen, which was however considerably smaller than the average size attained by this species, twelve pairs of mesenteries were perfect throughout nearly the whole length of the œsophagus. It is certain, therefore, that the adult *S. troglodytes* possesses more than six pairs of perfect mesenteries.

Acontia are known to be present in *S. troglodytes*, *S. miniata*, *S. nivea*, *S. rosea*, and *S. venusta*, so that in these five Actiniæ we have the presence of acontia unassociated with the special arrangement of mesenteries, which Professor Hertwig claims for the *Sagartidæ*.

Gosse's original genus *Sagartia* contained some species which have been since removed from it; but he himself (Actinologia Britannica, p. 127) stated that if at any time the genus should be broken up, he would retain the name *Sagartia* for the most typical group which contains *miniata*, *rosea*, *ornata*, *ichthyostoma*, *coccinea*, *venusta*, and *nivea*. Before Gosse had suggested this limitation of the term, Milne-Edwards (1857, Histoire Naturelle des Coralliaires, vol. i., p. 273) considered that Gosse had applied the name *Sagartia* to species too widely differing to be grouped together, and proposed that *S. venusta* should be made the type of a genus which should retain the name *Sagartia.* The close affinities existing between *S. miniata*, *S. nivea*, *S. rosea*, and *S. venusta*, show that these forms, at least, must be referred to a single genus, and the laws of priority in nomenclature compel us to keep for this genus the name *Sagartia.* But these four species have been shown to have an irregular number of numerous perfect mesenteries, and therefore cannot be included in the family *Sagartidæ*, as re-defined by Professor Hertwig; so that if we give the name *Sagartidæ* to Professor Hertwig's family, we shall have to exclude from it the genus from which it gets its name.

As this step is inadmissible, it is clearly necessary either to extend Professor Hertwig's definition so as to include the genus *Sagartia* as above limited, as well as the genera with the arrangement of mesenteries discovered by Professor Hertwig, or else accepting his definition to change the name, leaving the term *Sagartidæ* for that family which will include the genus *Sagartia.*

[Explanation of Plates.

EXPLANATION OF PLATES.

Plate I.

Fig. 1.—Diagram of a transverse section through the upper portion of the œsophageal region of *S. venusta*. Specimen γ.

Fig. 2.—Diagram of a transverse section through the lower portion of the œsophageal region of *S. venusta*. Specimen α.

Fig. 3.—Transverse section through the middle of the œsophageal region of *S. venusta*. Specimen α.

Fig. 4.—Diagram of a transverse section through the lower portion of the œsophageal region of *S. venusta*. Specimen β.

Fig. 5.—Transverse section through the upper portion of the œsophageal region of a specimen of *S. nivea*.

Plate II.

Fig. 1.—Transverse section through the œsophageal region, near the oral disk of *S. venusta*. Specimen β.

Fig. 2.—Transverse section through the lower portion of the œsophageal region of *S. venusta*. Specimen γ.

Fig. 3.—Transverse section through the middle of the œsophageal region of *S. miniata*. Specimen γ.

Fig. 4.—Diagram of the arrangement of the mesenteries in *S. miniata*. Specimen α.

Fig. 5.—Diagram of the arrangement of the mesenteries in *S. miniata*. Specimen β.

Fig. 6.—Transverse section through a small specimen of *S. troglodytes*, taken near the oral disk.

XVIII.

SLATES AND CLAYS OF IRELAND (BRICKS, ETC.). BY G. H. KINAHAN, M. R. I. A. WITH INTRODUCTION AND BUILDING NOTES BY R. CLARK.

[Read January 18, 1888.]

PART II.—THE CLAYS OF IRELAND (BRICKS, ETC.).

THE Irish Clays to which attention will be directed are: *Alumite*, or Alum Clay: *Diatomite*, or Diatomaceous Clay; *Fire-clay*, *Porcelain*, or China-clay; *Fuller's Earth*, *Pipe*, *Potter's*, and *Brick-clays*.

The *Alumite* occurs as a subordinate in the Tertiary *Iron-measures*, Co. Antrim; it is used in the manufacture of alum, &c. (vol. v., p. 251).

Diatomite[1], when of good quality, is nearly pure silica, being made up solely of diatoms; it is now used in the manufacture of dynamite to mix with the nitro-glycerine. It usually occurs as an accumulation under, or associated with, peat, in bowl- or saucer-shaped hollows. Lately it has been discovered in a number of places in North Scotland, but as yet, in Ireland, it has only been found in the valley of the Bann, Cos. Londonderry and Antrim (page 147).

Fire-clay is recorded in the different coal-fields and tracts of coal-measures. In the Co. Tyrone (*Coal Island* and *Annaghone*) it occurs in quantity, and of excellent quality (page 164). In the Leinster coal-fields, also, as pointed out years ago by Griffith, it is plentiful and good; but for some unknown reasons it never appears to have been utilized. In the Connaught coal-fields, where the quantity is less and the quality inferior, it was for a short time manufactured into bricks and other fire-ware; but there are no records

[1] NOTE ADDED IN THE PRESS.—More recently, on account of the quantity of silicia it contains, it has been proposed to be used in the manufacture of fire-resisting cases for metal pipes, &c., specimens of which are exhibited in Glasgow at the present time (June, 1888).

of the fire-clay having been used elsewhere, except very locally for the lining of hearths.

A steatitic clay, the "back," or weathered portion of the beds of pure phyllite and intrudes of steatite, is also used for hearths and the lining of forges (vol. v., p. 254).

An unctuous clay, called *Doab* in Connaught, occurs in places in the granitic and metamorphic areas of Galway, Mayo, Donegal, &c. It is very commonly used for making floors and for mortar; while from some of the purer varieties whitewash can be made.

Porcelain, or *China-clay*, or *Kaolin*.—A clay due to the decomposition of very felspathic rocks; it may occur as a surface accumulation, or as the weathered portion of a felspathic dyke or intrude, or it may be artificially made. Baron von Richthofen has proved that Kaolin is manufactured by the Chinese from petrosilex or granulite; its name was derived from "Kaolin," *anglice*, "Low ridge," the name of the hill on which the China-clay was originally manufactured. The name is now applied promiscuously to the artificial and natural clays.

At *Kilranelagh*, near Baltinglass, Co. Wicklow, kaolin of a fine quality has been obtained; at Tullow, Co. Carlow, there is a porcelain clay, but partially impregnated with iron; while a little S. E. of Westport, Co. Mayo, a decomposed petrosilex forms a dyke of kaolin. Lewis mentions "clay fit for porcelain and every other description of earthenware" as having been sent from Mayo to England, but he does not mention the locality where it was procured. The Ballymanus dyke, Co. Wicklow, is a silicious kaolin. In different places there are felspathic rocks suitable for the manufacture of porcelain clay. Near the sea, in the country south-westward of Roundstone, Co. Galway, there are dykes of very pure felsite, suitable for kaolin manufacture, while in the same county, near the city and in other places in the vicinity of Galway Bay, are very pure leptinites and other felspatic rocks. At Belleek, Co. Donegal, kaolin is manufactured from a pink orthoclase; this is kept for the finer ware (*Belleek ware*), while the clay for the delf and common wares is made from imported stone.

In the Co. Wicklow, in the vicinity of the Ovoca mines, and in other places, there are very pure felsites and leptinites. Attention was directed to these years ago by Weaver; but as yet they have not been utilized. The water power of the Ovoca and of the smaller rivers might easily be applied to the crushing and grinding down of these stones into kaolin.

Fuller's Earth is probably a product of the decomposition of basic igneous rocks; it may occur as a dyke, as in places in North-West Galway, or as beds, or accumulations associated with the drifts. Formerly Fuller's earth was very extensively used for thickening cloth; but this is now done by other means, and the clay trade has consequently died out, it being used only by some of the country folk.

Pipe-clay is more usually found among the drift deposits, but in the Cos. Tyrone and Tipperary beds of it occur in older geological formations. The pipe-clays of these counties were more used formerly than they are at present. The Tipperary clay was at one time exported to England to be manufactured into "cups and saucers, and all the finer kinds of wares."—(G. S. M.). There seems to have been, in former times, a considerable trade in tobacco-pipe making in Dublin, Cork, Athlone, Brosna, near Roscrea; Cahir, in Co. Tipperary, and other places; but now this trade has greatly decreased, except in Dublin, and perhaps Cork.

Potter's Clay and *Brick-clay.*—These are more or less similar; the finer varieties being called Potter's clay, or even Pipe-clay. They occur more or less scattered over the country in patches and beds associated with the surface accumulations, but vary very much both in quality and quantity. They also occur as subordinate beds in some of the series of rocks, such as the Fire-clays in the coal-measures; the marls in the Trias; and the Alumite, Lithomarge, and Bole in the Tertiary Dolerites. These older clays, except the Alumite, have been very little utilized; but lately at Kingscourt, on the confines of Cavan and Louth, an excellent brick has been made from the Trias clays; and as this class of clays is also found in other places in Ulster, a similar trade might be started in other localities. Some of the shales in the Lower coal-measure are easily reduced into clay, excellent for brick-making, yet we only know of one place, viz. Cashel, Co. Tipperary (p. 164), where this has been done. There are also the "spoil banks," or waste heaps, at the different slate quarries; the material in general, if ground down, being eminently suited for brick-making. The removal of such heaps would not only be a source of profit, but it would be also of great benefit to the quarries to clear away the heaps that are now so much in the way, and cause such additional expense. There would be every facility for such a trade in connexion with the slate workings in the vicinity of the Suir, to the westward of Waterford, as fuel could be brought and the brick sent away in boats.

Many of the Irish facing bricks are panelled, and a few like those of Castle Espie, Co. Down, and Courtown, Co. Wexford, are perforated. Perforated bricks cost less for carriage, but are not as lasting in face-work as the solid brick, damp and frost making their way into the perforations, thus making the bricks liable to moulder away.

The prices of bricks, especially in the country places, change so rapidly, according to the time of year and demand, that it is impossible to give them accurately. Even in Dublin at one time they may be much higher or lower than they were a few months previously; we have tried to give a fair average; our estimate, however, may be, for some places, too low.

ANTRIM.

Alumite, or Alum Clay.—This occurs as one of the members of the Iron Ore-measures in the Tertiary Dolerites. It has been already mentioned and described in the first Paper of the series on Irish Metal Mining (vol. v., pp. 251 and 261).

Diatomite, or Diatomaceous Clay.—The only Irish localities for this clay at present known are those in the Cos. Antrim and Down in the alluvium of the Bann Valley, to the northward of Lough Beg; it being locally known as "Bann Clay."

Bann Clay occurs on the north of Lough Beg, where it is mixed with grey stiff clay for the manufacture of bricks. Between Lough Beg and Portglenone it is from four to five feet deep, and is applied to similar purposes. At Annaghcrew, north of Portglenone, it is only one foot thick; but further northward, south of Portna, it has increased to two feet. Still further northward it is again found along the narrow flat north of Kilrea, and can be traced as far north as Ballynacree House. At New Row, where there are brick works, it is four feet thick, and lies on five feet of peaty clay—(G. S. M.). This clay is brownish-grey in colour, weathering white. It is nearly pure silica, being made up almost entirely of the shells of Diatoms. ("Guide to Belfast," &c., by *Belfast Naturalists' Field Club*, p. 73.)

At the present time the sole use it is put to is to mix it with clay to burn into bricks of an excellent quality. It is, however, evidently capable of being more profitably employed. For some time dynamite was manufactured with silicious clay imported from the Continent; but rather recently diatomite, or diatomaceous clay was discovered in Scotland, and since then its presence has been proved in various places, which has led to the introduction of a new and profitable industry. The "Bann Clay" is apparently equal to many of those Scotch clays, and superior to others; it may therefore be suggested that here probably there is a valuable source of profit at present unknown.

BRICK CLAY is found in several places within the county, and manufactured. Bricks are made in the neighbourhood of Antrim, 16*s*. to 25*s*. per 1000, $8\frac{3}{4}'' \times 4'' \times 3''$, weight 6 lbs; in many places within four miles of Ballycastle, 15*s*. to 20*s*., $8 \times 3\frac{1}{2} \times 2\frac{1}{4}$ and $9\frac{1}{4} \times 4\frac{1}{4} \times 3\frac{3}{4}$, weight 6 lbs.; near Ballymoney, $8\frac{1}{4} \times 3\frac{1}{4} \times 2\frac{1}{4}$, weight 4 lbs.; in the vicinity of Larne, 24*s*., $9 \times 4 \times 3$, weight $6\frac{1}{2}$ lbs.

Bricks are made in great quantities near Belfast; the best coming from Haypark Works, Ormeau-road, size $9 \times 4\frac{1}{2} \times 3$, 30*s*. to 35*s*. per 1000. Demand very brisk; works over twenty-five years old.

The fire-bricks in use in Belfast and other places are from Glasgow, 55*s*. per 1000.

For the following information in connexion with Belfast, &c., we are indebted to *Mr. William Swanston.*

BELFAST.

(*Cos. Antrim and Down.*)

CLAY PIPES.—One of the so-called "Dane pipes" was found in an ancient carn on Scrabo Hill, associated with Roman remains, and silver coins with Hiberno-Danish characters of about A.D. 1017. Both the pipes and the coins are supposed to be of much later date than the carn. "Dane pipes" have also been found elsewhere, as in the excavations for the main sewer, High-street, Belfast, in Carrickfergus, in Dromore, in Lisburn, and in Larne. They are found near the surface, or in connexion with old buildings. The place or places where they were made are unknown. At present in Belfast there are about five manufactories on a small scale, the clay being imported from Devonshire.

Pottery.—In Dr. Molyneux's "Tour in the North of Ireland," 1708, we find, "Here we saw a very good manufacture of earthenware, which was nearest to delft of any made in Ireland, and really is not much short of it. It is very clear and pretty, and universally used in the North, and I think not so much owing to any peculiar happiness in the clay, but rather to the manner of testing and mixing it up." On the map of Belfast, 1791, there are two distinct factories marked "Pottery and China Manufactory." According to George Benn, "History of Belfast" (1877, p. 355), these manufactories were relinquished in 1799. It is not known where the clay was procured.

Old bricks are found in Carrickfergus and Dundrum Castles, but they appear to be much more recent than the original structures. They are much smaller than those now in use, and tradition says they were imported from Holland in the reign of William III. At the present time in the neighbourhood of Belfast, and elsewhere in the Cos. Antrim and Down, bricks, flooring-tiles, ridge-tiles, drain-tiles, and such like, also flower-pots, are manufactured, generally from the washed "Till," but also from the clays of the Keuper marls. In all cases the presence of clay in a suitable position is the main desideratum in establishing works. It has been the custom in the neighbourhood of Belfast to take ground likely to come in soon as building sites, and make bricks on the spot.

ARMAGH.

Potter's Clay is mentioned by Lewis (1837) as found in this county; but no locality is given.

Pipe-clay of a good quality, and in a stratum 41 feet thick, is said to have been got at a depth of 30 feet when sinking a well a little west of Ardress House.—(G. S. M.)

Very good red Bricks are made in various places in the vicinity of *Armagh*, 20*s*. to 25*s*. per 1000, $9\frac{1}{2} \times 4\frac{1}{2} \times 3$; while those made in the vicinity of Lurgan are inferior, 25*s.* per 1000, $9 \times 4\frac{1}{4} \times 2\frac{3}{4}$, weight, 7 to 8 lbs.

Along the river Callan, eastward of Moy, a greyish-whitish brick-clay occurs.

CARLOW.

Most of the so-called Carlow bricks are made in the Queen's Co., in the county west of the Barrow. (*See* QUEEN'S Co., p. 162.)

Kildavin, near Newtownbarry, "worked into various articles of pottery, which find a market not only in the neighbourhood, but in Kilkenny and Waterford."—(G. S. M.)

FIRE-CLAY.—(*See* KILKENNY, p. 157.)

CAVAN.

POTTER'S CLAY occurs in nearly every townland in the N. W. of the county; and some of it is of the best and purest kind (*L. D.*). Sir Charles Coote, in the Statistical Survey, 1801, directs attention to the potter's and brick-clays.

Patches of BRICK-CLAY producing bricks of the most durable quality are also common. Bricks are made in different places within three miles of *Bailieborough*, 25*s.* to 30*s.* per 1000, $9 \times 4\frac{1}{2} \times 2\frac{1}{4}$, weight $6\frac{1}{2}$ lbs., and very inferior brick near Cavan.

FIRE-CLAY.—In the *Lough Allen*, or *Connaught Coal Field*, the recorded fire-clay beds are thin, and in general of inferior quality. One mile N. W. of the Arigna Iron Works there is a bed three feet thick, but thinning out northward and southward; this was formerly worked by the Arigna Coal Company, and very fair bricks made out of the clay.

CLARE.

POTTER'S CLAY found in places in the west of the county.

BRICKS of a red colour are made at Clare Castle, Manus, Ballycorick, and Rossmanaher, from the clay of the River Fergus Valley, 20*s.* to 30*s.* per 1000, $9\frac{1}{2} \times 4\frac{1}{2} \times 3$, weight $6\frac{1}{4}$ lbs.

FIRE-CLAY.—In the West Munster Coal Field (*Cos. Clare*, *Limerick*, *Kerry*, and *Cork*) various beds are recorded, being from six inches to two or three feet thick, under most of the coals. In places, especially in Clare, Kerry, and Limerick, these clays ought to be capable of being worked profitably, the peat of the country being used to burn the bricks, &c. Moreover, in some localities the small coals on the clays, which are now valueless, might be worked as a by-product.

CORK.

Tobacco-pipes have been for a long time, and are still, made in *Cork city;* formerly some of the clay was brought from the Co. Clare, but now it is all imported from England.

There was, until a few years ago, bricks and coarse pottery made in Cork, the clay being brought from Youghal.

Coarse bricks were made at Derrylinn from a local clay, and finer ones at Balvelly (Great Island), also from a local clay. They were somewhat like the Bridgewater bricks, but softer, and after a time threw out a "white salt." At Ballinphealing, near Ballinhassig, bricks are made. On the *Douglas channel*, about three miles from Cork, the slob of the estuary is wrought into bricks, which are used in large quantities for stud work. The clay, if washed, will not burn; but when dried and unwashed it burns into a durable brick; cost, 11*s*. to 14*s*. per 1000; size, $8\frac{3}{4} \times 4 \times 2\frac{1}{4}$; weight, 4 lbs. Similar clay, got at *Ballinalee*, three miles from Kinsale, is also used for bricks, 12*s*. to 14*s*. per 1000. In the vicinity of Mallow inferior bricks are made from a local clay, 20*s*. to 35*s*. per 1000, $9 \times 4 \times 2\frac{1}{2}$. Near *Skibbereen* a few bricks are made.

"In the neighbourhood of *Youghal* there is, near the surface, a ten-foot-thick bed of very good reddish shaly clay, very smooth and close, but having a slight mixture of sand. This clay is manufactured into bricks and coarse pottery, tiles, draining-pipes, flower-pots, &c.: lately some ornamental flower-pots, of a light-red colour, well shaped and cheap, were made, the material, however, is coarse. The bricks, $9'' \times 4\frac{1}{2}'' \times 2\frac{1}{2}''$, are very superior, and formerly were extensively sent to Cork, Waterford, and Dublin. About 2,000,000 of the Youghal bricks were used in roofing the tunnel of the Great Southern and Western Railway as you go into Cork. Best bricks of a fine clear brownish-red, 25*s*. per 1000, a softer kind of a dull light-red colour, 20*s*. per 1000." (*J. Budd.*)

The Youghal bricks were used in the building of the Tipperary barracks. They are not now in the Dublin market, it is said on account of prohibitory freight. Some of the Dublin builders who have used them say that "they are the best in Ireland."

FIRE-CLAY (*See* Co. Clare, *ante*, p. 149).

DONEGAL.

POTTER'S CLAY occurs on Arran Islands, in the *Rosses*, in *Tory Island*, and at Drumarda on Lough Swilly; it has been used a little in the manufacture of coarse pottery. PIPE-CLAY is found frequently, but little used. *Dr. Parland* in his Statistical Survey, 1801, called attention to the pipe- and brick-clays in Drumarda. At that time the natives of Tory "made clay-pots, in which they boiled potatoes or anything else."

BRICKS are made at *Moy*, two miles from Ballyshannon, but they are unshapely, 8*s*. to 12*s*. per 1000; a few are made near *Donegal*. They are also made at *Milk Island*, near Letterkenny, and at *Ramelton*, from the clay of the "isles" or flats margining Lough Swilly; at Drumskillin, in Inishowen, $9 \times 4\frac{1}{2} \times 3$, weight $5\frac{1}{2}$ lbs.; Strawbridge, very inferior quality; Burnfoot railway station, 20*s*. per 1000, also draining and other tiles; and Ardnaree, five miles from Millfort, 18*s*. per 1000, $9\frac{1}{4} \times 4\frac{1}{4} \times 3\frac{3}{4}$, weight 8 lbs.

In the blue brick clay margining Lough Swilly, about a mile eastward of Ramelton, Mr. Mahony found a fossil deer's horn.

DOWN.

In *Ballymacarret*, the eastern suburbs of Belfast, there were china and delft works for many years; whence the clay, &c., was procured we were unable to learn. (*See* BELFAST, *ante*, p. 148.)

Very good BRICK-CLAY occurs near *Banbridge*, from which red but not well-made bricks are manufactured; but a first-rate brick could be made from the clay, 25*s*. to 28*s*. per 1000, $9 \times 4 \times 2\frac{1}{2}$; inferior bricks are made at *Downpatrick*; red at *Kilkeel*, 20*s*. to 25*s*. per 1000, $8\frac{1}{2} \times 4 \times 3$, weight $6\frac{1}{2}$ lbs.; small red bricks at Rostrevor; in different places in the neighbourhood of Newry, 20*s*. to 24*s*. per 1000, $8\frac{1}{2} \times 4\frac{1}{4} \times 2\frac{3}{4}$, weight $6\frac{1}{2}$ to 7 lbs, and very inferior at Newtownards. There is good brick-clay near Portadown, and extensively wrought.

Hard red bricks are made from the clay of the boulder drift west of Waringstown. This clay also occurs in cuttings along the

Lisburn and Banbridge Railway. Very superior bricks are made near Maypole, north of Dromore.—(G. S. M.) Brick-fields were started in plastic clay near Ballyhorney, and at Ardtole, near Ardglass.

Castle Espie.—In this neighbourhood there is an extensive trade in bricks, principally for the Belfast market, and in tiles. *Terra-cotta* also has been attempted there. The bricks are of a red colour, moulded, and perforated, and equal, if not superior, to the best Bridgewater bricks. They are made from the washed boulder clay.—(G. S. M.)

DUBLIN.

PIPES.—Tobacco-pipes were made in the neighbourhood of Dublin at a very early date. Quantities of those known as "Dane-pipes" were found in Baggotrath, in the excavations for Waterloo-road. The early manufacturers possibly used Irish clay; but in later years the material was probably imported. Francis-street has long been the great home of the Tobacco-pipe makers; the "Crown L," made half a century ago by Loughlin, were world-famed. At present there are about nine tobacco-pipe makers in Dublin.

Dr. Frazer, M.R.I.A., one of the best authorities on the antiquities of Dublin, thinks it likely that the "Dane-pipes" were of English manufacture (*Introduction, ante*, p. 145); but in Baggotrath there were in different places heaps of the *debris* of pipes, similar to those now to be seen near a pipe-kiln, which lead us to believe they had been made on the spot.

FULLER'S EARTH occurs in places, but it is not now as valuable as formerly. In different places associated with the gravels above the boulder-clay there are POTTER'S and BRICK-CLAYS; but, unfortunately, in many places there is a heavy off-baring of gravel that makes the clay expensive to get.

Tradition has it that the houses in Merrion-square, and neighbouring houses, were made from clay procured near Merrion, also clay raised in the Square. Lately, while building the new streets between Cork-street and the South Circular-road, the bricks were burnt on the ground. When Waterloo-road was being made from Upper Baggot-street to Donnybrook, a bed of potter's or brick-clay was found. There are regular brick-yards and potteries in various places about Dublin, making use of clay raised on the spot. Regular brick-yards exist at Balbriggan and Ellistown, four miles westward of Lusk.

Kill-o'-the-Grange.—The pottery and brick-yard at this place is of long standing; formerly it had an extensive trade in coarse pottery, flooring and roofing-tiles, draining-tiles, chimney-pots, flower-pots, and bricks. Some years ago the bricks, through careless work, got for a time into disrepute, but of late years they have been good, though not equal to those of Kingscourt, Co. Cavan; size 9 × 4½ × 3; delivered in Dublin at 44*s.* per 1000; cartage about 10*s.* per 1000. Leinster Hall, on the site of the Theatre Royal, built of them.

Foxrock, a little more than a mile S.W. of Kill-o'-the-Grange. —Bricks were made here a few years ago.

Clondalkin.—The bricks made here are the "old Co. Dublin stock-brick," and are 9 × 4½ × 3. They were extensively used formerly; all the old buildings in Dublin and the best old streets were built of them; price, about 45*s.* per 1000. The clay was laid out and turned during the winter, and hand-picked, to remove all the lime-gravel. The bricks were principally made at the Fox and Geese, Ashfield, and near Red Cow. They were formerly made at Cloverhill, ninth Lock, Grand Canal, and are still made by Flood and a few others, but from want of proper care they have much deteriorated in quality; colour brownish-yellow; about 350 go to the ton.

The red bricks to be seen in some of the old mansions, in Rutland-square for instance, were made at Clondalkin; they did not, however, stand the weather, the faces yielding to atmospheric influences. Hence has arisen the custom of "Wigging," or renovating the faces with Venetian red. This custom to a great extent is confined to Dublin, and is not to be approved of, as the brick wall is re-pointed with plaster of Paris, flat pointing being always better than French pointing.

Ratio.—1000 Athy stocks equal 2½ cubic yards. 1000 Dublin stocks equal 3½ cubic yards, both in Flemish (*Irish*) and English bond. An Irish perch of brickwork is 21 ft. × 12 in. × 9 in.

[The "Flemish bond" which is that generally used in Ireland, except perhaps in Belfast, consists of headers and stretchers alternating, while the "English bond" is a coarse of headers, then three courses of stretchers, then a course of headers, and so on.

The Co. of Dublin stocks that were used when building the Theatre Royal, Poolbeg-street, were so good, that after it was burned, and when the Leinster Hall was being built on its site, the old bricks were so firm and intact that most of them were used in the new building. Co. Dublin stocks, at 45*s*., dropped out of the market through the importation of the Cardigan brick at 39*s*. The latter is an inferior article, as the Co. Dublin brick is probably worth 5*s*. per 1000 more than the Cardigan red stock. The supply is now limited in consequence of their being undersold by the Kingscourt and English bricks. The Dublin stock is neither panelled nor perforated.]

Mount Argus, Harold's Cross.—The bricks made here are red and grey in colour, $9 \times 4\frac{1}{4} \times 2\frac{3}{4}$, perforated, price 38*s*. per 1000. They are good and well burnt, but contain lime. The works have been open only a few years, yet they have great custom. These bricks have been used in the buildings of the Royal University, and in many others for front work.

Portmarnock. Brick and Terra-cotta Work. Red brick, good class, $9 \times 4\frac{1}{4} \times 2\frac{3}{4}$, delivered in Dublin, common 43*s*. 6*d*., facing, 47*s*. 6*d*., chamfered, bullnoses Scotia, 50*s*., others moulded 55*s*. per 1000; used in new houses in Sallymount-avenue; Leeson-park; Rathmines National School, &c.; new wing of Incurable Hospital, Donnybrook, &c., &c. These bricks, especially those in the Rathmines School, look extremely well.

Pelletstown, one mile S. W. of Finglas. A good clay, capable of making good bricks. Has not been worked for some time.

Recent Brick Structures.—Besides those already mentioned there are M'Gough Home, Cullenswood, *Courtown, Co. Wexford*; facing Bridgewater. Guinness's House, &c., Earlsfort-terrace, *Bridgewater*.—In all the red facing of the new houses in Pembroke and Rathmines Townships, and the North Circular-road, built prior to about the year 1885, *Bridgewater* nearly solely used. National School and Teachers' Residence, Rathmines, *Portmarnock*. —New Station, Westland-row, various bricks.

[The brick trade, like all other trades, suffered during the general depression which affected the country in 1852, and subsequent years; and before it could recover, foreign bricks had in a great measure taken the place of the Irish, principally Cardigan and Bridgewater; the latter commenced to be run on about 25 years ago. The Kingscourt brick is a first-class article, equal to the Bridgewater, and of a better colour; it has rapidly made its way.

Price of a cubic yard of brick-work—bricks 13*s*. (at 40*s*. per 1000), labour 9*s*., mortar 2*s*., scaffolding 1*s*. = 25*s*; 1000 build $3\frac{1}{2}$ cubic yards; 1 cubic yard = 27 cubic feet; 1 Irish perch = $15\frac{3}{4}$ cubic feet, or 21 feet long by 12 inches high and 9 inches thick. Ratio, Athy stock, 1000 = $2\frac{1}{2}$ cubic yards; Dublin stock, 1000 $3\frac{1}{2}$ cubic yards, in both English and Flemish (Irish) bond.

Fire-clay Ware.—Flue linings are extensively imported, principally from Chester and Glasgow, chief sizes 9 and 12 inches high, prices 3*d.* and 4*d.*, about 200 to the ton. Chimney-pots, 1, 2, and 3 feet high, principally from Glasgow, plain, moulded, and ornamented, from 1*s.* 5*d.* to 2*s.* 9*d.* each; freight, according to season, from 4*s.* 6*d.* to 5*s.* 6*d.*, Chester; while the Scotch freight would be about 10*s.* Scotch drain-pipes 3 feet long; Chester 2 feet 4″, 6″, 9″, and 12″ in diameter; prices, 4½*d.*, 6½*d.*, 8½*d.*, and 11*d.* in Dublin. Traps, dill's closets, &c., are also imported from Scotland and Chester.]

FERMANAGH.

BRICKS are made at *Newtownbutler*, for use at Clones, six miles, distance; *River Arney*, ten miles from Enniskillen, to supply that town; bricks, however, are very generally made all through the flats about Loughs Erne, 8*s.* to 12*s.* per 1000, 9 × 4¼ × 2¾, weight 6 lbs.; alluvial flats near Lisnaskea, 12*s.* to 15*s.*, 8¾ × 4 × 2¾, weight 6 lbs.

In the flats east of Upper Lough Erne there are considerable deposits of brick-clay extensively burned by the inhabitants, principally for local use. At Arney Bridge some kilns were worked by the late Lord Enniskillen for many years. In 1880 were turned out, between 1st April and 1st November, 402,795 pipes of different sizes, 100,000 bricks, 29,200 flooring- and roofing-tiles, 120 yards of ridge-tile, 1023 doz. flower-pots, 100 doz. saucers, and a few other articles, such as chimney-pots, &c.—(G. S. M.)

Belleek.—For some years china, including a peculiar glazed kind, *Belleek ware*, delft, &c., have been manufactured in this town. The best ware is made of kaolin, manufactured from a felspar vein in the neighbourhood, while impurer felspar for the common ware is imported. (See *Introduction*, p. 144.)

FIRE-CLAY.—(*See* Co. CAVAN, *ante*, p. 149).

GALWAY.

Tobacco-pipes and coarse pottery were formerly made at *Galway*, *Creggs*, and *Dunsandle*, from clay obtained in the respective vicinities. An excellent clay was discovered some ten years ago in the neighbourhood of Menloe Castle.

BRICK at *Annaghdown*, east of Lough Corrib, yellow, 16*s.* to 21*s.* per 1000, 8½ × 4 × 2¾, weight 5½ lbs.

In the flats near Clare-Galway and Athenry coarse bricks are made. In the early English Castle of Clare-Galway bricks were used. They are not rectangular; but were moulded slightly wedge-shaped, so as to fit in as voussoirs in a nearly flat arch.

In places near Portumna, Eyrecourt, Banagher, &c., in the flats of the Shannon, bricks and draining-tiles have been made, but not of the best class.

KERRY.

Very good Bricks made at *Listowel*, for about 20*s.* per 1000, size 9 × 4 × 3, weight 7 lbs.; fair at Tralee for about 23*s.* per 1000, 9 × 4½ × 2½, weight 7 lbs. On the Coal-measures in the east of the county there are, in places, brick and other clays.

Fire-clay.—(See *Co. Clare*, *ante*, p. 149.)

KILDARE.

The Fuller's Earth at the Hill of Allen was formerly very valuable, but is not now worked.

At Waterstown, two and a-half miles from Naas, a poor brick; but the bricks used to build Lord Stafford's ("Black Tom") castle at Figginstown, Co. Kildare, were of excellent quality.

The Athy stock-bricks are made in the neighbouring country (*Kildare* and *Queen's Co.*), and are sent in great quantities by the Grand Canal to Dublin, &c. Prices in Dublin from 30*s.* to 32*s.* per 1000, 1000 making about 2½ tons. They are neither panelled nor perforated. They have been largely used in the suburbs of Dublin; particulary Rathmines and Rathgar. Guinness's new malthouse and hop store are built of them.

Facing-bricks, 9 × 4½ × 3, were formerly made and brought by Messrs. Webster and Co. to Baggot-street Bridge for the Dublin market. They were a first-class brick; and the bricklayers state that they find them in the old buildings in splendid condition. They were used in the old Theatre Royal.

The grey-stock, 8½ × 3½ × 2½, is well burned, and suitable for factories and such buildings. Their tenacity exceeds that of any imported bricks. They are very suitable for chimneys; also for arches and walls where machinery is used. They bond more perfectly than most other bricks, and are therefore very suitable for being set in blocks built with templates. The engineer of Guinness's Brewery has found that after fifteen years the concrete arches under the engine-room have no break in them, this being due to the elasticity of the supporting walls of Athy bricks.

These bricks are well burned, and free from lime; but there is a slight difference as to quality according to the brick-yards in which they are made.

KILKENNY.

Good POTTER'S CLAY at *Castlecomer;* also in the neighbourhood. Prior to 1837, a pottery was commenced there, but failed for want of capital (*L. D.*). Some years later it was again started, but failed; now only a few kilns of bricks are burned.

PIPE-CLAY occurs, and has been worked both in the north and south of this county.

BRICKS are made at Glenmore, three miles from New Ross, with clay obtained below high-water mark, in the estuary of the Barrow. The salt in this clay causes the bricks to become damp in wet weather, and to yield with frost if used in outside work; 12*s.* to 15*s.* per 1000, $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$, weight 7 lbs. *Ballywater*, two miles from Callan, inferior, 25*s.* per 1000, size $9 \times 4 \times 3$, weight 7 lbs. *Kilkenny*, in different places in the vicinity, 25*s.* to 40*s.* per 1000, $9\frac{1}{2} \times 4\frac{1}{2} \times 3$, weight $6\frac{1}{2}$ lbs. *Castlecomer*, also tiles, drainage-pipes, and coarse pottery.

FIRE-CLAY.—In the Leinster, or Castlecomer Coal Field (*portions of Kilkenny*, *Queen's Co.*, and *Carlow*), thick beds occur under most of the coals. Sir R. Griffith, in his Report (1820), spoke very highly of them, yet they seem never to have been utilized. The best bed is under the "Old Colliery," or "Three-foot Coal"; but this is now unattainable, as the expense of draining the old workings and removing the fallen roof would leave a profit out of the question. Those beds that might perhaps be more easily utilized are the four-feet-thick bed under Ward's seam (*Rushes*), and the fire-clays in Towlerton and Woodland, all at the eastern brow of the table-land, as these could be worked by driving in levels; besides, the associated thin seams of coal might be worked as a by-product. There are also in a few places in the strata below the coals (*Middle and Lower Coal-measures*) independent beds of clay that might be worked; and perhaps also the clay under No. 1, or *Gale Hill Coal.* But in all the places where the coal has been extracted, the old workings would have to be unwatered at great expense before the clay could be obtained, if we except the margin or outcrop of the beds, which in places might be wrought by surface openings.

KING'S COUNTY.

Pipe-clay, near Blackball, north of Brosna. Formerly tobacco-pipes were extensively made in Brosna ; but the village was destroyed over a quarter of a century ago, and the pipe-makers migrated. The Blackball clay was also used by the late Lord Rosse for lining his furnaces.

Very fair Bricks are made at several places within three miles of *Birr*, or *Parsonstown*, 15*s.* to 25*s.* per 1000, $9 \times 4 \times 2\frac{1}{2}$, weight 7 lbs. Bricks of good quality were made at Rahan, Ballywilliam, &c., within two and a-half miles of *Tullamore*, and sent by the Grand Canal to Dublin, Edenderry, and other places, 15*s.* to 20*s.* per 1000, $8\frac{1}{4} \times 3\frac{3}{4} \times 3$, weight $5\frac{3}{4}$ lbs. The bricks now made are of inferior quality, and are not in demand in Dublin. They absorb damp, and can only be used in buildings that are to be plastered or dashed. They have bad bearing qualities, the material being poor and not well burned, 18*s.* per 1000.

LEITRIM.

At the western base of *Benbo* there is a bluish-white Fuller's Earth. At *Dromahaire* there was, at one time, an extensive pottery. There is Potter's Clay at the town of *Leitrim*, four miles N. N. E. of Carrick-on-Shannon.

At *Leitrim* there are red Bricks of three qualities, 15*s.*, 20*s.*, and 25*s.* per 1000. A good grey brick at *Killucan*, one mile from Carrick-on-Shannon, and at *Dromahaire*, nine miles from Manorhamilton, which it supplied thence, 18*s.* to 22*s.* per 1000. Mohil, red, of good quality, 20*s.* to 25*s.*

Fire-clay.—(*See* Co. Cavan, *ante*, p. 149.)

LIMERICK.

Inferior Pipe-clay at *Rathmore*, in Manasteranenagh parish.

In the flats of the Shannon, about three miles from *Limerick*, Bricks and Tiles are made with clay of a bad quality, 17*s.* to

23*s*. per 1000, $8\frac{3}{4} \times 4\frac{1}{2} \times 3$, weight 7 lbs. Near *Newcastle West* the bricks are inferior; although a very good clay occurs in the neighbouring *Coal-measure* hills. *Ballyseed*, near Askeaton, a poor brick, 15*s*., $9\frac{1}{4} \times 4\frac{1}{4} \times 2\frac{3}{4}$, weight 6 lbs. North-west of Ardagh the late Colonel Dickson erected brick and tile works on a bed of clay.—(G. S. M.)

LONDONDERRY.

POTTER'S and BRICK-CLAY along the Moyola river at *Castledawson*, from which coarse pottery and bricks are made. In the parishes of *Aghadowey* and *Agivey*, south of Coleraine, "a coarse kind of earthenware, bricks, and water-pipes." (*L. D.*)

Good BRICKS within a mile and a-half of *Coleraine*, 12*s*. per 1000, $8 \times 4 \times 2\frac{1}{2}$. *Muff*, N. E. of Derry, very good bricks, 15*s*. and 20*s*., $8\frac{1}{2} \times 4\frac{1}{2} \times 2\frac{3}{4}$. *Ballyronan*, three and a-half miles from Magherafelt, bad bricks. Good in several places in the vicinity of Limavady, 7*s*. to 9*s*. per 1000.

"A few miles above Coleraine, on both sides of the Bann, is a reddish or brownish brick-clay in many places, not much used at present; but it is used near Glasgort, and also about a mile west of Coleraine, south of 'Irish Houses.' South of the Agency bridge, the diatomaceous, or 'Bann Clay' (*Diatomite*), is extensively used for brick-making." (*F. W. Egan.*)

West of the Bann, and east of Ballynacree House, there is brick-clay. Near Balnamore House a red laminated clay was formerly manufactured into tiles; while near Glasgort, S. W. of Agivey, similar clay of reddish and bluish-grey colours is now made into bricks, tiles, flower-pots, &c.—(G. S. M.)

Below the peat at Littlebridge, near Castledawson, there is a stiff brown clay, used for brick-making, while "Bann clay" is found below the peat to the west of Church Island, as also further north.—(G. S. M.)

LONGFORD.

Potter's Clay in abundance at *Ballinamuck*, eastward of Longford town.

Brick-clay.—Near Granard, a bad red brick, 20*s.* to 25*s.*; $9 \times 4 \times 2\frac{3}{4}$; weight, 7 lbs. Near Longford, 30*s.* to 32*s.*; $8\frac{1}{2} \times 4 \times 2\frac{3}{4}$; weight, $4\frac{1}{2}$ lbs. Some few years ago a large trade in bricks and tiles was started in Longford, the bricks being sent by canal and rail to Dublin and elsewhere. This industry, however, had to be discontinued, on account of the prohibitory railway rates and the unnavigable state into which the Royal Canal was allowed to fall.—(*Parl. Comm. Irish Industries*, 1885, p. 578).

LOUTH.

Bricks of red colour are made in many places, from one to four miles from *Ardee;* 24*s.* to 32*s.*; $9 \times 4 \times 3$; weight, $7\frac{1}{2}$ lbs.; and $8\frac{3}{4} \times 3\frac{7}{8} \times 2\frac{7}{8}$; weight, $6\frac{3}{4}$ lbs. In various places in the vicinity of Drogheda bricks are made; they are from inferior to good in quality; 26*s.* to 33*s.*; $9 \times 4\frac{1}{2} \times 3$; weight, from 6 to $6\frac{1}{2}$ lbs. Good red bricks near Dundalk; 30*s*; $9 \times 4\frac{1}{4} \times 3$; weight, $6\frac{1}{2}$ to 7 lbs. Dundalk bricks have been largely used in Belfast and in other towns.

MAYO.

"Clay fit for porcelain and every other description of earthenware is found in inexhaustible beds, and cargoes of the finer sorts are shipped for England. Fuller's earth and pipe-clay are also abundant, and very good clays for bricks abound in every barony." (*Lewis*, 1837, vol. ii., p. 356.) At the present time it is hard to verify the localities above referred to; but probably they may have been situated in Erris, as there is a tradition that clays were formerly shipped from Killala and Ballina.

Bricks and Tiles of a grey colour are made in several places in the vicinity of *Ballina;* bricks, 20*s.* to 30*s.*; $8\frac{3}{4} \times 4\frac{1}{2} \times 3$; weight, 6 to 7 lbs. Cushlough, two and a-half miles from Ballinrobe, 20*s.* to 30*s.*; 9 × 4 × 2½; weight, 5½ lbs. Different places near Swineford, pale-red bricks; 9 × 4¼ × 2¾; weight, 6 lbs. Lisconnell, two miles from Swineford, pale-red bricks, ridge- and drainage-tiles. Near Westport, as it would seem, no bricks have been made, although there is good clay in the vicinity. The detritus from the slate workings, if ground up, ought to burn into excellent brick. When the town was being built, bricks were imported from Liverpool at a cost of £3 per 1000.

FIRE-CLAY.—Beds of this clay of good quality occur in the small outlying Coal-measure patches near Balla.

MEATH.

Ferriferous POTTER'S CLAY occurs at *Knock*, in Morgallion barony, formerly wrought into coarse earthenware. A pottery was also once at work at *Gravel Mount.* At *Brownstone*, four miles south-east of Navan, a "valuable stratum of Potter's clay"; and at *Dunshaughlin* "a superior Potter's clay."

BRICKS.—*Knock*, ten miles from Kells; good quality; red; 20*s.* to 30*s.*; 9 × 4¼ × 3; weight, 6¼ lbs.; also superior flooring-tiles. *Killeary*, nine miles from Kells; same colour, quality, and price; also ridge and other tiles. *Athboy*, good quality; yellow; 25*s.* to 35*s.*; 9 × 4 × 3; weight, 7 lbs. Similar bricks made at *Castletown*, eight miles from Navan. *Oldcastle*, in several places; 20*s.* to 25*s.*; 9 × 4 × 3; weight, 7 lbs. None of these bricks seem to have ever been in the Dublin market, although suitable.

In this county, in the vicinity of Kingscourt, county Cavan, first-class bricks are now being made from the Keuper marl and clay in the drift; red; panelled; 9″ × 4″ × 3″; free from lime; equal to the Bridgewater, and slightly darker in colour; superior for facing; they have rapidly taken their place in the Dublin market; at kiln, facing brick 38*s.*, stock 30*s.*; in Dublin from 47*s.* to 50*s.* per 1000; here are made also unglazed kitchen-tiles, in two sizes, 9 and 6 inches square.

MONAGHAN.

POTTER'S CLAY and unctuous earth near *Castleblayney;* and at Glaslough, where a glazed pottery was made. Potter's Clay also occurs in Tydavnet parish.

BRICKS of a good quality are made at one to four miles from *Carrickmacross;* 27*s.*; 9 × $4\frac{1}{4}$ × $2\frac{3}{4}$; weight, 7 lbs. In several places near *Castleblayney*, 20*s.* to 25*s.*; $8\frac{3}{4}$ × $4\frac{1}{4}$ × $2\frac{1}{2}$; weight, 7 lbs. Near *Clones*, of poor quality; 25*s.*; $8\frac{3}{4}$ × 4 × $2\frac{1}{2}$; weight, $4\frac{1}{2}$ lbs. In the vicinity of *Monaghan*, 20*s.* to 30*s.*; $8\frac{1}{2}$ × 4 × $2\frac{1}{2}$.; weight, $6\frac{1}{2}$ lbs.; and in other places.

"Elsewhere the clays of the drift, cleared of the stones, are made into an inferior class of brick."—(G. S. M.)

QUEEN'S COUNTY.

POTTER'S CLAY has been found in different places, and has been worked a little near *Abbeyleix*. At *Mountmellick* a most extensive pottery for coarse ware, such as crocks, tiles, garden-pots, &c., was carried on for a number of years; these works, in later years, turned out a vast number of drainage-tiles. At *Arless*, Killeran parish, there was a manufacture of roofing-tiles, formerly extensively made to supply the Dublin market, before the great introduction of slate into that city. This industry died out entirely in 1840.

BRICKS of good quality are made in great quantities in different places in the low country west of the Barrow; those in *Graigue*, a suburb of Carlow, being intended principally to supply that town; 18*s.* to 20*s.* Large quantities are conveyed by the Grand Canal to Dublin, New Ross, Waterford, and intermediate places. The "Athy brick" has already been mentioned (*ante*, p. 156).

At *Forest* and *Clonsast*, and in several places near Mountmellick, a poor, yellowish-red brick.

FIRE-CLAYS.—These have not been utilized (*see* KILKENNY, *ante*, p. 157).

ROSCOMMON.

In various places in this county there are clays suitable for TOBACCO-PIPES and coarse POTTERY. Near Roscommon town there have been several small potteries. At *Kilmain*, three miles S.S.E. of Roscommon, a small pottery, from local clay. *Knockcroghery*, very ancient works, tobacco-pipes, and pottery. The whole county of Roscommon has long been supplied thence with coarse earthenware.—(G. S. M.)

In the townland of *Curries*, south-east flank of Coarse Top, a large pottery was once worked, the bed of clay being three feet thick. Smaller potteries were rather frequent in the neighbourhood. Nothing is now known of them but their sites, marked on the Ordnance Map.

Along the shore of *Lough Ree*, especially near St. John's Point, are clays locally manufactured into tobacco-pipes. *Tubberpatrick*, N.N.W. of Strokestown, very fine Potter's clay.

BRICKS.—Neighbourhood of *Boyle;* fair class; grey; 18*s.* to 25*s.*; $8\frac{1}{4} \times 4 \times 2\frac{3}{4}$; weight, 5 to 6 lbs. In different places near *Castlereagh*, grey; 20*s.* to 25*s.*; $8\frac{1}{4} \times 3\frac{3}{4} \times 2\frac{1}{2}$; weight, $4\frac{3}{4}$ lbs. *Wakefield*, four miles from Roscommon; grey; not very good; 20*s.*; $8\frac{1}{2} \times 3\frac{3}{4} \times 2\frac{3}{4}$; weight, $4\frac{1}{2}$ lbs.

FIRE-CLAY (*see* CAVAN, *ante*, p. 149).—Fire ware was manufactured at Arigna when the iron and coal were being actively worked there.

SLIGO.

M'Parland, writing in 1801, states that "brick-clays," fine and fit for pottery, occurs where the Sligo road departs from Lough Gill, proceeding to Ballintogher.

BRICKS are made at *Lough Gill*, about three miles from Sligo, Collooney, and Dromahaire; price, 20*s.* to 22*s.* per 1000; average size, $8\frac{1}{2} \times 4\frac{1}{4} \times 2\frac{1}{2}$; weight, $5\frac{1}{2}$ to 6 lbs.

FIRE-CLAY.—(*See* CAVAN, *ante*, p. 149).

TIPPERARY.

Pipe-clay.—*Loughloheny* and *Ballymacadam*, south-east of Cahir; pipe-clay, associated with lignite. Formerly it sold freely on market-days in Clonmel, Cahir, &c., principally for cleaning soldiers' belts, &c.; it was also exported as Potter's clay.

Potter's Clay.—Killenaule.

Bricks.—One mile north-west of Cashel, as pointed out by O'Kelly, bricks are made from a bed of shale at the base of the *Coal-measures*. "The shale is dug up and exposed to the air, when it rapidly decomposes into a kind of tenacious yellow clay."—(G. S. M.) 20*s*. to 25*s*. per 1000; $9\frac{1}{2} \times 4\frac{1}{2} \times 2\frac{1}{2}$; weight, 6 lbs. Near *Clonmel*, 30*s*.; $9 \times 4 \times 3$; weight, 6 lbs. Near *Nenagh*, about 25*s*.; $9 \times 4\frac{1}{2} \times 3$; weight, 6 lbs. *Drumakeem*, four miles from Roscrea, 22*s*.; $9 \times 4 \times 3$; weight, $6\frac{3}{4}$ lbs. On the banks of the Suir, about one mile from Thurles, 20*s*.; $9 \times 4\frac{1}{4} \times 3$; weight, $6\frac{3}{4}$ lbs. Near Tipperary, a poor red brick, 25*s*.; $9 \times 4 \times 3$; weight, $7\frac{1}{2}$ lbs.

Fire-clay.—In the *Tipperary*, or *East Munster Coal Field*, the fire-clays do not seem to have been as well developed as in Leinster; neither do they appear to have been utilized.

TYRONE.

Potter's Clay, manufactured into good flooring- and ridge-tiles, coarse earthenware, and flower-pots, at Moy and Killymoon.

"About Fintona good flooring- and ridge-tiles are made; also garden-pots and a great variety of crockery ware for country use."—(*M'Parland*, 1802.)

In the drift in the vicinity of Coal Island and Lough Neagh there are clays which, according to Hardman, are suitable for brick-making; but at the same time he points out that the bricks of the neighbourhood are in general made from the more clayey boulder-clay, "which has to undergo a sort of clarifying process, by being thrown into a pond of water, so that the pebbles and blocks sink to the bottom, and the finer mud, when it has subsided, is selected."—(G. S. M.)

Ballygawley, dark colour, 15*s.* to 20*s.*; 9 × 4 × 3; weight, 7 lbs. *Cootestown*, 18*s.* to 23*s.*; 9 × 4½ × 3. *Coal Island*, of different qualities; best, 25*s.* to 30*s.*; inferior, 20*s.* to 25*s.*; fire-brick, 40*s.*; flooring-tiles, &c. Gortin, bright red; hard; an excellent brick; made only for the local trade; 11*s.* to 12*s.*; 9¼ × 4¼ × 3; weight, 7 lbs. *Omagh*, not good; 15*s.* per 1000; 9 × 4 × 3; weight, 7¼ lbs. *Strabane*, red, hard; sent to Derry and various other places; 18*s.*; 9¼ × 4¼ × 3; weight, 7 lbs. *Drumnalong*, from 5 to 7 miles from Derry; very good; 15*s.* to 20*s.*; 8½ × 4½ × 2¾; weight, 6 to 6½ lbs.

FIRE-CLAY.—In the county Tyrone the beds of fire-clay are more numerous and thicker than elsewhere in Ireland. At the Creenagh Colliery pit the fire-clay was found to be four feet thick. In the clay-pit, townland of Derry, the clay was found to be of excellent quality; there is about eight feet of grey clay on one foot of black, and below the latter three feet of red and variegated, or a total thickness of twelve feet; while in the engine pit the clays are eighteen feet thick. They are used in the manufacture of fire-ware, and at the present time the Ulster Fire-clay Works Co. sell at Coal Island glazed sewerage pipes from 2″ to 24″ in bore, at from 7½*d.* to 14*s.* per yard; plain or butt joint-pipes, 20 per cent. less; compressed flooring-tiles, octagon and square, according to sizes, from 12*s.* 6*d.* to 25*s.* per 100; black or red centres, from 5*s.* to 7*s.* 6*d.*; chimney-cans, according to size and finish, from 1*s.* 6*d.* to 7*s.* 6*d.*; sewer-bottoms, from 7″ × 14″ to 23″ × 24″, at from 3*s.* 3*d.* to 6*s.* 6*d.* per lineal yard; flue-covers, from 15″ × 9″ × 2″ to 24″ × 24″ × 3″, at from 6½*d.* to 3*s.* 6*d.* each; blast coke and puddling furnace-blocks, cattle and glasshouse-blocks, D-shaped round and oval gas-retorts; unpressed fire-bricks, 55*s.* to 60*s.* per 1000; pressed, 65*s.* to 70*s.* per 1000; white-faced, 80*s.* per 1000; chamfered paving-bricks, 65*s.* to 70*s.* per 1000; vent-linings; oncomes; wall-, cope-, and ridge-tiles, horse-mangers and feeding-troughs. The prohibitory railway rates harass this industry.

At one time the Coal Island clay was made up into small oblong cakes, about a pound each, which had a ready sale as a substitute for Fuller's earth.

In the Annaghone Coal-field, which lies to the north of the main field, there is a considerable thickness of good fire-clay.

WATERFORD.

Potter's Clay occurs near *Dungarvan*, *Ringagonagh*, *Lismore*, and *Whitechurch;* while pipe-clay is found at *Ballyduff*, near Dromana, and *Ballyntaylor*. Very little use, however, is made of it.—(*L. D.*)

"Bricks are made about one and a-half miles above Waterford, at both sides of the Suir, from clay raised in the marshes; sold at the kilns from 25*s.* to 27*s.* per 1000; average size, $9 \times 4 \times 3\frac{1}{2}$, and weight 5 lbs. They are of bad quality, all the good bricks coming from Youghal, Co. Cork. In the mediæval English walls and towers round Waterford city bricks similar to what are now made were used; but none are found in the more ancient walls." (*James Budd.*)

"I have seen ancient pipes that were found in a rath; they were small, with bowls about three-quarters of an inch high. In Waterford city pipes have always been made within living memory; a few are made there still. The clay used was English (Poole, &c.). as the Irish clay contains either sand or iron; the sand could be washed out, but the iron could not always be got rid of, and often showed after the pipes were baked. Pipe-clay from Ringagonagh, and Ring, near Dungarvan, appears tolerably pure." (*James Budd.*)

WESTMEATH.

Very inferior bricks made in the flats of the Shannon, near Athlone; 18*s.* to 20*s.*; average size, $8\frac{1}{2} \times 4 \times 2\frac{3}{4}$; weight, $5\frac{1}{2}$ lbs. Castlepollard, a very fair brick, 20*s.* to 25*s.*

WEXFORD.

POTTERIES.—*Carleybridge*, Urrin River, near Enniscorthy, coarse pottery; *Oilgate*, between Wexford and Enniscorthy, flower-pots, &c. *Clohan*, south-west of Enniscorthy, pottery and tiles.

In very many places in the lowlands of this county there are extensive beds of *brick-clay*, which have been more or less locally used. They were worked considerably in the neighbourhood and vicinity of Wexford, especially near the College of St. Patrick, where Mr. Maddock manufactured bricks, enamelled tiles, &c. The best bricks were from 30*s.* to 35*s.* per 1000; average size, $9 \times 4 \times 3$; drainage tiles of five different sizes, 20*s.* to 60*s.*; and six-inch square red-and-black tiles, at 1*s.* per dozen. At one time there was a large trade in the flooring-tiles; but the workmen (English) could not keep themselves straight, and gave so much trouble, that Mr. Maddock gave up the works.—(G. S. M.) Inferior bricks, 20*s.* to 25*s.*

Enniscorthy, good quality, 18*s.* to 20*s.*

Courtown Harbour.—Here is an excellent clay in quantity, but the lower portion is a bed containing minute particles of limestone that cannot be washed out, and pass unbroken through the crushers. This layer or bed has by different owners, from time to time, been mixed with the superior clay, thus deteriorating the brick. The present proprietor, Mr. Funge, is careful to prevent this. The bricks at present in the market are, in general, $9 \times 4\frac{1}{2} \times 2\frac{7}{8}$; but all shapes and sizes are made to order. Price at kiln, 25*s.* to 40*s.*, according to quality; railway rate to Dublin, 11*s.* Ridge-, roofing-, and flooring-tiles of different sizes, from 6*d.* to 5*s.* per dozen, according to size and quality; also drainage-tiles.

WICKLOW.

BRICKS.—*Ballykelly*, three miles from Shillelagh; inferior; 18*s*. to 20*s*.; average size, $9 \times 4 \times 2\frac{1}{2}$; average weight, $6\frac{1}{8}$ lbs.; near *Bray*. Bricks were formerly made in various places near *Arklow*, but at present only at *Templerany*. Once a large business at *Ballybeg*, near Rathnew, and *Inchanapper*, near Ashford, &c.

XIX.

GRANITE, ELVAN, PORPHYRY, FELSTONE, WHINSTONE, AND METAMORPHIC ROCKS OF IRELAND. By G. H. KINAHAN, M.R.I.A., Etc.

[Read May 16, 1888.]

INTRODUCTION.

The eruptive and metamorphic rocks were chronologically classified by me in a Table accompanying Chapter xiii. of the "Geology of Ireland" (1878); and on further research I find no reason for material changes, although some minor modifications are necessary, such as the proposed classification of these rocks in Antrim as Eocene, on account of Mr. Starkie Gardner, Prof. Asa Gray, and other American palæontologists declaring that the plants found in the associated tuffose beds (*Iron measures*) are of Eocene and not Miocene types. The possible age of the exotic rocks of the S.E. of Ireland is now given for the first time. With these modifications the following Table has been brought up to the present state of our knowledge.

On account of the changes in nomenclature since 1878, when the first Table was published, some of the names have to be altered to those in the Table of Geological Strata, as given in these *Proceedings*, vol. v., page 204.

In the following Table the 1st column indicates the different formations with which the eruptive rocks are associated in Ireland. In the 2nd column is given the general classification of the eruptive rocks, to which metamorphic granite is added, so that it may be seen in what formations and localities the gradual change from unaltered, through metamorphic, into the eruptive rocks can be best studied. The remaining columns give the districts, or Territories, into which it seems most convenient to divide the country. In them the sign * denotes the existence, the sign ? the probable existence, of the rocks in the Territory indicated; while the columns are left blank when the rocks of the class are not represented, or are supposed not to be represented.

Table of the Eruptive and Granitic Rocks and Metamorphic Granite.

Formation.	Group of the Rocks.	S.E. Ireland.	Munster.	Galway and South Mayo.	North Mayo and Sligo.	Ulster.	Carlingford District.
Eocene,	5. Doleryte, euryte, and felstone (Trachyte),	?	—	?	?	*	*
	4. Elvan,	—	—	—	?	*	*
	3. Intrusive triclinic felspar granite,	—	—	—	—	—	*
	2. Intrusive monoclinic felspar granite,	—	—	—	—	—	—
	1. Metamorphic granite,	—	—	—	—	—	—
Triassic,	5. Doleryte, euryte, and felstone,	*	—	—	?	*	?
	4. Elvan,	?	—	—	?	—	?
	3. Intrusive triclinic felspar granite,	—	—	—	—	—	?
	2. Intrusive monoclinic felspar granite,	?	—	—	—	—	?
	1. Metamorphic granite,	—	—	—	—	—	—
Carboniferous,	5. Melaphyre, euryte, and felstone,	?	*	?	?	?	—
	4. Elvan,	?	*	—	?	?	—
	3. Intrusive triclinic felspar granite,	—	—	—	—	—	—
	2. Intrusive monoclinic felspar granite,	?	—	?	—	—	—
	1. Metamorphic granite,	—	—	—	—	—	—
Devonian and Silurian,	5. Melaphyre, diabase, euryte, and felstone,	?	*	*	—	—	—
	4. Elvan,	?	*	*	—	—	—
	3. Intrusive triclinic felspar granite,	—	—	—	—	—	—
	2. Intrusive monoclinic felspar granite,	?	—	*	—	—	—
	1. Metamorphic granite,	—	—	—	—	—	*
Llandovery and Ordovician,	5. Diabase, euryte, quartz-rock, and felstone,	*	—	*	*	*	*
	4. Elvan,	*	—	*	*	*	*
	3. Intrusive triclinic felspar granite,	?	—	*	*	*	—
	2. Intrusive monoclinic felspar granite,	*	—	*	*	*	*
	1. Metamorphic granite,	—	—	*	*	*	—
Arenig and Cambrian,	5. Diabase, euryte, quartz-rock, and felstone,	*	—	*	?	?	—
	4. Elvan,	*	—	*	?	?	—
	3. Intrusive triclinic felspar granite,	?	—	—	—	—	—
	2. Intrusive monoclinic felspar granite,	*	—	—	—	—	—
	1. Metamorphic granite,	*	—	—	—	—	—

Some of the granitic and eruptive rocks are eminently suitable for rubble work and walling; others for paving-setts, or kerbs or quoins; others for cut stone purposes; and the more valuable for polished work in monuments, pillars, slabs, chimney-pieces, &c.

Granites have been used both in ancient and modern times, and when well selected are an excellent and durable material. But it is evident that builders have frequently looked more to the easy and rapid completion of their work than to its durability, as has already been pointed out (vol. v., page 511) in reference to sandstone. This employment of undurable materials is instanced in many of the early ecclesiastical buildings and others in or margining the Leinster granite range, and in the more modern buildings in Dublin, for example, where good cut-work has lost all its sharpness on account of the stone disintegrating under the action of the weather. In Dublin this is not now so observable as it was forty or fifty years ago; as since then many of these crumbling edifices have been removed or re-faced. Well-selected stones have, however, stood the test of time in both ancient and modern structures, to which attention will be hereafter directed.

From time immemorial the granite boulders have been very generally used for various purposes—as for instance in the erection of the megalithic monuments and structures, especially in the so-called *cromleacs*, and in the fabrication of the *bullauns*, or stone basins, found in many places.

[The *bullauns* are usually more common in the neighbourhood of the ancient ecclesiastical settlements than elsewhere. They were probably employed in various ways; e.g. as mortars in which to bruise or crush corn, apples, &c., as baptismal fonts, &c. Some that are built into the walls of the churches may have been either fonts or holy water stoups. At Roscam, near Galway, the late Dr. William King found a peculiar oval pestle that exactly fitted one of the neighbouring *bullauns*, and may possibly have been made for it. In the counties Clare, Limerick, Tipperary, Queen's County, Wexford, and Wicklow, where some years ago much cider and perry was made for exportation, we find many of the cup-querns that were used for crushing the apples or pears, wrought out of granite erratics. In modern times, in Leinster especially, boulder stones have been extensively worked up into monuments, gate-posts, steps, sills, farm-rollers, &c. Erratics from the Leinster granite occur in the counties Kilkenny, Carlow, Kildare, Dublin, Wicklow, and Wexford; while in the King's Co., Tipperary, Galway, and Mayo, the granite blocks seem to come principally from the country north of Galway Bay; such have been found even in the counties of Cork and Waterford. Elsewhere in Ireland, according to the published records, the spread of erratics from the granite centres does not seem to be very observable; but in the neighbourhood of Ramelton, Co. Donegal, fifty years ago, there were numerous granite blocks on the drift-hills, which seem to have came from Barnesmore. Most of them were split up and utilized, principally in connexion with the quay and other improvements in Ramelton. Others occurred on the slate quarry hill near St. Johnstown, about nine or ten miles S.W. of Derry.

In the Co. Donegal at the present time bowl-shaped corn crushers, or *bullauns*, are in use for bruising oats for home purposes, and malt for distillation. These *bullauns* are generally wrought out of granite or gneiss boulders; but sometimes they have been cut in the solid rock; often in quartzyte, or quartzitic sandstone. In all cases the pestles now in use are of wrought-iron, made by country smiths.]

Polished Irish granite has of late years come into the market. Blocks procured from different places have, indeed, from time to time been used in monuments; but the first permanent trade seems to have been established in the neighbourhood of Newry. A trade in polished granite was carried on for a few years at Dungloe, Co. Donegal, which it is now proposed to revive; special quarries have been opened near Galway town; while the rocks of the well-known Termon quarries, Blacksod Bay, Co. Mayo, are now to be put on the market for polished work.

In the quarries worked near Newry (Cos. Down and Armagh) the rocks are bright and uniform greys; those near Galway are of very variable and unusual colours, with shades of red, green, yellow, and chocolate, all more or less clouded and spotted; while those from Blacksod Bay and Dungloe are brick-red, salmon, and grey, with white. Near Dungloe they are capable of being raised in blocks of large sizes. From various other places good stones have been procured and polished; but as yet no quarries have been opened.

GRANITE POLISHING WORKS AND QUARRIES.

Ulster Steam Polishing Company, Belfast, John Robinson & Son. *Quarries*, Castlewellan and Goraghwood. Mottled and fine bright greys (p. 251).

Newry Polishing Works, H. Campbell & Son. *Moor Quarries*. Mottled and fine bright greys (p. 251).

Bessbrook Granite Co., T. W. H. Flynn. *Quarries*, Bessbrook, Camlough, and Derranore. Mottled medium and bright greys. Rostrevor. Green (whinstone) (p. 250).

Mayo Granite Co., now being formed. *Quarries*, Termon Hill, Blacksod Bay. Greys, red, and salmon (p. 221).

Donegal Granite Co., now being formed. *Quarries* in the neighbourhood of Dunglow. Bright-red, greys, and white (p. 233).

Galway Marble Works, John Millar & Son. *Quarries*, Ballagh, Shantallow, Letteragh, and other places near Galway. Porphyritic and mottled reds, pinks, greenish-pink, yellowish, and chocolate (p. 219).

Arklow Sett Quarries, C. S. Parnell. *Quarries*, Arklow rock. Mottled green (granitone or dioryte); not in the market (p. 198).

Carnsore, Co. Wexford, Lord Keane's Quarries, Carne and Carnsore. Reds, and at the latter a course of delicate flesh-colour; not as yet in the market (p. 205).

Architects do not always use polished granites judiciously. Some stand the weather much better than others; and the latter, often more or less beautiful, are more suited for inside than for outside work. From an examination of outside polished works in Ireland, England, Scotland, Canada, and the United States, I find that many of the granites employed in outside polished work are not suitable therefor, especially some of the largely crystalline varieties. The harder and more compact the stone, the more lasting the polish.

[In Ireland the stones that seem best for retaining their polish are basalts and some of the other hard whinstones, if they do not contain iron, very silicious granite, quartz-rock, and quartzyte, as these, after ages of exposure, have retained the polish wrought on them during the glacial period. Such whinstones and granites would be costly and difficult to work, and few persons now-a-days would like to go to the necessary expense. Somewhat similar remarks might be made in reference to quartz-rock and quartzyte; the latter rocks, however, will not dress, nor even saw, across the grain.]

A granite quarry, to be profitable, ought to be able to produce large blocks suitable for monoliths and all sorts of monumental purposes, stone for all description of cut-stone work, paving-setts, kerbs, and channel stones; while the detritus should be ground up into coarse sand for the manufacture of blocks for paths and roadways.

For building, especially cut-stone purposes, the *Intrusive Granites* are usually much superior to those of *metamorphic origin;* as in the former, with but few exceptions, there are systems of what the quarrymen call "grains." These are lines, often recognizable only by trained eyes, along which the stones readily split. In general, there are two systems of "grain," at right angles to each other; and under such circumstances the stones can be split into rectangular blocks, or else slabs, of from a few inches to several feet in their various dimensions. Stones of this class are nearly always capable of long and heavy bearings, while they can always be dressed on any face. On the other hand, granites of solely metamorphic origin seldom have a regular "grain." If there be a "grain" it is always along, and never across, the planes of foliation; and such granites are unsatisfactory for fine cut-stone purposes, as they dress only on one face. But as they are hard, durable stones, and can usually be raised in large sizes, they are admirably suited for heavy work, where permanency rather than finish is required. To this general rule there is an exception, as some of the rocks, originally intrusive granite, and afterwards foliated by subsequent metamorphic action, seem to retain, more or less in their new state, their original "grain." The granitic gneiss, which is considered to be the most durable of all the stones that have been used in New York city, appears to belong to this class of metamorphosed intrusive granite; as do also the granites along the margin of the Slieve Croob intrude, Co. Down, and certain granites in the Castlebar and Lough Conn district, Co. Mayo.

The relations between the Irish granitic gneiss, or foliated granites, and their associated schists, are at present only partially understood.

The granites due to metamorphic action, whether called "foliated granite," "granitic gneiss," or "gneiss," in Iar-Connaught, Co. Galway, and in the barony of Kilmacrenan, Co. Donegal, are in no place intruded into the associated schists. It is therefore evident that they must be adjuncts of the schists, and not rocks that were intruded into the schists. In these portions of those counties there are, however, associated with the tracts of metamorphic granitic rocks and schists, newer granites that have been undoubtedly intruded subsequently to the formation of the metamorphic granites and their associated schists.

At the extreme south of the barony of Boylagh, with the adjoining part of Banagh, Co. Donegal, in the Lough Conn district, Co. Mayo, in the Slieve Crook district, Co. Down, and in south-east Ireland (Leinster granite range) the relations between the granites and the associated schists are different from those in Galway and Kilmacrenan.

In north-east Mayo, Lough Conn district, the foliated granite, or granitic gneiss, sends dykes and courses into the associated schists. It is therefore evident that these granites were originally newer than the associated rocks; while subsequently all were simultaneously foliated, the granite, as a mass, being newer than the schists, but the last foliation in all being developed by one and the same force. In the barony of Boylagh, Co. Donegal, the greater part of the foliated granites occurs similarly to those of Kilmacrenan. But at the extreme south of that barony, in the Glenties district, there are other foliated granites which seem to be of the same class, and to occur more or less similarly to the granitic gneiss of north-east Mayo.

In the Co. Down the Slieve Croob granite was intruded into the associated sedimentary rocks, while subsequently the margin of the intrude, and a belt around it, were invaded by metamorphic action, and foliation developed simultaneous in both; the strikes and dips of the foliation in both being similar.

In the oldest granites (Post Ordovicians) of the Leinster range there are two distinct structures allied to foliation. The first of these is locally known as the "grain" of the granite, it consisting of systems of parallel planes along which the rock splits easily. This structure is often more or less obscure, and only to be recognised by the eye of a practised quarryman; but in some places, especially in the counties Carlow and Wexford, it is very conspicuous, giving the rocks a gneissose aspect. This structure, when traced to the margin of the granite, is found to be quite distinct from the foliation of the schists, the first striking more or less obliquely at the latter.

The second foliation found in the oldest Leinster granite is confined nearly solely to the S.E. margin between Aughavannagh (south of Lugnaquillia), Co. Wicklow, and Killiney, Co. Dublin. This structure, as in the Slieve Croob granite, seems to be parallel to the margin of the intrude, and in places it strikes parallel to the foliation of the associated schists. The latter, however, is not always the case, as in some places the foliation of the schists strikes at the margin of the intrude. In this area there were at least two newer granites after the intrusion of the oldest of the Leinster range.

As has been mentioned, and as will be more particularly referred to when describing the different granite areas, a very general characteristic of the intrusive granites is a structure similar to the "grain" in the oldest granite of the Leinster range.

SUMMARY.

The Galway granitic gneiss, or foliated granite, and the similar rock in the Co. Donegal, are not found intruded into the associated schists.

The granitic gneiss of N.E. Mayo, and certain courses in the Glenties district, Co. Mayo, are found intruded into the associated schists.

The Slieve Croob granite, Co. Down, and its associated elvans, were intruded into the associated schist prior to foliation being developed in it.

The oldest (Post-Ordovician) granite of the Leinster range is intruded into the associated schists. The structure called the "grain" possibly was developed during the cooling; and it is perfectly independent of any structure in the associated schists, while the schistosity along the S.E. margin seems in part to have relations to the foliation in the adjoining schists.

Elvans and porphyries and some felstones often have characteristics more or less allied to those of the intrusive granite. But they are seldom capable of being raised in blocks of large scantling; and many of them are not suitable for long bearings. Some of them, however, break up naturally into squarish blocks, eminently suitable for building purposes; they usually dress and saw well; while some of them, when polished, are handsome stones. A few of the polished stones lately brought into the market by the Millars of the Galway Marble Works are allied with or belong to this class. Some of the felspathic rocks (*granulyte*) should be eminently suitable for the manufacture of glass.

The whinstones, including the granitic or coarse varieties (granitone, &c.), often break up more or less irregularly, some being rubbly; others, however, make good building-stones, or are suitable for cut and even polished work. As already pointed out, polish on basalt and other whinstone is very durable if the stone does not contain much iron. When of good quality, these can be finely worked on any face, are of fair scantlings, and are capable of long and heavy bearings. Many of them split readily into good durable paving-setts of suitable sizes. The stones in dykes and intrudes invariably split better than those in contemporaneous beds.

The metamorphosed whinstones, the "*hornblende rocks*" of Macculloch, are more or less granitoid. They can be raised in massive blocks very suitable for coarse work, such as piers, sea-walls, &c. Of late, ophytic varieties have been introduced into the London market, under the trade name of "green granite." These are principally from Sweden and Norway. But more recently, Mr. Flynn, of the Bessbrook Granite Company, has been manufacturing a green stone obtained at Rostrevor, Co. Down; while Mr. Parnell has exhibited a very handsome mottled stone from Arklow rock, Co. Wicklow.

The different varieties of hornblende and allied rocks are not uncommon in West Galway (Connemara); while they have been also recorded from places in Mayo, Donegal, Tyrone (near Pomeroy), Down, Armagh, Louth, Wicklow, Wexford, and elsewhere.

[The granitoid (or granite-like) hornblende rocks often partake, more or less, of the nature of ophyte (*serpentine*); some, indeed, being highly crystalline ophytes. This class of rock is usually found in tracts of highly metamorphic rock, such as those of Galway, Donegal, and Tyrone; but sometimes they occur elsewhere. In the metamorphic regions, where ophytes occur, there are also usually in connexion with them, or as independent masses, ophytic hornblende rocks of a granitoid aspect, like the Swedish rocks. Up to the present time no special attention has been called to these, and only rarely have they been recorded; but wherever ophytes occur, it is highly probable that they also will be found. Further on, in the different TERRITORIAL DESCRIPTIONS, the places where they are known to exist, or are likely to be discovered, will be mentioned. At present, however, as no quarries have been opened, nor trials made, it cannot be said if they can be procured of suitable dimensions. A very necessary qualification is that they be free from iron, as otherwise they are liable to discolouration and weathering.]

In the mechanically formed adjuncts of the volcanic rocks, such as the agglomerates and tuffs, there are some good building-stones suitable for cut-stone purposes. Many of them have already been described among the calcareous rocks and the sandstones; but they will again be referred to in their different localities.

Some felstones, whinstones, and tuffs have been changed into ophytes (*serpentine*) and steatytes (*soapstone*); they, with the allied camstones (*Pyrophyllyte*), have already been described in my

Paper on Marbles (vol. v., p. 405). Some of the steatytes and camstones have been locally used for lining furnaces and the like; but as yet there has not been any regular trade in them, although they seem capable of being cheaply wrought into fine bricks.

Typical quartz-rock (*Greisen*, Cotta) is sometimes apparently an intruded rock. On account of its usual splintery, rubbly nature, it is not generally fit for building purposes, except for the rudest walls.

Gneiss is generally a hard, durable stone; and some, if regularly jointed, can be raised in naturally square blocks of both large and small scantling, suitable both for heavy and for light work. It is capable of long and heavy bearings. This rock is usually difficult and expensive to dress, quickly wearing out the tools. All samples will dress on the foliation surfaces; but many will not dress, though some may be sawn, across these.

Good schist, like slate, is durable, and if naturally jointed makes good building-stones, as it rises in more or less flat-bedded blocks. In some places the mica schists are ferruginous (*ferriferous micalyte*) and rapidly assume the appearance of having been burnt.

Many of the fine-grained, or the close granites, are eminently suitable for paving-setts, on account of their hardness and the readiness with which they split, as also some of the elvans and whinstones; but in order to be useful in this way, the stone must not only split easily into the required sizes, but it must not be liable to become slippery when worn by traffic. Many stones, eminently suitable for paving in all other respects, become dangerously slippery, even after a little wear.

A practice has been lately introduced of breaking up the waste of granite quarries into gravel and sand for walks, or for the manufacture of granite concrete blocks for streets, drives, and walks. This granitic concrete is much superior, in every way, to asphalt; but it has not come into general use, being much more difficult to repair when a pathway is cut across to lay down water, gas, or other pipes. This, however, might be remedied if the concrete were manufactured in narrow blocks, say eighteen inches wide, one course of which might be raised without interfering with the rest.

GLASS.—The granulyte (veins of segregation) in the Killiney and other Dublin granites, when fine-grained, highly felspathic, and nearly micales, as also the nearly similar elvans in the marginal micalyte, have been pronounced suitable for use in the manufacture of ornamental and bottle glasses.

Similar elvans, as hereafter mentioned, occur in Cos. Kildare, Carlow, and Kilkenny, west of the granite range; while associated with the laccolites at Little Rock, Arklow, further north at Lewis Ville, Kilbride, as also in Croaghan Kinshella, and neighbouring hills, there are fine elvans similar to, if not identical with, the Devonshire granulyte now (1888) imported by the glass-bottle makers of Ringsend, Dublin.

For the convenience of description, Ireland may be divided into four TERRITORIES, namely—(1) the *Leinster*, or *south-east*; (2) the *Munster*, or *south-west*; (3) the *north-west and north*; and (4) the *north-east* [excluding Antrim, put, for convenience, into (3)]. These limits have been regulated as much as possible with reference to the affinity of the *Exotic rocks* in each of them to one another. The above division agrees in the main with this affinity; except in regard to the last two divisions, the later rocks occurring in both. This, however, is so partial that it does not disturb the general arrangement.

In this, as in my earlier papers on the *Economic Geology of Ireland*, I am indebted for much information to previous writers, and to numerous correspondents, to whom again I return sincere thanks; as often as possible the names of the local contributors are given in connexion with their information, thus authenticating the various statements.

LEINSTER, OR SOUTH-EAST IRELAND.

Chronological Account.

[Queen's Co., King's Co., Kildare, Dublin, Wicklow, Carlow, Kilkenny, Wexford, Waterford.]

As indicated in the Table (*ante*, page 170), the granitic and allied rocks in south-east Ireland are of different ages, and are varied in character and composition. Prior to giving the TERRITORIAL DESCRIPTIONS, it seems advisable to treat of the rocks chronologically, more fully than could be done in the Table.

CAMBRIAN and ARENIG (?) Whinstones, Eurytes, Felstones, and Quartz-Rocks, with granitic roots (?)

In the Co. Wexford these rocks are more usually metamorphosed (schist, hornblende rock, gneiss, and granitic rocks). Elsewhere they are not as numerous, and are unaltered.

[Some of the whinstones and quartz-rocks (*Greisen*, COTTA) were evidently intruded or accumulated contemporaneously with the associated Cambrians; sometimes as bedded sheets, sometimes in protrusions, on and around which the sedimentary rocks were deposited. As adjuncts to these, there seem to have been granitic roots (*elvans, &c.*); these, however, are difficult to trace out satisfactorily, on account of the surface accumulations. In the Co. Wexford and elsewhere, it is apparent that, in the later formations the whinstones (*gabbro, diabase, &c.*) were associated with masses of agglomerate. Some altered masses of whinstones, with their adjuncts of Cambrian age, are the rocks that have been picked out by Dr. Callaway, and declared to be of Archæan age. The greater part of the quartz-rocks are unquestionably Cambrian, as to their material (we cannot now stop to go into this question); but some of the dykes may be of later age, as similar rocks are found extending up into the Ordovicians. It is therefore clear that there must be older and later quartz-rocks, and that consequently the exact age of isolated exposures cannot be positively stated. In the granite, in some places in the Co. Wicklow, there are masses of quartz-rock specially peculiar, from having in them an independent structure, indistinguishable from bedding: this is very conspicuous in the "White Rock," a little north of Tinahely. Some at least of these masses are contemporaneous with the granite, such as the mass near Hacketstown, which graduates into a conglomeritic rock, and the latter into the associated granite. In general, however, the mass of the quartz-rock has a hard, well-defined boundary, the strike and dip of the lines of structure being regular.]

ARENIG (*Post-Cambrian* and *Pre-Ordovician*). In the Co. Wexford, at Carne, Carnsore, and in the Saltee Islands, there are intrusive and metamorphose granites, later than the accumulation of the Cambrians, and older than that of the Ordovicians. These have not been recognized as occurring in any other part of this territory.

ORDOVICIAN, Whinstones, Eurytes, Felstones, Quartz-Rocks, and their granitic roots.

[The granitic rocks in the laccolites (*Gilbert*) or root masses, are in general very felspathic, often hornblendic (*syenyte*); but whether hornblendic or micaceous, their minerals are in very minute crystals or flakes, especially the latter, which are often so minute as only to be microscopically perceptible. In the early accumulations (*Black Shale Series*) there are quartz-rocks, sometimes as protrudes, but usually as dykes, some being felspathic. In the middle group (*Ballymoney Iron Volcanic Series*) whinstones, (*diabase* and *gabbro*) are frequent in protrudes, bedded sheets, and dykes. They are often associated with tuffs, which are more or less calcareous, and some even impure limestones. There are also some peculiar protrudes of agglomerate, a few being in mass, but in general they are of smaller dimensions. The latter are invariably more or less calcareous, containing, in some places, nodules of limestone, while in others they merge into impure limestone. That these were contemporaneous protrudes is probable, because in places they extend into interbedded sheets and lentals. In the upper group (*Kilmichael* or *Slate Series*) there are also whinstones generally occurring as protrudes, or intrudes (?), some of which have been changed by methylotic action, into serpentine (*ophyte*), soapstone (*steatyte*), or some allied rock. The exact age of the youngest intrusive rocks is uncertain, as where they occur there are no rocks newer than Ordovician, by which their age might be determined. Some, however, are probably of later than Ordivocian age, as hereafter mentioned. Jukes appears to have been the first to point out that some of the schists, especially the hornblendytes, are metamorphosed intrusive rocks. Usually, if a course of whinstone has been metamorphosed, the central rib is changed into hornblende rock or hornblendic gneiss, while the margins have become hornblendyte (*hornblende schists*). Matthews, of Baltimore, when writing of the American rocks, suggests the alteration to be due to metamorphosis, or molecular displacement, and Dr. Teall more recently has come to a similar conclusion. Examples of such alterations can be seen in the courses of whinstone in various places in the more highly altered rocks of S.E. Ireland (Dublin, Wicklow, and Wexford), those of Connaught (Galway, Mayo, Sligo, Leitrim, &c.), those of Ulster (Donegal), and in those of North America (Dominion and States). In other places that I have not seen similar changes may have taken place. Some of the ophytic-hornblende rocks, among the highly metamorphosed rocks, are very similar in aspect and composition to the so-called "Swedish green granite."]

Materials for Glass.—Associated with the masses of exotic rocks there are, in places, granites which graduate into elvan; some of the latter, already mentioned as at the Little Rock, Arklow, are very felspathic, and eminently suitable to be used in the manufacture of glass. Some of the elvan veins, and the granityte veins in the Leinster granite, or in its vicinity, are also very felspathic, and might be similarly utilized.

Llandovery, or May Hill Sandstone (*Post-Ordovician* and *Pre-Silurian*). Granites, Elvans, Quartz-Rocks, Felstones (?)

[In the Leinster hill range the granites are lithologically very varied, but petrologically they seem to be divisible into the following, viz. :—Leinster Type; the Aughowle Type, or *pegmatyte*, similar to that occupying the parish of Aughowle; and the Aughrim Type, best seen in the vicinity of Aughrim.

The "Leinster Type" granites (*Haughton*) are evidently the oldest, and seem to be intrusive, the date of their intrusion being after the accumulation of both the Cambrians and the Ordovicians. They have all the general characters of an intrusive granite, and at their margins break up through the schist. Nevertheless, in various places, such as Scullogue Gap, between Mount Leinster and Blackstairs, and elsewhere, there are in the granite, seams, or lenticular beds of schists, coinciding in strike and dip with the "grain" of the granite. These are difficult to account for in an intrusive mass; yet that the mass is intrusive seems unquestionable; because if we cross the strike of the "grain" at right angles, this grain is found to be oblique and unconformable to the stratification of the marginal schists. When describing these inliers of schist in the country margining Mount Leinster, Jukes suggests that they "are mere tongues of mica-schist and gneiss, let into the granite while that was yet fluid, portions of that molten matter being, at the same time, squeezed and injected between the beds of the aqueous rocks for some distance, all this taking place of course while the two rocks were buried deeply under many thousand feet of superincumbent rock." (G.S.M.) The grain so characteristic of intrusive granite is probably introduced by thrusting.

[NOTE IN PRESS.—Since this was in type, a report on the N.W. Highlands of Scotland by the officers of the Geological Survey of Scotland has been published in the *Quarterly Journal of the Geol. Soc. Lond.*, vol. xliv., No. 175, pp. 378, &c. In this Paper the effect of thrust in producing foliation is very exhaustively explained, and such thrust would explain the "grain" in the Leinster granite. As, however, the different systems of thrusts that have from time to time affected the rocks of this territory have still to be worked out, we cannot here refer further to the subject.]

The Leinster range granite, as pointed out by Jukes, seems always to be margined by rocks of Ordovician age, and never by the older Cambrians. The Ordovicians to the eastward of the great granite intrude were altered by metapepsis, or regional metamorphism; those to the westward of the range by paroptesis, or contact metamorphism. Towards the western margin, especially, but also in smaller tracts elsewhere, there is growan. Portions of this growan are evidently decomposed Leinster Type granite; but some of it, especially in the Co. Dublin, seems to be composed of "Aughrim Type granite." This latter granite is evidently much newer than the former, and it is supposed to be of either Devonian or Carboniferous age, perhaps even later. Generally the Leinster Type granite is more or less even-grained, but some of it is porphyritic.

Associated with this granite are intrudes of QUARTZ-ROCK, as at the White Rock, northward of Tinahely.

The ELVANS and the FELSTONES, the adjuncts of the Leinster Type granite, cannot be satisfactorily traced, being so much obscured by drift; they occur in the associated schistose rocks.

Some of the whinstones in the schists are also probably adjuncts of the Leinster Type granite; this, however, can only be suggested, as it has not as yet been proved.

AUGHOWLE TYPE GRANITE, OR PEGMATYTE.—This forms a considerable tract in the parish of Aughowle, at the junction of Carlow and Wicklow. The rock is a pegmatyte, made up of large crystalline pieces of quartz and felspar (often microcline), with flakes of mica. The rock is not recognized in the country as a granite, but is called "some sort of a bastard rock." In aspect it is somewhat similar to the pegmatyte of Ontario and Pennsylvania, in which are situated the "mica mines;" but, unfortunately for the home country, the veins of mica in the Aughowle pegmatyte are of very small dimensions. In the mass of the rock the mica is usually on the faces of the felspar. The *Plumose granite* of Jukes is a variety of this pegmatyte, in which the mica is arranged like plumes of feathers. This pegmatyte is similar to the *endogenous granite* of Sterry Hunt, which he considers is due to the deposition of minerals from solution in open veins or spaces. If this was the origin of the Aughowle pegmatyte, there must have been in the granite mass a large cistern full of water, highly charged with mineral matter, which was gradually being deposited as the water evaporated. In the associated Leinster Type granite, especially to the southward, the composition of the "endogenous veins" is more or less similar to that of the Aughowle pegmatyte. The exact limits of the Aughowle pegmatyte are uncertain, the rocks being so much concealed by drift.

The *growan* used to be largely sold in the city of Dublin, under the name of "freestone," for domestic purposes. The disintegration of the Leinster Type granite, especially that of the Co. Carlow, seems to be due in a great measure to the contained quartz being made up of acicular particles; but at the same time there must be some peculiarity in the felspar that causes it also to decompose; possibly the mica also may have peculiarities. The disintegration of the Aughrim Type granite seems in a great measure to be due to the quantity of marcasite in it, and to the white mica (*margarodite ?*). Growan is an excellent fertilizer on limestone soil, or on the tracts of limestone drift. As pointed out by Haughton, most of the rich lands of the Co. Carlow are due to the admixture of granite and limestone debris.

The growan due to the disintegration of the Leinster Type granite ought to be useful in the manufacture of china and coloured glass; but it does not appear to have been tested.]

DEVONIAN (?), CARBONIFEROUS, TRIAS (?), EOCENE (?). Granites, Elvans, Felstones, Eurytes, Whinstones.

[The rocks in Croaghan, north of Philipstown, King's Co., are a protrude of carboniferous age; but the ages of the other later exotic rocks in the same district are more or less open to conjecture. The granite of the AUGHRIM TYPE may occur as outliers in the schistose rocks, as it does near Aughrim and Rathdrum, or in different places as intrudes in the older granite (*Leinster type*). Under the latter circumstances, on account of the paucity of natural or artificial sections, it is difficult to separate one variety from the other; but J. Chaloner Smith, when reconstructing the railway between Kingstown and Killiney, observed and pointed out two distinct classes of rocks, one evidently of much later age than the other—the later rocks occurring as intrudes partly in the old granite and partly in the mica schist.

The exact age of this granite is uncertain. It may be *Silurian*, or *Devonian*, of a similar age to the volcanic products so well represented in the provinces of Munster, Connaught, and Ulster; or it may be of the same age as the just mentioned Croaghan protrudes (Carboniferous), or even of that of the Mourne Mountains granite (*Triassic*). There is no petrological evidence by which its age can be determined; but lithologically it has affinity to the Mourne granite, being slightly albitic—so it may possibly be of similar age (*Triassic*).

The *Aughrim type* granite is an even, free-working stone, jointed in squarish blocks, and having two "grains," along which it splits easily. It is very pyritous (*marcasite*), and liable to disintegrate in concentric coats; so that the outer parts of a block may be much affected by weathering, and liable to peel off in spheroidal shells, while the middle part of the block may be quite sound. A constant adjunct of the intrudes is the "iron masking" of the neighbouring rocks. These seem to have been impregnated with a solution that deposited marcasite, and this, by rapid decomposition, has stained the rocks, which, from their appearance, are locally called "burnt rocks."

These *burnt rocks*, connected with the intrudes of the Aughrim type granite, are similar to the "burnt rocks" containing the mineral channels of the Cos. Wicklow and Wexford, which formerly led me (volume v., p. 304) to suggest that the intrusion of this granite and the formation of the mineral veins were contemporaneous, that is, belonging to one and the same period of vulcanicity.[1] The mineral veins, however, did not accumulate all in a moment; the great "sulphur lode," as also all the other lodes, with one or two slight exceptions, are made up of thin laminæ, parallel to the "foot-wall," and more or less oblique to the "hanging-wall;" consequently it is evident that the shrinkage fissures, now occupied by the lodes, opened very gradually, the lodes being augmented successively by very thin parallel laminæ. The formation of the fissure may have been due to this vulcanicity, the fissure giving opportunity for the production of the lode, and the filling stuff being leachings from the surrounding mineral-charged rocks. In one of the deepest workings in the *East Ovoca Mines* (Cronebane) the lode is cut out by an intrude of granite.

In some few places adjoining the intrudes of the Aughrim type granite there are ribs, or narrow strips, of the associated rocks, which have been changed apparently by "local metamorphism" into gneiss. Ribs and patches of altered jasperized, or baked rocks, often occur isolated; the ribs are peculiar, and seem to be due to aqueo-igneous heat, which found a passage along a line of fissure or jointing. Some of these altered rocks, which are very felsitic (leptinyte, or white-stone), will be mentioned further on.]

In places in the granite and schist areas there are newer dykes of whinstones and felstones, which Du Noyer suggested might possibly be of Tertiary age. Some of the whinstones are very like the melaphyres of the Croaghan protrude (in King's Co.); and in places they are cut and displaced by fissures filled with, of course, later felsytes. I have elsewhere suggested the possibility that these melaphyres and felsytes may be adjuncts of the intrudes of the "Aughrim type" granite.

Territorial Description.

Introductory.

In the *Queen's Co.* there are no known exotic nor metamorphic rocks.

In the *King's Co.* and *Kildare* there are isolated exposures of eruptive rocks; Carboniferous whinstone (*melaphyre*) and tuff at *Croaghan*, north of Philipstown, and at The Chair, to the northward of the town of Kildare; very little used.

---

[1] According to the Australian miners and geologists (*see* Jack's "Report"), burnt, or "iron-masked" rocks, as they call them, are favourable to the occurrence of gold. This may have some bearing on the existence of the gold of the Co. Wicklow, as "iron-masked" rocks occur in the water-sheds of the valleys in which the "placers" are situated; but, at the same time, gold is not recorded from the tracts in which the greatest masses of these "iron-masked" rocks occur.

Extending south-westward from Dublin Bay to near New Ross on the River Barrow, in the Cos. *Dublin, Wicklow, Kildare, Carlow, Kilkenny*, and *Wexford*, is the great Leinster surface exposure of intrusive granites, with outlying smaller exposures to the S.W. in Kilkenny, and to the eastward in Wicklow and Wexford. In the last-mentioned county, in the Carnsore district, a considerable proportion of the rock is granitic gneiss (*granite of metamorphic origin*).

South-east, south, and south-west of the Leinster granite range, in the Cos. Wicklow, Wexford, Waterford, Kilkenny, Carlow, Kildare, and Dublin, there are in the Cambrian, Ordovician, &c., beds, sheets, masses, and dykes of doleryte (?), melaphyre, diabase, euryte, felstone, and elvan; the probable ages to which each belong having been already discussed. Most of the older ones are more or less altered; some being also changed by methylotic action into serpentine (*ophyte*), soapstone (*steatyte*), or other allied rocks.

[The methylotic rocks have already been tabled and described in the Paper on IRISH MARBLES AND LIMESTONES (vol. v., pp. 404–412).

In the area of the Leinster granite range, the granite is generally used for all building purposes; but in the Co. Wexford, in the neighbourhood of the granite outliers, that rock is rarely used, the houses, walls, and fences being built of clay.

When quarries are opened the stones are rarely used, except for farm fences and road material; for the latter a quarry will not be opened if gravel can be obtained, even though it may have to be carted for miles. In places where very superior road metal could be easily procured by quarrying in the granite or whinstone, this will not be resorted to, although the roads have to remain nearly impassable in consequence.]

The granite varies greatly in quality; some of it is very coarsely crystalline, some very fine; it is of every degree of durability; some hard durable varieties are good for tool work, others not so. Their different qualities will be mentioned in connexion with the different quarries and districts. In some places the granite in use is procured solely from loose blocks and erratics; the latter in places occurring in greater or less quantities outside the limits of the granite areas. Formerly the granite of those districts, where it has two "grains," along which the stones split readily, with plugs, into rectangular pieces, was in great demand, being easily and cheaply wrought into columns, pillars, farm-rollers, posts, sills, jambs, &c., procurable in considerable lengths, and capable of long bearings. Of late years, however, it has become the fashion to use iron articles instead of granite for many of these purposes.

Neither the felstones nor whinstones, seem to have been much utilized in ancient or modern times. There are, however, some green tuffose rocks, very durable, that dress easily and well, and were used in the old structures. The beautiful doorway of the old church at Mogue, near Ferns, Co. Wexford, illustrates the work they are capable of; as also some carving in the Seven Churches, Glendalough.

CO. DUBLIN.

Granites.

The granite of the Co. Dublin, as a general rule, is not considered to be well adapted for cut-stone purposes, on account of the difficulty of working it into mouldings; and a freer working stone procured from Golden Grove and Ballyknockan, Co. Wicklow, has been generally preferred and used; nevertheless, as the sequel shows, there has also been a large consumption of the material obtained near Dublin.

Dublin is largely flagged with granite slabs: these have been principally wrought from the erratics and loose blocks, or from small quarries on the flanks of the Three Rocks and neighbouring hills. These blocks have been also extensively worked into quoins, and sometimes used for dressed-stone purposes; but for the latter they were generally unsuitable, as shown by the disintegrated condition of much of such work. Within the last two or three decades many of the old dressings have had to be removed and replaced.

Moreover, the stones quarried for flagging used to be, and are still, badly selected, as will be seen by the uneven weathering of the slabs in the pathways. Of late a most undesirable trade has sprung up in granite for common walling purposes and other cheap work; the stones being supplied by the farm occupiers, who raise the stones in slack time, and during winter cart them down from the Dublin hill slopes. This practice is very injurious to the repute of the Dublin granite, as the stone thus procured soon becomes weathered and discoloured. Some of the window-sills, &c., quite disfigure, on account of their dirty colour, many of the newly erected houses in the suburbs of Dublin. These cheap stones have done away with the former trade in limestone; so that most, if not all of the quarries of the latter, which were formerly worked to supply Dublin are now closed, such as those in the Kimmage district, to the southward, and those between Lucan and Leixlip to the westward (vol. v., page 421).

[NOTE IN PRESS.—Some of these limestone quarries have been reopened for use in the piers of the Loop line Railway connecting Westland-row and Amiens-street.]

The *Killiney, Bullock, Dalkey, and Kingstown Quarries.*—The granites here are harder and more durable than those of Wicklow and Carlow; but as the latter tool more freely, and can be procured at cheaper rates, they have been preferred by the Dublin builders. The local stones are capable of being raised in very large blocks, and were extensively used during the building of the Kingstown piers and jetties, they having been procured from two quarries, now filled up, near the land end of the East Pier, and from extensive workings in the north face of the *Telegraph Hill.* Stones from these quarries were also used extensively, by the permission of the Board of Works, in the construction of the permanent way, the old stations, and the old offices of the Dublin and Kingstown railway.[1]

In the neighbourhood of Bullock and Dalkey granite has been largely quarried in different places, for use in the public and private buildings of the neighbourhood of Kingstown and elsewhere. Various light-houses round the coast, as that at the south entrance to Bearhaven, Co. Cork, were built by the Ballast Board of stones procured here, while Kylemore Castle, Connemara, the seat of Mitchell Henry, Esq., which was contracted for by a Dublin builder, although close to the great granite area of Galway, has facings and dressings of "Bullock granite."

The granulyte (or veins of segregation in the granite), when fine-grained, felspathic, and nearly micaless, as also the nearly similar elvans in the adjoining mica schist, have been pronounced suitable for use in the manufacture of ornamental and bottle glass (vol. v., page 619).

During late years, a very good class of granite was quarried at

[1] The newer works at the Kingstown and Dublin Stations are of Ballyknockan stone.

the *Glenageary Railway Station*, to build the Townhall, Kingstown. It is a handsome streaked stone, which works easily and well. The quarry was closed after the work was completed.

A good class of granite has also been lately quarried near Dundrum, and used largely in Dublin.

"In the bridges, and harbour, and quay works, Dublin, we have used Killiney and Bullock granite most extensively; also Penrhyn, Dalbeattie, and Newry granites—all good stones, when properly selected. The Dublin mountain granite is generally coarse-grained, full of mica, and decays rapidly in comparison with the Killiney stone." (*B. B. Stoney.*)

Wilkinson states:—"The granite at Kingstown is much more durable than the Blessington (Co. Wicklow) stone; but the latter is of a more pleasing and lighter colour, is easily converted, and is, besides, generally prepared on the spot by local workmen, at a cheaper rate than it could be wrought in Dublin."

[The latter portion of Wilkinson's statement would seem to suggest the advisability, as a general rule, of having the stone wrought at the quarries, and not at the building which is being erected. This is controverted by an eminent architect of the present day, who has publicly stated that the stone should be brought to the building, and manipulated under the eye of the architect.

The disadvantage and loss due to stone being wrought at the works, and not in the quarries, may be seen at the present moment in the works now being carried on during the erection of the buildings for the Science and Art Museum, Kildare-street, Dublin.

The stone being used for the finer work is sandstone, from Mountcharles, Co. Donegal, it being brought from the quarry in squared blocks. As little waste as possible is allowed; yet in cutting out a column or pillar at the works there is a loss of one-fifth of the block; and if it is a capital or other such feature that has to be executed, there is a much greater loss. There is also the primary cost of squaring the blocks in the quarry; so that if a bad stone is sent up, it has become too costly to be thrown away, and must be used, although faulty, as is ocularly demonstrated in the south-west corner column of the new building.

If the stones were wrought at the quarry there would be the following savings:—The cost of the squaring of the blocks, the cost of the carriage of the waste, and the increase in the rate of wages necessarily paid in Dublin. The ancient Egyptian, Roman, and other builders, and even the early English and Irish ones, were more sensible than those of the present day;[1] as they not only wrought the stones at the quarries, but even cut columns and such like out of the rocks *in situ*, as is now done in places in the United States.

There is the expense of supervision, on which great stress has been laid; but whether the work is done in the quarry or at the building, superior operatives have to

---

[1] Ballyknockan granite quarry, Co. Wicklow, and places in Carlow, Wexford, &c., are exceptions to this rule, as presently mentioned.

be employed—men who can use their own judgment, and are not solely depending on the architect; so that on this score there will be no great difference as to expense.

It appears, therefore, as has been proved at the Ballyknockan and other granite works in the Leinster range of hills, that the cutting and dressing of the stones can be more economically performed at the quarry than at the edifice which is being erected.

All the stonecutters in Wicklow, Carlow, Kilkenny, and Wexford, seem to be also smiths, having their small forges in which they repair their jumpers, chisels, hammers, wedges, &c.; the tools blunted during a day's work being renovated at night, to be ready for use next day.]

The principal granite structures in Dublin, when Wilkinson wrote in 1845, were the *Parliament House*, at present used as the offices of the Bank of Ireland, flanking walls. *Trinity College*—new buildings, Co. Wicklow granite; upper part of Library re-faced with similar rock in place of sandstone (later about 18 rows of columns of Wicklow granite were erected in the open corridors beneath the Library to support its floor.) *Post Office*—facings, Dublin and Wicklow granite. *Rotunda*—Wicklow and Kilgobbin granite; the latter in bad preservation. *King's Inns*—facings, Wicklow granite. *Four Courts*—facings from Golden Hill and Kilbride, Co. Wicklow; entrance-gate and walls, Co. Dublin granite; this last now much decayed. *Custom House*—some of the facings in chiselled granite, in good preservation. *Castle*—entrance-gate and some of the dressings, much decayed. *Nelson's Pillar and the Wellington Testimonial*—Glencullen and Kilgobbin granites which seem to have been well selected, and have stood well. (The O'Connell Monument, Glasnevin, was also of Glencullen granite, selected by Jukes.) *St. George's Church*—walls faced with Dublin granite. *St. Paul's Church*—Glencullen stone. *St. Werburgh's Church*—columns, &c., which are much decayed. *St. Thomas's Church*—dressings and facings. *Metropolitan Church*, Marlborough street—faced with Dublin granite. *St. Francis Xavier's and St. Paul's* — porticos, entablatures, pediments, towers, &c., Ballyknockan, Co. Wicklow. Wilkinson specially calls attention to the very good examples of Grecian, Ionic, and Roman Ionic work in the capitals of the pillars of these structures. Since 1845 granite has been used in the following buildings as well as in others:—

Stock Exchange, Anglesea-street—Ballyknockan. *Gate Piers, St. Stephen's-green*—Ballyknockan. *North Wall Branch of Bank of Ireland* — Ballyknockan; colours very uniform. *Porch at National Insurance Office*, Dame-street—Ballyknockan. *Fountain* *at O'Connell's Bridge*—Goragh Wood granite. Pedestal of *Dargan's Statue*, Leinster Lawn—part of a granite boulder from Ballagh, Galway. *Mercer's Hospital* — facings of new wing; rough scabbled Ballyknockan granite. *St. Peter's Church*—new facings, rough scabbled Ballyknockan granite; dressings, sandstone. *New Buildings, Science and Art Museum, Kildare-street*—dressed facings, Ballyknockan granite. Some of the stones seem to be badly selected. *Museum Buildings, Leinster Lawn*—Dublin granite, seems to have been well selected. *Saint Anne's Church*—facings, &c., Ballyknockan, with limestone and sandstone string courses. *Saint Andrew's Church*—rubble facing, Dublin granite, limestone dressings. *Unitarian Church, Stephen's-green, West* — rough-picked Dublin granite; facings, dressings, &c., limestone and sandstone. *Methodist Church, Stephen's-green, South*—columns and portico. *Blind Asylum Church, &c., Leeson Park*—Buttresses, cut Ballyknockan; facings, rough Dublin; windows, &c., limestone. *Methodist Church, Charlestown-road, Rathmines*—dressings, Ballyknockan; facings, badly selected Dublin granite. *Methodist Church Temple-road, Upper Rathmines. Westland-row Railway Station*—facings, dressings, &c., Ballyknockan. *Trinity College, new Medical Schools and Museum*—facings, dressings, &c., Ballyknockan. *St. Andrew's Church*—Ballyknockan? and Dublin. *Loop Line*—caps of piers and springings, Aughrim and Dublin. *St. Patrick's House, S. Circular-road*—facings, a poor Dublin granite. Also string-courses, wall-caps, window sills in most of the brick houses, Wicklow and Dublin; the latter, in the new structures, generally badly selected.

The stones that have been used by the *Ballast Board* in the quays and other works have been already mentioned.

[The granites which are principally used at the present time for cut-stone purposes are from Ballyknockan, Stepaside, and Glencullen. *Ballyknockan*, about 4*s.* per cubic foot in the rough; carriage about 5*s.* per ton; all cartage by road; about 11 cubic feet to the ton. *Stepaside*—sills 1*s.* 4*d.* per lineal foot, in squared blocks, about 2*s.* 6*d.*; cost of working into sills, steps, quoins, &c., about 1*s.* 2*d.* for Stepaside, and 1*s.* 6*d.* for Ballyknockan; moulds and chamfering, about 1*s.* 3*d.* more for working Ballyknockan than Stepaside. All cornices, string-courses, sills, columns, &c., extra to cubic dimensions. *Aberdeen* sent only wrought, price about double Ballyknockan. *Goragh Wood* mostly used for monumental purposes. (*R. Clarke.*)]

The employment of a bad-class of Dublin granite, especially in the new buildings in the suburbs, cannot be too highly censured.

Some of these stones, after a few years' exposure, have already disfigured what would otherwise be chaste structures; while in some forty or fifty years, or even less, most of this granite will be more or less decayed.

In connexion with the Leinster granite range there are in many places, as already mentioned, surface-stones on the granite ground and on the marginal metamorphic rocks. These have been very generally utilized, being easily split and worked; and, as hereafter more specially mentioned, different places have got a character from these stones, which have not been obtained from any quarry, but solely from erratics of good quality accidentally found therein. Outside of the Co. Dublin the principal quarries are in the Cos. Wicklow and Carlow; and although Wexford and Kilkenny stones are well known, there does not seem to be any workings that could be called quarries in these counties.

Quarry near *Dundrum.*—Recently opened, very fair stones, but requiring to be well selected.

Goldenball and Kilgobbin.—Small quarries in different places, and surface stones, about eight miles from Dublin; where they have been extensively used for flagging and quoins, and formerly for dressed work. Good stones can be procured by selection, as shown by the Wellington Testimonial, Phœnix Park. "Grey, usually largely crystalline; quartz and felspars about equal; mica olive colour." (*Wilkinson.*)

Killiney and Ballybrack.—Small quarries in various places; about eight miles from Dublin. "Best stones, light grey, very felspathic: mica black-and-green. The stones are very variable, belonging to the older and later granites, and have to be carefully selected." (*Wilkinson.*)

Kingstown and Dalkey.—"Very variable in quality and texture; from highly crystalline to fine, and from very hard to friable; shades of grey; in the coarse varieties grey and black mica; in the fine, black mica grey quartz and whitish felspar. In some varieties there are crystals of sphene (*Titanite*)." (*Wilkinson.*) Some very fair veins of stone were cut when the railway between Kingstown and Killiney was re-constructed; used in the Dalkey, Bray Head, and Greystones Coastguard stations.

Glencullen.—Good bright colour; free working. "The Glencullen granite is a favourite with builders, on account of moderate prices and quick delivery. On account of its quality and cheapness it has been used in different coastguard stations in Louth and Dublin in preference to the local limestones." (*M. Mellon.*)

In the coastguard stations along the east coast the dressings and other cut-stone, especially for long bearings (steps and sills) have been largely procured in the Co. Dublin. *Glencullen granite*, "Clogher Head, Co. Louth; Rush and Malahide; Ringsend, with some *Dalkey stone*; here they were also used for facing; at Arklow, Co. Wicklow, and Kilmichael Point, Co. Wexford, with *Aughrim stone*. Ringsend, with *Glencullen stone*; Dalkey, Bray, and Greystones, Co. Wicklow, with *Kingstown stone*, the first being also faced with punched ashlars; while the Bray building is faced with very superior rubble. (*M. Mellon.*)

All the authorities speak of the Dalkey and Kingstown stones as very durable. Many of the Glencullen stones disintegrate freely; but, if well selected, stand well, as in St. Paul's Church, &c., Dublin.

Whinstones, Eurytes, Felstones.

In the *Ordovicians*, to the north of the Co. Dublin, near Balbriggan, Donabate, and on Lambay Island, as also in the southern part of the county, near Saggart and Rathcoole, and in the *Cambrians* of Howth, there are dykes and other intrudes, principally of eurytes—that is the rocks intermediate between whinstones and felstones, being neither predominantly basic nor acidic. They may be of the same age as some of the newer eruptive rocks in the Cos. Wicklow, Wexford, and Waterford; but the precise age of the eruptive rocks near the northern end of the great Leinster granite range is not known; however, they are post-Ordovician and pre-Carboniferous. Some varieties, such as that known as the "Lambay porphyry," are a handsome, mottled, green stone, capable of taking a good polish. Specimens were exhibited by the late Lord Malahide at different times, some being now in the Dublin and other Museums. The Messrs. Sibthorpe never heard of it being in the market; but pieces can be obtained by favour, and have been manufactured into paper weights and table slabs of from 12 to 16 inches in diameter. At different times during the last 30 or 40 years, some of these stones have been suggested as good for "paving-setts." They work readily, as they split squarely and easily; but most of those that have been tried seem to have a soapy quality (*steatitic*) which is detrimental, as they would be slippery if subjected to traffic. [*Vide* papers on *Irish Arenaceous Rocks*, vol. v., p. 507, and *ante*, p. 6.] In Howth, Saggart, and other places quarries have been opened to supply road metal to Dublin, the Townships, and the local roads.

In the neighbourhood of Balbriggan are many intrudes of whinstone, some of which Jukes considered to be specially suitable for paving-setts.

GNEISSES AND SCHISTS.

Gneiss, is nearly, if not altogether, absent from the Co. Dublin. On the margins of the granite intrude there is in places a thin coating, having a gneissoid appearance. It is scarcely, however, a typical gneiss, the foliation being rather of a platy structure, introduced in the outer crust of the granite.

The *schists* are various, both here and in the adjoining portion of the Co. Wicklow. They may be either metamorphosed igneous or sedimentary rocks. If they were originally felstones they are now felsitilyte (*felsite-schist*), or felspathic *micalytes*; but if originally eurytes or whinstones, they are now, nearly always, some variety of *hornblendyte*.

["The thick courses of euryte and whinstone, as already mentioned, have usually a compact rib margined by schist. This is, generally, not the case with felstone courses; although it has been recorded as occurring in the Co. Galway. Some of the metamorphosed felstone courses in that country, near the town of Galway, are a granitic rock along the margins, but have a felstone or porphyry rib." (G.S.M.)]

In the schist districts this rock is extensively used for general purposes, especially the micalyte. It affords good serviceable stones, very durable; but some are unsightly, as they become by weathering "iron-masked." Micalytes ought to be used much more than they are, in sea-walls and piers; because when they can be raised as rough flags in large, or even fair sizes, if they are pitched, not built, in courses in the walls, no wave can work them out; while if the walls are left rough enough on the face, waves cannot rise so well on them, as they would otherwise do.

[These qualifications of schistose, slaty, and shaly rocks can be studied in various places round the coast of Ireland. On natural sea-margins the waves rise much higher on a smooth surface than on a rough one, or on a perpendicular wall than a sloping one. A wave coming on a rock will rise much higher than on an adjoining shingle beach, and on a perpendicular rock-cliff much higher than on a sloping one. This, of course, is intended to apply only to more ordinary cases. If a sea-wall rises directly from water so deep that there is but little breaking of the wave-crests above it, the face of the wall should be perpendicular. This is well illustrated when a north-easterly storm is driving the waves against the perpendicular rounded end of the west pier of Kingstown Harbour.]

WICKLOW, KILDARE, AND CARLOW.

Introduction respecting Granite.

[The granites of the north-west of the granite area, situated in Co. Wicklow (*Blessington district*), are much preferred by the Dublin builders to those of their own county, as not only are the stones kinder to work, but also, as pointed out by Wilkinson, they are wrought on the spot by native stonecutters, thus saving expense in various ways. We may again point out, on account of its importance, the advantage of cutting building stones at the quarry. *The stone can be cut more easily and cheaply when fresh than afterwards. The carriage to be paid for is solely that of the wrought stone, and not of blocks, a fourth or a third of which would have to be chipped away afterwards, while only sound stones are sent from the quarry. On the other hand, if the stone is sent in blocks, notwithstanding the most careful selection, some bad ones will escape detection; and these, after their carriage, will have become so costly that they cannot be thrown away, and have to be used to the detriment of the building.*

In the neighbourhood of Castledermot, Co. Kildare, and in the western part of the Carlow granite tract, the rocks are partly similar when sound; but in places tracts of growan come in. Some of this growan probably belongs to the newer granite; but a large portion is evidently disintegrated "Leinster type" (*Haughton*) granite.

At the junction of Carlow and Wicklow, near Shillelagh, in the district after which it may be called, is the *Aughowle pegmatyte*. This peculiar variety, already described (*ante*, p. 182), is so coarse and unsightly as to be suitable only for the very roughest field walls.]

In Kildare and in Carlow, both on the granite and on the marginal tract of schist, there are many granite erratics, now far less numerous than they were some years ago. These were formerly a considerable source of income to the occupying tenants, who split them up, and wrought them into pillars, earth-rollers, sills, window-stools, &c., or sold them to the stone-cutters and builders, who wrought them themselves. This trade, however, has greatly fallen away of late years, iron articles being used instead of stone in so many cases. The length of scantling supplied by these stones, and the long bearings of which they are capable, even with small transverse dimensions, are very remarkable.

These stones are very suitable for this class of work, as there are in them two systems of "grain," or concealed lines of splitting, in planes perpendicular to one another, along which the quarrymen can split the rocks, with plugs, to any required scantling.

[The operation of plugging, as practised in the south-east of Ireland, consists in making a row of round jumper holes, into which treble plugs are driven. If the stone is kind, the holes are from five to twelve inches deep, according to the size of the block; if the stone is tough, the holes must be deeper. Where a block has been split into slabs, these are again split with flat wedges into posts, sills, &c. Most of the inhabitants of these counties are quarrymen, and are skilled in splitting up the blocks, and many of thm spend their spare time as stonecutters.]

In this area the granite, for the most part, is not what can be called a first-class stone, being often more or less rotten or flaky, or even a growan, so that good stones cannot be procured everywhere. Those places in which good stone is known to exist are mentioned below.

Although granite has been so generally used in recent times, yet, as pointed out by Wilkinson, "in the ancient buildings of Co. Wicklow, slate-rock was the material more generally employed, mixed with rolled field-stones of quartz and granite. . . . In the buildings at the Seven Churches, Glendalough, the granite blocks are in many places much corroded by the weather, while the slate-stones indicate, by their present state, a greater durability." Some of the quoins in St. Kevin's Kitchen are of granite, which rock was also partly used in the Round Tower, "the semicircular arch in the doorway of which is cut out of a solid block of granite. There is also a very peculiar and ancient archway constructed of granite, which forms part of a gate-house, through which an old paved road was constructed. Large flat-bedded stones of this road still remain. The peculiarly worked bed and arched joints of this gateway indicate a rude and primitive construction."

CO. WICKLOW.

GRANITES.

Golden Grove and *Ballyknockan*, near Blessington (*Leinster type*), generally known in the trade as "Blessington stone." Bright grey, more felspathic and more easily worked than the Kingstown and

Bullock granites, but not as durable. At first it is superior as to colour; but when wheathered, it is much the same in that respect as the others. On account of its ready dressing and of its being worked at the quarries by the native workmen more cheaply than it or any stone could be when carted to the buildings in course of erection, it has been largely used in Dublin. "Probably a better evidence of the difference in working quality, and of the value of the facility of conversion, as compared with the cost of carriage, could not be adduced than the station-house and offices at Kingstown, of the Dublin and Kingstown Railway, which, although built on the solid granite rock, are constructed with stone brought from near Blessington—a distance of twenty miles." (*Wilkinson.*) These granites have been already specially referred to.

In other places in this neighbourhood small quarries have been opened, and good stones procured; all, however, have gone into the market under the name of "Blessington granite," and none of the workings have been extensive enough to have received a special name; it is, therefore, only necessary to state that in this locality good stone could be procured in other places if quarries were opened. Elsewhere, in the tract of the granite of the "Leinster type," the quarries that have been wrought in different places seem to have been only for local use, or some special purpose, as the stone from these is not known in the general market.

Ballynaclash, S.W. of Rathdrum, a dyke of fine elvan; at one time worked for paving-setts, for which it ought to be suitable, if the quarry was continued in depth.

Carrick, south of Rathdrum (*Aughrim type*), "Fitzwilliam quarry." Grey, even-grained, but containing more or less marcasite, which causes discolouration, was extensively quarried during the construction of the railway from Dublin to Wicklow.

"*Aughrim*, close, fine, and easy to work, used with Glencullen granite, for sills, steps, and other dressings in the Arklow and Kilmichael (Co. Wexford) C. G. stations; and with Carlow granite in those at Curracloe and Rosslare, both in Co. Wexford. The Carlow granite is a good variety, soft and close, hard and coarse, good and bad colour." (*J. W. Mellon.*) Extensively used on the railway between Killiney and Kingstown; also on the "Loop Line," Dublin.

Tinnakilly, north-east of Aughrim, worked in different places. In

"Edward's quarry" (opened by the contractor of the railway to Shillelagh), and thereabouts, the stone can be raised of very long scantling, and capable of long bearings; the stone is otherwise very similar to that of Carrick.

Railway Quarry, near Aughrim station (*Aughrim Type*). More or less similar to the Carrick stone; has been largely used at the Bray station, and in other places along the Kingstown and Wicklow Railway.

Shelton Abbey and *Glenart*, about a mile N.W. of Arklow. (*Elvan*). There are portions of a dyke in the Ordovician rock, broken and slightly shifted by the fault of the Ovoca River; a bluish-greenish stone, weathering yellowish grey. The quarries were opened and used for building the out-offices at Shelton Abbey, and the castle and out-offices at Glenart.

Near Lewisville, north of Arklow. A boss of bright grey, fine-grained granite, has been a little worked for local purposes.

Little Rock, Arklow.—A bright grey, fine-grained granite; used in the vicinity; the felspathic elvan associated with this rock is suitable for glass manufacture.

Croaghan Kinshella.—On the north and north-west slopes, extending into the county of Wexford, is a fine-grained, bright grey granite, regularly jointed, of apparently a good quality. It has not been made use of, except the loose blades of it for farm purposes.

Macreddan, four miles from Rathdrum. Hard, yet not very difficult to work.

Killanure, five miles from Shillelagh. Micaceous and quartzose; even-grained; works well.

Williamstown, seven miles from Baltinglass. Felspathic, black mica; coarse-grained; hard to work, as it splits irregularly.

Highfield, four miles from Baltinglass. A more easily worked and better stone than the last.

WHINSTONES, EURYTES, FELSTONES, QUARTZ-ROCKS.

In the north-western part of the Co. Wicklow, extending from the boundary of the Co. Dublin to near Baltinglass, there is a strip of *Ordovicians*, and associated intrusive rocks, very similar to those in Kildare, except, perhaps, that they are more altered. To the eastward of the granite area, and lying unconformably against the Bray and Newtownmountkennedy tract of *Cambrians*, there are more or less metamorphosed *Ordovicians*. In these there are, apparently some interbedded masses, as also dykes and other intrudes of whinstone, euryte, and felstone; while in the *Cambrians* there are a few whinstones (*diabase*) and intruded courses of quartz-rock. The quartz-rocks in the granite area has been already mentioned.

The whinstones, eurytes, felstones, and quartz-rock, altered or unaltered, are very little used. In one place, as already mentioned (*ante*, p. 181), between Roundwood and Annamoe, a mass of whinstone has been altered into ophyte (*serpentine*), more or less allied to the so-called "Swedish green granite." "The towns of Carnew, Shillelagh, Arklow, Rathdrum, Wicklow, Newtownmountkennedy, and Bray, are situated in the slate district; and this stone has in these places been generally used for all buildings. The rock produces large, flat-bedded stones, and makes good strong rubble-work; but being thinly laminated, it is not well suited for cut-stone purposes, as it cannot be worked across the grain. Granite is therefore almost universally used for this kind of work." (*Wilkinson.*) Some of the towns enumerated above are in the *Cambrian* area, where the rock used is rough slate, not the *Ordovician* schist.

There are whinstones in different places suitable for paving-setts. At the Rathdrum railway station, as also to the east of the Ovoca River, there is a very similar stone: this was worked a little, but injudiciously, the surface-stones only being wrought, which gave the setts a bad repute. Further southward, or down the valley, opposite Avondale demesne, in the townland of Shroughmore there is a stone very similar to the Welsh stone so much used in Liverpool. A little S. E. of the Ovoca railway station, a whinstone is quarried for general purposes. Some years ago it was made into setts for the Dublin market, but was not approved of, as it was said to become slippery. A little westward of Wooden Bridge a quarry was opened by Mr. C. S. Parnell, and good setts made; but the undertaking had to be abandoned, as the agent of the property demanded too high a royalty.

Big Rock, Arklow.—On this hill Mr. C. S. Parnell has opened quarries. "Four varieties of whinstone are worked—three blue, and one slightly greenish. The setts made are—No. 1, $4'' \times 4'' \times 4''$;

No. 2, 5″ × 5″ × 5″; No. 3, 5″ to 8″ × 3″ × 6; and No. 4, 5″ to 9″ × 4″ × 7″. The stones are not in sizes large enough for channels, kerbs," &c. (*W. Kerr.*)

To the north of Arklow, at the *Lewisville* granite, near *Snugborough*, and in different other places in the parishes of Kilbride, Ennereilly, Dunganstown, &c., there are stones of good aspect, but as yet untried. One variety rises in flags, and has been used for flagging in Arklow and the country farm-houses.

[The polish which the whinstones are capable of receiving and retaining can be studied by examining blocks and pieces in the glacial drift.]

Little Rock, Arklow, mass to the south of the hill. Nice-looking, mottled greenish, granitoid.

In the neighbourhood of the Ovoca mines there are great masses of "baked rocks" (*leptinyte* and *granulite*) mixed up with felstone, and often difficult to distinguish from one another. Some of these rocks, as pointed out years ago by Weaver, are suitable for the manufacture of kaolin (*porcelain clay*), while others can be cut and polished. A specimen from Bell Rock, south of the mines adjoining the tramway, gave a nice, streaked and mottled, light dove-coloured stone, that cut well and took a fine polish. Very pure leptinyte, suitable for the manufacture of kaolin and of glass, occurs in various places adjoining the intrudes of whinstone; these felspathic rocks also occur, more or less isolated, as in the vicinity of the Ovoca mines. The latter have not been made use of, although attention was directed to them more than half a century ago by Weaver.

Others of the shales have been baked into a black rock like touchstone, pieces of which have been manufactured by Mr. Russel, lapidary, Fleet-street, Dublin, into touchstones and into whetstones for the finer stone-cutting tools.

KILDARE.

GRANITES.

In the granite tract which lies to the south-east of the county, no large quarry has been opened in recent years on account of the number of surface-blocks of a superior class which occur there. The beautiful sculptured cross at Moyne, restored by the proprietor, Mr. Frederick Carroll, was cut out of a block of this granite, while the megalithic structures, commonly called cromleacs, in this and the Co. Carlow, have in most cases huge granite blocks as cover-stones. The covering-stone of the Kernanstown cromleac measures 16 feet × 13 feet × 5 feet. (G. S. M.)

"The interesting and beautiful architectural ruins of Castledermot form one of the most extensive erections in which granite has been used for Gothic architecture. They are in the later pointed style of Gothic, commonly known as the Decorated style, and contain many well-finished and delicately-wrought mouldings, which show that granite is not unsuited to such work. The stone is generally in good preservation." (*Wilkinson.*)

Newtown, near the mearing of the county and the town of Carlow. Grey, free-working, even-grained.

Dairy-farm, south-west of Castledermot. Grey, fine-grained, easily wrought, capable of producing fine and elegant work; can be raised in blocks of considerable size and length. "Some of this granite was considered so good that it was sent to Dublin for columns." (G. S. M.) The columns and other cut-stone work in the portico of the Presbyterian Church, Arran-quay, Dublin, are said to have been wrought out of stone here procured.

Knockroe, south-east of Castleroe cross-roads. Light-grey, even-grained, black mica. (G. S. M.)

Hallahoise, south of Bushfield. Similar rock to last. (G. S. M.)

Whinstones, Eurytes, Felstones, &c.

Towards the N.W. of the Co. Kildare, at the Hill of Allen and the Chair of Kildare, in the *Ordovicians*, there are interbedded tuffs and eurytes: the latter, according to Jukes, being somewhat similar to the Lambay porphyry. Towards the N.E. of Kildare, coming in from the Co. Dublin, and forming a narrow strip along the N.W. mearing of Wicklow, there are also *Ordovicians;* those nearest the granite being metamorphosed; while associated with them are whinstones, eurytes, and felstones, similar to those in Co. Dublin, but perhaps not as numerous.

The intrusive rocks appear to be very little utilized; but the slates, schists, &c., are generally used for all common building work. "The town of Naas is situated just on the border of the rocks, and is badly supplied with building-stones; cut-stone being generally obtained, either from the limestone, at some distance, or from the granite of the Wicklow range." (*Wilkinson.*)

CARLOW.

GRANITES.

In the north-eastern part of this county the granite is generally of a bad class, friable or coarse; but towards the western boundary of the granite tract, especially near Bagenalstown, some excellent stones have been procured, both from the surface-blocks and from quarries. Granite is the stone generally used, not only in this area, but also in the valley of the Barrow, to the eastward, for quoins, sills, gate-posts, walling, and all cut-stone purposes. It is also used for fences; split blocks 8 or 10 inches square, and about 8 feet long, being placed on granite pillars, of the same transverse dimensions. These fences are both durable and cheap, costing about 8*s*. to 10*s*. a perch.

"The Lunatic Asylum, Court House, Union Workhouse, and many other buildings in the town of Carlow, were erected of local granite, procured from different quarries. Can be had in nearly any scantlings. From hard to free, not difficult to work; used in punched, chiselled, moulded, and rubble work." (*J. W. Mellon.*)

In the north-eastern part of the Carlow granite ground the rock comes to the surface in different places; but it is often either a growan, or too friable for use, and it is always more or less coarse. In addition to the surface-blocks, the following seem to be the places in which the better stones can be quarried:—

Palatine, on the mearing of Wicklow and Carlow. Grey, coarse-grained, regularly jointed. (G. S. M.)

Ballyloo, about two miles northward of Nurney. Regularly jointed; has a tendency to break-up into cuboidal blocks. (G. S. M.)

Graigue na Spiddoge, nearly three miles north-east of Nurney. Coarse-grained; felspathic; well-jointed; easily raised. (G. S. M.)

Nurney. More or less similar to last. In places in this vicinity, as also to the S.W., in the country about a mile and a-half east of Leighlin Bridge, similar stones have been quarried. (G. S. M.)

The "Carlow Stone," which has been so largely sent by canal and road to Dublin, Waterford, Kilkenny, and intermediate places, has been procured from a tract about ten or eleven miles long, and from three to four miles wide, extending from Ballybegs, about seven miles N.E. of Carlow, south-westward to Ballywilliamroe, east of Bagenalstown.

In this area excellent surface-stones have been procured, especially at *Crane*, *Kildranagh*, and *Ballywilliamroe*, respectively, five to eight miles N.E., and two miles E. of Bagenalstown, the blocks vary in magnitude to ten tons and upwards, while some stones have been raised from workings. "In Bagenalstown, granite is the material generally used for cut-stone purposes, the solid stone being close to the town on the east." (*Wilkinson.*)

Ballybegs, about seven miles north-east of Carlow. Grey to yellowish; more or less felspathic; micaceous; some portions liable to discolour with iron. This quarry was formerly very extensively worked. Of it Wilkinson, writing in 1845, states: "This is the only quarry in the county sunk to any depth for procuring this stone. The quarry is about 40 feet in depth, and covers an area of about 300 square yards. The stone is procured in large, irregular blocks; the joints running nearly perpendicular, or at an angle of about 15°."

Kildranagh, about six miles north-east of Bagenalstown. Coarse, very felspathic; mica black and grey; lumps of semi-crystalline quartz. (*Wilkinson.*)

Newtown, about three miles east north-east of Bagenalstown. Felspathic; micaceous; some schorl; felspar rather reddish. (*Wilkinson.*)

Kilcurragh, near Bagenalstown. Grey to nearly white; loosely aggregated; felspar white and opaque; quartz; white, mica grey. (*Wilkinson.*)

In places near the margin of the granite, and in the associated schists, are elvans, sometimes so fine as scarcely to be distinguished, in a hand specimen, from a felspathic grit; while others are more granitoid. (*Jukes.*) This variety is fine and very micaceous. It attracted *Wilkinson's* attention, as it appears to have been much used by the early builders, it being more easily worked than the ordinary granite. From him we learn that in the old Wells Church, a mile and a-half south-west of Bagenalstown, it was worked up with limestone; but it is now much weathered. In Ballymoon Castle, about two miles to the east of that town, it was extensively used. This latter building is very interesting and peculiar. It is about 200 feet square; the walls being about 20 feet high, built in range-courses. Most of the stones selected for outside work have on the outer face a film of quartz, which has kept them until now, as sound as when first used, while any without the film are much disintegrated on the surface. The fine portions of the stone were worked with remarkable smoothness, and used for the splays of openings. Its good qualities for inside work are displayed in the interior of the building, protected from the weather, where they are still quite perfect, while exposed surfaces have weathered away to the depth of about an inch. Wilkinson observes that "the weathering has been most even, showing the equality in the texture of the stone."

[In the veins or courses of granite proceeding from the main intrusion mass, it is not uncommon to find the granite adjoining the joint surfaces, which are more or less parallel to the walls of the courses, coated with a film of quartz. We may here note that, as mentioned below, in the Co. Wexford, in some of the courses there are ribs of veined quartzyte; the vein or "grain" (to use the term applied to the similar structure in the granite) being parallel to the walls of the course. In these quartzytes (if they may be so-called) the perpendicular "grain" is regular; but the horizontal "grain" is not so.]

SCHISTS.

Schists occur in a small tract in the S.W. of the county, in the neighbourhoods of Newtownbarry and Clonegal. They are used for walling purposes.

KILKENNY.

GRANITES.

This rock occurs, as outlying exposures, S.W. and S. of Inistioge, in the parish of Jerpointchurch, and to the north-west of Tullagher, also in four small patches eastward of that town, south of Graiguenamanagh, in Brandon, and that neighbourhood, where it is the S.W. termination of the Leinster range; and adjoining the Co. Carlow, between Graiguenamanagh and Goresbridge. It is described by Jukes as "for a granite a very perishable stone, often decomposing on the ground to a considerable depth." In the vicinity of the granite are elvan veins differing from it "partly in the rareness or absence of mica, and partly in the fineness of grain; so that in a hand specimen the rock might be mistaken at first sight for one of the fine-grained *Ordovician* grits. (G. S. M.) These are similar to the Co. Carlow elvans. No large quarry has been opened; the stone, when required, being procured from the large granite erratics. These blocks are very numerous near Mount Loftus, adjoining the River Barrow. Many of them are roughly squared; as, some years ago, the Messrs. White, of Waterford, contemplated building a dry-dock there; and about 600 tons of squared blocks were brought by boat from this place. As the design for the dock was not carried out, the rest of the blocks were left here; while those boated to Waterford were sold for foundations, &c. Granite either from this county or Carlow, has been used in the following structures in Waterford:—For the fronting of the Savings Bank, new Courthouse, and new Bank of Ireland, along with limestone; new Methodist Church; Post Office Buildings, and the Clock Tower on the quay. (*J. Budd.*)

Whinstones, &c.

Whinstones occur as intrudes in the granite area, between four and five miles S.W. of Inistioge. *Euryte* (?) associated with *Tuff* is found at Ballyneale, three miles N.W. of New Ross. These are used only for road metal and farm purposes.

Margining the various small exposures and the large tract of granite, the *Ordovicians* are more or less altered into *schists*, which are used for local walling purposes

CO WEXFORD

Granite Rocks.

In the south-eastern part of the county, margining the sea, and in the Saltee Islands, there are granites and granitose gueiss of *post-Cambrian* and *pre-Ordovician* age (Arenig). The granites are partly intrusive, and partly of metamorphic origin, the latter graduating through schists into unaltered Cambrian. In the metamorphosed Cambrians are various metamorphosed volcanic rocks, with their associated tuffs and agglomerates. The latter are of very little value, as they rise in unsightly blocks, not well suited for sea-walls.

At *Carnsore* there is a vein of very superior bright red granite. It is regularly jointed, and capable of being raised in naturally square blocks of large scantlings, suitable for long and heavy bearings. It plugs and dresses well, and takes a good polish, as was exemplified in the specimens exhibited in the Dublin Exhibition of 1853. The vein ought to be cheaply and easily worked, while the stones could be shipped from Ballygeary. A short time since a company was formed to work this stone; but it was not allowed to proceed, as the agent of the property considered that the unavoidable accompaniments of the working of a quarry would be detrimental to the property. In the same neighbourhood there is a handsome, light-coloured, porphyritic granite.

In the neighbouring *Saltee Islands* there are grey and light salmon-coloured granites, which might be made use of with advantage, if there were facilities for working them in the neighbourhood of Carnsore.

In the same district, and near Greenore, there are green granites (Hornblende rock).

Granite Intrudes at Glenbrien, Ballynamuddagh, &c.—These occur in the county S.E. of Enniscorthy. On the old geological map of this district a considerable area of granite is here shown; but after careful examination it appears more probable that this really consists only of four or five small intrudes, with accompanying veins or dykes in the associated rocks, especially to the eastward.

Near *Ballaghkeen* there is elvan, graduating into granite; the latter in part growan. Near Ballymote and Corbally Bridge there is granite and elvan, the latter nearly white. Granite and elvan have also been quarried at *Ballynamuddagh* and *Glenbrien.* At the former the rock is fine and even-grained; irregular veins and other intrudes extend from it into the associated iron-masked schist, which is locally called "spawl stone." These rocks can be traced westward, apparently joining the localities at and near *Vinegar Hill*, and other places in the *Enniscorthy* neighbourhood, thus suggesting that the granite and elvan are of a later age than the Ordovician.

A long, narrow breadth of the S.E. marginal part of the great Leinster granite exposure lies within this portion of the Co. Wexford. In the schists outside of the margin, and running somewhat parallel thereto, there are a few courses of generally finer and more compact granite. In these there is a structure rudely parallel to their walls, giving them a bedded aspect; while in some of them, conforming to this simulated bedding, there are thick courses of quartz-rock, in some places of blackish or smoky colour. These quartz-rocks seem to be allied to those near Hacketstown, Co. Carlow.

All over the granite-ground, as also on the margining mica-schist, numerous surface-blocks abound, they being very conspicuous in the valley of the River Clody, to the N.E. of the summit of Mount Leinster. On this account no quarry has been opened in the main mass of the granite; but the courses in the schists are quarried at several places, to supply materials for walling and for road-mending; while for cut-stone purposes the large loose granite blocks are preferred. At Gorey the Norman columns and other dressed work of the cathedral were formed from them. The rock is generally more or less even-grained, similar to the Co. Carlow stone, except on the slopes of Blackstairs and White Mountains, where it is porphyritic with white crystals of orthoclase. This bright grey porphyritic rock would be very effective for ornamental purposes; but we could not learn that it has ever been so utilized.

[The inhabitants of the country near Blackstairs and White Mountains seem to be generally stonecutters and smiths, each having a little smithy attached to his cabin to repair and sharpen his tools. Formerly these people did a good trade, partly in cut-stone, but principally in gate-posts, farm-rollers, cider-presses, and paving-setts; large quantities of the last used to be sent to Waterford, New Ross, Wexford, Enniscorthy, and other small towns.]

Whinstones, Eurytes, Felstones, Tuffs, Elvans (Root Rocks, or Laccolites).

Crossing the Co. Wexford obliquely in a N.E. and S.W. direction, and extending into the Co. Waterford, there are more or less continuous massive sheets of whinstones, eurytes, felstones, and tuffs interbedded in the *Ordovicians;* while in the country immediately to the S.E. are dykes and other intrudes connected with them. Most of the intruded rocks in the zone of these volcanic rocks are more or less similar to the bedded masses; but one variety is very peculiar, having all the characters of a tuff, or agglomerate, and containing limestone concretions, but behaving in mass like a normal intrusion. These are conspicuous in the country S.E. of Ferns, and also to the N.E. of Adamstown; but their intrusive character can be best studied in the coast section between Kilmichael Point and Courtown Harbour. (*Ballymoney Section.*) The intrudes seen to the S.E. of the sheets are masses of elvan, apparently the laccolites or roots of the interbedded rocks. They are very fine-grained, and the mica is in exceedingly small scales, and seems to be sometimes replaced by minute crystals of hornblende. None of these rocks, whether bedded or intruded, seem to be in request, except in a few places, and only for mere local purposes. However, when the railways were being made they were used for building walls and bridges; when it was found that some of the green calcareous tuffs were very suitable for cut-stone purposes. That they are durable is proved by the state of preservation of the beautiful doorway of Clone Church, near Ferns.

[In describing the limestones of this county (vol. v., page 443) and the partly similar calcareous tuff in Limerick (vol. v., page 431), it was suggested that this class of stone is "not durable." But this may not be universally applicable. The stones after some time become discoloured, and seem to be decaying: this is due to the leaching out of the iron, which, however, seems to give them new life, and some at least of them will regain their green colour and acquire a permanent condition.]

Clone, a mile south-west of Ferns. Bright green; calcareous; fine; works easily; thin-bedded, and capable of being raised in stones of fair scantling. Used in the new church at Clone, in both walling and dressing. The suitability of this stone for minute and beautiful work, as also its durability, is well exhibited in the old church at Clone, especially in the doorway. In the old castle of Ferns, and in the early ecclesiastical buildings there, a similar stone was used.

Between Enniscorthy and Ferns the D. W. W. Railway has made excavations in calcareous tuff, and used the rock for cut-stone purposes, and for rubble work in the bridge and walls.

Between *Adamstown* on the S.W., and the parish of *Clone* on the N.E., are calcareous tuffs, some of which seem to be rich enough to burn into lime, while all, if ground up, ought to be good fertilizers, especially for boggy land.

Dunganstown, four miles S.S.W. of New Ross. Green, white, speckled granitone; a very nice-looking stone, like some of those formerly quarried in Egypt.

Localities of varieties of hornblende rock of good appearance.

Corcannon, S. W. of Arklow. Very fine-grained; olive green; slightly granitoid.

Ballybrennan, about three miles S.W. of Enniscorthy. Nice-looking; light green; mottled. *Aughnally* and *Crefoge*, southward of Enniscorthy. Pale, greenish-grey and yellowish-greenish; nice-looking; finely mottled.

Palace, east north-east of New Ross. A handsome green-and-white granitoid rock.

Ballaghboola, near New Ross. Greenish, white, speckled granitoid rock.

North of *Clogh*. Mottled green, fine-grained, slightly granitoid.

Crann Mountain and *Ballythomas*, N.E. of Wicklow Gap, at the north of the country. Nice-looking, greenish stones; some mottled in veins.

Quartz-Rocks and Schists.

The Quartz-rocks are almost entirely confined to the *Cambrians*; although they occur sometimes in the adjoining *Ordovicians*. In the neighbourhood of Wexford they have a horizontal structure, and can be raised in sizes suitable for walling. They have been extensively used in the buildings in the town, and for road metal; elsewhere they have been very little quarried.

The *Ordovicians* margining the granite in the north-west part of this county, as also a wide belt of the rocks of this formation on the south, and margining the Cambrians, have been altered into schists. The *Cambrians*, south-east of the trough of Carboniferous limestone that extends from Wexford Harbour, south-westward, to Duncormick, are also altered, sometimes to a very great extent, being changed into gneiss, or even granite, while those to the

N.N.W. and W. of this trough are not as much changed; in some places, such as at Cahore, to the N.E., and at Bannow, to the S.W., they contain fossils.

The schists belonging to both geological groups usually split into flat-bedded stones, suitable for walling; they are, however, very little used in the south-eastern part of the county, as the inhabitants, especially those of "The Baronies" (Forth and Bargy) prefer clay for the house-walls and fences. In the N.W. part of the county, however, they are slightly more in demand.

CO. WATERFORD.

The older rocks in this county, *Ordovicians*, are the south-westward continuation of those in Wexford, and like them belong to the middle group (*Ballymoney Series*). These are interbedded and intruded whinstones, eurytes, felstones, tuffs, &c. These are so similar in character to those of Co. Wexford that the reader may be referred to the descriptions just given of the latter.

It may, however, be mentioned that in places very small portions are changed into serpentines and steatytes; but none of them seem to be of sufficient extent to be commercially valuable. These rocks occur principally in the S. W. of the county between the River Suir and the sea; but there are also a few to be found west of Portlaw. In the *Devonians*, west of the Reeks of Glenpatrick, there are some dykes of whinstone; but none of these rocks have been specially sought after; although some of the fine green tuffs might be suitable for cut-stone purposes.

WATERFORD.—Model School, *Bagenalstown granite*; Court-house and Asylum, *Carlow granite*. The Savings Bank, new Court-house, new Bank of Ireland, new Methodist Church, Post-office buildings, and the clock tower on the quay, granite from either *Kilkenny* (Mt. Loftus) or *Bagenalstown*, has been more or less used for the facings of these buildings. Mount Congreve, Whitefield, &c., *Carlow* granite used for porticos, &c.

[The English when building the walls and the fortifications of Waterford and extending them, which they did two or three times afterwards, "requisitioned" the neighbouring farmers for so many loads of stone each. Those persons brought what was nearest to hand, which accounts for the varying composite character of the building in some of those erections. The mortar, however, that was used was of excellent quality. (*J. Budd.*)]

MUNSTER, or SOUTH-WEST IRELAND.

[Clare, Tipperary, Limerick, Kerry, and Cork. Although Waterford is also in Munster, as its rocks are so intimately connected with those of Wexford and Wicklow, it has been described with the S.E. district.]

Chronological Account.

The groups in this area are Ordovicians, Llandovery or May Hill Sandstone, Silurian, Devonian or Lower Old Red Sandstone, and Carboniferous.

[In Cork and Kerry, as already explained, there are types of strata not found elsewhere. The Glengariff Grits and Dingle Beds are a peculiar type of the Silurian, although somewhat similar rocks (*Mweelrea Beds*) occur in Cos. Mayo and Galway, and others in Fermanagh and Tyrone (*Fintona Beds*); while the Yellow Sandstone and Carboniferous Slate are different from any Carboniferous rocks elsewhere in Ireland.]

In the Anascaul beds (Ordovicians) there are to the north, and also some distance south of Anascaul, felspathic tuffs.

In the Ferriter's Cove series (Silurians) Dingle promontory, at Swerwick Harbour, Ferriter's Cove, north and south of Clogher Head, and in Inisvickillaun, there are whinstones, felstones, and numerous beds of tuff; in Beginish and Young's Island, also, there are tuffs.

In the Glengariff Grits (Silurians) there are intrudes and apparently interstratified sheets of euryte and whinstone with, in places, their associated agglomerates and other tuffs.

[The Glengariff grit eurytes are geologically both interesting and important, as they are characteristic of these Silurians. They occur not only here but in the Silurians of North Galway and South Mayo, in those of Fermanagh and Tyrone, and in the Silurian conglomerate at Cushendun, Co. Antrim.]

The "Lower Old Red Sandstone" of the Geological Survey maps (under Jukes) of Kerry and Cork is the representative of the *Devonian, or the passage-beds between the Silurian and the Carboniferous*. As their upper limits are not exactly defined, it is possible that some of the exotic rocks supposed to be in the Silurian may possibly be more properly in them. Elsewhere there are intrudes and apparently interbedded sheets of whinstone. In places at the base of the Lower Carboniferous Sandstone there is a peculiar quartzyte, while higher up are some intrudes or interbedded eurytes. But the greatest development of the exotic rocks are intruded and interbedded whinstones, eurytes, and felstones (?), with associated agglomerates and other tuffs at the junction of the CALP and FENESTELLA LIMESTONES, a second being higher up, partly below, and possibly also in the Coal-Measures, as hereinafter mentioned. Below the lower zone there are isolated intrudes or protrudes, usually elvans, but in some places felstones, whinstones, or even agglomerates.

There seems to be no evidence of the later exotic rocks in this territory, except, perhaps, some of the dykes in the CARBONIFEROUS SLATE, Co. Cork, which may possibly be of tertiary age.

Territorial Description.

CLARE, TIPPERARY, AND LIMERICK.

In places at the base of the *Lower Carboniferous Sandstone*, especially in the neighbourhood of Lough Graney, there is a peculiar quartz-rock, the basal rock of the formation. This rock, when well developed, is very pure, and seems to have been deposited from solution on the floor of the Carboniferous sea. This, in places, is replaced by a peculiar limestone. This quartz-rock has not been in any way utilized; yet it seems capable of being used as a substitute for flint in the glass and china trades.

In the *Carboniferous Limestone* of Clare there is a tuff at Meelick, a few miles north of the Shannon, while in Co. Limerick the exotic rocks are largely developed. In part surrounding and margining the Ballybrood *Coal-Measures* there are whinstones with their associated tuffs; and extending from them into the *Coal-measures* is a long whinstone mass, which may possibly have been intruded into the latter; but more probably it is a protrude, that is, a high rib, against and on which the *Coal-Measures* accumulated.

Outside, forming an oval ring, at the juncture of the *Calp* and the *Fenestella Limestone*, there are interbedded whinstones, eurytes felstones (?), and tuffs, with, in places, intrudes partly allied to elvan. The tuffs range from a fine rock, often calcareous, to conglomerates and massive irregular agglomerates.

Outside this oval, in places, to the south, are intrudes of elvan, with, near Castle Farm, a peculiar felstone, having, in places, an aspect like trachyte; while to the northward, at Maddyboy, there is a boss of elvan. In the north part of the county there are small detached exposures of tuff, euryte, and whinstone, to the south of Castleconnel, at Knockbrack, Limerick, Carrigogunnel, Kilpeacon, Rosborough, and Caharny, with smaller ones to the west, near Shanagolden.

There seem to be either intrudes, or protrudes of a rock that is apparently euryte (*Daubuisson*), around which the sandstones accumulated. They are quarried for rough walling and road metal. In the eastward part of the county, in the Bilboa River, near Doon, there are felstone dykes.

None of these rocks have been much utilized. In the neighbourhood of Limerick there are some considerable quarries in the tuffs, which are used for road metal and general walling purposes. For the latter they are eminently suitable, as they rise in flat-bedded, well-shaped blocks. In the new railway station, and in some other buildings in Limerick, they were used for quoins and facings. Generally throughout the country in which the exotic rocks occur they are only quarried for local purposes, principally for road metal; but for the latter purpose many of the quarries are in the tuffose rocks or limestone, and not in the more durable whinstone. Many of the elvans rise in ill-shaped blocks; but this is not so in the quarry near Caherconlish, where nice stones of fair scantling can be procured.

Small pieces of the following rocks have been cut and polished:—

Killeena, Co. Limerick. Red porphyry, with salmon-coloured and blackish spots; cuts and polishes easily, but shows verts.

Knockroe, Co. Limerick, S.E. end of boss. Very similar to last in colour; cuts and polishes easily, but shows verts.

Knockroe, centre of boss. A handsome porphyry; purplish, with red and white spots; cuts and polishes well.

Knockroe, at outside of boss. Striped purplish; cuts and polishes well.

Long Stone, Co. Tipperary. Buff, porphyritic; cuts and polishes well.

Cromwell's Hill, Co. Limerick. Shaded yellowish-brown; cuts well, polishes fairly, but shows minute vesiculars.

Kilteely Hill, N.W. of Priest's House, Co. Limerick. Yellowish-brown; slightly spotted; cuts and polishes well.

The following all cut and polish well; they are of various shades of grey, but none of them give handsome stones:—*Kilteely*, *Castlefarn*, *Knockdirk*, *Ballynard*, and *Coolnapisha;* all in Co. Limerick. The last is porphyritic; and in places the stone is changing into ophyte. Probably better stone might be procured in the vicinity.

Some of the conglomeritic tuffs, especially those near Lough Gur, can be easily raised in squarish blocks of large scantlings. These have not been much utilized in modern times; but some of the prehistoric forts, or cahers, were, in a great measure, built of them; the wall of the caher, or rath, being composed of megalithic blocks, placed on edge or end, and banked on the outer face with earth. The blocks were rudely fitted together; the interstices being filled in with smaller pieces.

[In treating on the MARBLES and LIMESTONES we mentioned the *Calcareous tuffs* of Limerick, and raised the question as to their durability. For further information on this subject see Wexford.]

In places the whinstones and eurytes of the Co. Limerick, appear suitable for paving-setts; it may therefore be suggested that an export trade from the port might be established; the stones being sent to England in the return colliers and other ships, instead of the ballast which they now so often carry on their return journeys. Some of the more calcareous tuff, also, seems to be capable of being utilized in the manufacture of hydraulic cements. Before, however, either of these industries were commenced, the likelihood of success and ultimate profit should first be thoroughly investigated.

CORK AND KERRY.

In the Dingle promontory, Co. Kerry, the tuffs in the Anascaul beds (*Ordovician*) and the tuffs, felstones (?), and whinstones in the Ferriter's Cove beds (*Silurian*) are not put to any special use, except for local farm purposes, as better stones can easily be procured. Some of the tuffs, however, rise in nice flat-bedded stones, suitable for walling.

In the Glengariff Grits (*Silurian*) there are in the islands of Valentia and Beginish, as also in the adjoining mainland (*Ballycarbery*), whinstones, felstones, and tuffs (conglomerate). These appear along the lines of stratification for the most part, and on account of the associated tuffs might be considered as interbedded; in places, however, they are evidently, in part, intrusive; more especially the felstones, as these have baked all the rocks in contact with them. These rocks do not seem to be put to any use; yet some of the whinstones might be capable of being wrought into good paying-setts, kerbing, &c., while freight in return ships from the western coast ought to be very low. Quarries could easily be opened on Valentia, or perhaps more easily on Beginish, or the mainland. The small dykes of whinstone, observed elsewhere, it is unnecessary to describe.

In the Killarney district adjoining the Horses' Glen (*Mangerton*), and in Glenflesk, there is a considerable exposure of euryte and its associated tuffs. These have been considered to be more or less inter-stratified with the associated Silurians; but this may be a misconception; the mass is perhaps the remains of a volcanic cone that protrudes into the associated rocks, which were deposited around and over it. The apparent continuation of the tuff into the associated grits and shales seems to be due to detritus from the tuff, deposited as tuffoid rocks from time to time, they thus having a tuff composition, but being of an age long subsequent to that of the accumulation of the volcanic cone.

These rocks have not been utilized, except for local purposes; yet some of them, especially in Glenflesk, are handsomely spotted, and porphyritic, in shades of red and purple, and ought to be valuable, if polished for ornamental purposes.

Near Lough Guitane there is a rock mapped by Du Noyer as felstone tuff. It is light-green in places, porphyritic, compact, can be raised in large blocks; should cut and polish well.

In the Bearhaven promontory, Co. Cork, in the *Devonians* of Cod's Head, Dursey Island, Crow Head Promontory, Horn Point, and between Kilkinnikin and Dunboy, there are whinstones, some being in dykes or other intrudes, while some seem to be interbedded. The dykes of Crow Head Promontory are distinct from the others, and may possibly be of TERTIARY AGE. All these rocks are more or less inaccessible, and do not seem to have been utilized.

In the *Carboniferous Slate* of the south and west parts of Bear Island, and thence eastward on the mainland along the north shore of Bantry Bay to White Ball and Black Ball Heads, there are numerous intrudes, and in places, apparently interbedded sheets of felstones and tuffs, with later intrudes of whinstones. To the northward there are felstones and tuffs, which seem for the most part, interbedded; higher up are some apparently bedded whinstones, while more southward, both on the island and mainland, are evident intrudes of whinstone; some of these are perpendicular dykes that overflowed, forming a cake on the present surface of the ground. This may possibly indicate that these whinstones are much newer than the other rocks of the country, and perhaps of *Triassic* or even *Tertiary age*.

In the *Carboniferous Slate*, near Black Ball Head, there is a small mass of agglomerate connected downwards with dykes of agglomerate, which come up through the Devonian and Yellow Sandstone; while extending eastward from the mass are felstones and whinstones, which appear to be interbedded with the associated grits and shales.

The exotic rocks of this area do not seem to be utilized, except very sparingly, although some appear suitable for paving-setts, kerbs, &c.

In the *Glengariff grits*, about five miles S.S.W. of Mallow, there is a boss of agglomerate; while in the *Carboniferous limestone*, three miles east of Kanturk, there is another larger one. The latter appears to be on about the same geological horizon as the before-mentioned zone in the Co. Limerick.

NORTH-WEST AND NORTH IRELAND.

[Galway, Mayo, Sligo, Roscommon, and Leitrim, in CONNAUGHT; and Fermanagh, Donegal, Tyrone, Londonderry, and Antrim, in ULSTER.]

Chronological Account.

It appears evident that at one time the greater part of this territory was a continuous tract of more or less metamorphic and granitic rocks; but it is now partially covered by masses of later rock, which, after deposition, have suffered considerable denudation. It is possible that these newer rocks may have extended, at one time, over the whole area; but of this there is no satisfactory evidence, except in relation to the Carboniferous, outliers of which are found everywhere throughout the area, the most important being small patches of the basal conglomerate on some of the high hills in Galway, Mayo, and Donegal.

The exotic and allied rocks to be described range from Cambrian to Eocene (?) in age, and vary in composition from basalt to granitic, and schistose rocks.

Cambrian and Arenig Granites, Elvans, Whinstones, Eurytes, Felstones, Quartz-Rocks, and Tuffs.—All these, in Connaught, are more or less altered into different varieties of hornblende-rock, ophyte, schist, gneiss, and granite; but in some places in Ulster they are very little, if at all, changed.

Ordovician and Llandovery Granites, Elvans, Whinstones, Eurites, Felstones, Quartz-Rocks (?) and Tuffs.—In Connaught most of these rocks are altered similarly to those of Cambrian age; but in Ulster many are unaltered; the whinstones are generally diabase and dioryte or allied rocks. Some of the quartz-rocks may possibly belong to this age.

Towards the end of the Ordovician, or during the Llandovery age, there occurred the most active metamorphism of which we have evidence in Ireland. In this territory it altered, in Galway, Mayo, Roscommon, and Sligo all the Cambrian, Arenig, and nearly all the Ordovician rocks. It also altered the similar rocks in Donegal, Londonderry, Tyrone, and Antrim; but here the action was not as universal, the Ordovicians and Arenigs (?) partly escaping.

Connected with this period of metamorphism was the production of the metamorphic granites of Galway, Mayo, Roscommon, Sligo, and Donegal, and the older intrusive granites of the same counties, with their accompanying elvans and other intrusive rocks.

[Some of the intrusive granite of Mayo, namely, that at Termon, Blacksod Bay, may have been pre-Ordovician, and therefore older than the others. The foliated granite of the Castlebar and Lough Conn district was foliated at the same time as the associated metamorphic rocks; it therefore must also be older, except that the foliation belonged to a second and more recent period of metamorphism, to be mentioned presently.]

Silurian and Devonian Granites, Elvans, Whinstones, Eurytes, Felstones, Quartz-Rocks, and Tuffs.—In Mayo some of the

Silurian rocks are altered; in the other counties they are not so. In places the basal euryte of the *Mweelrea beds*, Co. Mayo, is replaced by quartz-rock of a nearly similar nature to that mentioned above, as occurring at the base of the Carboniferous rocks in Munster.

In north-west Galway some of the bedded eurytes can be traced downwards by dykes to bosses of elvan and granite, in the Arenig rocks of Lugnanoon, south of the Kylemore valley.

Carboniferous Granites (?) Elvans (?) Whinstones (?) Eurytes (?) and Felstones (?).—It cannot be shown that any of the exotic rocks are certainly of Carboniferous age. In Mayo, to the S.W. of Croagh Patrick, are the *Corvockbrack granites*, coming up through, and altering, the Silurian rocks; they may, possibly, be of Carboniferous age; but one kind of elvan, that seems to be an adjunct of it, graduates into a uralitic gabbro, which may render this supposition questionable.

In West Galway, Mayo, Sligo, and Donegal, there are melaphyres, eurytes, and felstones, newer than the Silurians. These are very like those elsewhere that are known to be of Carboniferous age; but in West Galway, associated with them, there are dolerytes identical with those of Antrim. However, there are apparently, hereabouts, two systems of whinstone dykes of different periods.

[In connexion with the Corvockbrack granite is a tract of metamorphic Silurians. The exact time during which the metamorphism took place is uncertain; it is possible that it took place near the end of the Silurian or in the Devonian time, and that the interbedded eurytes in the Fintona beds (Cos. Fermanagh and Tyrone) are products of this metamorphism; but these rocks are similar to, if not identical with, the Bundorragha eurytes at the base of the Mweelrea beds (Co. Mayo), and consequently they are probably older than this granite. Furthermore, the granite is very similar to that elsewhere, which is supposed to be of Carboniferous age; and, if this is allowed, the metamorphic action must have taken place during the Carboniferous period. The above-mentioned Lugnanoon granite and elvan, south of the Kylemore Valley, are positively the root rocks of the Silurian eurytes, and are quite different from, and, as I believe, much older than, the Corvockbrack granite. If this is correct, the latter must be post-Silurian.]

Triassic Granites (?) Elvans (?) Whinstones (?) Eurytes (?) and Felstones (?)—Doleryte occurs associated with the Triassic in Co. Tyrone. In North Mayo there are post-Carboniferous exotic rocks, some of which are probably of Triassic age.

Eocene Elvans, Whinstones, and Trachites.—In Antrim and the adjoining parts of Londonderry are the great sheets of intrusive rocks of Eocene age, which have their granitic roots, or elvans, near Portrush, at Tardree, and other places. The elvans near Portrush are associated with metamorphosed *Lias*.

Territorial Description.

In *North-West and North Ireland*, including portions of Galway, Mayo, Sligo, Roscommon, Leitrim, Fermanagh, Donegal, Tyrone, Londonderry, and Antrim, there was at one time, as already mentioned, one large tract occupied by metamorphic and granitic rocks; the rocks now altered being the equivalent of the Llandovery (?), Ordovician, Arenig, and Cambrian, the metamorphism having taken place in or towards the end of the Llandovery age. All these strata having been contorted, upheaved, metamorphosed, and denuded before the overlying Silurian rocks were deposited on them, the patches of the later rocks that now partly separate the different tracks having had no special influence on the extent of the original area.

The areas of exposure of these metamorphic rocks may be conveniently grouped, for the purpose of description, into four districts, as follows:—*Galway and West Mayo; East Mayo, Sligo, Roscommon and Leitrim; Donegal, Tyrone, Londonderry, and Fermanagh; and Antrim.*

GALWAY AND WEST MAYO.

Galway is the foremost county of Ireland as to the variety in composition and colour of its granitic rocks, these varying from fine and nearly compact to largely porphyritic, and being of many colours, white, green, shades of red, greenish, yellowish, blackish, &c.; some being mottled and others clouded; while associated with them are variously-coloured elvans, porphyries, and felstones. The extent of the tract is about equal to that of Donegal, and about a third of the size of the Leinster granite area. To the southward the marginal granites have a bedded appearance; while to the north and north-east the foliated porphyritic granite (*granitic gneiss*) graduates through gneiss into schist. Coming up through the porphyritic oligoclasic granite, but more frequently in the adjoining gneiss and schist, are dykes and masses of the ordinary grey orthoclasic granite, and the varieties of oligoclasic granite so varied in texture, colour, and beauty.

The prevailing colour of the mass of the porphyritic *oligoclasic granite* is mottled pinkish, with smaller white and greenish crystals of felspar, and larger crystals, often twins, of flesh-coloured felspar, which give the rock its porphyritic character. Conspicuous accessories in this rock are titanite (*sphene*) and blackish hornblende. Towards the west of the county there is a less coarsely and more evenly crystalline oligoclasic granite (*Omey type*), in which titanite and hornblende rarely occur. In places, coming up through these oligoclasic granites, the gneiss and the schist, there are the ordinary light-grey or whiteish *Orthoclasic granites*, sometimes forming tracts, as in the neighbourhood of Oughterard.

In the north-west of the Co. Galway, near Kylemore, at Lugnanoon, there is a mass of much newer oligoclasic granite, graduating into elvan, it being of the same age as the sheets of euryte (*Bundorragha euryte*), in the Silurian rocks (*Mweelrea and Slieve Partry beds*).

[At *Lugnanoon, Omey Island, Illaun M'Dara,* and neighbourhood, very long blocks of large scantling might be raised; those in Illaun M'Dara and in Omey Island being very easily procured.

The boulders found on the Galway tract of granite extending from Lough Corrib westward to Kilkieran Bay are of very great magnitude; so that blocks of all probably required sizes could be obtained from them. Some of these boulders have undoubtedly split up since being left in their present position; but the majority of them, some of vast size, are as sound now as when the ice deposited them.]

GALWAY QUARRIES. As has just been mentioned, the granites, elvans and porphyries are greatly varied in texture, colour, and beauty. These have been brought lately into the market by the Messrs Millar, of the "Galway Marble and Granite Works," who are prepared to supply obelisks, columns, dies 3 to 4 feet square, caps, bases, headstones, and all kinds of monumental and other cut-stone and polished work. At present they can raise blocks 10 feet long by 2 to 3 feet square, and slabs from an inch upward in thickness, 9 feet long and 3 feet wide. The principal quarries now being worked are:—

No. 1, *St. Helen's, Taylor's Hill.*—Fine-grained; red, clouded with yellow, maculated with black and a little white; polishes well; can be got in blocks from 5 to 7 feet long; a very serviceable stone

S 2

No. 2, *Shantallow.*—Fine-grained; red; maculated white, with a little black; polishes well; blocks up to 5 and 7 feet long; a very serviceable stone.

No. 3, *Ballagh*, near Bush Park.—Porphyritic; red and greenish yellow, with large flesh-coloured crystals; polishes well; can be raised in long and very large blocks; a handsome stone. Here was obtained the pedestal for Dargan's monument, Leinster Lawn, Dublin.

No. 4, *Letteragh*, north of Rahoon House.—Lighter in colour than Ballagh stone (No. 3); coarser in grain than the St. Helen's and Shantallow; clouded and mottled greenish and purplish, with large bright-red isolated crystals and blebs of quartz; allied to an *elvan;* can square 4′ 6″ × 2′ 6″ × 2′; some blocks over 6 feet long. This has been only recently opened, and it is expected to improve in depth.

No. 5, *Shantallow* (again).—Chocolate-colour, with large bright-red crystals of orthoclase and blebs of quartz. A *granitone*, or basal elvan, seems to be allied to the *Bundorragha euryte.*

Messrs Millar's quarries, except No. 3, are in veins of granite or elvan, in which blocks suitable for general purposes, but not of very great size, are procurable; the granite No. 3, however, not only in the neighbourhood of Galway, as already mentioned, but in the whole county forming the north-side of Galway Bay and in Omey Island, can afford blocks as large as it is usually practicable to work. Some of the boulders on that tract that have stood the effects of weathering, since the glacial period, being as large as some of the mediæval castles (see G. S. M. sheets, 104, 105, &c.). The vein-granites, however, that are being worked by the Millar's are of sizes fit for all ordinary work, they being specially suitable for inside decoration; the diversity in colour and texture being most effective, especially if used in slab-work, such as dados and the like.

The uncoursed rubble used in Galway prison was procured from one of the elvans in Shantallow; very durable, but too hard for chisel-work. (*R. Cochrane.*)

Good building-stones of any scantling are procurable nearly everywhere in the granite region, at the surface or in blocks; consequently no large quarries have been opened, these easily procurable stones having been sufficient to meet local requirements; at the same time there are facilities for working a quarry for an export trade in various places where there is water-power at hand, and accommodation for easy and cheap shipment.

In different places in the vicinity of Galway, north-east of Barna House, and elsewhere in the tract north of Galway Bay, felsite-rock (*felsitic granite*) and felsites have been recorded (G. S. M.). All these rocks are more or less similar to the granulyte at present in use in the glass trade (*ante*, Introduction, page 179). *Leptinyte*, or hornstone, and very pure felstones occur in places in the neighbourhood of Galway, which seem capable of being manufactured into kaolin, while especial attention may be directed to the numerous compact pure felstone dykes in the country immediately south-west of Roundstone, all of which might be similarly used; some of course being more pure than others.

In Western Mayo, at *Corvockbrack* and *Creggaubaun*, to the south-east of Louisburgh, in the *Silurians*, there is a considerable intrude and veins of granites and elvans; white, shaded-white, various shades of grey, salmon-colour, and light-pink; all being capable of a good polish, and some would be very effective when polished; they rise in fair-sized well-shaped blocks. The locality, however, is very inaccessible; the roads to it being of the worst description of mountain paths; it also wants a seaport.

Termon Hill, at the south extremity of the Mullet, and north of the entrance into Black Sod Bay, is a mass of granite. This has been quarried at the coast in the vicinity of Termon at Fishery-quay. The quarries have lately been taken by The Mayo Granite Company, who are now preparing to supply, in polished work, columns with plinths and moulded bases, pilasters, steps, &c.; and, in dressed work, kerbings, crossings, paving-setts, quoins, sills, and any other required stones; colours of silvery-grey, salmon, and red shades. In the *Beaufort*, or *S. W. Quarry*, the stones are silvery-grey and pink; in the *Upper Quarry*, grey and red; and in the *Lower Quarry*, pink and salmon-colour. The stones that have been worked are very even-grained, the felspar and quartz predominating, while the mica is in small scales. Mr. Davies writes of this stone, "The grains of quartz, felspar, and mica are fine, and so well-cemented and compacted together that the stone is capable of a very high polish, while they are sufficiently large and distinct to afford a pleasing variety of colour." (*W. Davies.*) The rocks are traversed by two sets of parallel joints, perpendicular to one another; so that the stone is cut up into rectangular blocks of various widths, and lengths up to twenty-five feet or more. As the soles or nearly horizontal joints and the upright joints are at distances apart, from six inches to three feet, and in some places to six, nine, or more feet, there is every facility for raising, with wedge and windlass, ready squared blocks of any scantling, and suitable for any kind of work from setts and flagging to huge monoliths. Mr. Reilly, the superintendent, states that if required he could raise a block fifty feet in length and nine or ten feet or more in the square. "About forty years ago the stone was used by the Board of Works in building Termon and Belmullet piers, and also the canal bridge at the latter place, and now it appears to be of excellent quality, and shows no traces of weathering." (*P. J. Lynam.*)

At Annagh Head, also, near Erris Head, are handsome, clouded, and streaked variegated felspathic rocks (*Felsitic granite*), capable of being raised in large blocks. Specimens procured here were found to cut and polish easily and well, with very good results "The rock is red, and pink in colour, massively crystalline and foliated; it has all the appearance of being very well suited for the manufacture of kaolin, or porcelain clay." (*A. M'Henry.*) Of a polished hard specimen, Mr. Sibthorpe states "it has all the beauties of a limestone and the hardness of a granite."

[These rocks M'Henry considers to be Pre-Cambrian; they and the associated gneiss and schists are in aspect very similar to the *Primary gneiss of Sutherlandshire.*]

In the Owenmore Valley, west of Bangor, there is a small tract of gneissose granite; the rock, however, is so much jointed that it is not suitable for cut-stone purposes.

Elvans, Felstones, Eurytes, Whinstones, Quartzytes, Schists.

The *elvans* in Galway and Mayo are very varied in age, colour, and composition, graduating into felstones; and the basic elvans (*granitone*) into eurytes and whinstones. They occur more frequently in or adjoining the granite area; but they are not uncommon in the schist of the western and north-western parts of the county Galway. Some of them, especially near the town of Galway, as already mentioned, are of great beauty and variety.

In the west of the county, near Clifden, and thereabouts, there are *granitones*, probably of Silurian age. These are very suitable for harbour and cut-stone purposes, as they rise in squarish blocks of fair scantling, tool, and plug easily, and are apparently durable; although they do not retain their light-greenish colour.

At *Waterloo Bridge*, a little eastward of Clifden, a quarry was opened when the quay at that place was being built; and very good stones, suitable for cut-stone purposes, were procured. This rock is somewhat allied to granitone. It cuts and polishes well; it is of a mottled leek-green colour.

Elsewhere no quarries have been opened; except small ones for quite local use. The granitones, allied to hornblende-rock, and possibly suitable for ornamental purposes, are given on page 224.

The elvans, in connexion with the Corvockbrack granite, have already been mentioned. One of the associated felstones is partly decomposed into kaolin.

The *Felstones* vary from fine and compact to granular and porphyritic; some are very silicious (*felsytes*); others very felspathic. In colour they are of various shades of grey, blue, purple, green, and white. They are not in much, if any, request. Those near Roundstone, margining Galway Bay, have already been mentioned. In N.W. Mayo they are not very numerous. There is an exposure of them with dykes on Clare Island, Clew Bay; as also some dykes N.W. of Nephin, and others along the north coast. (G. S. M.)

In the metamorphosed Ordovician and Arenig (?) rocks are dykes of *euryte*, with their associated granitic roots at Lugnanoon. These seem to be of Silurian age, as they run into the interbedded sheets (*Bundorragha euryte*) that extend from the Atlantic eastward to Loughs Mask and Corrib. They are of various shades of purple and green, and some of them are nice-looking stones, and polish well, and might be used for ornamental purposes, especially those near Lough-na-fooey, where they are variegated and streaked. They do not seem to have been utilized for building purposes; good stone being so easily procured everywhere.

The *whinstones* are most varied in age and character. All the intrudes, dykes, and sheets associated with the Ordovicians, Arenigs and Cambrians (?) are changed into varieties of hornblendyte, hornblendic gneiss, and hornblende-rock; those least altered being pyroxenic-hornblendic. In the Silurians of Galway there are beds and intrusions of *diabase* (?), while in the different groups of strata there are intrudes and dykes of *melaphyre* (Carboniferous ?) *dolerytes* and *basalts* (probably Cainozoic). Peculiar rocks that weather easily, forming great roads or ravines, with perpendicular sides, are probably the roots of the interbedded Silurian whinstones. These rocks are not sought after; yet the friable whins should make good fertilizers, especially if used as top-dressing on the boggy, mountain slopes.

In N.W. Mayo there are whinstones of different ages. The Tertiary Dolerytes and Basalts occur very frequently; for the most part as dykes in the granitic and metamorphic rocks, but sometimes in the Carboniferous. They vary in character and in composition. In the Carboniferous Limestone, a little northward of Killala, there is an intrude of a very coarsely crystalline doleryte, which is partly ophytic. It polishes well, but unfortunately it generally contains a quantity of iron, which comes out under the influence of the weather. As it rises, however, in large blocks, and is very hard, it ought to be suitable for sea-walls, piers, and such like rough work.

In the Little Cannavar Island, Lough Corrib, there is an intrude of actinolite and tremolite rocks, which should be capable of being economically used in the manufacture of black glass.

[This trade is almost totally neglected in Ireland. At the Artizans' Exhibition in Dublin in 1885, there were exhibited black glass bottles made from tremolite rocks from Co. Antrim. This, however, does not seem to have been turned to much account. There would be a fine opening for bottle works in Galway, the materials being close at hand.]

Hornblende and Ophite Rocks.—These are sometimes metamorphosed whinstones; sometimes they are root-rocks and other intrusions, allied to basic elvan or granitone. None of those found in this territory have as yet been utilized for ornamental purposes; yet it is very possible that suitable stones might be procured, more or less in connexion with the Ophyte, in the following localities.

Co. Galway. In connexion with the two tracts of Ophyte near *Lough Ballard* and a short distance east of it, in the wild tract westward of Roundstone.

About half-a-mile south-west of *Bunowen Castle*, near the north shore of Galway Bay.

To the south and south-east of *Glendollagh*, or *Lough Garroman*, in the tract of hornblende-rock.

In the hornblende-rock tract at *Ardderry Lough*, north of Screeb.

In connexion with the large *Dawros* exposure of Ophyte, eastward of Ballynakill Harbour.

At *Curraghwongaun*, N.W. of the Kylemore Castle garden, there is a sort of eclogyte, a specimen of which was polished; it is a handsome clouded and streaked green-and-brown stone.

In *Leamnaheltia*, near the south shore of Lough Fee, in the mountain tract northward of Kylemore Lake; also possibly in connexion with some of the other areas of hornblende rocks in the Co. Galway.

Co. Mayo. To the west of the Corvockbrack granite, a little south-west of Loughnahaltora, in the townland of *Derrygarve*, there is a stone very like the Swedish "green granite," but brighter and handsomer.

In *Glencullen*, north-east of Mweelrea, and westward of Doo Lough.

In two or three places in the neighbourhood of *Lugaloughaun*, which lies in the hills between Leenaun and Westport.

Possibly, also, in connexion with the long, wide tract of *Croagh Patrick* Ophyte, that extends for miles south and eastward of Clew Bay; and perhaps on Clare Island, in connexion with the exposure of similar rock. Part of the Clare Island exposure is light green nice-looking stone. The more silicious portions of the Croagh Patrick Ophyte take a good and lasting polish, as may be seen in numerous polished fragments on the beach of Clew Bay and of Clare Island. This class of stone, however, would be expensive to work and polish.

"Stones for the rough rubble used in the backing of the walls of Galway Docks were procured out of the excavation for the dock. The rock is a very hard greenstone, in part porphyritic [Hornblende-rock]. It took an enormous quantity of the best special steel to drill holes in it, and of dynamite to split it. The stuff came out in large, irregular lumps, one to two tons weight, without bedding or cleavage. These were used in concrete for backing, while the face-work was of limestone from Menlo where we could have got blocks of almost any size required; but the blocks used were about five to twelve cubic feet." (*James Price.*) The hornblende-rocks of the neighbourhood of Galway town are very irregular in structure; but associated with them are hornblendytes or schistose rocks, more or less regularly bedded.

In various parts of the Cos. Galway and Mayo the slates or shales, and grits or sandstones of *Ordovician* age, graduate into schists and quartzytes respectively; in Co. Mayo a portion of the Silurians in the neighbourhood of Louisburg is changed into schists.

Most of these schists, as they rise in flat-bedded stones, are very suitable for walling, and are very generally used in the different areas.

Outlying Tract. A few miles north-east of Dunmore, Co. Galway, at the north-east extremity of Slieve Dart, there is an exposure of *felstone*. This stone is of a flaky character, which unfits it for building purposes; but it is useful as road metal.

About nine miles eastward of Westport, south of Ballyhean, there is a small hill of metamorphic rocks (*Ordovician*). These are in no place well exposed; yet among them we can find an ophytic hornblendic rock, or perhaps an *eklogyte*. This stone may possibly be suitable for ornamental purposes, as a specimen of it, obtained with a great deal of trouble, cut and polished easily and well. It is of handsome and unique green and brown shades of colour.

EAST MAYO, SLIGO, ROSCOMMON, AND LEITRIM.

The *Granitic rocks* are found associated with the schists, in the hills known as the Slieve Gamph and Ox Mountains. The largest exposure is in the former, constituting a long, wide, south-west and north-east tract, extending from the country north of Castlebar, past Lough Cullin and Foxford, into the Co. Sligo; while there is a much smaller tract further north-east in the Ox Mountains in the vicinity of Lough Easky: the former being on comparatively low ground, and the latter at a higher elevation. In the schist country, between the large mass of the granite and the Carboniferous rocks of the Castlebar district, there are small intrudes, courses, and veins of granite.

All the above granites are foliated, and now appear as a coarse gneiss, more or less similar in appearance to the Laurentian gneiss.

[There is a marked distinction between this gneiss and the granitic gneiss of the Co. Galway. The latter, although in places somewhat similar in aspect to that of north-west Mayo and Sligo, is evidently the result of the extreme metamorphism of sedimentary rock, as it graduates on the one hand into schist, and on the other into metamorphic granite. This, however, is not the case in regard to the rock now being described; as although foliated, and having its foliation in the same planes as that of the associated rocks, yet it is evidently an intruded rock, as it has well-defined, sharp boundaries at its various exposures.]

It has been pointed out by *Symes* that this rock could be raised, in some places, in blocks of very great size; but it works badly across the foliation, and is therefore not very suitable for cut-stone purposes. *Wilkinson* states "the rock is even-grained, but hard and difficult to cut; seldom used for any purpose, as there is very little demand for it in the immediate neighbourhood, and the limestone and sandstone are abundant in other parts. In a few places in roads, bridges, and common walls it has been used in the way in which granite is commonly employed, being split for rough-shaped quoins and common walling, and no dressing being necessary, it has proved sufficient for such purposes. Large blocks could be obtained, and it appears to be an even-textured stone, although the quality varies along the boundary of the district."

The granite has been very generally utilized in local County works: for instance, the Pontoon Bridge and Hotel were built of it.

Whinstones.—Intrusions of this rock occur in the schist area in the following localities, viz. on the north-eastward side of the Lough Easky granite; also four miles N.E., and about the same distance W. of Lough Cullin; also over three miles N.E. of Castlebar, and at Derrycoosh, W. of the same. Whinstones occur in the Carboniferous Limestone, in the valley of the Moy, close to the S.E. margin of the schist, and to the north-east of Turlough; and (in a very long narrow strip) near Castlebar; and (similarly) near the village of Cushinsheeaun; and about three miles S.W. of Westport.

In general these stones are excellent for road metal, or as large blocks for foundations, or other similar rough work; the Cushinsheeaun course is cut by the Great Midland Railway, and stone from it was brought by that Company to Dublin for such purposes, when they were constructing the Spencer Dock; but the stone of the long course, near Castlebar, weathers to a considerable depth into a coarse sand, and is apparently the same class of rock as the "Bohernacolley" rock of N.W. Galway. This detritus, as has been mentioned, should be useful as a fertilizer.

Hornblende Rock.—Four or five exposures are met with in the granite and schists, north and south of Foxford; one about a mile south of that town, containing large crystals of hornblende, white felspar, brown and black mica, &c. All these rocks are foliated, the foliation being parallel to that in the adjoining granite or schist; but they have distinct, well-marked boundaries. The rock is very tough. (G.S.M.)

Felstones.—Very few intrusions of this rock are reported from this district. One occurs on the east slope of Letter Hill, westward of Castlebar.

As in other districts, the *Schists* that split into flat-bedded stones are suitable for walling, and are much used locally. In some places, as in the neighbourhood of Ballysadare, and in a more limited area south of Lough Gill, and about Nephin Mountain the ordinary schist is replaced by quartzitic rock or quartzyte. In the vicinity of Westport is the peculiar pebbly quartzyte, suitable for rough, heavy work, which has already been recorded among the ARENACEOUS ROCKS (vol. v., p. 587).

OUTLYING LOCALITIES.

In the *Silurian* rocks of the Curlew Mountain range (Cos. Sligo and Roscommon) there are *Eurytes*, similar to those of Mayo and Galway (*Bundorragha Eurytes*, *ante*, p. 223), except that these are associated with peculiar tuffs or tuffose rocks. There are also intrudes of whinstone.

[The *Silurian* eurytes in the Mangerton district, Co. Kerry, are associated with tuffs, or, perhaps more properly, tuffose rocks (*ante*, p. 214); those of the Killary district (Galway and Mayo) are usually not associated with tuffs; they occur only in the neighbourhood of Lough-na-fooey and the Kilbride district; but here the tuffs are peculiar, as in general there seems to be no hard boundary between them and the rocks that seem to be normal euryte. In the Fintona district, hereafter mentioned, there are other peculiarities; as rocks that seem to be true eurytes are divided up into plates, so thin that some of them may be described as coarse slates. Near Cushendall, Co. Antrim, the rock occurs only as an intrude.]

In the hills westward of Lough Gara there are several exposures of euryte, which has quite a normal aspect; yet the greater part of this is in beds or layers, from a few inches to a few feet in thickness, as though the exposures were, at least in part, tuffs or tuffose rocks.

In this neighbourhood, as also to the north-east of Lough Gara, there are some large dykes of whinstone.

Some of the whinstones are utilized as road-metal, and the eurytes and tuffs rise in nicely-shaped and sized stones, suitable for walling, while they seem to be capable of being dressed. Some of them cut and polish well, and might be employed for ornamental purposes; none of them, however, seem to be made use of, except for farm fencing. They are at high elevations, and generally not easily accessible, while sandstone abounds.

More or less similar rocks occur also in the western part of this hill range, near Ballaghaderreen, and in the Charlestown district. Some of the latter, however, are intrudes, unaccompanied by tuffs.

At the western extremity of the range (Co. Mayo), appearing from under the Silurians, there is a small tract of *metamorphosed rocks*, probably *Ordovicians*, appearing from beneath the Silurians. These rocks are more baked than micacised, many of them being *leptinytes*, or white-rock; these are represented on the geological survey map as felstone. They are generally very pure stones, and should be capable of being manufactured into kaolin. In this tract there is also an intrude of euryte, and smaller ones of a pyroxenic-hornblendic rock. The latter is a nice-looking stone, cutting and polishing well; but it is excessively hard, and rises in rather ill-shaped blocks.

In the townland of *Uggool*, near the north side of the mouth of Killary Bay, there is a tract of elvan, a small piece of which cut and polished well; it is of a mottled yellowish red or light salmon colour.

South-east of *Drumsna*, Co. Leitrim, in the *Ordovicians*, there is a small boss of whinstone.

In the promontory called the Rosses, three to four miles north-west of the town of Sligo, there is a small exposure of metamorphic rocks. They are principally schists.

DONEGAL, LONDONDERRY, TYRONE, AND FERMANAGH.

Of the rocks in this part of the territory, those of *Donegal* are the most important.

DONEGAL.

In the north-west of this county, in the baronies of Kilmacrenan and Boylagh, there is a tract of gneiss and foliated granite, associated with eruptive granites (*gneiss series*), margined by areas of metamorphic rocks (*schist series*); the one passing gradually into the other. The metamorphic granite, gneiss, and schist seem to be due to one and the same action, while the older eruptive granite is allied to them like as is the granite in other metamorphic areas, such as those of Galway and Mayo. In Donegal a newer granite was intruded at a later time.

The older intrusive granite occurs principally to the westward, in a tract near the sea, to the northward and southward of Dunglow, and also further southward, in the group of hills at Barnesmore (Bluestacks, Croaghnagar, &c.), to the north-eastward of Donegal town.

The greater part of the younger granite occurs in the north headlands of the baronies of Kilmacrenan and Inishowen, it being in places much entangled with the associated schists, while extending from the granite tracts are massive courses of elvan and porphyry, which appear to graduate into basic felstones and whinstones.

These dykes and courses occur not only in the older rocks (*Metamorphosed Arenig* (?) and *Cambrian* (?)), but also in the later rocks (*Ordovician* (?) and *Llandovery* (?)); and it seems possible, if not probable, that the masses of granite may represent the laccolites, or roots of the sheets of Donegalyte, so conspicuous in the Killygarvan series of rocks (*Llandovery* (?)), occupying the county N. W., N. and N. E. of Rathmullen.

In the older rocks (Cambrian (?) and Arenig (?)) there were many intrudes and interbedded (?) masses of whinstone, which were variously altered, with the associated rocks, in accordance with the amount of metamorphism to which they were subjected; the whinstones being now represented by granitic rocks and different varieties of hornblende-rock. As some of the older sedimentary rocks were altered into gneiss, and others into schists, the latter being of all varieties down to nearly unaltered rock, so similarly the alteration in the associated intrusive rocks is of varied amount, some being greatly altered, and others only very partially so.

[The older rocks (*Arenig* (?) and *Cambrian* (?)), after their deposition, were distorted, contorted, thrusted, altered, and invaded by granite and other intrusive rocks, and then denuded, before the newer series of rocks were deposited on them. This seems to be satisfactorily proved; for although the later rocks were subsequently greatly disturbed, displaced, and even inverted in some localities, yet there are still ocular proofs that one series lies unconformably on the other, as at a little north of the Malin Coastguard Station; while in places the basal beds of the later series contain thrusted fragments of the granite, gneiss, &c.; thus proving the metamorphism and denudation of the older rocks prior to the accumulation of the others. Afterwards, however, the later rocks, and probably the older ones, were subjected to another period of metamorphic action.]

In the rocks (*Ordovician and Llandovery* (?)) above the unconformability, there are also many intrudes and sheets of whinstone (*Donegalyte*), and a few intrudes of felstone; while in places, associated with the Donegalyte, are small and large masses of agglomerate and tuffs; the most extensive recorded being in the neighbourhood of Croaghan Fanad. The lower portion of the later rocks is usually partially altered, while the upper series (*Kilgarvan group*) is generally not so. If the latter are altered, it is, for the most part, in isolated detached portions. In the Kilgarvan group are some well-marked, apparently interbedded, sheets of Donegalyte.

As a general rule, felstones and allied rocks are not common in the Co. Donegal; still in the northern and north-western parts there are many courses, dykes, and patches of elvan, porphyry, and felstone occurring, as adjuncts of the intrusion of the later granite.

The later granite occur in rocks that seem to belong to the older stratified formations (*Cambrian* (?) and *Arenig* (?)); but that they were intruded later than the accumulation of the younger formations (*Ordovician* and *Llandovery*) is proved by dykes of the porphyries and felstones from them being found in the latter. There are also in a few places intrudes of these granitic rocks in what may be outlying tracts of the later rocks.

In the western part of the county, especially, there are dykes of small dimensions, sometimes very numerous, of either melaphyre or doleryte, which are considered by M'Henry to be of the same age as the Tertiary rocks of the Co. Antrim.

Among these different rocks there are some which are eminently suitable for building purposes, and for cut-stone and polished work; but on account of their out-of-the-way position, very little use has been made of them up to the present time; and very few quarries have been opened, except for road and farm purposes. Now, however, inquiries are being made about them, and it is proposed to work them in several places. Some of the localities where they have been, or might be, worked with advantage, will now be mentioned.

Granite and Gneiss Quarries.

Barnesmore, about half-way between Donegal and Stranorlar, about eight miles from each. Granite, porphyritic, red, or flesh-coloured, can be raised in large blocks, and is capable of a good and fine polish.

The Barnesmore red granite was, a few years ago, worked by Mr. Flynn, who transported it by rail and road to the *Bessbrook Granite Works*, Co. Armagh, to be manufactured for monumental, architectural, and other cut-stone purposes, and for polished work. In the quarry, which was at or near the top of the south-west slope of the Gap, large blocks were detached and rolled down into the valley, there to be scabbled into blocks suitable for carriage. The work seems to have been discontinued on account of the great expense of the carriage. However, now that the West Donegal Railway has been opened, this cost of carriage might be much diminished.

In this neighbourhood there is also a bright-grey granite, fine-grained, compact, and more or less similar in aspect to the well-known Castlewellan stone, Co. Down. This grey stone has only been worked for local purposes.

[In places in this granite area there are veins of granitite, fine-grained, felspathic, and nearly micaless, similar to the rock now in use in the manufacture of glass.]

Minnagran, about nine miles from Glenties.—Gneiss; grey, coarse, gritty, loosely aggregated, and difficult to work. The quartz and felspar are in nearly equal, though variable, proportions, some beds being more micaceous than others. In the vicinity this is known as the "Minnagran millstone."

In the Glenties district there are large courses, or elongated tracts, of a coarse granitic gneiss, similar to those of the Castlebar district, Co. Mayo. Here, as in the Co. Mayo, the rock was originally an elvan or granite course, which subsequently was foliated and changed by metamorphic action into gneiss. This rock has not been utilized; but it is very suitable for coarse, heavy work like country bridges or harbour works.

Dunglow granite quarries.—In this neighbourhood, as stated by experts who have lately examined the country, there are inexhaustible supplies of granites of varied colour and texture, which are proposed to be worked by a company. Mr. Philip Brannon's report states that they range "from dark and almost purple reds into graphic, mottled and cloudy; rich bright red; bright red; faint tones of red (salmon, pink, rose, &c.); through deep grey, or blue, and very light silvery grey, into a beautiful resplendent white granite." The stones proposed to be worked are "fine and even-grained, without verts, and capable of receiving an even and good polish. As they are regularly jointed, both horizontally and vertically, the stones can be raised with very little waste. They are of long scantlings and large dimensions." The granite boulders scattered about would afford blocks large enough for any practical purpose. The stone in these boulders is perfectly sound, without any apparent joints or flaws.

It is proposed to work the stone principally *in situ;* finishing-work, such as planing, polishing, &c., being carried on in a factory near Dunglow. From these works it is intended to send into the market "cut and polished slabs, columns, lintels, sills, steps, basements, string courses, facing, dressing, or any other requirements for monumental or architectural ornamental works; also rough stone suitable for paving-setts, kerbing, quoins, facings," &c.

The quarries or places in the Rosses specially named are:—*Burton Port*, rich mottled; *Leckena*, dark to light salmon and light red; *Lefinn*, pink and brilliant red; *Garron Hill*, or *Toberkeen*, graphic mottled (purple and red); *Dunglow Hill*, light and dark greys; and *Lough-na-geeragh*, white.

As far back as 1865, Mr. William Harte, County Surveyor, Co. Donegal, who had used the Dunglow granite for various purposes in Derry and elsewhere, brought these granites under the notice of Griffith, Jukes, Haughton, and Scott, for their beauty and other qualifications. As these authorities approved of them, they were subsequently worked for a time by Messrs. Harte and Owen, especially at Lefinn. However, at that time polished granite was not appreciated as it is now, and as the works did not pay, they were discontinued. Mr. Harte specially mentions that the Dunglow granite improved in colour with time, when used in facings and such-like work in Derry.

Croagh-na-Shollog.—On the western flanks of this hill, about a mile south of Dunglow, Mr. J. R. Kilroe records a very red granite, capable of being raised in large blocks.

Glenveagh, west of Kilmacrenan.—Foliated granite; grey, durable, not too hard; used throughout in Glenveigh Castle. (*J. Cockburn.*)

Carrick, north of Milford.—Red, quartzose.

Glenieraragh, south of Glen Lough.—Gneiss; grey quartzose, compact, even-grained, durable, evenly jointed, and can be raised in naturally square blocks. Was used in the bridges of the new road from Glen to Barnesbeg.

Barnesbeg, between Kilmacrenan and Creeslough.—Granite; grey and red; even-grained, but of different textures; splits, punches, and dresses well. The stone occurs as loose blocks in the gap, no regular quarry having been opened; used for dressings in Kilmacrenan church and in various other places. (*J. M'Fadden.*)

In different places in the large granite and gneiss area that extends from the Atlantic north-eastward to Glen, there are veins and courses of good stones, suitable for nearly any dressed work, in which quarries might be opened. Quarries, however, are few, as the surface-blocks, or the neighbouring schists, supply stones sufficient for local county purposes, while, except from Lefinn, they do not appear to have been exported or used out of the district or its neighbourhood.

Magherararty, Bloody Foreland.—Granite; grey, durable, not too hard for a granite; used in the quoins, sills, window-heads, piers, chimney-caps, &c., of the Curvane Point Coastguard Station. (*J. Cockburn.*)

Torries, Arran Island.—Granite; pinkish-grey; coarse, but evenly crystalline; contains hornblende and sphene.

Lackagh Bridge, between Creeslough and Glen.—Foliated granite or gneiss; bright-pink, of a rare and beautiful shade, also shaded grey; even-grained. A hand specimen was inspected by Mr. Sibthorpe, who considered it ought to polish well. Used for dressed stone purposes in the Carrickart Roman Catholic church.

Finford, Fanad-within-the-Waters.—Granite; grey, pink, and shaded; even-grained; very easily worked; cuts and polishes well; used in some of the dressed work at Mulray, or Manorvaughan House.

Arraheernabin, on the north coast, near Fanad Lighthouse.—Granite; bright grey; even-grained; compact; works and dresses easily and well. Used in part of the dressed work in the new Lighthouse, Fanad, and at the Portsalon Pier, Ballynastocker Bay. A very general characteristic of the granite to the south-west of the last, in the tract between the road and the sea, is a natural and easy splitting up of the rocks into long rectangular pieces; and it may be suggested that these might be utilized in the construction of cheap and durable fences, similar to those in use in the Co. Carlow.

At the present time (1888) the Earl of Leitrim is exhibiting at the Olympia Exhibition, London, cut and polished granites from the neighbourhood of Mulroy Bay. It is proposed to form a company to work them. According to *Mr. Manning* the stones have been procured from the following places:—

Doaghmore.—Bright-grey and pink; even-grained. The polished specimens from these quarries were from surface-stones. The quarries are now being properly opened up, to get out a better quality.

Melmore, *Rinmore*, *Ballyhunan*, and *Arraheernabin.*—Principally grey granite, of a good quality; suitable for monumental and cut-stone purposes. "Specimens of green and red granite are found at Rinmore and Arraheernabin; but as yet no quarry has been opened on them, and what they may be suitable for is not known."

Tory Island, at the Lighthouse.—Grey granite, very similar to the above at Arraheernabin. Raised in the excavation for the gasometer, and used in the structure.

Dunaff, Inishowen.—A granite very similar to that of Doaghmore, at present not worked.

The Metamorphic granites are often good stones for building purposes; but many are obliquely foliated (*query*, metamorphosed quartzytes (?)) and these are not so; some quartzose varieties of the latter, however, are very suitable for road-mending, and are used for that purpose.

[These obliquely foliated granites are very similar in appearance to the felsitic quartzytes and sandstones among the schists and other rocks. The quartzytes, sandstones, and said granites all occur in irregular beds, and the oblique foliation in each is of the same character, while the constituents of the quartzytes and sandstones are such as would easily change into those of the granites. At the south entrance of Barnesbeg and elsewhere, there are rocks which it is difficult to say whether they ought to be classed as quartzyte or granite. All these circumstances have led me to believe that most, if not all, of the obliquely foliated granites were originally sandstones which have passed through the stage of quartzytes into their present condition. Others of the metamorphic granites are in mass, or in massive courses similar, respectively, to the intrudes and courses of the hornblende rocks and the Donegalyte, in the schists and allied rocks. This may lead us to suppose that they were originally intrudes of exotic rocks into the derivate rocks with which they are now associated.

In Ireland, as has been mentioned in the Introduction (*ante*, p. 173), there is generally more or less freedom from systems of "grain" or parallel splitting planes in all the granites of metamorphic origin: this, however, is not so noticeable in Donegal as elsewhere, as some of the metamorphic granites split remarkably well. Those, for instance, at Barnesbeg are reported by the stonecutters as "kind, plugging easily in all directions, durable, of good colour, yielding large and square scantlings, and capable of long and heavy bearings." (*J. M'Fadden.*)]

Malin. At the north extremity of Inishowen there is here quartzose gneiss with subdinate micalytes and hornblendytes (*Metamorphosed Cambrian* (?)), which, to the southward, are overlaid unconformably by quartzites (*Ordovicians*(?)). The typical gneiss to the westward is remarkable, as the foliation therein is horizontal. The quartzitic gneiss is all more or less flaggy, and suitable for building purposes, and some veins of it for flags. The locality is very inaccessible, and the stones have only been used for local purposes, and in the building of the Telegraph Station for the Trans-Atlantic Shipping.

Elvans and Felstones.

Courses and dykes of these rocks are well exposed in the neighbourhoods of Falcarragh, Dunfanaghy, Rosscuill, and other places in the north of Donegal, as also in some localities in the south of the county, while generally they are not common elsewhere. In some of the exposures there are nice-looking stones; but they are very little sought after, and no quarry of note seems to have been opened in any of them.

As is usually the case elsewhere, the stones of this class do not appear to be capable of producing blocks of as large or long scantlings as the granite; nor are they suited for long bearings, although some appear capable of bearing heavy weights.

"East-north-east of *Crow Hill*, near Castlefinn.—Felstone dyke; speckled greenish-grey; fine-grained; nice-looking.

"*Tirinisk*, near Castlefinn.—Porphry; purplish; spotted with white and dark-green.

"East-north-east of *Crossy Hill.*—Felstone; bright grey; speckled; fine-grained.

"*Woodland*, near Killygordon.—Euryte; speckled purplish; fine-grained." (*F. W. Egan.*)

Arran Island, west side.—Porphyry; purplish grey; mottled; speckled with white and black; compact.

Bloody Foreland.—Elvan or porphyry; purplish; handsome.

Whinstone.

(Donegalyte, diabase, dioryte, doleryte, &c.)

The majority of the Donegal whinstones are rough and ungainly, or are rotten, or come out of the quarries in more or less coarse shingle, and are more suitable for road metal than for any other purpose. In places, however, there are really valuable stones, especially in some of the dykes and other intrudes; but these have been used only in a few places for cut-stone purposes.

Ballyboe and Millbrook, a little west of Rathmullen.—Light colour; green and mottled; porphyritic to fine-grained; compact; durable; can be raised of long scantling, with considerable transverse dimensions; capable of long and heavy bearings; cuts and dresses on any face; polishes well.

The local name for the quarry is *See-agh*, while the stone is very generally called "Ballyboe green granite." About the year 1820 the quarries were opened during the building of the forts at Inch and at Rathmullen, while more recently blocks were used in the construction of the Rathmullen Pier; and for cut stone purposes in pillars for entrance gates, quoins, &c. (*J. M'Fadden.*)

It has been quarried in both townlands, and hand specimens take a ready and good polish. The porphyritic variety, when polished, is a light-green, with a whitish mottling, and would be effective as columns. Some of the measured blocks were over 15 feet long. This stone, like others of the same class, becomes a little discoloured at first, but subsequently freshens to a bright green.

Columbkill Lake, eastward of Millford.—A dyke at the north end of the lake. Green; fast colour; fine-grained; durable; dresses easily and well on any face; can be raised of fair scantlings; capable of long and heavy bearings. The quarry was opened to procure quoins, sills, window-stools, window-heads, while building the Hospital at the Milford Workhouse; since then it has remained idle.

Stone more or less similar to that at the Columbkill Lake dyke, but generally more bedded, occurs in other places in that neighbourhood, as also west of Mulroy Bay, and near Letterkenny.

Woodquarter, N.W. of Millford and west of Mulroy Bay.—Green, flaggy, with a peculiar purplish iron staining, or parting in the joint planes. Small quarries were opened in several places to procure stones principally for walling purposes. The stone dresses well, but in one quarry the mineral in the joints disqualifies it; as even a small portion of one of these partings will stain the stone and those in its vicinity. In a second quarry these iron partings do not appear to be so prevalent, and good sized stones might be raised.

Rough Park, about two miles N.E. of Letterkenny.—Apparently a bedded sheet of whinstone; green; flaggy; compact; dresses easily. Has been quarried in two places, and used as building stones, quoins, kerbs, and flagging, in Letterkenny. Durable as a building-stone and as kerbs, but not so good in flagging.

Lissnanan, about a mile N.N.E. of Letterkenny.—A very similar stone to that of Roughpark; lately used in Letterkenny for kerbs.

In the county between Lissnanan and Roughpark there are exposures of from two to four sheets of these green flaggy whinstones; but these are quarried only in the above townland. At the present time cut and dressed stone required in Letterkenny is brought all the way from near Strabane, Co. Tyrone; but this expense might be saved if a good and proper quarry was opened in one of these whinstone exposures. The vein in Rough Park is very favourably situated, being in a rise of ground, and near a good public road; while the stone in it seems capable of being raised of sufficiently large and long scantlings to suit the requirements of the town.

In Inishowen these flaggy whinstones are not uncommon, and have been quarried in different places: those best known are as follows:—

Dunmore. Six miles from Carndonagh, in the Culdaff direction.—Can be raised in blocks and slabs from 6 to 12 feet long; capable of long and heavy bearings; cuts any way, but the blocks more generally sawn; polishes well; of a good green colour; used extensively in the Poorhouse and other buildings at Carndonagh; also for tombstones. (*George Baggs.*)

Croagh. Seven miles from Carndonagh, and five from Moville.—A very similar stone to that at Dunmore; but does not weather as evenly. (*George Baggs.*)

Dunree. Close to the Fort where, as well as in the Lighthouse, it was used for flagging, window-sills, &c.; a very similar stone to that at Dunmore. The greater part of the Fort is built of a kind of quartzite, which dresses fairly well; this was raised in the immediate vicinity from a vein in the Ordnance ground.

Some of the Donegalytes and other whinstones, especially the dykes associated with the bedded sheets in the Kilgarvan (Rathmullen) district, seem suitable for paving-setts, channels, and kerbs. None of these stones, however, have been tested.

Metamorphic Whinstone.

(Hornblendyte, Hornblende-rock, and Hornblendic Gneiss.)

The principal zones in which the hornblendic-rocks occur are those northward and southward of the tract of gneiss and granite; they occur, however, in other places also, but principally where the associated rocks are more altered than usual, as in the Lough Derg district, in the south-eastern part of the county. As in other regions, so here also a common characteristic of the courses is a rib of hornblende-rock or gneiss in the middle, margined on each side with hornblendic-schist (hornblendyte). But some of the masses of whinstone, especially when in or close to the gneiss, have been completely changed into hornblendyte.

Many of the hornblendytes are capable of being raised in more or less shapely, flaggy masses; but in general they work rough across the foliation, or plane of the flag. Most of the hornblende-rocks and gneisses are best suited for coarse, heavy work, as piers, sea-walls, and such like. However, a few were observed to be more or less regularly-jointed, and to rise in naturally square blocks. These ought to be suitable for the large setts used in street-crossings, as on account of the difference in the hardness of their mineral constituents they wear rough.

Kinder varieties of the hornblende-rock, which are generally more or less ophitic, or epidotic, have been noted as being very similar to some of the "Swedish green granite" now in the London market; these, therefore, should be capable of being utilized for ornamental and monumental purposes. As, however, up to the present time, no quarries have been opened, it is not possible to give information as to the size and shapes of the blocks that could be procured. We can, however, state that some hand-specimens took an excellent polish, and were of a bright olive-green colour.

Hornhead. About two miles from Dunfanaghy.—Greenish; crystalline; slightly foliated; used locally.

Goldrum. S. W. of Lough Salt.—Green; slightly ophitic; can be raised in fair-sized, rather even-shaped blocks. Slabs of this stone were used in some of the old structures of the vicinity, and as farm-fences.

The hornblendytes are, in places, favourably reported as building material. According to *Wilkinson*, they were extensively used in Glenties. Some varieties, however, are inclined, on exposure, to become "iron-masked."

Schist.

The micalytes, phyllytes, and sericytes are very much in request for general building purposes in the districts where they occur, and even outside them, as they rise in flat-bedded, suitable stones; while in some places they are regularly jointed, and rise with natural faces. According to Wilkinson they are most durable.

Those in use, are, however, often badly selected; some of them are highly ferriferous, and if used as building-stones, the iron rapidly decomposes, and the stone becomes "iron-masked," giving the structure in which it was used an unsightly, rusty appearance. Among other places that might be mentioned, the use of badly-selected schists is very well illustrated at Ardara, and its neighbourhood, the aspect of the village being quite spoilt thereby. Another place where this is well seen is on the road from Kilmacrenan to Dunfanaghy, near Creeslough.[1]

If the planes of foliation in the schist coincide with those of the lamination, and if at the same time the rock is compact, free from many joints, and thin-bedded, it will produce flags. Good thin and thick flags, as mentioned in a former Paper, occur in various places (vol. v., pp. 549 and 619).

Barnes Lower. N.W. of Kilmacrenan, near the south entrance into Barnesbeg, *Anglice* little Gap.—Purple flags; highly micaceous; from about two to three inches thick; can be raised of fair sizes. Locally used for flagging, sewer-covers, &c.

[As these flags abound in the hills to the eastward, they might be extensively used in the erection of cheap effective and durable farm fences, similar to those that are in use near the Bangor slate quarries, and other places in Wales. The first cost of such fences would be more than that of those at present in use; but they would be much more effective and durable.]

Losset. North of Gartan Lake.—Flags similar to those at Barnes Lower. Used in the neighbourhood, and in Letterkenny and Rathmelton, for kerbing, flags, &c.

The quarries in the schists are generally small, having been opened merely to procure stones for local uses. Among the quartzytes there are some stones suitable for flagging, and others for heavy work, such as sea-walls and foundations. These have been already mentioned in the description of the Arenaceous Rocks (*ante*, pp. 549 and 619, vol. v., and *ante*, p. 12).

LONDONDERRY.

Towards the centre of the county, extending north and south from Lough Foyle, to and beyond Dungiven, is a basin of *Carboniferous* rocks. To the westward of this basin, with a few small exposures to the east thereof, are metamorphosed rocks. Those to the northward, coming in from the Co. Donegal, seem to be of *Ordovician* age, and are not as much altered as those to the south-

[1] In the Co. Wicklow the 'iron-masked'' rocks are locally called, from their appearance, ''burnt-rocks,'' while for a similar reason the hills south of the East Ovoca Mines are called the '' Burnt Mountain.''

east of the country; the latter being part of the Tyrone rocks, which are probably the equivalent of the *Arenig*, or perhaps *Cambrian.*

Associated with the Arenigs of Slieve Gallion are intrudes of granite, elvan, porphyry and felstone; while, in places both in these and the Ordovicians, are whinstone dykes of different ages.

The granite is not a durable rock, the exposures are of small extent; and as they adjoin the sandstones, there is no necessity to use them for building purposes. Some of the granites are handsome stones, especially those of *Carndaisy*; but Egan is of opinion that, as they are so much jointed, they could not be raised in blocks of sufficient size to be profitably used for ornamental purposes.

The elvan and felstone are in the neighbourhood of the granite: they, too, are not in repute. Some, however, are handsome; but as they are in out-of-the-way situations, and would be expensive to work, it seems unnecessary to dwell upon them further.

The *Whinstones* occur as dykes in scattered localities, and are not generally used as building materials; they are, however, employed as road metal.

Within the area of its exposure, the schist is the stone principally used for walling. It rises in flat-bedded masses; and as the joints are generally more or less regular, they give good faces for building purposes. This rock cannot, however, be dressed across the grain.

At Prehen (vol. v., p. 581), and several other places in the vicinity of Londonderry, there is a "book schist," or a rock with even laminæ, which give the transverse section the appearance of a number of leaves of paper laid one on another in a pile. This, has been extensively used in the town and its suburbs. Near Limavady the schist contains a good deal of iron, which comes out under the influence of the weather, giving the walls a dingy appearance. At Lislane, S.E. of Limavady, the schist was quarried for the railway works. (G. S. M.) Near Muff is an argillaceous schist (*phyllyte*), which rises in coarse, heavy slates. Elsewhere in the area are numerous quarries, the schists in these varying greatly, being micaceous, argillaceous, hornblendic, quartzytic, &c., but all more or less suitable for walling.

In the eastern part of the county, and extending in that direction into the Co. Antrim, and southward into Tyrone, are

Eocene Whinstones (*Basalt and Doleryte*), the western margin of the great sheets of these rocks, which occupy the greater part of the Co. Antrim.

Associated with these, to the northward, in the vicinity of Portrush are granite roots (*granitone*, or *highly crystalline diorite*); and in other places, as near Croagh, to the south, are conglomerates and other tuffs. In the Croagh neighbourhood there seem to have been one of the volcanic vents, from which the sheets were poured out.

The granitone occurs in the Skerries, off Portrush, and in *Portrush Head*, where it was extensively quarried for use in the Harbour Works.

In the *Basalt* region, the harder varieties of doleryte and the *clinkstone* (the local name for the fine basalt that has a metallic ring), are the materials generally used for ordinary building purposes. They can be raised in large well-shaped blocks, and scapple freely. Some, especially the clinkstones, polish well, and are very similar to, if not identical with those used in some of the monuments and statues of the ancient Egyptians and Romans.

The abutments and piers of Coleraine Bridge are built of these stones; they have also been used in Moneymore for quoins and string-courses, the facings being of the white limestone, as also in numerous other towns, and the country-houses in the area, sometimes only for quoins and dressings, but sometimes, also, for facings and rubble work. In the basalt region the quoins and dressings are sometimes of the white limestone, while the facings are basalt.

TYRONE.

In the east of the county, coming in from the counties of Antrim and Londonderry, is a small portion of the Ulster Tertiary Basalts and Dolerytes, while the northern part of the county is composed of metamorphic rocks, probably equivalents of the *Ordovician* and *Arenig* or *Cambrian*, the latter being much more altered than the former. Associated with these are metamorphosed igneous rocks with veins, dykes, and other intrudes of granitic and other newer exotic rocks. The Arenig (?) schists, especially their associated metamorphosed exotic rocks, seem worthy of notice.

In the south of the county, and extending westwards into Co. Fermanagh, are Silurians, with their associated granites, elvans, eurytes, and whinstones.

The descriptions of the Tertiary Whinstones of the Co. Londonderry are generally applicable to those of this county. Locally they are used for building purposes, especially for quoins and such like; where they have an effective appearance, if the facings are of white limestone, or sandstone. For finer work the far-famed sandstones of Dungannon are more generally used.

The *eurytes* and their adjuncts occur both as granites and elvans in the older rocks, principally in the metamorphosed Arenig or Cambrian, and as intrudes and interbedded sheets, with their associated tuffs, in the Silurians (*Old Red Sandstone type*).

These granites, generally speaking, although often very handsome red or variegated rocks, are shingly, or easily disintegrated, or full of joints, and consequently cannot be raised in blocks suitable for either general building or ornamental purposes. Some of the intrudes of porphyry and euryte, however, give well-shaped, good-sized blocks, and might be utilized, except that the sandstone of the county, being more easily worked, is preferred by the architects and stonecutters.

A little west of *Deveney Bridge*, to the south-east of Omagh, there is a large exposure, for the most part a compact purplish rock, which rises in large blocks and cuts, and polishes well; it is also easily plugged and dressed. In part of the mass the rock is an amygdaloid, spotted white and red, a really handsome stone, well worthy of being more known than it is at present. Some of the eurytes also, when porphyritic, are handsome; but they are often affected by a structure that causes them to rise in thin-bedded stones.

The bedded eurytes at Glenbeg, Shane Barnagh's Sentry Box, &c., are associated with tuffs. Some of these eurytes are very peculiar, as they are traversed by a structure exceedingly like bedding, which subdivides them not only into slabs, but also into what might even be called slates. This is very conspicuous in the neighbourhood of Back Bridge, where they have been quarried for slabs, for flagging, and for roofing purposes.

There are scattered dykes of felstone in the metamorphosed *Ordovicians*, a more considerable intrude occurring near *Creggan Hill*, about eight or nine miles S.W. of Newtownstewart.

In general these eurytes are ignored for building purposes, on account of the far-famed sandstones of the county being preferred; yet they are a good, effective, permanent stone, as seen, for instance, in the Coastguard station at Cushendall, Co. Antrim, where an identical euryte was used, as hereafter mentioned.

There are also a few dykes of whinstone in the Silurian rocks, but, as a general rule, these are used only for road metal.

Within the Slieve Gallion district (*metamorphosed Arenig*, or *Cambrian*) there is a granite very similar to that of Omey Island, Co. Galway, which is evidently newer than the associated schist, but older than the Pomeroy series (*Llandovery* (?)); and there are granites and elvans which seem to be the root-rocks of the interstratified *Silurian* eurytes. The older granite could be raised in large blocks, and is suitable for ornamental purposes; but the Silurian granites, although often a handsome red stone, are nearly always so much jointed that they could only be procured in stones of small dimensions.

The *Hornblende-rock* is greatly varied in character. In general it is very coarsely crystalline; but sometimes it is a fine blackish or grey hornblendic granite. In this tract there are Ophytes and Ophito-hornblendic rocks, some of the latter being very like the so-called "Swedish green granite." These rocks appear capable of being utilized for ornamental purposes. The localities in which they occur have been given in the description of the ophytes (vol. v., p. 407).

In the metamorphosed Ordovicians, west, south-west, and south-east of *Castlederg*, there are protrudes and courses of hornblende rock, as also to the westward of *Sion*, a little N.E. of *Newtownstewart*, on the S.E. slope of Bessy Bell, and a few miles S.W. of Gortin, in Ballynatub mountain. (G. S. M.)

Within the *schist* district, as about Strabane, Castlederg, and elsewhere, this rock is ordinarily used for common buildings. As to character it varies from fine argillaceous to more or less gneissose. Near Castlederg the surface is covered with many loose blocks of this micaceous rock, which are used for building. They are frequently split by an ingenious application of fire on the top of the stone, the expansion resulting from which is made to separate the stone in any part required." (*Wilkinson.*)

FERMANAGH.

In the north-west part of this county, near Belleek and Pettigoe, there is a small tract of metamorphic rocks, probably equivalents of the *Arenig* or *Cambrian*, coming in from Co. Donegal. These rocks, like those of the Slieve Gallion district, Co. Tyrone, are very much altered, and there are in them some interesting varieties of hornblende rock.

There are large dykes of whinstone in the *Carboniferous* and *Silurian rocks*, while in the latter, near the bounds of Co. Tyrone, there are also eurytes, more or less similar to those in that county. These rocks are not made use of, except to a small extent for road metal. (*T. Plunkett.*)

ANTRIM.

Overlying the greater part of this county are the well-known extensive sheets of *Eocene* (?) basalt and doleryte, and their associated agglomerates, conglomerates, and other tuffs, with, in places, intrudes of trachyte and granitic rocks (*granitone* and *nevadyte*).

In the neighbourhood of *Carrick-a-rede* there seems to have been one of the principal volcanic centres, the remains of the old volcano being still more or less visible, consisting of large masses of agglomerate, conglomerate, and more or less fine tuffs, cut up and displaced by numerous dykes and other intrudes of basalt, doleryte, and more crystalline rocks.

Slemish is considered by Traill to have been a volcanic vent. "It forms a bold ridge, 3000 feet long and about 1000 feet wide, which rises abruptly from 300 feet to an altitude of 1437 feet. It is an intrusive mass of dark, greenish blue, crystalline doleryte." In numerous places the sheets were due to fissure eruptions, the dyke that now fills the fissure merging into the sheet. This can be well seen at the iron mines in Glenarm.

Another well-marked volcanic centre was *Tardree*. Here, however, the adjuncts of the outburst were principally acidic rocks (*trachytes* and *nevadytes*), on which, in places, are lying raised-up portions of the doleryte sheets. Associated with the trachyte and nevadyte (the latter locally known as *Tardree porphyry* and *Tardree granite*) are some tuffose rocks, looking very like the Brohlthal of Germany, which, when manufactured into a cement, is called *Trass*, and is extensively used in the embankments in Holland. Whether the German and Antrim deposits are similar as to composition, has, however, still to be proved. Up to the present time the latter has been considered to be useless.

The Tardree volcanic outburst is probably one of the latest of those in the north-east of Ireland, the trachytic rocks bursting up through the basaltic sheets, and throwing up a small cone, partly lava and partly tuff, to be afterwards more or less modified by marine and atmospheric agencies.

In BELFAST, in the *Post Office and Water Commissioners' Office*, Bessbrook granite, Co. Armagh, was used; in the *Bank of Ireland*, Donegall-street, Newry granite; shops in *Ann-street*, capitals and columns, Goraghwood granite; and *Queen's Bridge*, Castlewellan, Co. Down, granite.

The Eglinton Chemical Company have lately opened quarries in the basalt at *Bookis* and at *Ballintoy*, between the Giant's Causeway and Ballycastle. They are sending into the market paving-setts 4″ × 4″ × 4″, 6″ × 5″ × 3″, 5″ to 7″ × 6″ × 3″ to 3½″, 7″ to 10″ × 7″ × 3½″ to 4″, 9″ × 7″ × 4½″, 6″ × 4″ × 4″, and all sorts of crossings, channels, kerbs, &c., with waste for macadamization.

The harder varieties of the doleryte and the "clinkstone," or basalt that has a metallic ring are generally used in the basaltic area for building purposes, as they can be raised in well-shaped blocks of various scantlings, and will scabble easily. "Whenever it occurs, tabular, massive, or columnar, it makes a very good stone for rubble work. It hammers fairly well, and is most durable; it is not used for cut-stone purposes, because it is so difficult to work, and has a very dark, forbidding colour." (*W. Gray.*)

"At and near Ballymoney and Coleraine it is of a better working quality than in the south of the county, where it is harder, and has sometimes been used for moulded work." (*Wilkinson.*)

"The nevadyte or *Tardree granite* is procured from a quarry some five or six miles north of Antrim. Grey, granular, durable; works well. Used for dressings, steps, quoins, piers, &c., in churches, country buildings, and other public structures in almost every town in Antrim." (*W. Gray.*)

In the north-east part of the county, in the Ballycastle district (barony of Cary), there are whinstones of *Carboniferous* age, as also metamorphosed intrusive rocks, associated with the tract of schists (*Ordovician* or *Arenig*). These schists and whinstones are very little used, as sandstone occurs in the immediate neighbourhood.

A little northward of Cushendun there is a tract of a handsome red elvan, which cuts and polishes well; but, unfortunately, it is so cut up with joints as to rise in pieces of small dimensions. (*A. M'Henry.*)

In the N. E., near Runabay, there is a similar elvan, the [illegible]m to brighter red; a very handsome stone. (*R. Clarke.*)

Associated with the *Silurian* conglomerates at Cushendall there is a purplish, sometimes lighter-coloured (dove colour), and porphyritic euryte intrude. The dove-coloured is a good, durable stone, and has been used throughout in the building of the Coastguard Station. The porphyritic variety ought to cut and polish well, and make a handsome stone. The dark-purplish variety is not approved of.

NORTH-EASTERN IRELAND.

[Down, Louth, Armagh, Monaghan, Cavan, Longford, Westmeath, and Meath. N.B.—Antrim, for convenience, is put along with N.W. and N. Ireland.]

Chronological Account.

The exotic and metamorphic rocks in this territory seem to belong to the following geological periods:—

Ordovician and Llandovery—*Granite, Elvan, Felstone, Euryte, Whinstone, Tuff,* and *Metamorphic Rocks.*

Silurian and Devonian (Lower Old Red Sandstone).—The Cavan granite is post-Ordovician and pre-Carboniferous; it ought, therefore to belong to the Llandovery, or Silurian, or Devonian times, probably Silurian; but this cannot be positively affirmed.

Similar remarks are applicable to the Slieve-Croob granite, Co. Down.

In the Ordovicians there are numerous dykes of whinstone, euryte, and felstone, which are cut off by the intrude of Mourne mountain granite. These must, therefore, belong either to the Silurian or Devonian periods, if that granite is of Carboniferous age; but if it belongs to the Triassic, then some at least of those dykes may be Carboniferous.

CARBONIFEROUS and PERMIAN.—The Mourne Mountain granite and elvan may possibly be of Carboniferous or of Permian age; but it appears to me more probable that they were intruded in Triassic times. There are, however, intrudes and dykes of whinstone, euryte, and felstone, which are older, and evidently either Carboniferous or Permian.

TRIASSIC.—The granites and elvans of the Mourne Mountain district, and their associated felstones, eurytes, and whinstones, as just stated, are supposed by me to be Triassic. South-westward of Carlingford Lough are the Barnavave, or Mount Fathom elvan and the Slieve Foze granitoid rock, with their associated whinstones, eurytes, and felstones, all being post-Carboniferous, while they seem to be pre-Tertiary, and were probably intruded during the Triassic age.

TERTIARY.—In the Carlingford district are dykes and other intrudes newer than the Slieve Foze granitoid rock, and all other rocks in the district, while some of them are apparently identical with the Tertiary rocks of Antrim. These rocks seem to have their granitic roots in the country westward of the Lough, and also in the great course of nevadyte coming up through the Newry granite (*Slieve Croob*) in the vicinity of Goragh Wood, Bessbrook, &c.

[Prof. Sollas has lately suggested that these are the remains of a very recent volcano in this district, the details of which he is working out at the present time.]

Territorial Description.

In some of the counties included in this territory no metamorphic nor exotic rocks are known to exist; those in which most are found are the counties Down, Louth, and Armagh, especially in the neighbourhood of Carlingford Lough.

DOWN, LOUTH, AND ARMAGH.

In the northern part of the Co. Down, near Comber and Newtownards, there are intrudes of whinstone in the *Triassic* rocks; these are principally used for road metal.

In the neighbourhood of Lurgan and Portadown, counties Down and Armagh, there is the southern extremity of the great Ulster sheets of *Eocene* doleryte and basalt; while at Markethill and Poyntzpass there are some small intrusions of the same.

Dykes of whinstone, euryte, and felstone, are very numerous in the *Ordovician*, especially in the eastern coast section and in the hills. Many of these, as already mentioned, are cut off by the intrude of the granite of the Mourne district; but some seem to be adjuncts of that granite, while others are probably of *Tertiary* age.

"The mountains around Carlingford Lough yield a good series of granites, all nearly of the same colour, but differing in texture; the finest being from Castlewellan, and the most open, or spotted from Goragh Wood and Bessbrook. Stones of any size can be had from Castlewellan, and good stone for all purposes from any of the quarries." (*W. Gray.*)

BESSBROOK GRANITE COMPANY, Co. Armagh. (*Thos. Flynn.*)

Five different qualities of granite:—

No. 1.—Bright-grey, spotted; probably the root rocks of the younger exotic rocks of the district, and allied to the *nevadyte* of the continental geologists; a very handsome stone; polishes well.

No. 2.—Bright-grey, fine-grained, very hard, durable; the typical *Newry* or *Slieve Croob granite;* here it is very hard, and eminently suitable for paving-setts, which have been supplied to the Tramway Companies of Wigan, Bristol, Chester, Southport, Newtown Heath (Manchester), Edinburgh, Chesterfield, St. Helen's, Swansea; and to the Corporations of Liverpool, Huddersfield, Preston, Chester, Salford, &c. Setts, 4″ cubes, 3″ × 6″, 4″ × 6″, 3″ × 5″, 4″ × 5″ and 4″ × 7″; special sizes if required.

No. 3.—Bright-grey; coarser than No. 2; it is not being worked at present.

No. 4.—Quarry in Barnesmore, Co. Donegal, as mentioned in the description of that county (*ante*, p. 232).

No. 5.—Rostrevor Quarry, Co. Down. Anorthite syenyte, of a bright-green colour.

The Company are prepared to supply all sorts of polished work in monuments, columns, and slabs, also pilasters, steps, sills, kerbs, channels, paving-setts, &c.

At the *Rostrevor Quarry* black paving-setts have been manufactured for many years; blocks are now being raised there which are sent to the Bessbrook polishing works, and there manufactured into monuments, slabs, &c. This stone is superior in colour to the Swedish "green granite."

[Specimens of the Irish polished granites are to be seen in a collection at the Science and Art Museum, Kildare-street, Dublin.]

MOOR QUARRIES, NEWRY, Co. Down—(*Campbell & Son*).—These quarries are in the *Newry* or *Slieve Croob* granite, and are capable of supplying blocks of the largest sizes required. Colour, rich sparkling grey; very durable; polishes well.

The polished granite is supplied for monumental and architectural purposes of any design or sizes required; also bases up to 40 cubic feet; plinths, or kerbs, from 5″ × 6″ to 9″ × 12″; coping, ashlar steps, landings, sills, crossing and channel-stones, paving-setts, macadamization stone, and gravel. The sills can be supplied in all required sizes.

ULSTER STEAM-POLISHING COMPANY, Belfast—(*Robinson & Son*).—Principal quarries, No. 1, at Goragh Wood, Co. Armagh, and No. 2, at Castlewellan, Co. Down.

No. 1, *Goragh Wood Quarry*.—More or less similar to the Bessbrook, No. 1, quarry (*nevadyte*, or Tertiary granite). A very handsome spotted grey stone; takes a rare polish. Can be raised in blocks of large sizes.

No. 2, *Castlewellan Quarry*.—Is a peculiar variety of the *Newry* or *Slieve Croob granite;* the black graining of the grey being elongated in oblique lines, giving the stone an unique and chaste aspect. It can be raised in blocks of almost any size. This stone was used in the Albert Memorial, Hyde Park. Stones up to 25 tons weight, and of great length, being supplied. It was also highly commended by Sir J. N. Douglass, Engineer to the Corporation of Trinity House, London, who used it in the reconstruction of Bishop Rock Light House, Scilly Isles, after a careful personal comparison of different granite quarries in Scotland, Cornwall, and Ireland. It was most favourably reported on, as being well adapted for resistence in batteries, after experiments at the Royal Arsenal, Woolwich.

On account of its extreme hardness it is eminently suitable for paving-setts. This hardness seems to be due to the re-arrangement of the minerals in the original granite by subsequent metamorphic action.

The Company are prepared to send into the market all requisites, polished, rough, &c., necessary for monumental, architect tural, building, and other purposes, columns, slabs, pilasters, steps, sills, kerbs, channels, paving-setts of any required sizes, and granite gravel for concrete blocks for pathways.

Besides the stones at present being worked there are others that appear worthy of being inquired after. At *Rostrevor-quay*, Co. Down, there is a dyke of a good green stone. This has been quite recently quarried for monumental purposes, as mentioned in the notice of the quarries of the Bessbrook Polishing Company. It had been previously worked for paving-setts and building purposes.

Fathom Mountain, Co. Armagh. In places in this mass of elvan there is a handsome pinkish-grey porphyry, spotted pink, white, and black. This rock has not been opened up as yet, and its capabilities are unproved.

Barnavave, South. A very fine-grained greenish-grey speckled elvan; cuts and polishes well. This stone, if it could be procured in sufficiently large blocks, ought to be useful for ornamental purposes.

As in this tract there is a great variety of exotic rock (grey, green, red, &c., elvans and whinstones), there ought to be other stones capable of being utilized in the hills (Cos. Armagh and Louth) westward of Greenore, and those S.W. of Newry. Traill says of the Carlingford felstone-porphyry, that from the great depth to which it weathers, no attempt has been made to open quarries in it. "It is highly porphyritic, of a pale pinkish colour, and appears to be a very beautiful stone," as seen in the cuttings for the Newry and Greenore Railway. He therefore is of opinion "that good quarries might be opened with advantageous results."

The *Mourne Mountain* granite at the margins of the intrude usually becomes an elvan. To the north-east, near Newcastle, it has been quarried for use in that town. Usually it is even-grained, pink mottled grey, and much coarser than the other granites of the Territory.

In the southern part of the county Louth, in the *Ordovicians*, there are numerous beds, dykes, and other intrudes of whinstone and euryte, as also beds of tuff more or less similar to those already mentioned in the Co. Wexford; they do not seem to be much utilized except for local purposes. Some of them, however, appear suitable for paving-setts.

These are very numerous along the coast section in the neighbourhood of Clogher Head, while inland they appear about *Collon*, S.W. of Dunleer, coming in from the Co. Meath.

MONAGHAN, CAVAN, LONGFORD, WESTMEATH, AND MEATH.

West of Bellananagh and S.W. of Cavan there is a limited tract of fine-grained grey and reddish granite, which is described as metamorphic and *post-Ordoviciam*. "The granite is generally broken up by irregular jointing, and thus can be but little used for building purposes." (G. S. M.)

A few felstone dykes have been noted in the vicinity of the granite.

In the *Co. Meath* there are whinstones S.E. and S. of Kingscourt, coming up respectively through the *Coal-measures* and the *Triassic*. To the N.E. of *Navan*, and at *Slane*, and to the S.W.E. and N.E. thereof, extending into Co. Louth there are in the *Ordovicians* numerous long exposures of whinstone, felstone, and tuff locally utilized.

Near Duleek and Naul, the latter being just within the Co. Dublin, there are similar rocks in the *Ordovicians*. Some of the whinstones near Balbriggan were considered by *Jukes* to be eminently suitable for paving-setts.

In Monaghan, Longford, and Westmeath there are not any metamorphic rocks; nor does there seem to be any exposure of exotic rocks in those counties.

XX.

ON THE FORMATION OF CRYSTALS OF CALCIUM OXIDE AND MAGANESIUM OXIDE IN THE OXYHYDROGEN FLAME. By J. JOLY, M.A., B.E.

[Read April 18, 1888.]

Lime cylinders which have been for some little time exposed to the oxy-coal-gas flame, in the production of the lime-light, will be found, on close examination, to exhibit a crystalline structure in the neighbourhood of the flame.

Broken up and placed under the microscope, it is seen that the structure of the lime cylinder has been altered around, and to some depth beneath the part played on by the flame, its amorphous character being changed to crystalline : a mass, apparently, of minute cubical crystals with high lustre.

This fact having come under my observation, I thought it desirable to make an experiment, using purer materials. Lime, made by the calcination of marble; oxygen and hydrogen, containing, probably, but slight trace of impurities, were accordingly employed. The lime was heaped in small broken pieces on a hearth of fire-brick covered with platinum foil, and among the pieces near the upper part of the heap, so as not to melt the platinum, the flame was directed. In a short time it was seen that crystals in aborescent forms were growing in the crevices close to the hottest part of the mass. After half an hour the flame was turned off and the lime allowed to cool, when it was found that very beautiful crystals covered the pieces of lime near those parts which had been most exposed to the flame.

These crystals are isometric, showing the cube and octahedron, the latter generally superimposed on the cube as a truncation of its angles. They are limpid or subtransparent white, with very high lustre, and have a plated structure on the cube faces.[1] The

[1] It is to be observed that fluorite has just such a plated structure, and its dominant cleavage is octahedral.

lustre dims in a couple of days if the crystals be left exposed to the moisture and carbonic acid of the air, ultimately becoming opaque and falling to pieces. Examined between crossed nicols, they are found to be optically inactive, a conformation of their true cubical character.

Their formation is by sublimation, a volatilization and subsequent arrangement of the molecules occurring at the high temperature of the flame. They are often, indeed, transported an appreciable distance from the point of greatest heat, building up in the manner of hoar frost, on the cooler surfaces. This frost of calcium oxide is in various branching forms, with parallelism maintained between the faces of the cubes on any one branch, the cubes being really continued one into the other, in a manner recalling octahedral strings of magnetite.

The cubes are hardly greater than one-fifth of a millimetre on the edge. Under the microscope their brilliancy is very striking.

So far as I can ascertain, crystallized calcium oxide has not before been directly prepared from the amorphous substance. Brügelmann has obtained it by heating the nitrate in a porcelain flask.[1]

Magnesium Oxide.—Pure magnesia, which has been caused to cohere by wetting it with water containing a little sugar, and then drying in small pieces, when exposed to the oxyhydrogen flame in a similar manner to that described in the case of calcium oxide, also develops small crystals. In this case the heating must be more prolonged, as the formation of crystals is less marked.

The microscope shows these crystals to be cubical in form, clear or translucent, and colourless, with high lustre. They are very minute, and are formed on the edge of the enamel of melted magnesia.

Regular cubes of the oxide have been previously obtained by igniting the amorphous substance in a current of hydrochloric acid,[2] and in this way, too, Deville prepared the mineral form of the oxide, periclase, which contains some iron.

---

[1] "Treatise on Chemistry," Roscoe and Schorlemmer, vol. II., pt. i., p. 190. Watt's *Dict.*, new ed., vol. i., "calcium oxide."

[2] Roscoe and Schorlemmer *tom. cit.*, vol. II., pt. i., p. 240.

XXI.

PRELIMINARY OBSERVATIONS ON THE GRANITES OF WICKLOW AND DOWN. By W. J. SOLLAS, M.A., LL.D., Professor of Geology, &c., Trinity College, Dublin.

[Read May 16, 1888.]

Granite, wherever it occurs in Leinster and Ulster, is a truly igneous rock, separated in every case by a clear line of demarcation from the schists which surround it.

The following statements are true of the main granitic masses of Wicklow and Newry :—

1. For some distance inwards from its boundary the granite is in many places foliated so as to assume a gneissose character. Good instances occur at the Scalp, and about the head of Glendalough, Co. Wicklow, and near Castlewellan, Co. Down. Mr. Traill has previously called attention to the instance near Castlewellan, and I have to thank my friend Mr. Teall for the suggestion that I should look for "crushed granite" in Wicklow.

2. The planes of foliation in the granite are parallel to those of the adjoining schists. The explanation of the erroneous opinion that in some cases the granite might result from metamorphosis (*i. e.* the melting up of sedimentary material) is to be found in this fact.

3. The foliation of the granite, in the case of the Leinster granite, is shown by microscopical investigation to be the result of pressure, acting on the previously consolidated rock.

4. Hence it follows that the phenomena of contact metamorphosis preceded in order of time the production of foliation. This is independently proved by the fact that the garnets developed by contact metamorphosis in the surrounding schists are traversed by cracks which are directed chiefly at right angles to the planes of foliation. These last are diverted on each side of the garnets.

5. The foliation of the granite and surrounding schists was simultaneously produced by great earth movements which took

place at the close of the Ordovician period, and before the commencement of the Carboniferous system.

6. Thus the intrusion of the granite both of Wicklow and Newry took place after the deposition of the Ordovician; it had already cooled and consolidated, at least for some distance inwards from its outer surface, before the period of crush; and it was foliated together with the Ordovician, so long previous to the commencement of the Carboniferous system, that by the time the Carboniferous limestone was in process of deposition, the overlying Ordovician strata had been removed from it by denudation.

The "soda-granites" of Wicklow and the granite of the Mourne mountains have a different history.

1. Neither are foliated at their margins. The "soda-granite," which occurs near Aughrim, penetrates schists which have been subjected to extreme pressure, as is shown by the perfect schistosity developed in the associated igneous dykes. Notwithstanding this, the granite, which is clearly exposed in a railway cutting near Aughrim, shows no trace of "crush."

2. The andalusite developed by contact metamorphosis in the schists adjoining the Aughrim granite is not crushed: the planes of foliation of the schists traverse it undisturbed.

3. These granites are therefore later than the earth movements which succeeded the deposition of the Ordovician rocks: that of Mourne is in all probability of Tertiary age, as may be the soda-granites of Wicklow, though, as I hope subsequently to show, this is not likely

XXII.

ON DIRECTIONS OF ICE-FLOW IN THE NORTH OF IRELAND AS DETERMINED BY THE OBSERVATIONS OF THE GEOLOGICAL SURVEY. By J. R. KILROE, H. M. Geological Survey, Ireland.

[Read April 18, 1888.]

The field observations of the Geological Survey, Ireland, being completed, it was considered desirable by the Directors to represent those bearing upon glacial phenomena in the northern half of the country on a general map, scale ten miles to one inch. In transferring the observations from the inch sheets already published, and those in the course of preparation, it became apparent that the striæ maintain two definite directions almost at right angles to each other. At a comparatively trifling number of points the striæ do not trend in either of the two prevailing directions, and are doubtless attributable to local ice-flows, which proceeded from minor independent glacial systems at some period of the ice age.

The two sets of above mentioned striæ are observable only north of a line drawn from Galway Bay to Strangford Lough; and as it is difficult to conceive how both sets could be the result of the same ice-movement, their existence is a very suggestive fact. This difficulty may be estimated when it is stated that both sets have been observed on the same flat surface in several instances; and occur alike in valleys and on the flanks and summits of some of the highest hills.

Directions of Striæ.—Of these two sets of striæ the direction of one is north to north-west, which, as evidence of ice-movement, will be considered hereafter; and that of the other is W. 25 S. swinging round to west in Donegal, and south-west towards Galway Bay. This westward direction is remarkably persistent, whether at 1200 feet above the sea near Glenarm; 1,250 feet in Slieve Beagh, county Tyrone; 1,100 in the Nephin group, or at the sea level near Belfast, Londonderry, or Sligo. To account for this uniformity of direction we must conceive the passage of an ice-sheet across the country with uninterrupted flow, and proceed to show that such an ice-sheet crossed the North Channel from the central Highlands of Scotland, forming a portion of what we may speak of as The Scottish Glacial System. That an ice-flow has invaded the east of Antrim from seaward has been fully established by my colleagues, Messrs Symes and M'Henry, by striatial evidence, and the occurrence in the drift of blocks of chalk and Fair Head basalt, which must have travelled westward from their original site. Blocks of schist from Cantire also bestrew the surface of Rathlin Island.

On the published Government maps of Ayrshire and Wigton numerous striæ are indicated, some bearing northward, and several westward, precisely as they occur in Ulster. The latter set evidently indicates an outward flow towards the Irish Coast, which, it cannot be doubted, was continuous with that which moved landward over the counties of Antrim and Down.

Extension of the Scottish Ice-sheet.—Dr. A. Geikie has supplied us with numerous interesting data,[1] and deductions therefrom, as to the extension of the *mer de glace*, which centred in the Scottish Highlands. Eastward it coalesced with the great Scandinavian ice-sheet, and south-westward with that which covered Ireland; so that a vast glacier probably extended from Cape Clear to North Cape—a distance of 1500 miles.

In considering the movements of this vast mass of ice, as it spread itself outward to reach the open ocean, and its immense thickness[2] in Scotland, it is easy to comprehend how it crossed the Minch, and overflowed the outer Hebrides, to a height of 1600 feet at least[3] in North Harris. I observed striæ bearing westward in the Nephin group at the 1100 feet contour line, in the course of my survey work in Mayo, in 1878. Dr. A. Geikie records striæ on Ben Lomond at 2250 feet above datum. We are, therefore, justified in concluding that the ice-sheet in the North Channel was of sufficient thickness to overtop the Antrim coast-line by perhaps 1000 feet. Striæ have been observed bearing westward from the entrance to Lough Foyle throughout the county of Donegal, to the

---

[1] *Scenery of Scotland*, by A. Geikie, LL.D., F.R. S., 2nd ed., pp. 251, *et seq.*

[2] In parts attaining 3000 feet, *Great Ice Age*, p. 100.

[3] Paper by James Geikie, LL.D., F.R.S., *Jour. Geol. Soc.*, vol. xxxiv., p. 832.

western seaboard. These can alone be attributable to the movement of an ice-sheet continuous with a mass which blocked up the adjacent oceanic area, and moved outward to the open waters of the Atlantic. Confirmatory evidence of such a movement is to be found in the occurrence of chalk-flints in the drift of Inishowen; also in the absence of granite boulders from the lower boulder clay of Glen Swilly,[1] and from that which rests on the granite and schist at the north entrance to Barnesmore Gap.

Hence we have strong reasons for believing that the ice-sheet which passed off the Wigton and Ayrshire coast, moving westward, flowed on to Irish soil, and urged its way across Ulster to escape on the western coast by the various bays of Donegal, Sligo, Mayo, and Galway. Dr. Hull considers that a glacial system, centred in the Mourne Mountains, diverted the flow of this ice-sheet southward, which would account for the absence of westward striæ south of the Galway Bay and Strangford Lough line.

THE IRISH GLACIAL SYSTEM.—Much has been done by the Rev. M. Close towards the elucidation of glacial phenomena in the Irish area,[2] and his map of the glaciation of Iarconnaught, prepared in conjunction with Mr. G. H. Kinahan, and published in 1872, has furnished important aid in the preparation of the maps accompanying this Paper. Dr. Hull, in his Physical Geology of Ireland, has described the glaciation of the country in considerable detail; and, on his maps,[3] indicates an axis of glacial movement coincident with a great central snow-field, which sent its flows northward and southward. This the author represents as stretching north-eastward between the counties of Galway and Antrim; and it is satisfactory to be able to state that all the evidence brought to light since the publication of his book in 1878 tends to the establishment of his conclusions.

It has been stated in the commencement of this Paper that the prevailing direction of one set of glacial striæ in the North of Ireland is northerly. South of the axis of glaciation the flow has been south-easterly over the central plain of Ireland, and towards the Irish Sea, even across the Mourne Mountains; the Fermanagh

---

[1] As observed by Mr. M'Henry.

[2] Paper on the General Glaciation of Ireland, with map, *Jour. Roy. Geol. Soc. Irel.*, vol. i., new series, p. 207.

[3] *Loc. cit.*, page 211.

hills also are glaciated up to 1000 feet, so that the Irish glacial system must have attained important proportions.

South-easterly striæ abound on the east coast of the county of Down, and some bearing northward occur on Rathlin Island. It is therefore obvious that the central snowfield extended at least to the coast line of Antrim, perhaps beyond it, towards the Scottish coast opposite. And it would seem, judging from the directions of striæ in Fermanagh and Donegal, that a spur or projection from the central snowfield extended westward to the head of Donegal Bay.

Relative Ages.—It remains to consider the Irish and Scottish systems of glaciation with reference to their relative ages. It is reasonable to suppose that a very considerable accumulation of snow and ice obtained in the Irish area during the period of intensest cold, while the Scottish system was gathering maximum strength; and that an ice-movement outward was concomitant with this accumulation. Such a movement would obviously be northerly in Ulster, and would maintain this general direction until the Scottish ice-sheet invaded this area, to move westward uninterruptedly. Previously-formed striæ would thus be to a large extent effaced, and replaced by those bearing westward. Some might remain, but would obviously be very few. Striæ bearing northward are, however, by far the most numerous, and may be seen to form the more recent set also, where observed in proximity to those bearing westward. From this we conclude that during decline, or possibly after decline and subdued revival of glacial conditions, an independent *mer de glace* flowed northward and southward, finding its axis of movement in the great central snowfield.

XXIII.

PRELIMINARY ACCOUNT OF THE SODA-GRANITES AND ASSOCIATED DYKES OF CO. WICKLOW. By Professor W. J. SOLLAS, D. Sc., LL.D.

[Read January 9, 1889.]

Since my detailed account of these rocks may not be ready for publication for some little time to come, I propose on this occasion to present to the Society a brief summary of the principal results already obtained.

Soda-Granite of Aughrim.—Just before the railway from Wooden Bridge enters the town of Aughrim it passes through a cutting which affords an excellent exposure of a fine-grained granite, strikingly white, but speckled black with mica. A glance at a geological map will show that this belongs to the same system of dyke-like intrusions as the similar granite of the not distant Cushbawn Hill, which lies a little to the north of Aughrim. The chemical composition of the Aughrim granite, as shown by my analyses, agrees very closely with that of the Cushbawn Hill rock, as determined by Dr. Haughton; the former is, therefore, like the latter, a soda-granite. Owing to the facility with which comparatively unweathered specimens of the granite at Aughrim can he obtained, I have selected it for a complete investigation, in preference to that of Cushbawn Hill.

The powdered rock, treated with a heavy fluid in a "Smeeth" separator, yielded first magnetite, titaniferous magnetite, iron pyrites, and zircon; then followed a mineral, which I regard as a species of epidote, having a specific gravity of from from 3·4 to 3·45; this was succeeded by biotite, which fell continuously from 3·17 to 2·875, the denser portions having the composition of Haughtonite; with the biotite were associated a green mica and chlorite—the latter a late stage in the alteration of the biotite, the former possibly a first product of its decomposition. Between 2·875 and 2·71 muscovite fell, and at 2·56 this was accompanied by opaque white felspar, partly altered into muscovite (possibly also into meionite, but this is a point I am still engaged in investigating); plagioclase felspar continued to fall from 2·756 down to 2·616, between 2·66 and 2·64 it was accompanied by a large quantity of quartz; finally, from 2·56 to 2·523 soda-bearing microcline and orthoclase were precipitated.

In thin slices the rock presents a holocrystalline granitic texture. By weighing camera lucida sketches of its component minerals as seen under the microscope, its mineral composition was estimated to be approximately as follows:—

	Per cent.
Microcline, ...	9.129
Other kinds of Felspar, . .	51·354
Biotite, ...	7·096
Quartz, ...	31·814
Epidote (sp.), ...	·607
	100·000

In describing the constituent minerals, I shall take them as nearly as possible in the order of their consolidation.

Zircon.—This occurs in small crystals of more than one form; the commonest presents the combination (IOO), (OIO), (III), the next in frequency the same pinnacoids, but with a more acute pyramid, probably (3II); the form (IIO) (III) is only occasionally met with. Minute rod-like crystals of a mineral (rutile?) which polarizes in brilliant colours occur as inclusions within the zircon; fluid cavities are also present. The zircon itself occurs as an enclosure, and this in all the other constituents of the rock, except microcline. The mineral which it chiefly infests, however, is biotite, and this presents the usual pleochroic aureole around its guest; not unfrequently also it occurs within crystals of apatite, with a coaxial orientation.

Apatite.—Hexagonal prisms of this mineral are somewhat abundant as inclusions within the biotite, and when not actually inclosed within it they usually occur in its vicinity.

Magnetite.—Irregular crystals and grains of magnetite are present, some of primary consolidation, others the result of alteration of biotite.

Epidote.—An interesting species, probably of epidote, of which

I have not yet completed the investigation, occurs sometimes in association with biotite, and most frequently with its green variety, sometimes also as an inclusion in the central parts of the zonal plagioclase felspar, and sometimes in plates filling up the interstices between adjacent crystals of felspar.

A preliminary analysis of 0·0750 gramme gave the following:—

		Per cent.
Silica and other oxides (TiO_2, &c.),	0·0298	39·70
Alumina, ferric oxide, &c., . . .	0·0268	35·00
Lime, ...	0·0162	21·60
Magnesia, ...	0·0005	0·66
Water, ...	0·0012	1·60
	0·0745	98.56

Further treatment gave:—

		Per cent.
Silica, ...	0·0240	32.00
Other oxides, associated with silica,	0·0058	7·70
Alumina, ...	0·0056	7·46
Glucina (?), ...	0·0031	4·13
Ferric, and other oxides, ...	0·0140	18·66

The optic axial plane is situated at right angles to the chief cleavage, the dispersion is inclined, and ρ is greater than ν.

Biotite.—Sections of this parallel to the basal plane sometimes present a hexagonal outline, but are more frequently quite irregularly bounded, and the hexagonal outline, even when present, is usually more or less ragged. Sections more or less normal to the the basal plane are rectangular, sharply bounded laterally by the basal plane, but almost always much eroded at the ends. Interlaminated with the brown mass of the crystals a green coloured portion occurs. It is usually sharply bounded by the straight cleavage planes, and more often occurs in the interior than towards the exterior of the crystal. Along the cleavage planes of this green part crystals of epidote have been developed; magnetite also has been extruded.

Clusters of zircon and apatite crystals, common enough within the biotite, may also be seen lying in the minerals immediately adjacent to it, especially where its boundary is most ragged. In some instances a crystal of zircon may be observed half immersed in biotite, and half projecting from it. These facts point to a partial solution of the biotite after its first formation.

Zonal Felspar.—One of the most remarkable features of the rock is to be found in the beautiful zonal structure of the plagioclase felspar. The central mass or core of each crystal consists of a calcareous plagioclase, such as labradorite or andesine, though anorthite may sometimes be present in sharply-defined grains. Surrounding the core follow successive zones or envelopes of other felspars, varying, in composition, but becoming progressively poorer in lime and richer in soda, till in the outermost zone even albite itself may be reached. The core has frequently a dusty appearance, owing to the presence of opaque granular matter, but the envelopes are usually clear and transparent. Muscovite is frequently richly developed as small crystal plates lying along the planes of cleavage. It is here, indeed, next to the margins of the biotite, that this constituent is chiefly collected. The species of epidote before alluded to also occurs in the felspar core, and contributes no small share in some instances to its bulk. Repeated twinning, usually so characteristic of plagioclase felspar, certainly occurs, but comparatively rarely.

The zonal felspar is idiomorphic, and thus stands in striking contrast to the microcline. Certain idiomorphic non-zonal felspar crystals I leave to my completed account for detailed description.

Quartz.—This occurs in allotriotropic grains, which, as they precisely resemble those of ordinary granites, do not call for special description.

Microcline.—This, like the quartz, is allotriomorphic, filling up the spaces between the other constituents; while, however, a plate of quartz may consist of several crystal grains, all differently orientated; a plate of microcline, on the other hand, however irregular in form, and even when nearly cut in two by other closely adjacent minerals, yet retains the same optical orientation over its whole extent, thus recalling "ophitic" structure. In some cases it extends between closely approximated granules of quartz in narrow irregularly-bounded strips, and then appears to have consolidated later than the quartz.

Summary of Events.—Zircon and apatite were the first constituents to separate out from the original homogeneous glass, apatite followed, sometimes including previously-formed crystals of zircon, next the highly basic and ferruginous biotite; the already existing crystals of zircon, and soforth, serving apparently as nuclei. The aureole around the included zircon crystals is probably richer in ferrous salts than the rest of the biotite, and may be possibly looked upon as another instance of the early excretion of the more ferruginous compounds. Considering the easy fusibility of biotite, and the large extent to which water enters into its composition, its consolidation at this stage is not a little remarkable. Stable only under the conditions which existed at the time of its formation, a good deal of it, with change of conditions, subsequently became destroyed, leaving clusters of zircon and apatite crystals to mark its place; the biotite now present in the rock may thus bear but a small proportion to that originally crystallized out. Part of it further gave rise, by re-action with other constituents of the glass, to muscovite; and possibly epidote and other minerals were formed from it at the same time. The conversion of biotite into muscovite, during the consolidation of granite, appears to be a process of common and wide occurrence in this district.

The more calcareous and basic plagioclase then crystallized out (in some cases about fragments of muscovite), as its growth proceeded the lime became exhausted and the successive envelopes became poorer in this constituent, and correspondingly richer in soda. The growth of the felspar was not uninterrupted; there were periods when solution was substituted for deposition, as is shown by the rounding off of the angles of some of the zones. Solution also took place when the felspar crystals were completed, as is shown by the character of their junction with the succeeding quartz. Muscovite also developed along the cleavage planes, perhaps by a kind of schillerisation. After the plagioclase the excess of silica consolidated as quartz, and finally the microcline, crystallising partly contemporaneously with, and partly subsequently to the quartz, completed the structure of the rock.

Porphyritic Soda Microgranite of Aughrim.—East of the margin of the soda granite, towards Wooden Bridge, two or more thin dykes of a fine-grained felstone-like rock occur as intrusions in the Ordovician schists; analysis shows that some of these have approximately the same composition as the adjacent granite, of which they are evidently apophyses.

In thin slices the rock is seen to consist of a microgranitic basis, with crystals of zonal, and other felspar scattered through it, as well as occasional plates of chlorite, and associated epidote, magnetite, and zircon. The basis consists of minute crystals, grains of felspar, muscovite, and quartz. The zonal felspar crystals have, in many cases, been broken and cemented together again by a subsequent deposit of frequently non-zonal felspar. About the margins of the felspar crystals a fringe of smaller and irregularly-shaped ones sometimes occur.

The chlorite complexes are evidently derived from biotite, and represent the biotite of the previously described granite.

The minute muscovite crystals of the basis are frequently arranged more or less in parallelism, especially in the neighbourhood of the larger felspar crystals, and when two of these occur in close proximity, the narrow band of matrix lying between them presents exceptionally large and parallel crystals of muscovite.

No trace of microcline is to be detected.

The history of this rock would thus appear to have been the same as that of the main mass of granite from which it was derived up to a certain point, *i.e.* as far as the formation of the zonal felspars. When this stage had been reached, an eruption into schists took place, leading to rapid cooling, and, as a consequence, to the microcrystalline character of the matrix.

Soda-Granite of Coolboy.—In thin slices this presents very much the same characters as the soda-granite from Aughrim. According to Dr. Haughton's analyses it is, however, about 7 per cent. poorer in silica, and in accordance with this the difference between the angle of extinction of the core and the outermost envelope of the zonal felspar is on the whole greater than in the case of the Aughrim rock. Microcline, though present, is less abundant.

Soda-Granophyre of Croaghan-Kinshella.—This remarkable rock contains, according to Dr. Haughton's analyses, a larger proportion of soda and a smaller proportion of potash than any other of the rocks of this group. Its mineral composition, as calculated by Dr. Haughton, is as follows:—Albite, 62 per cent.; quartz, 38 per cent. If we calculate the percentage of different felspar molecules present, directly from the percentage of lime, soda, and potash present, we obtain the following:—Albite, 47·12 per cent.; anorthite, 4·41 per cent.; orthoclase, 2·37 per cent. Disregarding the potash, and supposing the anorthite and albite molecules united in the same felspar, this would give an albite felspar of approximately the composition, Ab_{12} An; or if the orthoclase be included, a potash, containing albite, having the composition Ab_{24} An_2 Or_1 results, and the total quantity of felspar in the rock becomes 53·9 per cent., and of quartz, 46·10 per cent.

In thin slices crystals of felspar and rounded granules of quartz are revealed, the latter inosculating with the former in a micro-pegmatitic fashion; patches of chlorite, with associated epidote and magnetite are also visible, and point to the original presence of biotite, which has since become converted into chlorite by weathering; from the patches of chlorite thin yellowish films and streaks extend outwards, running between the adjacent minerals, and filling whatever cracks and revealed cleavage planes may be present.

The felspar crystals never show zonal structure, but they present other features of great interest. Many of them show very fine frequently-repeated twinning on the albite plan. When symmetrical extinctions can be observed, the angle of extinction, measured from the twinning trace, amounts to about 15°: this confirms the suggestion that the principal felspar present has a composition approaching Ab_{12} An_1.

Other crystals present a microperthite structure, and the angle of extinction for the interrupted lamellæ of these agrees closely with that of the albite crystals. This suggests the idea that the perthitic structure is simply a phase of synthetic twinning on the albite type; and this is clearly the case, for in some instances a large felspar plate will show the usual repeated albite twinning over one-half of its area, and over the other microperthitic structure, the optical orientation of the lamellæ in the two halves being identical. In a few cases twinning on the pericline plan is superadded to that on the albite type, and the microperthite then becomes microcline, or rather albite with the structure of microcline. Some of the felspar present does not show twinning; this usually extinguishes at from 20° to 21°, and is possibly albite or soda-microperthite, cut parallel to the face OIO. In some cases a crystal may be observed in which twinning is present over the greater part, but suppressed over the remainder of the section.

The quartz is present in rounded granules, penetrated by occasional apophyses of felspar. Each granule of quartz is the centre of a micro-pegmatitic area: such an area consists of the central quartz granule and a number of surrounding or partly surrounding crystals of felspar, which are "pegmatised" for a variable distance outwards from their junction with the quartz, sometimes the pegmatitic structure extends throughout the felspar crystal; sometimes it stops less than halfway across. When the felspar is in excess of the quartz intergrown with it we may fairly speak of the pegmatisation of the felspar, but sometimes the reverse is the case, and the felspar occurs included, pegmatite fashion, in a granule of quartz, and then one must speak of the pegmatisation of the quartz.

The quartz of this rock, as of that of the Coolboy granites, has a very dusty appearance, owing to the great abundance of inclusions, some liquid and gas cavities, and some of an indeterminable nature, but certainly solid.

The history of the consolidation of this rock diverged from that of the preceding varieties at a very early stage, for the highly acidic glass, remaining after the excretion of the biotite, contained so little lime, that the first felspar to consolidate was albite; soon after the appearance of this, the quartz separated out as granules, and this and the albite continuing their growth simultaneously, at last intercrystallized to form micropegmatite: the microperthite structure seems to belong to a somewhat later phase than that of the normal albite twinning.

Correlation of the foregoing rocks.—The name given by Haughton to these rocks is an exceedingly appropriate one. The most coarsely crystallised are evidently granites, but distinguished from normal granite by the abundance of plagioclase felspar, the average composition of which probably approaches $Ab_4 An_1$ or $Ab_3 An_1$. This involves an excess of soda, and hence the distinctive name. The presence, however, of soda bearing felspars (often of the nature of anorthoclase, which may be present in the soda granites) is a characteristic of the rocks known as keratophyre, rhomben-porphyr, and pantellarite; and the bulk analysis of quartz-keratophyr does not differ widely from that of some of the soda-granites. I extract the following from "Teall's Petrography," page 371, and place Dr. Haughton's analysis side-by-side for comparison:—

	1.	2.	3.	4.
SiO_2 (TiO_2, ZrO_2),	70·32	71·22	63·8	63·58
Al_2O_3, ...	11·24	13·84	17·60	13·60
Fe_2O_3, ...	4·80	3·21	3·40	6·71
FeO, ...	—	0·78	0·50	4·47
MnO, ...	—	0·12	—	—
CaO, ...	3·01	1·26	2·70	—
MgO, ...	0·73	0·20	1·00	2·58
Na_2O, ...	3·39	6·27	5·10	5·25
K_2O, ...	2·27	1·57	2·61	0·32
OH_2, &c., . . .	1·62	1·61	0·76	2·94

1. Soda granite from Cushbawn Hill (Haughton).
2. Quartz keratophyr from the Harz (Teall, *l. c.*).
3. Soda granite from Coolboy (Teall, *l. c.*).
4. Keratophyr from the Fichtelgebirge (Teall, *l. c.*).

In the soda-granophyre of Croaghan-Kinshella we have CaO, 0·89, Na_2O, 5·58, K_2O, 0·40.

The mineral constitution of these rocks is very similar, except that so far I have not been able to determine the presence of either augite or hornblend in the soda granites, and one or other of these minerals appear to be an essential constituent of keratophyr. It is by no means certain, however, that some of the mineral which appears to be epidote may not prove to be the missing constituent. I may note that the illustrations of quartz kersantite,[1] given by Barrois in his geology of Asturia, "Asturies de Galicie" (plates 1 and 2), suggest a resemblance to the soda-granite of Aughrim and Coolboy, except for the very manifest augite or amphibole which the former contains.

NOTE ADDED IN THE PRESS.

The supposed species of epidote is, as I had imagined, a variety of allanite; and augite is certainly not present in the rocks.

---

[1] According to Rosenbusch (*Mikroskopisch Physiographie*, p. 337), this quartz kersantite should be regarded as a diorite-porphyrite.

*

XXIV.

ON THE DOLOMITE OF HOWTH. By W. F. SMEETH, B.A., B.E. (Petrological Laboratory, Trinity College, Dublin). (Plate III.)

(Communicated by Professor Sollas.)

[Read December 12, 1888.]

Two patches of dolomite occur in the neighbourhood of Howth. Both are on the coast line, and border on the junction of the mountain limestone and Cambrian rocks. They are evidently a portion of the mountain limestone, which has suffered alteration, under the action of solutions containing magnesia.

The rock is of a light-brown colour, due, as is shown in thin slices under the microscope, to the presence of a brown oxide of iron, mechanically included. The brown colouration does not extend inwards very far from the surface, but ends somewhat abruptly along certain jointings of the unchanged limestone beneath. Along the line of junction blocks of unaltered limestone occur in the midst of the dolomitized portions, and show progressive stages of alteration. These facts point to the introduction of the magnesia in solutions from above.

The rock was found on analysis to have the following composition :—

	Per cent.
Calcium carbonate, ...	53·00
Magnesium carbonate, . . .	32·43
Alumina, Ferric oxide, Silica, ...	14.29
	99·72

On separating the mineral constituents of the powdered rock by means of Thoulet's solution, dolomite fell between specific gravities, 2·825 and 2·835, and on analysis yielded the following:—

	Per cent.
Calcium carbonate, ...	55·25
Magnesium carbonate, ...	44·70
Ferric oxide, ...	0·53
	100·48

The silica of the rock occurs in the form of minute but well-formed prisms of quartz, with the usual pyramidal terminations. It is chiefly confined to certain cavities in the rock to be mentioned directly; but some minute crystals occur disseminated through the general mass: in the latter positions they are no doubt residual, left behind from the mountain limestone; in the former they must have been deposited at the time of infilling of the cavities.

The ferric oxide may have been originally deposited as ferrous carbonate, which has since become altered by oxidation. It now occurs as thin films, and in minute particles disseminated through the rock.

In common with most other magnesian limestones, the rock is excavated by a great number of cavities. These are for the most part irregular in shape and fortuitous in distribution. They are lined, first of all with a film of iron-oxide, and next with well-formed crystals of calcite, generally in the form of dog-tooth spar. These then are the chief sources of the calcium carbonate which the rock contains over and above that combined with the magnesium carbonate in the form of dolomite.

In addition to the preceding cavities there are others present in the rock, of a somewhat different character: they do not occur all through the rock, but only in certain regions: they appear to be more abundant near the surface than deeper in the interior, and in detached blocks than in the rock *in situ*, but this is probably due to weathering, which may reveal them by oxidising any ferrous salt they may contain. Their chief extension is along a series of parallel planes, at right angles to which they are very narrow. (Plate III., fig. 1.)

Like the irregularly-shaped and distributed cavities, they are lined with ferric oxide and calcite, and on any face of the rock at right angles to their extension present themselves as a series of parallel markings, long in comparison with their breadth, edged with brown, and white in the middle. Under the microscope they present in thin slices the following characters (Plate III., fig. 2). All round the edge of the fissure the iron oxide, which in the surrounding parts is scattered like fine dust through the dolomite crystals, becomes a continuous film, thus forming the dark border. The crystals of dolomite immediately beneath the ferruginous film, forming the wall of the cavity, are exceedingly well-formed rhombohedra, giving well-defined sections showing the traces of the two sets of rhombohedral cleavages. This form—as shown by Renard—is quite characteristic of dolomite, and distinguishes it from calcite, which only rarely occurs in primitive rhombohedra (as was also pointed out by the Abbé Renard, "Des Caracteres distinctifs de la Dolomite," 1879. Dr. Sorby, however, represents primitive rhombohedra of calcite as occurring in several limestones: see "Address to the Geological Society of London," 1879, pl. XII., fig. 2; pl. XIV., fig. 1 (reprint). Dr. Sorby does not state whether the crystals shown in these figures had been specially examined with a view to determining the absence of magnesia.)

The central part of the fissure is entirely filled up with calcite, in large clear grains with rounded edges. Similar grains occur also in the midst of the dolomite crystals which mainly compose the rock, and these, like those in the fissures, are all distinguished by the absence of iron oxide. Whether a film of calcite, as the Abbé Renard supposes, is also present and holds together the dolomite crystals, I cannot say, but I did not succeed in finding any trace of it.

It would appear from the foregoing that the fissures were produced during the conversion of the limestone into dolomite; that round their margins the crystals of dolomite, having more room for growth, became larger and better formed than those which compose the mass of the rock; that over the surfaces of these a coating of ferric oxide was formed; and finally, owing to the passage of water through the rock, holding calcium carbonate in solution, calcite was deposited filling up all the chinks.

In conclusion, I may perhaps be allowed to offer a suggestion as to the cause of these curious cracks. No explanation is at all obvious; but it is evident that since the particles of the rock have separated along parallel planes, that there must have been a tendency for them to split in that way instead of indiscriminately. The most probable cause of such a tendency is pressure; and on examining the surrounding district it is seen that the beds of limestone (on the edge of which the dolomite occurs) have been bent into a kind of basin: one effect of this would have been to compress the portions round the edge tangentially, thereby setting up a tendency to cleave in directions parallel to the dip, *i.e.* approximately in the same direction as that in which the parallel cracks are found to extend.

EXPLANATION OF PLATE III.

FIG. 1.—Fragment of Dolomite from Sutton, Howth, County Dublin, showing the parallel cavities. Slightly enlarged.

FIG. 2.—Part of a section of the above, magnified to show the structure about one of the cavities.

(*d*) Dolomite Crystals.
(*f*) Lining of ferruginous matter.
(*c*) Calcite grains filling up the cavity.

XXV.

ON THE GEODINE GENERA, *SYNOPS*, VOSM., AND *SIDONOPS*. A CORRECTION. By Professor W. J. SOLLAS, D. Sc., LL.D.

[Communicated January 9, 1889.]

In my Report on the Tetractinellid Sponges of the *Challenger* Expedition, I have defined the genus, *Synops*, Vosm., as follows:—"Poriferous and oscular surfaces distinct; oscules the simple openings of excurrent chones; pores in sieves overlying incurrent chones."

My friend Dr. Vosmaer has kindly directed my attention to the last part of this definition, truly remarking that it is at variance with that originally given by him,[1] in which the pores are described as simple, and not sieve-covered openings. At Dr. Vosmaer's request I have re-examined the fine specimen of the type species, *Synops pyriformis*, Vosm., which I owe to his kindness, and with the result of fully confirming his views. I have, indeed, to confess to an oversight, for there can be no doubt that in *Synops*, Vosm., the openings of the incurrent, like those of the excurrent chones, are quite simple, and not sieve-covered.

This character *Synops* shares with *Isops*, Soll., and Dr. Vosmaer recognising this, wrote to me some time ago, inquiring whether the two genera should not be merged into one. At that time I was under the influence of the error just corrected, and imagined that in the character of the pores of *Synops* there existed quite sufficient grounds of distinction. With the disappearance of this imaginary difference, the distinction between the genera to my mind breaks down, and *Synops* becomes a synonym for *Isops*. Dr. Vosmaer is now, however, inclined to maintain a distinction, on the ground that the oscules are congregated in *Synops* in shallow depressions; this is, however, possibly explicable as a result of growth. Specimens

---

[1] Vosmaer, Report on Sponges, "Willem Barents," p. 20, 1882.

of *Isops* and *Synops* are found together in the same area, but those of *Isops* are always smaller than those of *Synops*, which are evidently more fully grown.

Whatever may be the fate of Vosmaer's *Synops*, it is quite clear that my *Synops* is a misnomer, and must be replaced. I propose to substitute for it *Sidonops*. When making my preliminary examination of the *Challenger* material, I had assigned in MS. to the sponges wrongly called *Synops* the name *Kalops:* my subsequent error is all the more unintelligible. *Kalops*, however, is preoccupied.

This renders necessary the following corrections:—

On page cxlix. of the *Challenger* Report (vol. xxv.), for *Synops* read *Sidonops*, and for the type species substitute *Sidonops neptuni*, Soll., for *Synops pyriformis*, Vosm.

For *Synops* read *Sidonops* in each of the following cases:—

Synops neptuni, p. 227; *Synops nitida*, p. 231; *Synops vosmaeri*, p. 234; *Synops macandrewii*, p. 265; and for *Synops pyriformis*, Vosm., p. 266, read *Isops pyriformis*,

In conclusion, I have to express my best acknowledgments to Dr. Vosmaer for affording me the opportunity of making this correction.

XXVI.

ON THE OCCURRENCE OF PALLAS'S SANDGROUSE (*SYRRHAPTES PARADOXUS*) IN IRELAND. By ROBERT F. SCHARFF, B. Sc., Ph. D., M.R.I.A., Curator of the Natural History Department, Museum of Science and Art, Dublin.

[Read December 12, 1888.]

A quarter of a century ago (in the year 1863) there occurred, to use the words of Professor Newton, a Tartar invasion of Europe unparalleled in the annals of ornithology. This was the irruption of Pallas's sandgrouse, of which hundreds, and probably many thousands, left the sandy deserts of Tartary and passed in a westerly direction across Central Europe. The extreme west attained by the migrants on this occasion was Naran, Co. Donegal. Had they not been ruthlessly slaughtered, the species would have flourished in Western Europe, having actually bred in Jütland and Holland.

It is remarkable that, after an interval of twenty-five years, the species has reappeared in Europe, many having crossed the North Sea, and arrived in England. Our earliest information regarding this present irruption is derived from Dr. A. B. Meyer, of the Royal Zoological Museum at Dresden, who wrote to *Nature*, May 12th, 1888, on the subject. Dr. Meyer describes the reappearance of the sandgrouse in large flocks, consisting apparently of innumerable individuals. The first record of their arrival in Europe was established by their appearance on the 21st April, at Plock, and in the markets at Warsaw. By the 27th they had reached Saxony, in Germany, and on the 5th of May they were seen on the island of Rügen, in the Baltic. All the flocks tended westward.

The native habitat of Pallas's sandgrouse is the sandy steppes of Central Asia. It breeds in Southern Siberia, and is resident in Turkestan. In severe winters, when there is much snow, it visits Northern China. In the following summer they leave that part of

China, passing the great wall, to the plains of Tartary, where they nest in the sand.

In the great desert of Gobi, the well-known Russian explorer, Colonel Prjevalski, found the species wintering from the middle of October, often meeting with flocks of several thousand individuals. These flocks feed largely on the seeds of the *Agriophyllum gobicum*, a plant related to our goosefoot, or common wild spinach (*Chenopodium*). They are also fond of the young, juicy shoots of Salicorniæ. That they would, if unmolested, soon become habituated to the food to be found in this country is evidenced by the fact, that those killed at the date of the last irruption in Norfolk were recorded by Mr. Stevenson to have had in their crops the seeds of plants common on the sandy coast of the country, but without trace of insect or other animal food.

They fly with great swiftness, making a peculiar sound with their wings, so that a large flock can be heard at a considerable distance.

This second European irruption was predicted by Professor Newton, who, writing in the *Ibis*, twenty-five years ago, said: "Unless some physical change occurs in the Tartar steppes, which may have the effect of relieving the pressure, another outpouring may be safely predicted, and probably the thrice-found channel will be again used by the emigrating population."

The pressure to which the Professor alludes is that arising from the natural increase of the numbers of the bird, which has few enemies in its own haunts, and whose powers of flight are so great, that healthy and vigorous specimens have no difficulty in escaping the attacks of falcons.

The Syrrhaptes is the highest type of the group to which it belongs, and from the short time necessary for incubation, and the rapid growth of the young, has increased to such an extent, that it may literally have been seeking new pastures, and endeavouring to extend its range. It could not traverse northward for climatic reasons; eastward its range is limited by the Pacific; southward is the larger bird of the same genus (*S. tibetanus*), and it could only therefore proceed westward; hence the exodus has now occurred again.

The first report of the arrival of Pallas's sandgrouse in England this year came from Winterton, in Norfolk. Mr. E. R. Boult observed a flock of fifteen feeding in a barley-field on May 13th. By the end of the month of May reports were sent in from all over England and Scotland.

This sandgrouse made its first appearance in Ireland this year on the estate of Mr. David Sherlock, near Tullamore (King's Co.). Five specimens were observed by this gentleman on May 20th, one of which—a female—he kindly presented to the Science and Art Museum. On the same day a good-sized flock appeared on the west coast of Ireland, in Co. Clare. Mr. Burton, of Carrigaholt Castle (Co. Clare), secured two of these birds—both females. He likewise made a donation of one of his specimens to the Museum, and it was set up by Mr. Williams with expanded wings, so as to show them in their full extension. A few days later a specimen was shot at Killough (Co. Down), and sent for preservation to a Belfast taxidermist. A second capture in the north was reported about the same time from Limavady (Co. Londonderry), and it probably belonged to the same flock.

The Rev. Henry Hewson of Belmullet, to whom I am much indebted for this information, states that five or six birds were noticed in the county Mayo about the beginning of June, and three of them were shot, one of these having been forwarded to Mr. Tank, a Dublin taxidermist, as reported by me in the September number of the *Zoologist*. On the 4th of June three specimens of the sandgrouse were seen on the wing by a gentleman near Malahide, in Co. Dublin, and the fact was duly published in the *Field*.

The Rev. P. Keatinge, of Athlone, was good enough to send me a communication to the effect of his having met with a flock of sixteen specimens at Woodpark near Annaghdown (Co. Galway), on June 8th. One of these was captured and kept alive for some time by a farmer, and after its death it was sent to Dublin to be stuffed. A week later (June 16th), a dead female specimen was picked up at Clontarf (Co. Dublin), having been maimed by flying against a telegraph wire. The next day we heard again from the west, that two specimens were shot out of a flock of four at Athlone (Co. Roscommon). Mr. Ussher, of Cappagh, reported in the *Zoologist* that he had received a sandgrouse from Rosslare (Co. Wexford), which seems to be the only specimen killed in the south of Ireland, although Mr. Rohu, of Cork, tells me that half a dozen or so were seen near Mallow.

The invasion of Ireland by the sandgrouse now suddenly ceases, and nothing is heard about it for nearly a month, until a report comes from Mr. Barrington, of Fassaroe, of his having received a male specimen from Mornington (Co. Meath). Three others were shot on that occasion, one of which was eaten by a Dublin gentleman, who told me that it was as dry as a chip. Mr. Harrison, of the Mornington Lighthouse, was good enough to forward me particulars, and according to his statement these birds were shot out of a flock of fourteen, on July 11th.

Meanwhile Mr. Lloyd Patterson, of Belfast, kindly sent me a note, saying that four additional specimens had been killed in the north—one at Dungannon (Co. Tyrone), and three on Copeland Island, at the mouth of Belfast Lough.

Although I have taken some trouble to find out whether any of the sandgrouse were bred in Ireland, nothing could be ascertained to show that such had actually been the case. In fact nothing definite has been seen or heard of this singular bird in Ireland between the date of the last occurrence and the end of November, when a specimen was said to have been shot at Portumna (Co. Galway). When I was in Belfast the other day, I saw several specimens at Mr. Sheals's, the bird-stuffer, and I hear that four were obtained at Kircubbin (Co. Down), on November 20th, and another at the same place, on the 1st of December.

Now, if we look through the observations I have just made, it will be noticed that we have records of twenty-eight specimens having found their death in Ireland up to the present. Many more may have been killed of which we have no information. Another fact made apparent by these investigations is, that several distinct immigrations have taken place from the east. The most westerly point reached by these birds, and precisely ascertained, was Belmullet (Co. Mayo). This is considerably further west than Naran, in Co. Donegal, which was the extreme west attained in 1863.

The immigrations I refer to began at the end of May and lasted to the middle of July, when they ceased until the end of November. It would be rather difficult to say, with any degree of accuracy, how many specimens of this bird found their way to Ireland; however, I hope I may be excused for attempting to arrive at some estimate of the numbers. Taking the first flock in round numbers as consisting of about twenty; the second which appeared in the north of ten; the third of about twenty, and the fourth of ten; we get altogether sixty birds. To these may be added the various other records from the north and south—the one from Co. Louth, and the last from Co. Down—accounting for another forty altogether, which brings up the number to 100 approximately. It is quite possible, however, that the number of specimens that found their way to this country exceeded many hundred. Following their instinctive desire to explore the extreme west, hundreds may have perished in the waves of the Atlantic, thus putting a stop to their enterprising spirit.

XXVII.

ON GEOLOGICAL UNCONFORMABILITIES. By G. H. KINAHAN, M.R.I.A., Etc.

[Read January 9, 1889.]

There appears to be a very general misunderstanding as to the ordinary character of an unconformability between two geological formations. In a simple unconformability the later rocks lie on the upturned edges of the older; but as far as my experience goes, such simple unconformabilities, especially among the lower Palæozoic formations, are the exception and not the rule; as in most cases of junction now exposed, the later rocks often accumulated, as much against, as on the older rocks. In such cases the older and later rocks may strike and dip nearly similarly. Fortunately, in Ireland, when such are their relations, one set is generally more or less metamorphosed, while the other is not so, and under such circumstances the boundary can be drawn by the lithological distinctive characters; but if neither one nor the other is altered, or if both are altered, it is often very difficult to say where the exact boundary is. I have found that marked distinctions in groups of rocks usually leads an observer to overlook their relative positions; and it is not until the groups display very similar characters that he looks back on other places and learns that, except for the distinct mineral arrangements, the mapping of the rest of the boundaries would not have been as easy as he had found it.

Among the older rocks, to the want of a simple unconformability, is to be added the complications due to foldings, contortions, faults, and thrusts (reverse faults), all of which add to the intricacies of an unconformable boundary; more especially so if both the older and later rocks have been metamorphosed.

My difficulties, I presume, have been felt by others; it may, therefore, be useful to lay before the Society some general notes on the basal beds of the different rock groups as they can be seen in Ireland, with more special descriptions of the complicated unconformabilities.

Eocene.

Under the basalts or dolerytes of Ulster there are, in many places, a thin conglomerate (flints in a white limey matrix) associated with shales, and in a few localities a bed of iron ore or of lignyte. If the Tertiary rocks lie on the Trias or Ordovician the conglomerate is conspicuous; but if they lie on the white limestone (*Cretaceous*) it is not so.

Cretaceous and Jurassic.

On account of the distinctive colours of the white limestone and the red Trias rock the boundary between them is conspicuous; there is, however, no regular basal conglomerate; but in places there are lenticular patches of pebbly limestone containing "greensand" fossils. These seem to have accumulated in hollows. In other places the Cretaceous rocks appear to graduate downwards into the Jurassic; no conglomerate occuring at the base of the Jurassic.

Trias and Permian.

Between the Irish Trias and Permian there is no well-defined boundary; nor between the supposed Permians and the Carboniferous.

The red beds of the Trias are distinguished from those of the Carboniferous by their colour and lithological characters; but the supposed Permians have no distinctive characters except palæontologically.

At Cultra, on Belfast Lough, the relations between the rocks in which are found fossils of Permian types, and the associated Triassic and Carboniferous rocks are very obscure.

At Templereagh, Co. Tyrone, the dolomyte, in which were found fossils of Permian type, seems to be a bed in the Trias.

At the marble quarries, Armagh, the conglomerate and sandstones, said to be Permian, as far as they can be seen, might be either the basal beds of the overlying Trias, or arenaceous members of the underlying Carboniferous; while the rocks in the Benburb section (Counties Tyrone and Armagh) are evidently sandstones of Carboniferous age.

CARBONIFEROUS.

The *Upper Old Red Sandstone*, now known to be the lowest group of the Carboniferous, usually has at its base a conglomerate or breccia that rests unconformably across the edges of older strata. These conglomerates nearly always comply with the recognised formula for a typical unconformability, *a conglomerate lying across the upturned edges of older strata;* yet in a few places this rule is not followed, as under the conglomerate there may be sandstones, or even shales; or, as in the Co. Clare, a peculiar limestone or quartz rock; while in the Slieve Aughta, Co. Galway, in places, both the older and later strata lie horizontally.

DEVONIAN.

Rocks belonging to this group, that is, the passage or "gap rocks," between the Carboniferous and the Silurian, seem to be represented only in S.W. Ireland.

In the Co. Kerry they have a well-marked basal conglomerate lying unconformably on the Silurian (*Dingle Beds*); while in the Co. Cork they are a regular passage group, passing conformably upwards and downwards into the Carboniferous and the Silurian (*Glengariff grits*), respectively.

SILURIAN.

Some of the Silurians which are of the *Lower Old Red Sandstone* type have a basal conglomerate lying unconformably on upturned older strata, but more usually the basal boundary is more or less complicated.

At Cushendun, Co. Antrim, the basal conglomerate lies unconformably on metamorphic rocks.

In the Pomeroy district, Co. Tyrone, the boundary between them and the Ordovicians is so obscure that it has not been satisfactorily determined; while at Lisbellaw, Co. Fermanagh, there is a massive basal conglomerate, as pointed out in a previous communication.

In the Curlew mountains, between Charlestown and Ballaghaderreen, the base of the Silurians is still in dispute, while the Silurians N.E. of Clew Bay, in Croaghmoyle and thereabout, are principally conglomerates and breccias, which are easily distinguishable from the associated older rocks.

At the south margin of the Louisburgh Silurian Basin, S.W. of Clew Bay, there is a conglomerate; and thereby the boundary is indicated; but to the N.E., where both the Ordovicians and the Silurians are metamorphosed, the base of the latter is obscure.

In the Galway and Mayo Basin of Silurians the boundary has different phases. To the north-eastward, in Slieve Partry, the rocks, when principally massive conglomerates, are easily distinguished from the associated older strata; but the north boundary here and in Mweelrea is obscure, as there is no basal conglomerate, while the Silurians and Ordovicians are very similar in their composition and in their strike; thus the boundary between them would be difficult to trace, if it were not that along most of it there is a bed of felstone (euryte), or a peculiar quartzy-rock; but where these are absent, as they are to the westward, the rocks of Silurian and Ordovician age are scarcely distinguishable. The older rocks south of the west portion of the basin are metamorphosed, and, consequently, the south boundary was easily traced: otherwise it would have been difficult to make out, as only in a few places are there small patches of the basal conglomerate, while the older and later rocks have in general very similar strikes and dips.

In the Dingle promontory, Co. Kerry, the boundary between the lowest group of the Silurians (*Smerwick Beds*), and the Ordovicians (*Anascaul Beds*) is obscure, but here it is possible that the Smerwick Beds may be the *passage or "gap" rocks* between the Silurians and the Ordovicians, and that through them there may be a regular sequence.

In the Co. Waterford, at Knockmahon, a conglomerate lies unconformably on the Ordovicians; but farther westward, at Bunmahon Head, and in Ballydowane Bay, this conglomerate appears as masses in the Ordovicians; in the Commeragh mountains, however, there are massive conglomerates lying unconformably on the Ordovicians.

ORDOVICIAN.

The basal boundary of this group of rocks is still more complicated.

In the County of Dublin, and the adjoining portion of the County of Wicklow, there is no actual junction seen between the Bray Head rocks (*Oldhamians*) and the Ordovicians; but, in places, the rocks of the different groups are so near together that there is no room for a basal Ordovician conglomerate, except at Moneystown Hill, near Roundwood, where a slate conglomerate seems to be the basal rock. To the south, in the Carrick mountains, the black Ordovician shales seem to be plastered against the older rocks.

In the Co. Wexford, near Poulshone, to the south of Courtown Harbour, the black Ordovician shales are plastered against a protrude of the older rocks; while from Cahore south-eastward to Bannow Bay there is no conglomerate at the base of the Ordovicians. However, between Ballygeary Bay and Greenore there is a basal conglomerate lying on the upturned edges of the metamorphic rocks; while the same thing probably occurs near the village of Tagoat.

Further S.W., along the south shore of the parish of Bannow, there are junctions exposed. To the eastward, in the townland of Ballymadden, a slate conglomerate lies on and against the older rocks; but to the westward the boundaries are very obscure, the Ordovicians being plastered against protudes of the older rocks, or let down among them. (See Map and Section, *Geology of Ireland*, pages 18 and 19.)

To the west of Bannow Bay, in the cliff south of Fethard, there is a slate conglomerate that lies unconformably on the strata to the south. The age of the rocks to the south of this unconformability is disputed; they possibly may be equivalents of portions of the Welsh Cambrians, or of the Arenig group.

If the boundaries are complicated among the unaltered, they may be expected to be more so among the Metamorphic rocks, which have been subjected to thrusting, faulting, and various other vicissitudes. In N.W. Mayo, and Counties of Donegal, Londonderry, and Tyrone, they are still in dispute. It does not, however, appear necessary to go into detail in connexion with these, as the object of this Paper is sufficiently answered by the description already given.

NOTE ADDED IN THE PRESS.

In a subsequent communication reasons have been given for supposing that the *Bray Head Series* is older than the Welsh Cambrians, and should be separated from them into a new group, for which the name Oldhamians is proposed. If this suggestion is correct, the Oldhamians will represent one of the series of "gap rocks" of Chamberlaine's *Agnotozoic Epoch;* that is, one of the series of rocks which accumulated subsequent to the end of Huronian time, and prior to the Primordials (Cambrians).

XXVIII.

NOTE ON THE ORIGINATION OF TURBULENT MOTION IN VISCOUS LIQUIDS. By G. F. FITZ GERALD, F.T.C.D.

[Read January 9, 1889.]

In a viscous liquid moving near a fixed surface the motion is laminar if the rate of change of motion with distance from surface is not too great. Under these circumstances a small deviation from laminar motion is gradually destroyed by the viscosity. If we consider the forces acting on any wave supposed superadded to the laminar motion, we see that the pressure, on what may be called the windward side of the wave, is greater than on the lee side on account of the viscosity of the liquid; and if the change of velocity of the liquid with distance from surface be great enough, the difference of pressure may be great enough to cause the wave to become greater and greater notwithstanding viscosity, just as the wind causes waves in the sea, and the waves will ultimately break, which corresponds to a production of turbulent motion. If the waves, originally produced be of short wave length, they would be more affected by the viscosity stopping them than larger ones, and so only turbulency of a definite size would be produced. This theory seems to account for most of Professor Osborne Reynolds' observations.

XXIX.

ON RECENT PHYSICAL QUESTIONS OF GEOLOGICAL INTEREST—BEING A PRESIDENTIAL ADDRESS TO THE ROYAL GEOLOGICAL SOCIETY OF IRELAND, 1889. By A. B. WYNNE, F.G.S.

[Read February 20, 1889.]

Upon assuming the highly complimentary position in which this Society has placed me, while endeavouring to conform to usage, I am constrained to plead extenuating circumstances for lack of leisure to prepare an address more worthy of your attention.

The first duty I have to perform is to record with sorrow the appearance on the death roll of former Fellows of the name of William Hellier Baily, F.G.S., M.R.I.A., who was for many years a frequent attendant at our meetings and contributor to our publications.

After an illness of several months' duration he passed away on the 6th of last August, at the age of sixty-nine, leaving behind a long list of his many contributions to Palæontological literature. Of these his notes alone, in the explanatory memoirs of the Geological Survey of Ireland, of which he was a senior member since 1857, refer to no fewer than 66 of its published maps, and he was besides the author of "Characteristic British Fossils," as well as of numerous other less important papers and publications. His presence linked us with a brilliant period for geology, with the times of De la Beche, Lyell, Phillips, Murchison, E. Forbes, Jukes, Darwin, Salter, Morris, and others his contemporaries, men who have done so much to increase the tide of advancing energy in connexion with our science. As a colleague who had long since won a position in the field of geological research through the medium of its palæontological aspects, we are called upon to pay to his memory a fitting tribute of respect and regret.

The rapid development of geological knowledge, both practical and theoretical, in modern days, would render an attempt to review even the most recent stages of progress a labour demanding the entire time and thought of a calm and extensive leisure, together with the possession of peculiar qualifications. Hence I refrain from what is out of reach, and as an additional reason for avoiding the discussion of geologically allied subjects, I may mention that I have been a follower of the rugged, yet varied and most interesting, paths pursued by Field Geologists applying where they can the information to be gleaned from the work of their brethren in the laboratory or the study—but chiefly engaged in tracing out amongst the rocks themselves those records of structural geology which become at once the object and the test of all true deductions connected with the historical aspect of the science.

To Field Geologists have come within these later years strange revelations in more than one direction, closely linked with their pursuits, and of surpassing interest. To some of these I would briefly ask your attention now, leaving the deeper study of problems still undergoing investigation to abler hands.

The marvellous display of former mechanical earth-movements of thrusting and shearing, which has afforded a key to the latest interpretations of the geology of the Highlands, is the issue of extensive researches on the part of Nichol and the older Scotch geologists, followed by Lapworth, Judd, Bonney, and others, and further continued by the Geological Survey; its officers being still engaged in the task of reducing the complexities of that very intricate region to intelligible order. In another direction we may notice the attention lately devoted to the subject of wide-spreading Palæozoic glaciation, as evidenced by the details advanced in support of an ancient Carboniferous to a Permian glacial period, and both may be regarded as among the most prominent geological questions of the day.

You are aware that a warmly-waged controversy as to the ages and abnormal positions of certain formations in the Scottish Highlands held the field for years, but now, after a considerable lapse of time, the conclusions arrived at by distinguished observers have been found seriously affected, and in part or entirely set aside, by the discovery that this complicated district abounds in evidence of enormous transplacements, whereby whole masses of the rocky strata have been shifted through lateral distances, varying from the smallest limits to ten, or it may be twenty miles.[1]

These earth-movements have not been necessarily horizontal, their gliding-planes being often more or less highly inclined or even vertical, and judging from the sections given by the officers of the Survey—in what professes to be only a preliminary, but which seems an almost exhaustive report,[2] so far as the description of numerous details is concerned—it appears that many of the more nearly horizontal master-thrusts, with their minor branches, habitually tended to deviate in an upward direction, as if this was the position in which least resistance was encountered to the "piling up" of disrupted sections by the enormous force in action—force which has sometimes ground the rocks to powder, like flour in a mill. Nor have these movements been confined to one geological period in particular, for we find their presence recorded in the original Archæan gneiss as belonging to two consecutive systems, while another subsequent and perhaps more manifest development is for the present referred to as "Post Lower Silurian."[3] In many cases the westerly direction of the movement appears to have been determinable, and it is a common feature to find the mass of rocks associated with one thrust plane sharply cut off by the lower surface of another, or whole complexes of these thrust-riven rocks assuming the condition of a magnified breccia, truncated, transgressively invaded, and overlapped by other displaced masses, likewise impelled forward by similar movements belonging to different systems into which these crust-migrations are capable of being grouped.[4]

An invariable accompaniment of these crust-movements is the extensive regional metamorphism and deformation of the rocks, found to affect both those of aqueous and of igneous origin, "dolerites becoming changed through diorite into hornblende schist," "false-bedded grits and quartzites into quartz schists," "felsite into sericite or mica schist," "archæan gneiss into slaty schists," and "annelide tubes in quartzite being drawn out and trans-

---

[1] Scores of Miles in the Alps. Heim, Lapworth, and Page's Geology, p. 112.

[2] Quarterly Jour. Geol. Soc., Lon., August, 1888.

[3] Recent work of the Geological Survey in the Highlands, Q. J. G. S., L., 1888.

[4] Recent work, Geol. Sur. in N. W. Highlands, Q. J. G. S., L., 1888, pp. 390, 430, 433.

formed into flat ribands," showing that the rocks have been not only compressed but stretched.

To such an extent has this deforming metamorphism veiled the original characteristics of one formation, that the various consecutive movements affecting it have become the most convenient means to use in treating of it chronologically, and we further learn that a whole rock group of now uniform character may have been reconstructed from different rocks of different ages and of diverse kinds, their identity being more or less completely lost in the process of alteration. Again, one widely-extending system of induced pressure-foliation may be superseded by another of later date, entirely or partially obliterating the first, a result that can scarcely be thought improbable when we find it stated that in certain beds of *mylonitic* structure the molecular movements resulting from pressure have caused their particles to flow[1] within the rock.

While it appears that these thrust-planes may be dislocated by the ordinary shifts of orthodox faulting, often present in the same sections, they seem to be, in a general way, distinguishable from fault planes by their displacements being approximately lateral, the throw of faults being usually more or less nearly vertical, and besides, they are further differentiated by the circumstance that faults have no particularly essential connexion with the metamorphism of the beds which they traverse.

Faults upon a grand scale with displacements of thousands of feet or a mile are recorded[2] as occurring in different parts of the Highlands, yet even these enormous dislocations become dwarfed in comparison with the horizontal transplacements of mountain masses for several miles,[3] movements which must certainly rank amongst the most stupendous revelations of structural geology.

As a prelude to the discovery of these thrust-movements, our notice was directed to marked inversion or overfolding of strata in connexion with several of the world's greater mountain chains, as well as in the Highlands, this feature being relied on to account for superposition of more highly altered upon less or quite unaltered rocks.

---

[1] Lapworth, Page and Lapworth's Geology.

[2] Judd, Address to Geol. Sec. Brit. Assoc., Aberdeen.

[3] Recent work, Geol. Survey, Q. J. G. S., L., 1888, p. 429.

Such inversions in the Alps, the Appalachians, and the Himalayan ranges are on record, one or both of the features of overfolding and thrusting having been put in evidence to explain similar anomalous relations between altered and other rocks in various mountain regions. On the flanks of the Himalayas the axes of compressed anticlinal folds have been traced by Medlicott, longitudinally resolving themselves into faults, and bordering the western part of that chain there are certain crushed lines of junction between different groups, coincident with their strike, which, though I could not exactly call them faults, seemed to have as close connection with the force of thrust, associated with the neighbouring mountains, as Mr. Medlicott found reason to believe existed in rather similar positions to the eastward.

The localization of the evidences of these crust movements, of folding, shearing, thrusting, and metamorphism, points to their intimate connexion with the causes of true mountain structure. We do not hear of them in regions where the rocks are in a state of horizontal repose, even though they may be mountainous regions but belonging to the other kind of mountains left by erosion; for the reason that disturbance has been absent. In these cases the nearest approach to any lateral movement that I am aware of exists in the sidelong creep described by Mr. Barlow as affecting the walls of the great cañons of Western America, and attributed by him to the vertical presence of superincumbent masses, imparting to the underlying beds an internal motion towards points where deep erosion has deprived their materials of support. This movement is also shown *not* to have been accompanied by metamorphism of the rocks.

It seems we may fairly gather from the accounts given, that in the Highland province of special disturbance the *thrust* movements date from the earliest periods, while the more prominent *fault* dislocations chiefly belong to much later geological times.[2] How far this may be merely accidental or otherwise does not as yet appear, but there is reason to believe that the earth movements were intimately connected with the production of one of the oldest of mountain chains—that which stretched from Scandinavia to the north of

---

[1] Barlow, Quarterly Jour. Geol. Soc., Lon., vol. xliv., p. 783.

[2] Judd, Address to Brit. Assoc., Aberdeen.

Scotland, or still further westward by Donegal and Mayo, through a tract which has since frequently, if not continuously, been the theatre of mountain formation growth and decay, and which, though its skeleton alone remains, still presents the finest mountain scenery of the British Isles.

Regarding the great subterranean movements alluded to, the question will arise: in what way has this crust moving force originated, and how has it been locally applied: was it chiefly or entirely in action during past geological eternities, or is it in progress still? From the nature of the subject, in order to seek for answers we must wander amongst theories, endeavouring to grasp detailed or definite ideas, which those best acquainted with the physical aspects of the case have only approached, and the most hopeful result will be an arrival at the most probable of possibilities.

The more strongly we realise that great masses of the earth's crust have travelled bodily past or over one another through miles of space, the more urgent becomes the demand to know how they were afforded room to move, or where the movement begun or ended?

We are told that the folding of rocks has only been produced at a certain depth in the crust, beneath which depth the compression usually attributed to contraction becomes exchanged for tension or stretching.[1] This of itself conveys an idea of expansion.

Quite lately Dr. Ricketts has urged[2] that the tangential pressure resulting from subsidence of portions of the crust is quite inadequate to cause the many folded contortions of strata so commonly observable. He adduces a simple experiment in support of this, showing that to bend a horizontal lath 10 feet long into an open arch 6 inches in height, would only reduce the limits previously occupied by its ends to the extent of little over $\frac{3}{4}$ths of an inch, that is, about the $\frac{1}{160}$th part of the length of the unbent lath. From the mere recollection of any ordinary section in folded rocks it will be evident that these, flattened out to their original limits, would occupy much more than the $\frac{1}{160}$th of the length of the section in

[1] Mr. C. Davison, Phil. Trans. R.S., vol. 178, p. 240; Hull's Physiography, p. 55.
[2] In the Geol. Mag. for February, 1889.

excess; indeed, an excess of half of the compressed sections' length would be more probable, and hence it would appear that if the folding resulted from downward pressure upon arched beds, the conditions would require the arch to have had a height about equal its own span.

Another method of accounting for the folding and thrusting under notice is suggested by my colleague, Mr. Kilroe[1] (who has been unavoidably prevented from placing his views before you to-night).

He suggests that continual submergence of accumulating deposits from superincumbent pressure would of necessity involve attenuation of the lower strata coincident with thickening and folding of the beds beneath other regions, where vertical pressure became reduced, either by bulging, due to contraction of the crust in cooling, or by denudation, or both together; the space necessary for such thickening or folding being afforded by the upward bulging of areas of least vertical pressure. He adds further that, as Tresca[2] proved, solid bodies flow as if they were viscid under very great pressure, which implies attenuation of the mass when the pressure is greatest; and he instances the rolling or drawing out of ellipsoidal pebbles into lenticular bands of schist under great pressure, as in the case of the Moberg conglomerate in Norway described by Reusch.[3] This pressure would be accompanied in the regions affected by the development of heat (moderated by certain conditions) and also by chemical reactions, shown by Spring to have taken place under excessive pressure without the application of external heat.

To gain an idea of this pressure he takes as an illustration the lower Silurian formation, with an approximate thickness of 20,000 feet, which would mean 1300 atmospheres, or 10 tons of pressure to the square inch in its lowest strata. But he supposes this pressure inactive towards producing metamorphism until the disturbance of the cosmical equilibrium; this once disturbed, changes would be initiated which might become manifest in widely separated regions though others escaped metamorphism, in con-

[1] J. R. Kilroe MS.

[2] Tresca, l'ecoulement des corps solides.

[3] Die Fossilien frühender krystallinischen Schiefer, pp. 24, 25.

sequence of the pressure remaining regionally inactive as to the production of motion. The metamorphism here suggested would be commensurate with the magnitude of the pressure and the amount of movement which obtained.

From the considerations the following series of alterations in the crust might be deduced:—

1st. A state of quiescence or equilibrium followed by the formation of a dome or bulge, resulting, say, from contraction, and consequent relief from vertical pressure.

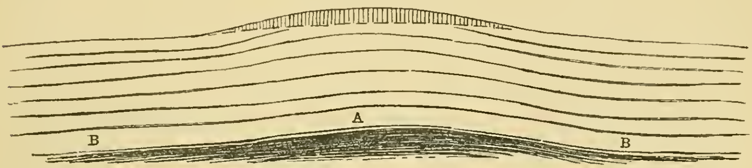


FIG. 1.

Initiatory stage, dome, or bulge in the crust, relieving vertical pressure at A, remaining active at B, B.

2nd. An accumulation of crumpled and not necessarily metamorphosed strata towards the region of disturbance, with increasing elevation of the bulged crust, accompanied by denudation, and deposition of the material in the subsiding areas. By the motion thus originated, regional metamorphism would be initiated, and would continue until the pressures were equalized in the affected regions—until, in fact, cosmical equilibrium was restored.

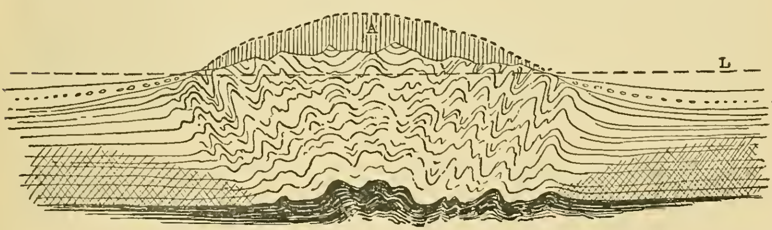


FIG. 2.

Further stage. A, dome or bulge denuded, the materials being deposited on the flanks. Depression and attenuation result in metamorphism, where the figure is cross-hatched, folding taking place under A. L, original surface.

3rd. The formation of a new arch or dome over an area of regional metamorphism, and consequent folding of the altered rocks after a period of quiescence.

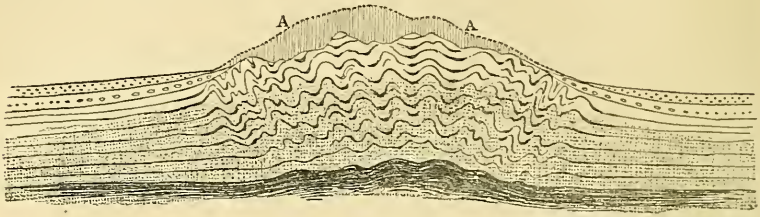


FIG. 3.

Folding of a previously metamorphosed region, under the area of a new dome or bulge, A, A.

4th. Owing to an excess of denudation on one side of an elevated area, or other cause, subsidence on one flank of such an elevation might differ from that on the other; when the tangential thrust from each side, overcoming friction, and acting in parallel but not directly opposed lines, the rock masses of one side would have a tendency to pass over or under those pressed towards them from the opposite direction, the overlying rocks tending to move upward towards the position of least resistance, and this transitive action might be continued even until the surface was reached, or at least the thrust masses had come within reach of exposure by denudation.

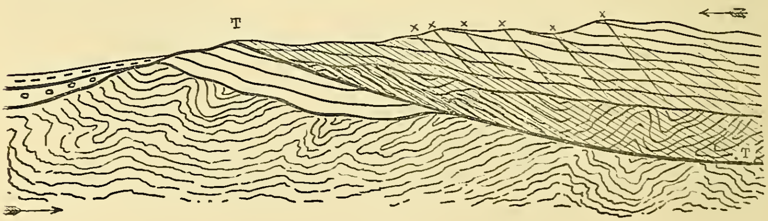


FIG. 4.

Ultimate result of the earth movements, which may produce folding and metamorphism. T, a major thrust plane; x x x x x x minor thrusts. Arrows show direction of unequally opposed motion.

Mr. Kilroe's suggestions, here condensed, however theoretical or tentative, convey at least the impression of affording a satisfactory explanation of those features connected with earth movements which have been under consideration. And it may be hoped that if he works them out in more detail an important step may be gained towards the solution of this interesting question.

If we follow our American colleagues, Messrs. Powell and Gilbert, in assuming that "all large mountains are new mountains," taking for example the Alps and Himalayas as being mainly formed in the Tertiary period, having now such structural examples before us as the Highlands present, we can hardly press this generalization to the conclusion that, were it possible to examine the central skeletons of these ranges, there would not be disclosed a recurrence of consecutive stages of disturbance and regional metamorphism of similar kinds, showing perhaps a direct relationship between lateral displacement and the depth at which it occurred, influenced by the amount of the then overlying materials, and varying, it might be, in intensity or form, when the overlying load was greater or less.

Admitting the rashness of venturing amongst obscure possibilities or questionable theories, yet, for the moment, supposing with the majority, that the earth's crust overlies a viscous substratum enclosing a solid nucleus, and that consequently mobility of the outer envelope may be conceded where, from any cause an impetus can be found, the result would be those combinations of tangential and vertical (or gravitation) pressure which are generally regarded as having accompanied the forcing of all folded strata into narrower lateral limits. If this be so, it does not seem unreasonable to imagine that the dragging of one deep-lying portion of the crust beneath or over another might become but a question of the cohesion or weakness of parts of the crust itself. The earliest theories of the spheroidal formation of the earth have been connected with its rotation, and if this connexion can be extended to such dragging movement, it would be further interesting to note the latitudinal direction of the Scotch displacements to the westward—a direction that, in the absence of actual proof, might vary towards the east or west, according to whichever of the contiguous displaced masses was regarded as that which moved the most.

We can realize the descriptions of the striking natural features observed with much greater facility than we can imagine their causes, let these be what they may, and as our knowledge stands it is wisest not to indulge in dogmatic assertions. At any rate, to discuss such matters further here would be to recklessly invade regions of profound speculation, far beyond my purpose in directing your attention to one of the grandest problems of modern geological research.

Regarding now the second subject of interest to which I asked your attention, that is to the more recently advanced views as to the existence of a Carboniferous to a Permian glacial period, it will be granted that this question presents less of novelty than the phenomena previously referred to.

For very many years glaciation has occupied a prominent place in geological investigation, and there have been numerous references to more ancient glacial agencies than those which have made the Pleistocene glacial period familiar to us.

In 1874 Mr. H. F. Blanford (*Geol. Soc. Jour.*, vol. xxxi., p. 534) noticed the extension of later Tertiary glaciation, both beyond the limits of Europe and of the temperate zone: in Lebanon, as shown by Dr. Hooker; in various parts of the Himalayan range, as observed by Dr. W. T. Blanford and Mr. Theobald; and in the Naga Hills, Assam, as recorded by Major Godwin Austin. It was claimed for the Himalayan region, and discussed by Messrs. Theobald, Campbell, and Medlicott[1], that part at least of this glaciation was of older date than post-pliocene, and coincident with great changes in the elevation of that chain. Mr. H. F. Blanford did not endorse this view, arguing that the conditions of physical geography did not support it, and that the evidence favoured the supposition of a general prevalence of the frigid state during later Tertiary time; hence that general glacial conditions might have obtained also in the Permian, or between this and the Carboniferous periods.

So far back as thirty-eight years ago Dr. Haughton[2]—to whom our Society is so deeply indebted for constantly sustained and sustaining interest and support—recorded the occurrence of probably ice-borne granite boulders embedded in the Dublin Carboniferous limestone[2], and Dr. Croll, in his great work *Climate and Time*, having first given reasons of weight why the marks of such essentially terrestrial phenomena as glaciation should leave few or no records in the ocean beds, which form the pages of Historic Geology, proceeds to furnish numerous instances of the traces of

---

[1] Records Geol. Sur. Ind., Mem. G. S. I., vol. iii. p. 170.
[2] Haughton, Jour. Geol. Soc. Dub. (now R. G. S. I.), 1851.

glaciation revealed amongst the strata of all the great formations from Cambrian to Tertiary.

A few years after Dr. Haughton brought the Carboniferous boulders into notice, Sir Andrew Ramsay advocated (1855) the glacial character of certain Permian boulder beds in central parts of England[1], and in 1856 my former colleague, Dr. W. T. Blanford, F.R.S.[2], now president of the Geological Society of London, suggested the existence of glacial conditions in connexion with the Talchir, or basal boulder beds of the great Gondwana system in central India, these beds with boulders being now, after much discussion, relegated to Carboniferous times.

In 1873 Dr. Hull, F.R.S.[3], recorded the discovery in the north of Ireland, near Armagh, of Permian glacial boulder deposits similar to those described by Sir A. C. Ramsay in the west of England; and from 1856 down to the last year we find frequent records by much more than a dozen of our geological brethren, tending to establish the co-existence of glacial conditions with boulder beds of Carboniferous or Permian age. At places so distant from each other as India, South Africa, and East Australia, Dr. Oldham[4], The Rev. Mr. Clark[5], Sir R. Daintree[6], Prof. Selwyn[7], Dr. Feistmantel[8], Dr. W. T. Blanford[9], Messrs. H. F. Blanford[10], Wilkinson[11], Jack[12], R. D. Oldham[13], and David[14], are amongst those whose writings refer to the Australian series; Messrs. Wyley[15], and Griesbach[16], Dr. Sutherland[17], and others

---

[1] Ramsay, Q. J. G. S., xi.

[2] W. T. Blanford, Mem. G. S. Ind., vol. i. p. 49.

[3] Hull, Mem. G. S. Ireland, Sh. 47.

[4] Oldham, Mem. G. S. Ind. iii., p. 209.

[5] Clark, Trans. Rl. Soc., Vict., vol. vi., etc.

[6] Daintree, Rept. on Ballair, Melbourne, 1886, p. 10.

[7] Selwyn, Melbourne, Minls. of Victoria, Off. Cat. Inter. Col. Exhib., 1866–7.

[8] Feistmantel, Rec. G. S., Ind., vol. ix., p. 78, T. R. S., N. S. W., 1860.

[9] W. T. Blanford, Manual G. S. Ind.

[10] H. F. Blanford, Q. J. G. S., vol. xxxi., p. 528.

[11] Wilkinson, F. R. S., N. S. W., vol. xiii., p. 106.

[12] Jack, Rept. Bowen R. Coal, p. 1879, Brisbane.

[13] R. D. Oldham, Rec. G. S. I., xix. p. 43.

[14] David, Q. J. G. S., xliii., p. 190.

[15] Wyley, Q. J. G. S., xxiii., p. 173.

[16] Griesbach, Q. J. G. S., xxvii., p. 57, 1881; Rec. G. S. I., vol. xix., p. 57.

[17] Sutherland, Q. J. G. S., L., vol. xxvi., p. 514.

contributed to the records of the South African rocks, and the Brothers Blanford[1], Dr. Oldham[2], his son, R. D. Oldham[3], Dr. Waagen[4], Messrs. Fedden[5], Medlicott[6], and Theobald[7], Ball[8], Dr. King[9], and Dr. Warth[10], have dealt with the central India Sinde and Salt Range boulder deposits, referred to the Talchir[11] horizon, which their colleague, Mr. Griesbach, C.I.E., found again near Herat, in Afghanistan, when attached to the late Boundary Commission.

In the Salt Range I mapped the beds, but Mr. Theobald secured the first striated boulder from them, Dr. Oldham and Mr. Fedden having performed similar service as regards Dr. Blanford's original Talchir boulder beds.

Not long since I was able to exhibit to this Society, and afterwards at the British Association in Birmingham, one of the most perfect of the Salt Range facetted pebbles (now in the Museum of Trinity College). Others were shown at Birmingham and in London by Dr. Blanford, and others still are figured in the Records of the Geological Survey of India, parts 1 and 3, 1888.

All of these boulder beds, from anything I have myself seen or read, present more of dissimilarity than resemblance to the later glacial accumulations with which we are so well acquainted, chiefly in their more regular stratification or inter-stratification compared with the recent deposits, their entire aspect suggesting something different in their conditions of formation. Their base is usually a dark green or blackish silt weathering olive, and often filled with igneous or crystalline boulders of various sizes, from some feet in diameter to mere pebbles, amongst which I often found it difficult to obtain any with distinct striation, though most perfect examples

---

[1] Blanford's Q. J. C. S., xxxi., G. S. Ind., Brit. Assoc. Report, 1873, Rec. G. S. Ind., vol. ix., p. 79; xx. p. 49.

[2] Oldham, M. G. S. I., vol. iii., vol. ix., Art. 2, p. 30.

[3] Oldham, junr., Rec. G. S. Ind., xix., p. 39, pt. ii., p. 127.

[4] Waagen, Rec. G. S. Ind., 1878, pt. i., p. 22, xix., xxi., p. 22, p. 89.

[5] Fedden, 1872, Rec. G. S. Ind., viii. p. 2.

[6] Medlicott, Rec. G. S. Ind., v. xix., p. 3, p. 131.

[7] Theobald, Rec. G. S. Ind., vol. vii., p. 86, 97.

[8] Ball, Rec. G. S. Ind., vol. vi., p. 28.

[9] King, Rec. G. S. Ind., xxi., p. 116, ft. note.

[10] Warth, Rec. G. S. Ind., vol. xx., p. 117; xxi., p. 34.

[11] Man. G. S. Ind., pt. 1, p. 109.

have been found. The general opinion seems to be that these pebbles, which are all derived from unknown or distant sources, have been sculptured elsewhere and brought to their present situation, enclosed in floating ice through the agency of river transport.

So many people have been engaged upon the subject of the glacial relations of these beds that considerable controversy might have been anticipated and has occurred, both as to the precise age of the deposits, and as to the actual fact of the glaciation of their transported fragments. Time would not permit of my following these discussions, but I may summarise the conclusions of the latest contribution to the general subject by Dr. Waagen[1] who (as usual) contends vigorously for the glacial character of the whole of these boulder-beds, and thence for the existence of a Carboniferous to a Permian glacial period, affecting a quarter of the earth's surface, or even much more, this ancient ice-age being regarded as of quite as great, or greater, importance than that of the Pleistocene glacial period.

The theory advanced by Dr. Waagen has been constructed, so to speak, upon Sclater and Haeckel's lost continent of Lemuria (also referred to by Mr. H. F. Blanford, *l. c.*), which is supposed at one time or another to have united both Africa and Australia with the Indian peninsula. This great continent is supposed to have been but slightly disturbed after its materials were deposited upon folded Archæan rocks, and its features to have been sculptured mainly by denudation, which eventually divided the continental land into smaller areas, these originating, under severe climatal conditions, glaciers and large rivers. In the upper carboniferous period the cold became intense over the region south of the equator, but in Permian time, regarded by Dr. Waagen as but a portion of the Carboniferous period, the conditions of great cold extended northwards embracing Europe, and enveloped the whole earth except South America, becoming again prominently displayed in the Permian Hawkesbury beds of Australia. Under these cold conditions the delicate flora of the carboniferous age perished, though its marine fauna survived longer; and the plants having

---

[1] "The Carboniferous Glacial Period" (translated), *Rec. Geol. Surv. Ind.*, vol. xxi., pt. 3, 1888.

been replaced by others of Permian type, and of more hardy nature, the formations present a mixed or alternating assemblage of a marine Carboniferous fauna, and a terrestrial Permian flora. For the Northern Indian region Dr. Waagen assumes that the Permian fauna migrated with warm currents from China, to be suddenly extinguished by cold northerly currents in the earliest Triassic times. As to the Carboniferous glaciation of Europe he finds insufficient evidence, and does not notice the granite boulders in our Carboniferous limestone, but he considers the extension of the glacial conditions into Permian times in Europe as beyond all doubt.

This is the barest possible outline of a Paper which shows strongly the breadth and subtlety to which palæontological views of geological history may be extended. We must not, however, suppose that the theory which Dr. Waagen builds with much reliance upon data widely separated will be at once accepted; indeed he seems to have based his largest deductions upon assertions of his own, not universally recognised, thus: the Carboniferous age of the whole of the Salt Range boulder beds appears to have been all that he wanted to reconstruct the geological and glacial conditions of a very large part of the world's surface in that period; but this very point of age may be regarded as open to question, for it is on record[1] that the fossils upon which the assumption of the carboniferous age of the boulder beds is based are enclosed in transported pebbles from a source as unknown with accuracy as that of the crystalline and porphyritic boulders in the same deposits; and though some parts of these Salt Range boulder beds certainly underlie strata containing Carboniferous organisms to the westward, towards the east other parts of their detrital accumulations, which have furnished the most perfectly striated and many-sided facetted pebbles, are physically inseparable from layers containing the supposed early Cretaceous *Cardita beaumonti*, and pass by gradation upwards into the base of the Eocene or Nummulitic limestone.[2] Taking this as an instance of uncertain grounds for world-wide conclusions, while admiring the ingenuity and research of the retrospect, we may place greater confidence in the more cautious general opinions of others favouring the glacial character of the

---

[1] Oldham, Rec. Geol. Sur. Ind., xix., p. 127.

[2] R. D. Oldham, *loc. cit.*, p. 129. Wynne, Mem. G. Sur. Ind., vol. xiv.

Talchir boulder deposits and their distant representatives over the great area referred to. The possibly glacial character of the beds in most cases will leave sufficient matter for contemplation, whether we regard their widely scattered exposures as belonging to one or more than one definite horizon.

The main conclusions as to the sculptured fragments being really evidence of glaciation, appears to rest prominently upon mere inability to say by what other agency these pebbles can have been striated and facetted or the larger blocks transported. As a rule, they are all foreign to the localities in which they are found, and competent observers have declared they never saw a glaciated pebble presenting similar characteristics. Some have sought to attribute the cutting of their sharp-edged facets to wind and natural sandblast, but this idea has not received support[1], nor can I contribute anything in that direction from observations of my own, though I have been encamped on a sand tract set so actively in almost constant motion by the wind as to convert the castaway empty bottles of one day into ground glass by the next. The sculptured fragments have been compared with a striated pebble from the old red conglomerate of Cumberland, said to have been marked by friction since the rock was consolidated, without this origin for this sculpture being admitted, and neither will the evidence of earth tremors, afforded by the worn indentations of the horns of our fossil Irish Elk, suit the case, for even supposing sufficient friction of this kind established to produce the results since the fragments became embedded, there is nothing to show how so many as twenty facets, cut at different angles on a single pebble, could have been formed in this way, other than by revolving in an icy mass. On the whole, the evidence afforded by these pebbles goes to show that, while the agency of ice affords the nearest approximation to accounting for the features presented, both by themselves and their matrix, differences exist between their strongest characteristic sand those of the more recent glacial deposits, which have not been yet fully explained. There is also the difficulty of bringing widely separated data concerning these boulder deposits into such relation as to afford sufficient grounds for attri-

[1] See a recent Paper upon effects of Sandblast, by R. D. Oldham, Rec. Geol. Surv. Ind., pt. 1, 1889.

buting to all a common origin and the same horizon, unless this term be so indefinitely used as to dilute its value in a proportionate degree.

The systematic accumulation of further facts may confirm or modify the now somewhat speculative ideas put forward regarding this palæozoic ice age, still the balance of evidence is at present in its favour, and we should bear in mind that if one glacial period be taken as established, another may also have prevailed upon the earth in other and remoter times.

I have thus endeavoured to bring to your notice, as briefly as possible, two out of the many subjects which have recently engaged the attention of geologists—two subjects which appear to possess more than ordinary interest. And, in conclusion, I would ask you to gather from their consideration elsewhere that, as the years of our science increase and its votaries multiply, the expanding field of its investigations becomes ever a land of promise wherein the realization of things undreamt of in the philosophy of our fathers will still reward the search of those who labour to complete the history of the earth.

NOTE ADDED IN THE PRESS.

Since the above was written information has been received that Trilobites have been discovered in the Obolus zone of the Salt Range, and that these Trilobites are supposed by Dr. Waagen to be of Cambrian age. This would materially alter the views already published as to the Silurian, or, as Dr. Waagen subsequently suggested, Carboniferous age to which this fossiliferous zone might be referred.—16th March, 1889.

XXX.

ON THE TEMPERATURE OF THE WATER OF BALLYNOE SPRINGS, NEAR QUEENSTOWN. By Prof. EDWARD HULL, LL.D., F.R.S., F.G.S.

[Read December 12, 1888.]

Having been invited by the Town Commissioners of Queenstown to report on the Ballynoe Springs with a view to their utilization for the supply of the Township, I visited the district towards the end of last year (1887), and have made observations on the phenomena connected with the outburst of these springs, some of which—and especially those on the temperature of the water—may be worthy of record in the "Proceedings" of this Society.

These springs issue forth in several distinct jets at the western base of the ridge of old red sandstone on which Queenstown is built, and almost on the line of high water of ordinary tides. The water itself is pure and permanent* not having been *perceptibly* affected by the long drought of the year 1887, though, doubtless, somewhat diminished in consequence.

But the special feature regarding these springs to which I wish to direct attention is the temperature of the water itself.

In order to determine the quantity of water yielded by the springs special apparatus were designed by Mr. C. G. Doran, water-surveyor to the Commissioners; and while observations on the quantity were being taken it occurred to me that those on the temperature might also be of value, with a view of arriving at some conclusion regarding the depth below the surface of the source of supply; that is to say, of the underground reservoir in the strata. The reasons for this proposal may be briefly stated. It is well known that the temperature of the strata, or rocks forming the earth's crust, increases with the depth, below a certain point or imaginary stratum, called by Humboldt, "the stratum of invariable temperature." All the rock above this stratum is liable to annual variations of temperature, becoming warmer in summer and colder in winter; but at a depth of some feet the temperature

* An analysis of the water was made by Mr. R. J. Moss, Analyst for the Roy. Dub. Soc.

is constant all the year round, and is (approximately) that of the mean annual temperature of the locality. The actual depth of the "invariable stratum" is found to vary in different localities, and the stratum itself is necessarily thick, as the variations in temperature alternate very slowly as we approach the position of no variation. Observations for determining the depth of the stratum have been made both at the Paris and Greenwich observatories. At Greenwich it was found (in 1858) that the deepest of several underground thermometers, 25 feet from the surface, showed a range of variation amounting to 3·42° Fahr., so that the stratum of no variation lies at a greater depth than 25 feet. For the southern parts of the British Isles, a depth of about 50 feet is, doubtless, a sufficiently close approximation.

The observations taken by Mr. Doran on the Ballynoe Springs resulted in the interesting determination that the temperature is constant, and that it is that of the mean annual temperature of the locality, namely, 51° Fahr. The observations were carried on throughout the month of March, a period of the year in which the temperature of the air varies considerably; and were twenty in number. Observations on the temperature of the air were taken at the same time, and are given in the following Table :—

Observations *on the Temperature of the Water of the Ballynoe Springs, taken during the month of March,* 1888.

Date (1888).	Temperature of Water.	Temperature of Air in Shade.	Time of Day.
March 2	51° F.	41° F.	3.20 p.m.
,, 3	51 ,,	46 ,,	3.0 ,,
,, 6	51 ,,	48 ,,	5.23 ,,
,, 7	51 ,,	46 ,,	6.0 ,,
,, 10	51 ,,	53 ,,	11.0 a.m.
,, 12	51 ,,	42·5 ,,	?
,, 13	51 ,,	46 ,,	11.45 ,,
,, 14	51 ,,	47 ,,	12.25 p.m.
,, 15	51 ,,	42·7 ,,	2.10 ,,
,, 17	51 ,,	47·5 ,,	2.50 ,,
,, 19	51 ,,	47 ,,	2.50 ,,
,, 20	51 ,,	47 ,,	2.45 ,,
,, 21	51 ,,	48 ,,	3.0 ,,
,, 22	51 ,,	52 ,,	3.30 ,,
,, 26	51 ,,	44 ,,	12.0 noon.
,, 28	51 ,,	44 ,,	12.25 p.m.
,, 29	51 ,,	39·5 ,,	2.20 ,,
,, 30	51 ,,	55 ,,	2.30 ,,
,, 31	51 ,,	47 ,,	1.0 ,,

As regards the question of the depth of the underground reservoir from which the Ballynoe Springs have their origin, it must be concluded, from the above observations, that the great body of the water is derived from strata at a depth of about 50 feet under the hill behind Queenstown. This hill rises to a height of 305 feet above the sea, and on the summit there is a plateàu for a considerable distance, while the strata rise at high angles to the surface, and range nearly east and west, parallel to the coast line below the town. The direction of the coast where the springs break forth is at right angles to the direction of the beds; and we must suppose that the underground water-surface ascends from that of the H. W. level at the springs inland with the rise of the ground till it reaches a level of about 250 feet above the sea, at which it remains constant till the ground again falls towards the margin of the sea, and the depression of the Annebrook valley. The original source of supply is, of course, that proportion of the rainfall which percolates downwards through the joints, fissures, and bedding-planes of the strata. The percolating waters, on reaching a depth of about 50 or 60 feet enter the permanently saturated strata, and down to an unknown depth constitute an underground reservoir and ultimate source of supply to the Ballynoe Springs.

BALLYNOE SPRINGS.—*Additional Observations by* MR. C. G. DORAN.*

Date.	Time.	Temperature.		OBSERVATIONS.
		Shade.	Spring.	
1888.		°	°	
Dec. 18th.	Noon.	50·00	51·75	It will be seen that the temperature of the Springs is constant at 51°·75 Fahr. according to these observations by Mr. Doran. In the former series the constant temperature was 51°·00. The difference 0°·75 between the one series and the other must, I think, be attributed to some change due to contraction of the glass of the instrument, which was the same as that used in the former cases. E. H.
,, 24th.	2.45 p.m.	46·00	51·75	
1889.				
Jan. 14th.	1.45 ,,	48·00	51·75	
,, 21st.	4. 0 ,,	51·00	51·75	
,, 30th.	1.30 ,,	57·00	51·75	
Feb. 5th.	2. 0 ,,	46·00	51·75	
,, 20th.	2.20 ,,	53·00	51·75	
,, 24th.	5. 0 ,,	39·00	51·75	
Mar. 10th.	4.35 ,,	48·00	51·75	
,, 13th.	5.25 ,,	54·00	51·75	

* NOTE ADDED IN PRESS, *March* 27, 1889.

XXXI.

NOTES ON BUNODES THALLIA, BUNODES VERRUCOSA, AND TEALIA CRASSICORNIS. · By G. Y. DIXON and A. F. DIXON. (Plates IV. and V.)

[Read February 20, 1889.]

Bunodes thallia.

BIBLIOGRAPHY.

1854.	*Actinia thallia*,	P. H. Gosse, *Ann. and Mag. of Nat. Hist.*, ser. 2, vol. xiv., p. 283.
1855.	*Bunodes thallia*,	P. H. Gosse, *Ann. and Mag. of Nat. Hist.*, ser. 2, vol. xvi., p. 294 : *Trans. Linn. Soc.*, vol. xxi., p. 274 : *Proc. Linn. Soc.*, vol. ii., pp. 372-4 : *Manual of Marine Zoology*, vol. i., p. 29.
1856.	„ „	P. H. Gosse, *Tenby: a Seaside Holiday*, pp. 131, 361—363, 386, 391, pl. XXIII., fig. c.
1857.	*Cereus thallia*,	Milne-Edwards, *Histoire Naturelle des Coralliaires*, vol. i., p. 266.
1858.	*Bunodes thallia*,	P. H. Gosse, *Ann. and Mag. of Nat. Hist.*, ser. 3, vol. i., p. 417.
1859.	„ „	P. H. Gosse, *Actinologia Britannica*, pp. 195-7, pl. IV., figs. 5 and 6.
1880.	„ „	A. Andres, *Le Attinie*, vol. i. (*Fauna und Flora des Golfes von Neapel*, vol. ix.), p. 213.
1885.	„ „	A. S. Pennington, *British Zoophytes*, p. 167.

WE have here quoted every reference to *Bunodes thallia* with which we are acquainted, but it may be stated that all the original observations previously made on this species of Actinia, are contained in the description first given by Gosse (Ann. and Mag. of

Nat. Hist. ser. 2, vol. xiv., p. 283), which the same author repeated in *Tenby*, and supplemented in his *Actinologia Britannica.*

GENERAL DESCRIPTION.

Form.

Base.—Adherent to rocks; exceeding the column ; the lines of the insertions of the mesenteries scarcely visible.

Column.—Flat or sub-conical in contraction; pillar-shaped or cylindrical in extension, rising to full twice the diameter. The lines of the insertions of the mesenteries are usually scarcely visible, but when the animal is much dilated, they appear as marked depressions. The surface is corrugated, not pierced with cinclides, and studded with an indefinite number of vertical rows of sub-equal and equidistant suctorial warts, which run between every alternate pair of the lines of the insertions of the mesenteries from the base to the margin of the disk, where the topmost wart of the row usually stands, raised conspicuously on the slight parapet. The substance is firmly fleshy.

Disk.—Flat or slightly concave; hardly, if at all exceeding the column; bounded by a low parapet, marked by the lines of the insertions of the mesenteries.

Tentacles.—Indefinite in number, 30–60; submarginal; apparently in two or three series; all sub-equal; in length equal to half the diameter of the disk; highly retractile; at times presenting a fluted appearance; in extension, the inner tentacles are stout at the base, and from about half their length taper to a blunt point, the outer tentacles being less stout, and of equal length; in contraction, a tentacle may be reduced in diameter, so as to resemble a thread, or in length, so as to resemble a wart. When the animal is well expanded, the inner tentacles are nearly erect, the intermediate over-arching outwards, and the outer horizontal or slightly drooping. They readily grasp objects presented.

Mouth.—Continually varying; sometimes raised on a cone, sometimes thrown into folds, sometimes widely gaping. Grooves indefinite, each marked with a very inconspicuous pair of tubercles. Oesophagus ribbed and corrugated; frequently partially protruded.

Colour.

Base.—Dirty flesh-colour, changing towards the edge to a pale olive-brown; lines of insertions of mesenteries, same colour.

Column.—Pale olive-brown below, becoming somewhat darker above; warts somewhat greyer than the surrounding surface, and assuming a darker hue from their transparency when swollen, and when depressed exhibiting a dark spot at their centres; the warts which rise over the parapet often exhibit at their tips some of the white colouring of the tentacles. The lines of the insertions of the mesenteries are of the same colour as the rest of the column.

Disk.—Lines of insertions of the mesenteries are dark olive-green throughout, the spaces between them and the mouth, and for about one-third of the distance between the mouth and the tentacles, being filled up with opaque white or yellowish-grey; when the disk is expanded, this arrangement of colour gives the appearance of a series of rays starting from the mouth; when the disk is contracted, there appears to be a whitish band enclosing the mouth. The rays which start from the œsophageal grooves are crossed by a dark olive line, which separates them from the œsophageal tubercles.

Tentacles.—Transparent white, pellucid below, more opaque above; sometimes they appear to be marked with more or less intense vertical lines, but a magnifying glass shows that this appearance is due to their surface being fluted when not fully extended, the white lines being slight wrinkles raised on the surface of the tentacles. While the outer covering of the tentacle tube would thus appear to be coloured with white, its inner lining seems to be dark olive, for when the tentacles are reduced to the thread-like condition, they may be seen to possess a dark olive core.

Mouth.—Oesophagus grey; œsophageal grooves rather whiter, often shining through the transparent olive-green of the disk; œsophageal tubercles white, inconspicuous.

Dimensions.

One inch to two inches in height, and sometimes reaching an inch and a-half in the diameter of the column.

We are indebted to the kindness of Miss James, of Babbacombe, for eleven specimens of this scarce and interesting anemone. They were procured at the Ore Stone, near Torquay, from between tide-marks. This is a new locality for this species, which was previously known as occurring only at Lidstep and Ilfracombe, both in the Bristol Channel.

The description given above of the form of this anemone has been based on Gosse's description, but certain changes have been introduced so as to make it apply to those specimens which we have examined. The description of the colour is based on these latter specimens alone. They were identically the same in this respect with each other, but did not correspond with any of Gosse's varieties. The points in which we have differed with Gosse in describing the form are—(1) the number and arrangement of the warts, and (2) the number of the tentacles.

First, then, as to the number of warts :—

Gosse, in his earliest account of the anemone (*Ann. and Mag. Nat. Hist.*, ser. 2, vol. xiv., p. 283 : *Tenby*, pp. 361-363), says there are twenty-five to thirty longitudinal rows of warts, and about twenty-five warts to each row. In the account subsequently given in his monograph (*Actin. Brit.* p. 195) the same author gives the number of rows as about thirty-six, and the number of warts in each row as about twenty-five. We have thought it better to state the number as indefinite : it evidently depends on the size of the specimen, and in those we examined the largest number of rows we found was forty, and the smallest sixteen ; the number of warts in each row varies also with the size of the animal. There is no doubt that the warts are developed in the alternate spaces between the lines marking the insertions of the mesenteries, that is, in the endocœles, as we shall see presently. Gosse also states that the margin is "serrated with the elongated topmost warts of all the rows." We did not find this to be invariably the case; in some specimens (and these were the larger ones) the topmost wart of only every alternate row rose above the parapet.

Secondly, as to the number of tentacles:—

Gosse gives a definite number and arrangement. He says (*Actin. Brit.* p. 195) they are "set in four rows: 6, 6, 12, 24-48." We were able to count the number of tentacles with complete accuracy in only four of our specimens, and these four were found to possess 60, 46, 44 and 32 tentacles respectively; and though we could not discover the precise number in the remaining seven specimens, we can state positively that they did not each possess the definite number given by Gosse: the number of tentacles as well as of warts depends on the size of each specimen. It should be observed that Gosse himself, in his first account of the species, described the tentacles as "*about* 48 in number" (*Ann. and Mag. Nat. Hist.*, ser. 2, vol. xiv., p. 283: *Tenby*, pp. 361-363). This description was based on a dozen specimens obtained at Lidstep, and it seems that Gosse was led to adopt the definite and precise number given in the monograph from the examination of the four other specimens that were found at Ilfracombe. The arrangement of the tentacles we were unable to ascertain. In this matter again there is a discrepancy between the two accounts published by Gosse. The earlier one states that the tentacles are set in two rows; the later one says that they are set in four rows, but that the first three rows are so nearly equidistant from the centre that on a cursory inspection there appear but two rows altogether. There is evidently some relation existing between the number of tentacles and the number of rows of warts. In two specimens we found the number of tentacles was double that of the rows of warts; these were the two specimens mentioned already as having 46 and 32 tentacles respectively, and in them we found 23 and 16 rows of warts respectively. These were the only two specimens in which we were able accurately to ascertain the numbers both of tentacles and rows of warts, but in the other specimens our observations, though not enabling us to give the same precise information, lead us to form the conclusion that the number of tentacles is double that of the rows of warts. The transverse sections, which we will presently describe, confirm this opinion. The mouth is usually so puckered or the œsophagus so unequally protruded that it is very hard to ascertain either the number or the position of the grooves. One of the largest specimens we examined—that previously mentioned as having sixty tentacles—had its mouth always so thrown into folds as to have five corners. These corners were permanent in position, and were probably each marked by the presence of a groove, but of this we could not be certain. When killed, the specimen contracted so unequally that we could make no transverse sections of it which would be of any use. This was very unfortunate, as of course longitudinal sections gave no information as to the number of grooves and directive mesenteries. One specimen had four, another three, and the remainder either one or two grooves.

The warts of *Bunodes thallia* are frequently used as suckers. They may be employed to moor the animal temporarily in the same way as the suckers are used in *Sagartia nivea*, Gosse (*vide* these Proceedings, *antea*, p. 123), or for the purpose of attaching minute extraneous particles of shells or sand. The specimens obtained by Gosse at Lidstep were not troglodyte in habit, but adherent to the open rock, and therefore easily detached. Those to be found at the Ore Stone, Torquay, on the contrary, are generally fixed in small clefts and rock-borings, with only their disk and tentacles expanded above the surrounding levels, and are consequently very hard to procure. They extend a considerable way above the extreme low water-mark, and may be obtained at any tide, some of the specimens we examined having been procured when the moon was seven days old.

Structure.

Tentacles.—Examination of a transverse section of a tentacle which does not present the fluted appearance described above, shows the usual three layers, endoderm, mesoglœa, and ectoderm, concentrically arranged and equally distributed, the mesoglœa being slightly pleated on its ectodermal side. But if a section be made across a tentacle presenting the fluted appearance, it offers a very different aspect. The endoderm is slightly and the ectoderm deeply crenated along their outer edges, while down the centre of each crenation of the ectoderm there are prolonged strong pleatings of the mesoglœa, and the mesoglœa itself rises in strong ridges at points corresponding to the centre of each crenation of the ectoderm, and to the depression between those of the endoderm. The crenations of the ectoderm and endoderm, also the ridges of the mesoglœa are tolerably regular in size and position all round the tentacle, and it is their presence, of course, which gives rise to the fluted appearance in the living animal (Pl. IV. fig. 1).

Professor Hertwig found similar flutings in the tentacles of *Dysactis crassicornis*, R. Hertwig, and transverse sections of the tentacles of this Actinia exhibited a somewhat similar structure to what has been described in *Bunodes thallia*; in *Dysactis crassicornis*, however, the muscle lies in the mesoglœa. (Hertwig, "Challenger" Report. Supplement, p. 17.) Gosse mentions flutings as being on the tentacles of the genus *Bolocera* (*Actin. Brit.*, pp. 186 and 351), and we have found similar markings in *Tealia crassicornis;* but of this hereafter. There would appear to be no doubt that there is one tentacle rising from each endocœle and exocœle respectively. In two of the specimens in which we were able to count the tentacles during life, we found, on cutting transverse sections of the body, that the number of mesenteries was precisely the same as that of the tentacles, there being forty-six tentacles and twenty-three pairs of mesenteries in the one, and thirty-two tentacles and sixteen pairs of mesenteries in the other.

Warts.—A transverse section shows that the warts are developed only in the endocœles and in the spaces between the directive mesenteries. They appear much more conspicuously in a longitudinal section of the body wall cut down through one of the endocœles: here they are seen as evaginations of the body wall, the endodermal muscular layer being not so thickly pleated throughout the region of evagination as in the other parts of the wall (Pl. IV. fig. 4). There is a considerable accumulation of black pigment granules all through the endoderm, but especially in the evaginated portion in each wart. Precisely similar structures (endodermal saccules) have been observed and figured by Hertwig in *Tealia bunodiformis*, (R. Hertwig, "Challenger" Report, p. 36, pl. 8, fig. 4), and by Jourdan in *Bunodes verrucosa* (An. des Sci. Nat. Zool. ser. 6, vol. x. (1879–1880), p. 78, pl. 7, fig. 48). Hertwig, however, did not identify these evaginations with the warts which he states to have been present in *Tealia bunodiformis*, and Jourdan considers the warts (verrues glandulaires) to originate from the ectoderm alone. Jourdan's theory has been criticised and rejected by Professor Hertwig ("Challenger" Report, pp. 84, 85), in describing *Bunodes minuta*, R. Hertwig. The learned German author found that the constitution of the wall of that Actinia was exactly similar to Jourdan's figures of the wall of *Bunodes verrucosa;* but the result of his investigations led him to see that the warts were solid growths of connective substance, and he accordingly declared himself to be against the acceptation of the term "verrues glandulaires." We believe the evaginations above described to be the warts, for the following reason: the rows of warts are in the living specimen seen to lie in each alternate space enclosed between the lines marking the insertion of the mesenteries, that is, in the endocœles, or possibly (so far as external examination can show) in the exocœles; but a series of transverse sections made throughout the entire animal show these evaginations occurring only in the endocœles; and a longitudinal section through an endocœle displays them in numbers, while a longitudinal section through an exocœle exhibits none. It is needless to observe that no other than a papilliform or wart-like structure would appear as an evagination, both in the transverse and the longitudinal sections (Pl. IV. figs. 3 and 4). If further proof is necessary, we may add that these structures are found in sections of *Bunodes verrucosa*, *Bunodes minuta*, *Tealia bunodiformis*, and *Tealia crassicornis*, as well as in the form now under discussion, and all of these species are known to possess warts of similar appearance, while the suckers possessed by the genera Sagartia and Cylista are very different in appearance.

The Mesenteries.—Each mesentery possesses two well-developed endodermal longitudinal muscles (Pl. V. fig. 1). The mesoglœa in the chief longitudinal muscle is thrown into a complicated series of pleatings, along which the muscle fibres are arranged, the whole exhibiting, in transverse section, what Professor Hertwig has well termed a "meandrous complication." The second longitudinal muscle lies close to the body wall on the same side of the mesentery, while on the other side there is seen projecting into the exocœle a strong parieto-basilar muscle. The two last mentioned muscles are found to be more strongly developed in sections cut near the base. Follicles containing spermatozoa were found on some of the mesenteries in some of the specimens, but no ova were detected. The usual unicellular glands were present in the free edges of the mesenteries.

The mesenteries are arranged in pairs, and are indefinite in number; one specimen we found to possess thirty, one twenty-three, one twenty-two, and one sixteen pairs. The number of directive mesenteries, which always corresponds to the number of œsophageal grooves, is also indefinite; the specimen with twenty-three pairs of mesenteries had two pairs directive; that with twenty-two pairs of mesenteries had three pairs directive; while the specimen with thirty pairs of mesenteries had amongst these four pairs directive, and that with sixteen pairs had but one pair directive. The pairs of mesenteries are not all of equal size, but we have been unable to divide them into orders. There is, however, generally a tendency to alternate arrangement. There is nothing constant in the number of mesenteries developed between the directive pairs. In the specimen mentioned as possessing two pairs directive, there were on one side seven, and on the other fourteen pairs, separating the two pairs of directive mesenteries. In the specimen possessing four pairs directive, two of the directive pairs enclosed four ordinary pairs between them, while the other two directive pairs enclosed three ordinary pairs. The two groups of mesenteries so constituted were separated on the one side by ten, and on the other by nine pairs of ordinary mesenteries. All the ordinary mesenteries were in pairs, though some of these were unequal, one of a pair being rudimentary.

In the specimen possessing three pairs of directive mesenteries (Pl. IV. figs. 2 and 3) a very remarkable arrangement of mesenteries and grooves was observed. There were in all twenty-two pairs of mesenteries; in a transverse section near the oral disk, at one end of the œsophagus, there was one groove, at the other end of the œsophagus, in close proximity to each other, were two grooves; corresponding to the groove that stood alone was a pair of directive mesenteries, one of which was rudimentary—a peculiarity observed by Professor Hertwig as occurring in *Tealia bunodiformis* ("Challenger" Report, p. 37). Each of the grooves at the other end of the œsophagus was in connection with a pair of directive mesenteries, and between the latter were three pairs of ordinary mesenteries, two of which pairs reached the œsophagus in a section cut at this level. Each of the last mentioned directive pairs were separated from the first mentioned pair of directive mesenteries by eight pairs of ordinary mesenteries. In sections cut lower down across the œsophagus the two neighbouring grooves gradually approached one another, and the proximal mesenteries of the directive pairs corresponding to these two grooves gradually diminished in size, and, eventually, failing to reach the œsophagus, became irregularly united by their free margins with each other, and with the three enclosed pairs of mesenteries. Thus we found, corresponding to what was here a single groove, a pair of directive mesenteries, with a series of smaller mesenteries interposed between them (Pl. iv. fig. 3).

Of the pair of directive mesenteries in the remaining specimen, one mesentery was rudimentary, and never reached as far as the œsophagus, while the other was fully developed.

Circular Muscle.—There is a strongly-developed endodermal circular muscle lying in the corner formed by the oval disk and the body wall. In logitudinal sections of the animal it bears a general resemblance to that figured by Professor Hertwig in *Tealia bunodiformis*, but we have been unable to discover any anastomosis of the pleatings of the mesoglœa.

The result of the foregoing observations is to establish a close relation between *Bunodes thallia* and *Tealia bunodiformis.* In one point only is there considerable divergence between Professor Hertwig's description of the "Challenger" form and the account we have given above. Professor Hertwig says the warts in *Tealia bunodiformis* are irregularly scattered with a tendency to arrangement in longitudinal rows, while in *Bunodes thallia* we have found that the warts are arranged in regular vertical series. It was long believed that in *Tealia crassicornis* the warts were irregularly scattered, but we believe that even in that species too they are vertically arranged in the endocœles, and that the apparent irregularity in arrangement is due to the unequal expansion of the animal. We have been led to this conclusion from a careful examination of some young specimens of this well-known species which we shall presently describe.

With all respect to such an experienced observer as Professor Hertwig, we would venture to suggest that the three specimens of *Tealia bunodiformis* which came into his hands were unequally contracted, and that hence the warts, though vertically arranged in the endocœles, were apparently irregularly scattered. Of course if we are right in identifying the warts with the "endodermal saccules," it is plain that they are regularly arranged, for these structures are only found in the endocœles (intraseptal spaces) in both species.

The points in which *Bunodes thallia* resembles *Tealia bunodiformis* are the following: (1) the possession of "endodermal saccules;" (2) the form and arrangement of the mesenteries; and (3) the nature of circular muscle.

In order to ascertain, if possible, whether these characteristics should be looked upon as affording generic or specific distinctions, we were led to examine the two native forms which externally, at least, present the greatest similarity to *Bunodes thallia;* these are *Bunodes verrucosa*, and *Tealia crassicornis*.

Tealia crassicornis.

We have examined several living specimens of this well known form. We found that the arrangement of tentacles given by Gosse, viz., 5, 5, 10, 20, etc., is invariably present. Though the warts usually appear as irregularly scattered over the surface, they are really arranged in vertical rows between every alternate pair of lines of the insertions of the mesenteries[1]. This is most easily seen to be the case in young specimens, as they expand equally with greater readiness. We cut transversely two young specimens in which we had previously ascertained the arrangement of tentacles and warts to be as above stated, and we found the arrangement of mesenteries to be as follows :—

There are two pairs of directive mesenteries attached to the œsophagus throughout its entire length, even to those portions of it which form the lappets, and project below the rest of the œsophagus. The œsophageal grooves are strongly marked, and correspond to the directive mesenteries. At either side between the directive mesenteries are four other primary pairs, all perfect, that is, reaching the œsophagus throughout its entire length. Intercalated between these are a secondary series of ten pairs, which reach the œsophagus in the region of the oral disk, but not below. Then there comes a tertiary series, consisting of twenty pairs,

---

[1] Agassiz (Comptes rendus T. xxv. p. 678) has described a pentamerous arrangement of parts in *Actinia* (*Rhodactinia*) *davisii*, a species since shown to be identical with *T. crassicornis*.

which nowhere reaches the œsophagus. The edges of the mesenteries are thickened so as to form a trifid band, and to exhibit in transverse section the appearance of a trifoliate leaf, the middle lobe of which alone contains the unicellular glands (Pl. v. fig. 5). The free margins of the mesenteries are arched upwards, so that a transverse section near the lower end of the œsophagus cuts a mesentery reaching it in two places, each fragment having a trifid end hanging free, and one being attached to the œsophagus and one to the body wall. The directive mesenteries, however, are not arched, but run with straight margins from the end of the œsophagus to the base.

The warts are seen to be in the endocœles, and are more numerous above than in the region of the base.

Occasionally the tentacles of *Tealia crassicornis* are somewhat contracted, and exhibit the fluted appearance described in *Bunodes thallia;* but this phenomenon is not of very frequent occurrence. A transverse section of a tentacle in this condition presents an appearance somewhat resembling that of a tentacle of *Bunodes thallia*, and still more that of a tentacle of *Dysactis crassicornis* as figured by Professor Hertwig, the muscle being mesodermal. ("Challenger" Report, Supplement, Pl. ii., figs. 6 and 7.)

Bunodes verrucosa.

We have carefully examined twenty-three adult specimens of *Bunodes verrucosa;* all of these except one had the arrangement of tentacles described by Gosse, viz., 6, 6, 12, 24. The one exception had forty-six tentacles; in this specimen there were only five tentacles in the inmost row, but the radius and white mark at the spot where the sixth tentacle should have been developed were quite conspicuous, and there were only twenty-three tentacles in the outer row. Furthermore, all of these specimens had the arrangement of warts described by Gosse, that is, six primary rows corresponding to the six inmost tentacles; and six secondary rows corresponding to the secondary row of tentacles; twelve tertiary rows corresponding to the tertiary row of tentacles, and finally twenty-four small rows placed one between each of the rows formerly mentioned, and corresponding to the outer row of tentacles. Beside this evidence of the hexamerous arrangement may be adduced the number of mesenteries, which in this species may generally be counted through the base of the living animal, as the lines of their insertions appear as rich pink on a gray or drab ground. An examination of the base shows plainly that these lines correspond with the arrangement of the warts. All the specimens we have seen had two œsophageal grooves, each with its two conspicuous tubercles.

A longitudinal section through the body wall exhibits a very similar appearance to what we find in *Bunodes thallia* (Pl. v. fig. 2). The evaginations are just as conspicuous, and the circular muscle is strongly developed; it is endodermal, and projects into the body-cavity as a thick cord. In a transverse section of this cord the mesoglœa is seen to be divided into two main branches, the smaller of which is superior, and lies next the disk. Each branch has many ramifications (Pl. v. fig. 3). In the oral disk, near the œsophagus, the mesoglœa is again thrown into pleatings, and thus is formed a second circular muscle immediately enclosing the mouth (Pl. IV. fig. 2*x*).

Some of the specimens on which these observations were made, while under examination, gave birth to a number of young. We killed these immediately on their ejectment from their parents' mouths, and examined them by transverse sections. In the region of the oral disk twelve mesenteries, arranged in six pairs, two pairs being the directive mesenteries, reach the œsophagus; this arrangement, it will be seen, corresponds to that in the same region in the genus *Halcampa*. A section made a little lower down shows that four of these twelve mesenteries stop short of the œsophagus, and so we have the arrangement reproduced which obtains in the lower sections in the genus *Halcampa*. The arrangement of the eight perfect mesenteries of *Bunodes verrucosa* at this stage, just as Professor Haddon (these *Proceedings*, vol. v., p. 479) has proved in the case of the genus *Halcampa*, corresponds precisely to the arrangement in the genus *Edwardsia*. As the sections get lower, the number of mesenteries increases, but the pairs of "secondary mesenteries" do not appear simultaneously in each of the exocœles. At the level of about the middle of the œsophagus, a pair of very small mesenteries appears in the exocœles on either side of that pair of directive mesenteries, whose longitudinal muscles are turned in the same direction as those of the perfect mesenteries adjoining. At this level we accordingly find sixteen mesenteries which, in arrangement, conform to that described by Blochmann and Hilger (1888, Morphologisches Jahrbuch, 13 Band, 3 Heft), in *Gonactinia prolifera*, Sars.

Lower down two other pairs of small mesenteries appear. These are developed in the exocœles nearest the last mentioned small pairs of mesenteries. The arrangement at this stage corresponds to that found in the adult *Peachia hastata*, Gosse. (*Vide* Faurot, *Comptes rendus*, Tome xcviii., No. 12, 1884, p. 756.) Finally, still lower down, two more pairs of mesenteries appear in the remaining unoccupied exocœles, and so present to view twelve pairs of mesenteries which correspond to the regular hexactinian type, except that only eight mesenteries are perfect and reach the œsophagus (Pl. v. fig. 4). It is to be noted that the sections which exhibit these various phases of development are very close together, and that the "secondary mesenteries" quickly become of equal size. Thus, in a single young specimen of *Bunodes verrucosa*, by making transverse sections at different levels, we obtain illustrations of the permanent conditions met with in several different genera, viz.: *Edwardsia*, *Halcampa*, *Gonactinia* and *Peachia*. We may add that we have arrived at precisely the same results in similar investigations carried out in the case of young specimens of *Actinia mesembryanthemum* and *Cereus bellis*.

We think it may fairly be stated, as the result of these observations, that *Bunodes thallia* and *T. bunodiformis*, if not identical, should at least be looked on as more closely allied to each other than to either of the two other forms with which we have compared them.

Gosse included in his family *Bunodidae* all those species "the surface of whose column is studded with persistent tubercles, and which are not provided with marginal spherules, nor with perforations of the integument." He constituted *Bunodes* and *Tealia* the typical and sub-typical genus of this family, the distinguishing characteristics of these two genera being the possession of tubercles (warts) arranged in vertical lines (*Bunodes*), or irregularly scattered (*Tealia*). Professor Hertwig found among the "Challenger" material an Actinia which, according to Gosse's definition, he had to refer to the genus *Bunodes*, but which had more in common, as he thought, in its structure with the genus *Sagartia*. He accordingly rejected the family *Bunodidae*, relegated the genus *Bunodes* to the *Sagartidae*, and established a new family *Tealidae*, of which he made *Tealia crassicornis* the type, assigning as the most important character of the family the possession of a strong endodermal sphincter. In the Supplement to the "Challenger" Report, Professor Hertwig, for reasons there stated, withdrew the name *Tealidae* in favour of the older designation, *Bunodidae*, which has been adopted by Andres in his great monograph. Professor Hertwig, however, still maintains that the endodermal sphincter should occupy the first place in the diagnosis of the family. In the family so defined by these three authors the forms mentioned in this Paper must be included. But it is remarkable that if the family be a natural one, it contains forms so widely separated as far as the numerical arrangement of their parts is concerned. It would be, indeed, surprising if an adult *Tealia crassicornis* with its parts in multiples of five, an adult *Bunodes verrucosa* with its parts in multiples of six, and an adult *Bunodes thallia* with no apparent numerical symmetry, should be relegated to the same family.

DESCRIPTION OF PLATES IV. and V.

b. Free edge of mesentery.
d. Unicellular glands.
ec. Ectoderm.
en. Endoderm.
me. Mesoglœa (mesoderm).
ml. Longitudinal muscles of mesenteries.
ml'. Second longitudinal muscle.
mp. Parietobasilar muscle.
mr. Longitudinal muscle of tentacle.
ms. Circular muscle.
rh. Directive mesenteries.
s. Œsophagus.
sr. Œsophageal groove.
t. Tentacle.
w. Warts.
x. Inner circular muscle immediately surrounding the mouth.

Plate IV.

Fig. 1.—Part of a transverse section of a tentacle of *Bunodes thallia*, showing the fluted appearance assumed in semi-contraction.

Fig. 2.—Transverse section of a specimen of *B. thallia*, which possessed three œsophageal grooves. The section was taken in about the middle of the œsophageal region.

Fig. 3.—Portion of transverse section of the same specimen, taken lower down, and corresponding to the part between the directive mesenteries marked * in Fig. 2. This section shows the manner in which two of the grooves become confluent towards the base of the œsophagus, and the arrangement of the mesenteries enclosed by the corresponding directives.

Fig. 4.—Vertical section of body wall of *B. thallia*, made through the middle of an endocœle, showing the warts ("endodermal saccules").

Plate V.

Fig. 1.—Horizontal section through a mesentery of *Bunodes thallia*.

Fig. 2.—Vertical section through a portion of body wall, oral disk, and protruded œsophagus of *B. verrucosa*, showing the warts, circular muscle, and the muscular pleating immediately surrounding the mouth.

Fig. 3.—Vertical section through the circular muscle of *B. verrucosa*.

Fig. 4.—Transverse section of a very young specimen of *B. verrucosa*. The section was taken at such a level that the pairs of "secondary" mesenteries which appeared last (those on either side of the directive mesenteries near the top of the figure) are just visible as prolongations inwards of the mesoderm into the endoderm.

Fig. 5.—Half a transverse section through a young specimen of *Tealia crassicornis*, showing the regular pentamerous arrangement of the mesenteries. The primary pairs of mesenteries are marked i., the secondary pairs ii., and at the top of the figure two tertiary pairs are marked iii. The section was rather oblique, the upper end of the figure being nearer to the oral disk than the lower.

XXXII.

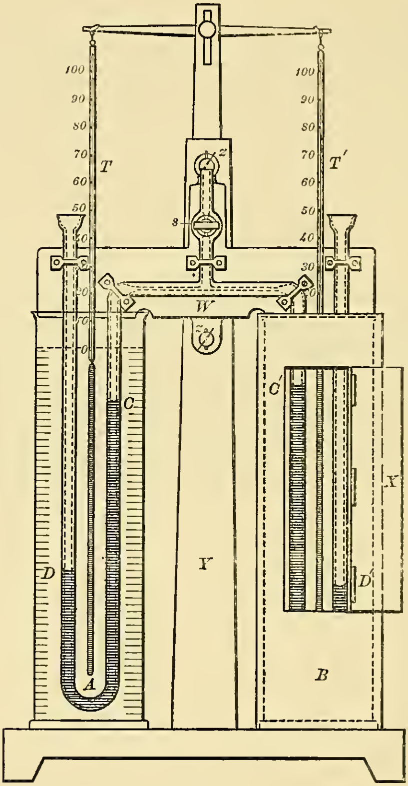
NOTES FROM THE PHYSICAL LABORATORY OF THE ROYAL COLLEGE OF SCIENCE: ON THE DETERMINATION OF THE ABSOLUTE EXPANSION AND THE DENSITIES OF LIQUIDS. By Professor W. F. BARRETT, Royal College of Science, Dublin.

[Read January 9, 1889.]

The well-known arrangement of Dulong and Petit for determining the absolute or true expansion of liquids (wherein the dilatation of the vessel holding the liquid is eliminated) consists essentially of a U tube filled with the liquid under examination, the two limbs of the U being maintained at a constant difference of temperature. This method depends on the hydrostatical law that the heights of any two or more columns of liquid in communication, when in equilibrium, are inversely as the relative densities of the liquids. As the height is independent of the sectional area of the vessels holding the liquids, the expansion and consequent increased capacity of the glass on the warm side does not affect the result. To prevent the mixing of the warm and cold liquid column the communicating tube is made of very small bore. There is, however, a slow interchange of liquid besides other experimental difficulties connected with this arrangement. Regnault greatly improved the apparatus by using an air space in the communicating tube between the two liquid columns, whereby the fluid pressure was transmitted, but mixing prevented.

The arrangement I have devised is in principle the same as Regnault's, but it has the advantage of being very simple and inexpensive, and as it has been for some time in use in my laboratory, with most satisfactory results, it may be useful to make it more generally known.

Two glass U tubes are connected by a cross piece, furnished with a stopcock, *s*, in the manner shown in the accompanying sketch. Each U tube is immersed in a vessel of water; on one side, *A*, the water is at the temperature of the air, on the other, *B*, at some higher temperature. The vessel of warm water is jacketed with a tin cylinder, having an aperture furnished with a door, X, wide enough to allow the readings to be taken. After the U



tubes are half filled with the liquid whose expansion is to be determined, a difference of level in the liquid in the two limbs of each U tube is produced by either aspirating or blowing into the cross piece and closing the stopcock. As a matter of practice it is better to diminish the air pressure so that the liquid in the U tube is caused to stand as shown in the drawings.

Specially constructed thermometers, *T*, *T′*, with open scales and long bulbs, give the temperature of the water in each vessel.

The long cylindrical thermometer bulb saves the necessity for frequent stirring of the warm water, as any differences of temperature in the water are summed up by the thermometer bulb extending through the different strata; hence the reading of the thermometer gives the true mean temperature of the whole mass of water. After thermal equilibrium has been established between the liquid in the U tubes and the water around them, the vertical difference of level, *CD* and *C′D′*, in each tube is carefully read by means of a kathetometer, and the thermometer in each vessel also read. Another pair of temperatures and another pair of differences of level are quickly obtained, and furnish a second experiment with the same liquid. To enable the liquid to be easily changed, the U tubes are fastened to a cross piece of wood, *W*, which is fixed to the upright, *Y*, by buttons *z*, *z*: turning the buttons allows the U tubes to be removed from the vessels *A*, *B*, when the liquid can be emptied and the tubes cleaned.

The calculation of the coefficient of expansion is very simple. The pressure on the surface of the liquid at *C* and *C′*, being that of the air common to the two, is the same; the pressure on the surface of the liquid at *D* and *D′*, being that of the atmosphere, is also the same, and greater than that at *C*, *C′* by a column of liquid equal to the vertical distance between *C* and *D*, or *C′* and *D′*. Hence, as the whole is in equilibrium, the pressure of the liquid column, *CD*, is equal to the pressure of *C′D′*; but the liquid in *B* is warmed, and its diminished density, consequent on its dilatation, will cause the column *C′D′* to be longer than *CD* by an amount proportional to its dilatation; this, again, is directly proportional to the coefficient of absolute expansion of the liquid to the length of the column *C′D′*, and to the difference of temperature between *A* and *B*. Let k be the coefficient of absolute expansion of the liquid, h the difference of level *CD*, and h' the difference *C′D′*; t being the temperature of the water in *A*, and t' the temperature in *B*. Then

$$h' - h = k \,.\, h'(t' - t),$$

whence,

$$k = \frac{h' - h}{h'(t' - t)}.$$

The atmospheric pressure is assumed to be constant throughout the course of an experiment, but an error is apt to arise from the hot water in B slowly warming the air in the tube above CC', and thus creating a gradual increase of pressure on the surface CC'. The pressure of the vapour of the liquid also adds its effect to that of the expanded air, and sufficient time must be allowed to elapse for the vapour to attain its maximum pressure. This error may be neutralized by taking three pairs of readings: first, $C'D'$ and the temperature t', then CD and its temperature t; then, again, $C'D'$ and its temperature t''; if the readings are made at a uniform rate, the mean of the first and last readings of $C'D'$ and of t' and t'' may be taken as the correct readings of the warm liquid and its temperature. The source of this error may further be lessened by making the volume of air above CC' as small as possible; hence the advantage of raising, rather than depressing, the level CC', and the object of the constriction of the glass tube forming the cross-piece. Capillarity, it is true, causes the liquid surface to be more or less curved, but by using U tubes of sufficient bore, and reading the same part of the meniscus in each case, the error from capillarity may be rendered insensible.

An actual experiment with petroleum is given as an illustration of the working of the apparatus.

Absolute Dilatation of Petroleum.

Mean of first and last reading of	h'	$= 139{\cdot}4$ mm.
,, ,, ,,	t'	$= 46^\circ{\cdot}0$ C.
Reading of	h	$= 134{\cdot}2$ mm.
,,	t	$= 7^\circ{\cdot}5$ C.
	$h' - h$	$= 5{\cdot}2$ mm.
	$t' - t$	$= 38^\circ{\cdot}5$ C.

Whence the coefficient of absolute dilatation between 7° and 38° C. is

$$0{\cdot}000992 \text{ for } 1^\circ \text{ C.},$$

which, allowing for the low range, does not sensibly differ from the coefficient given in Clarke's Tables.

The same apparatus may obviously be used for determining the *densities* of liquids, the densities of two liquids, ρ and ρ', being inversely as the height of the liquid columns h and h', or

$$\frac{\rho}{\rho'} = \frac{h'}{h}.$$

Here, of course, the surrounding water in both A and B is kept at the same temperature. For the determination of the point of *maximum density of water* the apparatus is extremely useful in laboratory practice, different pairs of temperatures in A and B, near the point of maximum density, being taken in successive experiments.

XXXIII.

NOTE ON SOME JAPANESE CLOCKS LATELY PURCHASED FOR THE SCIENCE AND ART MUSEUM. By ARTHUR A. RAMBAUT, M.A.

[Read February 20, 1889.]

I am enabled by the kind permission of the Director of the Science and Art Museum to describe some Japanese clocks, which appear of considerable interest as throwing some light on the method of reckoning time employed by the Japanese until very recently.

These clocks are three in number. Though differing in other respects they agree in this particular, that the time is recorded, not by a hand rotating about an axis, but by a pointer attached to the weight, which projects through a slit in the front of the clock-case. This pointer travels down a scale attached to the front of the clock, and thus points out the hour.

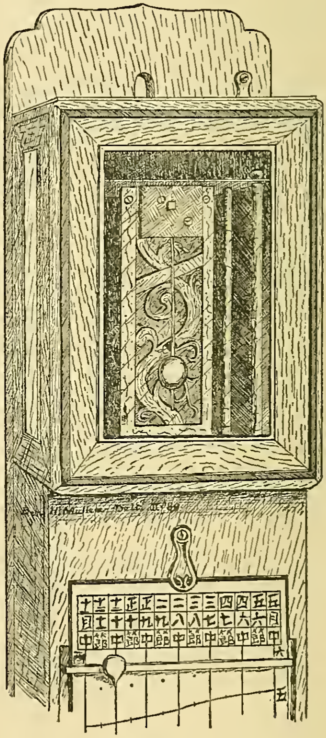


Fig. 1.

In the case of the largest of the three clocks, the upper part of which is shown in figure 1, there is a slit at each side of the dial, and the dial itself is of an elaborate construction, as shown in figure 2. The ends of a straight bar of metal are bent at right angles, and passing through the slits are attached to the weight. On this bar there is an index which moves stiffly up and down it, and can be set at any required point along it. The symbols on the dial are Chinese words and numerals, which were generally adopted in Japan, along with the Chinese weights and measures, &c., many hundreds of years ago.

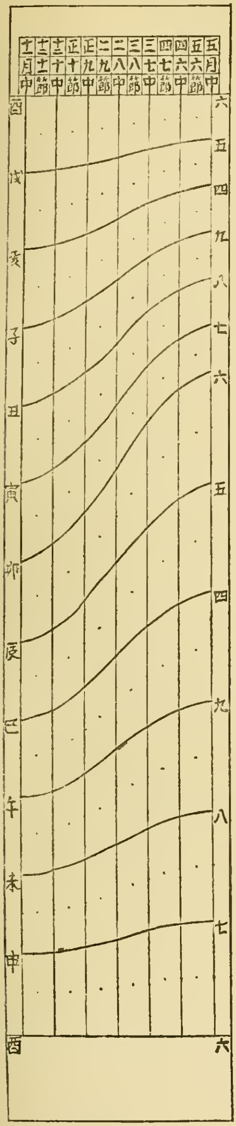


Fig. 2.

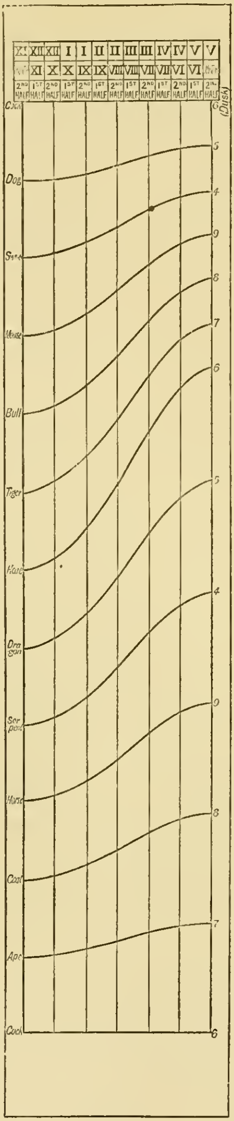


Fig. 3.

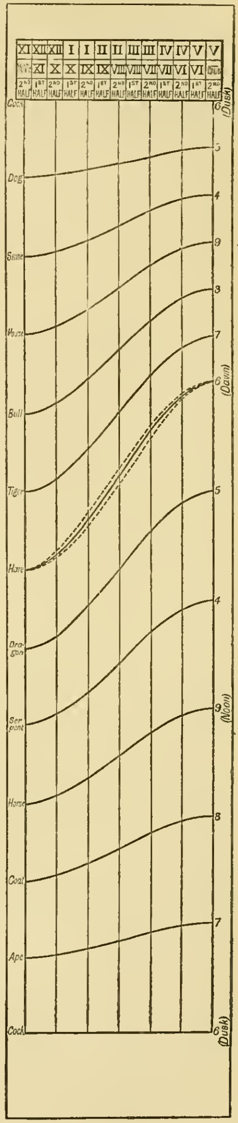


Fig. 4.

The symbols in the first two rows at the top of the dial represent the numbers of the months as shown by the Roman numerals in fig. 3. The symbol at each end of the second row corresponds to the word "month." In the third row the two symbols 中 and 節 occur alternately. These symbols denote the first half and second half of the month, respectively.

The comparison of these periods of time with our ordinary months is very much complicated by the intricacies of the Chinese calendar; for although the Chinese, if their records are authentic, had determined the length of the year with very great accuracy ages before any precision was attained in this quantity by Europeans—reckoning it at $365\frac{1}{4}$ days as early as 2000 B.C.—still the years which are commonly employed and which are used for chronological purposes are lunisolar years, and an elaborate system of intercalary months has to be maintained in order to keep the seasons in their proper places.

As far as I have been able to ascertain, the Chinese civil year commences at the first new moon after the Sun enters the sign of Pisces. The Chinese new year must therefore lie between 22nd January and 20th February. The months also are lunar months, and the year consists of twelve of them. The civil year, therefore, consists of 354 or 355 days only, and consequently it becomes necessary every third or fourth year to introduce an intercalary month. Now it is obvious that according to this style of reckoning, no two years, unless they happened to be separated by some multiple of the Metonic cycle of 19 years, would be similar.

I find, however, in Hoffman's Japanese Grammar a reference to a *solar* year, which is divided into twelve equal parts, each of which is again divided into two. In Williams' Chinese Observations of Comets, there is given a Table of the 24 divisions of the Chinese year in which the 24 periods contain in all 365 or 366 days, but, unfortunately, there is no reference to or explanation of it in the text.

I conclude, therefore, that in addition to the lunisolar year of varying length, which was used for official and chronological purposes, there was the uniform solar year of $365\frac{1}{4}$ days employed for other purposes for which it was found convenient.

I find, according to Williams, that the first of these 12 double divisions of the solar year corresponds to the 5th of February, according to our style of reckoning, and that the second half of the second period and the second half of the eighth period correspond to the 22nd of March and the 22nd September, respectively, and are called the "*middle of spring,*" and the "*middle of autumn.*"

We thus see that the vertical lines represent six nearly equidistant dates. The first line on the left corresponds to the 22nd December, and the others, taken in order, represent 21st January, 20th February, 21st March, 21st April, 21st May, 22nd June, 22nd July, 23rd August, 23rd September, 22nd October, and 22nd November. In fixing on these dates I have been obliged to take the mean of the dates as given by Hoffman and Williams, as they sometimes differ to the extent of a couple of days, and agree only in one case, that of 22nd December.

This small ambiguity, however, makes very little matter from our present point of view, the essential point to observe being that the spaces between the lines represent a month approximately; that the middle line represents the spring equinox, and the last line on the right the summer solstice. The figures in the second row show us that for the second half of the year we return across the dial in the opposite direction, the middle line representing the autumnal equinox, until the first line or the winter solstice is once more reached.

It is now necessary to give some explanation of the series of curves traced on the dial.

I have not been able to find any reference to clocks of this kind in any of the books to which I have had access; and some of the descriptions of the Japanese time-reckoning which I have come across are actually misleading. I think, however, that a study of the curves themselves will furnish us with a key to the principle of their construction, and the explanation to which I have been led appears to me a very simple and satisfactory one.

This is, perhaps, the place to mention that I have consulted several persons who have been resident for some time in Japan, but none of them has ever seen a clock of this construction in actual use. I have also shown them to a young Japanese gentleman who informs me that he has heard of their being used in rural parts of Japan about twenty or thirty years ago, but that they have been almost completely superseded by clocks made on the European plan, and he was unable to throw any light on the principles underlying them.

The Chinese divide their days into 12 portions of equal length, each of which is again divided into two. These 12 portions are called after the signs of the Zodiac, and are, reckoning from midnight, as follows :—Mouse-time, Bull-, Tiger-, Hare-, Dragon-, Serpent-, Horse-, Goat-, Ape-, Cock-, Dog-, and Swine-time. The middle of Mouse-time corresponds to midnight, so that this period lasts from 11 P. M. till 1 A. M. The figures on the left-hand side of the dial are Chinese, representing these different divisions of the day. They commence at the top with Cock, and proceed in the order just given.

The *Japanese*, on the other hand, reckoned time by hours of variable length, depending on the season of the year. But at what moment they commenced the day, and when their night began, is not at all clear. Hoffman is most inconsistent with regard to this point. He says that the Japanese measurement of time fixed according to our hours is alone of value for an equinoctial day, and then immediately afterwards states that a midsummer's day, *including the morning and evening twilight*, being about 17 h. 58 m. long, one of the divisions of a Japanese day would contain 2 h. 58 m.

Now, it is evident that if the curves are hour-lines at all, they cannot be intended to divide the day from sunrise till sunset, and the night from sunset till sunrise each into equal portions, as was in ancient times common enough (*cf.* the Hemisphere of Berosus), and is still done in some of the out-of-the-way parts of Europe. For on this hypothesis all the divisions would be of the same length at the equinoxes only. Hence the first line would have to represent the equinoxes. That this is not the case is clear from the curves themselves, to say nothing of the evidence afforded by the symbols contained at the top of the dial. For if it were, we should expect the day to increase continually till the solstice (which would be represented by a rise in the curve), from which point the day would again diminish, and the curve would fall in a similar manner till the equinox was again reached. The last line therefore would represent the solstice. There would, however, on this hypothesis be a provision for only one-half of the year. But at the equinox the change in the length of the day is most rapid, so that we should expect the curves to rise most abruptly close to the first line. Now this is not at all the nature of the curves which rise most steeply at the middle line, and this fact alone would lead us to suppose that this line represents the equinox, as we have already seen from other considerations.

The second part of Hoffman's remark about the twilight, however, gives us a clue to the principle on which the dial is constructed.

At midwinter, in the latitude of Tokio (35° 43′), when the Sun's hour angle is 90° (that is approximately at 6 A. M. and 6 P. M.), the Sun is about 13° below the horizon. At that time, therefore, the twilight will be just becoming noticeable, though for some little time before, in the morning, and after, in the evening, there would be more or less light.

If we assume, therefore, that the day always begins when the Sun is 13° below the horizon, or when the twilight first becomes bright enough to attract attention,[1] we shall have at midwinter the day and night of equal duration, and all the divisions of the same length. As the year advances the day increases; at first slowly, but as we approach the equinox more and more rapidly, after which the change becomes slower and slower till the summer solstice is reached. From this point the day diminishes again in a similar manner till we arrive at the winter solstice.

These changes are exactly what we see represented in the sixth curve, which, on this hypothesis, represents the *beginning of dawn.* At first its height increases very slowly; at the equinox it increases most rapidly, and this rate of increase falls off again as we approach the solstice. The other curves are found merely by dividing each vertical line, from the point at which the "dawn" curve cuts it to that at which it is cut by the bottom line, into six equal parts, and similarly dividing the upper portions, so that the "dawn" line is the only one which concerns us.

On this hypothesis I have traced a dial for the latitude of Tokio (Fig. 3), the curves on which agree fairly well with those on the clock-dial considering the nature of the problem.

In the first place, I cannot be sure that the clock was made for this latitude; and in the second, since the curves were probably, in the first instance, determined by rough observations of the actual

[1] The amount of twilight then visible is almost exactly that of a midsummer's midnight at Dublin, or more accurately at Rush in the same county.

appearance of twilight, and then perhaps handed down from one person to another, we could scarcely expect any great accuracy.

It will be observed that the greatest discrepancies between the clock curves and those I have computed occur in the summer half of the year. This arises from the fact that the clock curves are symmetrical with regard to the equinoctial line, whereas they ought to rise more abruptly in the summer than in the winter half of the year. This want of symmetry is due to the fact that we are not dealing with the time of the sun's appearance on a *great* circle such as the horizon, any changes in which at one side of the equinox we should expect, neglecting the eccentricity of the earth's orbit, to find counterbalanced by corresponding changes at the other side; but we have to do with the time of its appearance on a *small* circle 13° below the horizon, the changes in which will not take place symmetrically in the two periods. This will be seen more clearly from the following formulæ. If we want to determine the hour-angle of the sun when on the horizon, we have, if δ is its declination, ϕ the latitude, and h the hour-angle,

$$\cos h = -\tan\phi \tan\delta.$$

Now to change the sign of δ in this merely changes the sign of $\cos h$, so that for each value of h, corresponding to a particular value of δ, we have $180 - h$ corresponding to $-\delta$.

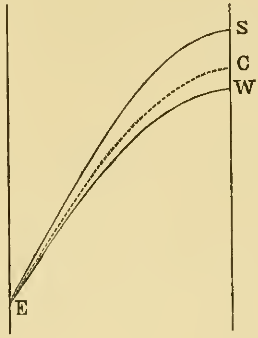
On the other hand, if we want to determine the hour-angle of the sun when at a distance x below the horizon, we have

$$\cos h = \frac{-\sin\phi \sin\delta - \sin x}{\cos\phi \cos\delta}; \qquad (1)$$

in which, by changing the sign of δ, we may or may not alter the sign of $\cos h$, but we also alter its absolute value.

It appears to me very likely that a primitive people, having observed the changes in the length of the day throughout the year, would assume that any want of symmetry in the curve they obtained, if they noticed it at all, was due to errors of observation, and would accordingly take a series of mean values to suit both halves of the year from which to construct their curves.

It is also worthy of remark that the curve of "dawn" as found on the clock falls between the two branches of my curve, as shown in accompanying diagram, where EW represents the winter and ES the summer half of my curve, and EC the clock curve.



Now, assuming that these lines do denote the hours, and were obtained somewhat in the manner just suggested, we are in a position to make a more accurate determination of the place from which they come.

We have the hour angle of the sun when it reaches some definite distance (x) from the horizon at midsummer represented by the distance between the asterisks on fig. 2. The proportion this bears to the whole length of the dial gives us the midsummer hour-angle of the sun when at this depth (x) below the horizon, which is thus found to be 126°. At midwinter, when the sun reaches the same distance from the horizon, its hour angle is similarly 90°. We thus obtain two equations for x and ϕ, viz.:—

$$-\sin x = \sin \phi \sin \delta + \cos \phi \cos \delta \cos 126° \qquad (2)$$

and

$$\sin x = \sin \phi \sin \delta$$

in which $\delta = 23° \ 27\tfrac{1}{2}'$.

From these equations I find

$$\phi = 34° \ 6'\cdot 5 \text{ and } x = 12° \ 54'.$$

I have traced (see fig. 4) the curve of which the ordinate (h) is given by the equation (1). It is the lower of the two dotted curves. The upper one is the same curve inverted, and the continuous curve lying between the two is found by taking the mean of the ordinates of these and running a curve through the points thus found. It is symmetrical with regard to the equinoctial line, and represents equally well the changes in the length of the day in the two halves of the year, and on comparison it will be found to coincide exactly with the "dawn" curve on the clock-dial.

I therefore conclude that the curves were made in or about the latitude 34° 6·5′, and that they represent the variable hours in the manner described above.

The Japanese call the six periods into which their days and nights are divided "Tokis," and each toki is again divided into two. They number them from midnight and noon in a somewhat curious manner. The hours are struck on a bell or drum, but as the numbers one, two, and three strokes are used only as signals for the army and in convents, they have to do without these in their clocks, and they get out of the difficulty in the following way:—Midnight is the first "Toki," accordingly they subtract 1 from 10 and strike 9. For the second "Toki" they subtract 2 from 10 and strike 8, and so on till noon, when the same process is begun again.

The figures on the right-hand side of the dial represent these numbers, as shown on the two dials I have drawn.

The second clock, though slightly different in construction, depends on the same principle. At one side of the slit through which the pointer projects is a series of 13 indices, with the same Japanese symbols engraved upon them which have already been described in the case of the first clock. These indices are capable of moving up and down, so as to suit the varying length of the hours at different dates. At the other side of the central slit is a reversible dial, on one side of which is a scale with intervals corresponding to the hour spaces on the 5th line from the left in the clock already described. This side of the dial carries symbols at the top of it denoting "2nd half of the 4th and 6th months." On the other side of the dial the intervals on the scale correspond to the hour spaces down the line of dots between the 4th and 5th vertical lines on the first dial, the symbols at the top representing the words, "1st half of the fourth and seventh months." From this it is clear that the clock was intended to have seven of such reversible dials, which would cover the whole 24 periods into which the year is divided. The scales on the two sides of this dial supply two equations of the same form as equation (2), from which I obtain $\phi = 33° 46'$ and $x = 12° 18'$. The two dates to which the scales correspond are, however, so close together (being separated by only 15 days) that these values are liable to considerable error.

The third and smallest of the three clocks is in one respect, perhaps, the most interesting. It has a single pointer attached to the weight, as in the case of the second clock, but differs from the others in being controlled by a balance spring instead of a pendulum. There are traces of a set of movable indices, as in the case of the second clock, but these have been removed, and a slip of metal cemented along the slot in which they used to slide, and on this slip are marked spaces of equal length. We have, therefore, in the case of this clock, which has been remodelled by the previous owner in accordance with western ideas, actual evidence of the great Europeanizing influence which is at present so active in Japan.

NOTE ADDED IN PRESS.

Since this Paper was read I have been enabled, by the kindness of Mr. H. A. Cosgrave, to examine another Japanese clock belonging to a friend of his, which is constructed on the same principle as those described above. It has a reversible dial, similar to that of the second clock described. From the two scales on this dial I find $\phi = 30° 7'$, and $x = 13° 1'$. This value of ϕ would bring us down as low as the island Yakemosima, at the south point of Japan; but the value of x agrees very well with that found on page 339. I am also indebted to Prof. Alexander, of Trinity College, Dublin, for a description of a curious clock which he came across in Japan, and which was controlled by two balance wheels oscillating in different periods, one for the day and the other for the night. There was an arrangement in the clock by which, when the wheel that was working during the daylight hours had performed the proper number of oscillations, it was automatically thrown out of gear, and the other came into play to "rule the night." The two wheels were regulated by a movable pointer like the regulator of a watch, but the time of oscillation of one was diminished as the other was increased. It was thus possible to adapt the clock to keep correct Japanese time for any season of the year. In a clock of this construction, of course, the spaces on the dial representing hours or "tokis" are all of equal length.

I ought also to mention that for the drawing of the upper part of the clock-case (Fig. 1), and the tracing of its dial (Fig. 2), I am indebted to the kindness of Mr. Mullen of the Science and Art Museum.

XXXIV.

ON THE ECONOMIC GEOLOGY OF IRELAND. By G. H. KINAHAN, M.R.I.A., Etc.

[Read January 9, 1889.]

GENERAL SUPPLEMENT.

[In this Supplement is given such information as has been obtained since my several Papers on this subject were published. I may, however, refer briefly to the suggestion that some of the oldest Irish rocks, although not the equivalents of the Laurentians, may nevertheless be possibly Pre-Cambrian.]

INTRODUCTORY.

Agnotozoic.—The improbability of any of the Irish rocks being equivalents of either the Huronians or Laurentians has been already suggested. It must, however, be remembered that in America there is a great interval between Huronian and Primordial strata, and that the "Gap rocks" have been found to exist in Maine, Manitoba, and other places in America. Chamberlin has proposed to call the time of their deposition the Agnotozoic Epoch, which suggestion was adopted by the late Dr. Irving.

The American Primordials would seem, from their fossils, to be the equivalents of the Welsh Cambrians; and the latter, up to the present, are considered by most people to be a portion of the same formation as the Bray Head Series. For this classification, however, there does not seem any good reason, as both were classed together solely because one was considered to be the oldest English and the other the oldest Irish formation. But on examination it is found that both lithologically and palæontologically they are quite different.

For some time it has been known that there are Pre-Cambrian rocks in Scotland, while Blake, Hicks, and others believe they have proved their existence in England and Wales; therefore the presence of Pre-Cambrian rocks in Ireland may also be expected.

In favour of a Pre-Cambrian age for the Bray Head Series, the following may be noted :—The Welsh Ordovicians pass downwards conformably into the Cambrians; but the Leinster equivalents of the Ordovicians do not pass thus into the Bray Head Series, as there was evidently a considerable interval between the accumulation of these distinct groups of rocks. Furthermore, in the brief description of the Baginbun Promontory, Co. Wexford (*Supplement, Irish Arenaceous Rocks, antea*, p. 13), it was shown that to the south of Fethard there is an unconformability between the Ordovicians and a group of older fossiliferous rocks; while the latter are quite unlike in every way those of the Bray Head Series; it therefore seems probable that they may be a portion of the true Cambrian. Under these circumstances it appears expedient that the rocks of the Bray Head Series should be called by a separate and distinctive name: and for them the term "OLDHAMIANS" may be suggested.

The Pre-Cambrian age of the *Oldhamians* seems to be also suggested by the geology of Galway and Mayo, where the equivalents of the *Ordovicians* pass downwards conformably into a great thickness of strata, quite distinct from those of Bray Head; while in the Mullet, or N. W. Mayo, this group of rocks lies unconformably on certainly one, and possibly two, groups of older strata.

After careful consideration, it seems to me highly probable that the *Oldhamians* of S. E. Leinster, and the older rocks of the Mullet, and other places in W. Mayo, are AGNOTOZOIC; while some of Griffith's older rocks in the Cos. Tyrone, Londonderry, Donegal, and Antrim, might also possibly be similarly classed.

So far back as 1861, the late Prof. Harkness, in his Paper "On the Rocks of portions of the Highlands of Scotland . . . and their equivalents in the North of Ireland" (*Jour. Geol. Soc. Lond.*, vol. xvii., p. 270), expresses the opinion that the Malin Head gneiss is of the same age as the upper Archæan Rocks of Sutherland, Scotland.

CARBONIFEROUS SANDSTONE.—It had been anticipated that small outliers of Carboniferous rocks might be found to occur, if properly searched for, on some of the high hills in Donegal and elsewhere. During a late visit of Dr. A. Geikie (Oct. 1888) to S. W. Donegal he discovered, on Slieve League, two considerably-sized tracts of Carboniferous Sandstone; while it seems probable that a third, but smaller one, exists further north, to the west of Ardara, as the breccia and conglomerate in places on the shore of Loughrosbeg Bay are similar to the basal Carboniferous conglomerate of other places.

MINES AND MINERALS.

Gold.—Slieve-an-Orra, Co. Antrim.—It now appears that the tradition of gold being found here was due to a promoter of the Antrim Mining Co. having made the statement, on the supposition, that *orra* signified *aurum.*

Silver.—Camaderry, Glendalough Lead Mines, Co. Wicklow. Associated with the lead of this lode were found some handsome sprays of native silver; also the peculiar form of calcite, called Schiefer Spar.

Silver Copper.—Silver in the west of Cork seems to occur as often in tetrahedrite as in chalcopyrite.

Silver Lead.—Clonmines and *Barretstown*, Bannow Bay, Co. Wexford. *Fraser*, in his Statistical History, states that the Danes had a mint at Clonmines. From Mr. *George Griffith's* "Chronicles of the Co. Wexford" we learn that there was a mint at Clonmines in the reigns of Henry VIII., Edward VI., Mary, and Elizabeth. The first record quoted refers to Clonmines Silver Mines, in July, 1550 (King Edward's reign), and others refer to it and Barretstown up to 1565 (Elizabeth's reign). During this time the mines appear to have been worked on and off under different agents. In 1552 they were worked by Almains, or Dutch miners, under Joachin Gunderfilgen; while, in 1565, the agent was one Walter Pepparde; but on account of the "constant quarrelling going on between persons trying to get the mines into their power they ceased to be worked for many years." The Clonmines mine seems to have been extensive, yet there is now no record of its site. Barretstown was reopened about the year 1840; but, as already mentioned, it was not a success. Other mines, worked by the English in the sixteenth century, were near Enniscorthy.

Iron—Manganese.—Calliagh and Tattin Heive, Co. Monaghan, S. S. W. of Rossmore Park. According to Adeney, this contains 35 to 50 per cent. of iron, and about 7 per cent. of manganese. The outcrop of the lode has been traced for over half a mile. (*W. F. de V. Kane.*)

The analysis of the iron ore of Logwood Hill, Calliagh, is given by Mr. W. E. Adeney as follows :—

Ferric oxide, ...	42·2
Alumina, ...	7.55
Manganese peroxide, ...	6·24
Cobaltous oxide, } Nickelous oxide, }	·03
Lime, ...	·35
Magnesia, ...	·21
Phosphoric acid (P_2O_5), . . .	·03
Water (expelled at 120° C.), . .	3·47
Loss (on gentle ignition), . . .	3·21
Insoluble matter ignited, . . .	37·00

The Insoluble matter contained 29·51 of silica and a trace of titanic acid.

Copper.—Tullig, near Anascaul, Dingle Promontory, Co. Kerry. There is an old tradition that copper was found here. (*W. M. Hennessy.*)

Molybdenite and *Molybdene.*—Murvey, Roundstone, Co. Galway. In this locality the oxide (molybdene) seems to be in considerable quantity, accompanying the sulphide (molybdenite).

Nickel.—Glenisky, near Kylemore, Co. Galway. In the magnesian rock there is a trace of nickel. (*J. R. Kilroe.*)

Steatite, or *Pyrophyllite.*—Co. Donegal. Moneydarragh, 3½ miles N.W. of Moville, barony of Inishowen. There is a bed, 3 to 6 feet thick, so soft that it can be dug out with a spade.

Pyrophyllite ?—In the strike of this bed, two miles to the N.E., near Crossroads, a similar rock was observed, but of less thickness.

Owenbeg river valley, 10 miles west of Letterkenny, and S.W. of Gartan Lake. Strings and veins of steatyte run along the bedding, of a buff-coloured dolomyte, from ½ an inch to 3 and 6 inches thick ; this steatyte seems to be very pure and suitable to be used as *French chalk.* (*A. M'Henry.*)

Ballintemple Mine, Woodenbridge, Co. Wicklow. According to the record of Sir W. W. Smyth and the late Mr. Wylie, the thickness of the lead vein was five inches ; while we learned, through the late Mr. Henry Robinson, Captains Barclay, and Argall, sen., also from various miners, that the vein rarely exceeded that thickness, while often it was less. Eventually it dwindled down to a mere string, which was driven and sank on, without finding any improvement. No one in the county seems ever to have heard of an eighteen inch vein (*Geol. Survey Memoir*, Sheets 138 and 139, p. 31), while it seems remarkable, *if such a champion lode was discovered*, that immediately afterwards the mine should have been abandoned.

In Appendix D (*ibid.*, pp. 41 and 42) three of the Plans, &c., Nos. 5, 6, and 7, lodged in the Mining Record Office, are omitted; while the numbers given, 5 to 20, are not those on the lodged documents. For the survey of the old workings the public are indebted to Captain P. H. Argall, and not to Captain Higgins, as is incorrectly stated (*ibid.*, footnote, p. 29). For other inaccuracies, see descriptions of the Ovoca Mines, these *Proceedings*, vol. v., pp. 305–315, and Capt. Argall's Paper on the East Ovoca Mines (these *Proceedings*, vol. ii., p. 211).

Ovoca Mines.—The following details, not previously given, may be of importance to future adventurers :—

Although Weaver seems to have had some doubts about it, yet previous to my survey the general opinion was, that the *Mineral Channel* had a similar strike and dip to those of the country rocks. During that examination, assisted by Captain P. H. Argall and the late Gerrard A. Kinahan, I proved it was not so, as the channel generally creeps across the strata, and a careful and prolonged examination led to the following conclusions :—

A large fissure gradually opened, during which process it was being filled with laminated *faultrock*, the strike of the laminæ being parallel to the walls of the fissure, while now they dip southward. Subsequently, in the western portion of this *channel* (Ballymurtagh, Ballygahan, Tigroney, and West Cronebane), a newer fissure also gradually opened along the north margin of the mass of faultrock, this fissure gradually filling with laminated sulphur ore; its laminæ being parallel to the foot (north) wall of the lode, while it is slightly oblique in dip to that of the hanging (south) wall. A peculiarity in this main sulphur lode is, that in depth the ore is more coppery than higher up. Afterward in this portion of the channel, to the south of the main sulphur lode, perpendicular lenticular fissures opened. A few are transverse, but in general they are longitudinal, but slightly oblique to the main lode; so that, although distinctly separate from the latter in West Cronebane, Tigroney, and Ballygahan, in Ballymurtagh they joined into it; yet in no case, in depth, do they seem to have penetrated it. These perpendicular veins were known as the "copper lodes," and all of them in the country east of the Ovoca river were extracted by Weaver.

In the middle portion of Cronebane (Yellow Bottom) the main sulphur lode seems to have been proved by Weaver, and subsequently by Argall. As the "copper lodes" do not extend into it, it was called in Weaver's time "Dead ground."

In the east portion of Cronebane (Magpie Mine), Connary, and Kilmacoo, the phenomena were different, as here two nearly parallel fissures opened in the faultrock. In the north fissure or lode the filling stuff, although laminated, consisted largely of black and greyish white flucan (hence the name Magpie), while the ore was coppery, friable, and not of the hard nature of that in the western mines. This north lode, although in one place heaved north, is always at the north margin of the faultrock, as far N.E. as the Kilmacoo N. and S. fault, where it and the channel appear to be heaved north about six furlongs, as shode stones occur thereabouts in the townland of Rockstown. The south lode is not so continuous, as it is cut out in Connary by an intrude of felstone; it is a flucan course, containing veins and pockets of kilmacooite (these *Proceedings*, vol. v., p. 310). As the profitable reduction of this peculiar ore is still undiscovered, the lode has been very little explored.

South of the Magpie and the Yellow Bottoms there are five or six E. and W. lodes apparently in the country rocks. They were proved by Weaver and were being explored by Argall when the mines were stopped; they are known as Madam Butler's, Yellow Bottoms, Morgan's, Discovery, Blueburrow, and Raddle lodes. Madam Butler's lode contains copper ore mixed with kilmacooite, and was worked in part by Weaver.

The north lodes, Ballymurtagh, Ballygahan, and Cronebane (Castle Howard), occur in fissures nearly parallel to the mineral channel. The last was discovered during my survey, while its exact position was proved by Captain Argall. This explorer also opened up Weaver's Boat level in Castle Howard, and found that the driving had been discontinued a short distance west of where it ought to have cut the north Cronebane lode. This level is an important consideration if the East Ovoca mines are again worked, for if it was continued eastward this north lode would be cut in depth, while the Magpie and Connary mines would be unwatered, thereby saving the expense of pumping.

The minor lodes in the country north of the mineral channel are in nearly parallel fissures. Those in Knockanode, to the north of Ballymurtagh, were very extensively explored without success. Plans and sections of the Knockanode workings are lodged in the Mining Record Office, London.

It should be put on record that the Carysford Mining Company opened a cast across the country from Kilcarra to the sea, near Arklow Rock. They are said to have only found two small lodes of lead and one of sulphur; for some reason they missed finding the source of the great Gossan ramp, in the S. W. portion of the Glenart Woods.

Limestones and Marble.

DONEGAL.

Derrisclígh, south of Glen Lough.—A very pure compact white limestone, but apparently not of very great extent. (*S. B. Wilkinson.*)

In the neighbourhoods of *Carndonagh* and *Culdaff*, Inishowen, a dark, nearly black limestone, that splits, punches, and chisels well; can be raised in good-sized blocks. (*G. Baggs.*)

Crohy, south-west of Dungloe.—A handsome, peculiarly streaked, spotted and mottled black, green, and white ophicalcyte. "Thin-bedded, and not of any great extent or quantity." (*J. R. Kilroe.*)

Polished specimens of this stone can be seen in the Geological Museum, Trinity College, Dublin, and in the Science and Art Museum, Leinster House, Dublin.

DUBLIN.

In the new railway station, Westland-row, also in the Loop Line City of Dublin Junction Railway, the limestone for rubble work was procured from Jordan's quarries at Rathgar, and Bayley's quarries at Finglas. The Rathgar stone is very good for foundations, coming out in stones about 12 to 15 inches thick; stones from one ton to twenty-five cwt. are easily obtained. The layers are very even and the stone tough.

The Finglas stone is not as even on its beds, yet the masons prefer it for faced work, as it is more easily worked, and gives a more even face. The strata, however, are generally irregular, and the quarry beds are not easily kept horizontal in the work, there being so many "nuts."

For the Loop Line the limestones for cut-stone purposes were procured from Tullamore, Cavan, and Meath. (*T. B. Grierson.*)

GALWAY.

Merlin Park.—In the lower black beds of this quarry there is a most beautiful compact marble, equal and similar to the Italian that is used for clock-stands and the like. This superior stone, unfortunately, has been found, as yet, only in lenticular patches of very limited extent.

MAYO.

On the road from Beltra Lough to Castlebar, about three miles from the latter, there is a nice-looking white Limestone. (*R. G. Symes.*)

Sandstones.

KILKENNY.

Kiltorcan Quarry, near Ballyhale.—Buff-coloured, fine-grained sandstone (Novaculite, or honestone), well known from its fossils. Here there was formerly a considerable trade in the manufacture of hones for local use and exportation.

The stone is eminently suitable in every way for the purpose, being of good quality, and readily splitting into convenient sizes. Unfortunately, however, the trade has long since died out. (*A. M'Henry.*)

Clays and Bricks.

ANTRIM.

Belfast Delph.—In the loan collection at the Free Library, Belfast, was exhibited a lady's shoe made of blue and white delph.

It is marked "Belfast, 1707." Through Messrs. Patterson and Swanston I learned of a second, figured by Benn in his history of Belfast, and marked "Belfast, 1724."—*M. H.*R.* These authorities, and others who have examined the shoe, question its having been made in Belfast, as it is identical with some old Scotch and English wares.

DUBLIN.

In connection with the brick trade of this county, Dr. Frazer has called our attention to a lease of part of Rathfarnham, dated 14th January, 1679, in which there is a covenant giving his family power "to dig up any part of said premises, and to burn bricks thereon."

[In the enlargement of the Westland-row railway station the facing of the walls is composed of perforated Bridgewater brick of first quality, and the hearting of Cardigan bricks of second quality; except in some of the walls that had not to carry much weight, where there is a Bridgewater facing and granite backing. In the arching are red Kingscourt bricks (*Thompson, Bros.*), and Kingstown bricks of second quality. For the brickwork in cement in the piers for the roof and the columns were used first quality Chester fire-bricks, about 2⅝ inches thick. In the City of Dublin Junction Railway (Loop Line), the principal bricks were buff, from Torrington, North Devon, and Aston Hall; dark-brown fire-bricks from Chester, and Farnley brick with enamelled faces in places where light was required to be reflected; in the Loop Line enamelled bricks were used in the St. George's-quay abutment.

At Kingscourt some of the bricks are pressed, while others are wire-cut. The pressed brick used in the facings were of good quality, and those used in places on the Wicklow line for small works appear to have stood well. The wire-cut, or unpressed bricks, have sometimes a tendency to split vertically, or across the brick, when set on their proper bed: this happened in many instances, as they broke across, although well flushed in mortar.

In the case of a brick splitting horizontally the fracture is not nearly so injurious as when it splits vertically. In the first case the superincumbent weight will generally keep the pieces in position; but if there is a vertical crack it is much more likely to cause a settlement. The Kingstown bricks were used at the Merrion Station, Dublin and Kingstown Railway, in a parapet wall next the sea; but whether the sea air affected them or not, they have become greatly pitted on the face, and have deteriorated considerably. (*T. B. Grierson.*)]

WEXFORD.

Killiane Pottery and Delph Manufactory.—At the end of the seventeenth century, during the Cromwellian settlement, a Quaker, Jonathan Chamberleyne, from Staffordshire, established a pottery in Great Killian, on Wexford Harbour. It was first for coarse pottery, made from the clay of the country; but about 1719 he established a delph manufactory, when, it is supposed, he imported materials from England. The delph was such a success that china was attempted. This, at first, was so successful that five kilns were built and loaded, but in the baking they proved a total failure, and the ruin of the adventure. Some of the ware made at Killiane was in use in that neighbourhood as late as 1876. (*Griffith's Chronicles of the Co. Wexford.*)

Granite, Elvan, &c.

CO. ANTRIM.

Tardree Volcanic Rocks.—It is the opinion of M'Henry that the trachytic rocks at Templepatrick and Tardree were laccoliths which originally did not appear at the surface; their present exposure being due to denudation. They were intruded after the greater part of the basalt; but that there were intrudes of the latter after the genesis of the laccolith is proved by the basaltic dykes that traverse them.

The tuffose rocks of Tardree, in appearance somewhat like the Brohlthal of Germany, were tried by Mr. Ritchie of Belfast, who failed to make a hydraulic cement from them.

At Templepatrick M'Henry has discovered a portion of the basal Eocene conglomerate which has been baked by the trachyte, and the contained flints changed into *agates.*

DUBLIN.

There is a handsome porphyritic granite in the Three Rock Mountain, containing very large salmon-coloured crystals of felspar (Microcline). This stone, when polished, is very effective, and would be suitable for inside work, but for outside work the mica (muscovite?) would be prejudicial, as it would weather out. Two polished slabs of this rock are exhibited in the mineral collection in the Museum of the College of Science, Stephen's-green, Dublin.

Granite for footpaths and crossings ought to be very carefully selected. This is not the case in Dublin, where some of the stones at present in use are quite unsound, and will in a short time rot and wear away; while others have unsound corners, which rapidly decay, leaving holes in the paths and crossings. Such unsound corners result from the cutting of too large a flag or crossing-stone out of a granite block, the outer part of which is weathered. The effects of these rotten corners are conspicuous in many of the pathways and crossings.

LEITRIM.

Arigna Flags.—Recently a light railway has been constructed to the collieries in this district, and it is now proposed to extensively work the excellent coal-measure flags (vol. v., p. 579), which formerly were very little utilized on account of the difficulty of transport.

MONAGHAN.

Two and a-half miles S. W. of Smithborough there is "an evenly crystalline, dark-blue basalt dyke. Two other dykes occur in the county E.N.E. of Castleblayney." (G. S. M.)

In *Lisserard*, *Knockaturley*, and *Ramany* there is a dyke of green, mottled white, granitone, over a mile and a-half in length. In the latter townland, about two miles from the Monaghan railway station, the rock is exposed in a water-cut, and is found to be a sound, good stone, which appears capable of being raised in good-sized shapely blocks. A specimen was sent to Mr. Brindley, of Westminster, who highly approved of it for polishing purposes. It seems to be also well adapted for paving-setts. (*W. F. De V. Kane.*)

CO. WICKLOW.

Aughrim and Tinnakilly Granite Quarries.—The soda granites (keratophyre) in these localities, as previously mentioned, are more or less pyritous, and are supposed to be of Carboniferous or later age. They occur as intrudes in the schists and in the older granite (*Haughton's Leinster type*), having been probably "laccoliths," their present appearance at the surface being due to denudation.

Some of these rocks on weathering become clouded, or spotted with rust; but the better stones are only more or less speckled, these different appearances being due to the varying amount of iron present. From a careful examination of the place it would appear that usually the laccoliths consist of irregular shells or slightly-curved layers; the outer shells as well as the adjoining schist being highly impregnated with iron (marcasite), while in depth or nearer the centre it is not so. In depth the rock seems to become less and less pyritous; so that, if *well selected*, clean bright stones may be procured. There are also in these granites black or greyish, more or less pyritous, micaceous eyes, the majority of which, especially if they have a pyritous margin, weather into a rusty spot on the face of an otherwise bright clean stone.

From the structures in which this stone has been used we learn that the badly selected stone will become rusty, and remain so, while the better class, after a time, lose the rust speckles, and become clean and bright. It would appear, therefore, that the faces of the good stones, if treated with acid (*hydrochloric, or that acid mixed with nitric*), might be artificially weathered, thereby getting rid of all the surface iron prior to the stones being used. The iron in the "eyes," except where it occurs as a vein, might be similarly got rid of.

In the new railway station, Westland-row, Dublin, the granite for rubble was brought from Kingstown, Sandycove, and Dalkey, most of it being procured while doubling the line from Kingstown to Killiney. The granite for cut-stone purposes came from Dalkey, Kingstown, and Aughrim, Co. Wicklow. In the Loop Line (City of Dublin Junction Railway), the granite for cut-stone purposes has been principally procured from Aughrim, Co. Wicklow, but some is Co. Dublin granite. (*T. B. Grierson.*)

XXXV.

TABLES FOR THE EASY CONVERSION OF BRITISH INTO METRICAL MEASURES. By G. JOHNSTONE STONEY D.Sc., F.R.S.

[Read March 20, 1889.]

Two comparisons between the metre and the yard have been made with 'great care,' viz.: Captain Kater's (which is that commonly quoted) and Captain Clarke's (see *Phil. Transactions*, 1867).

According to Kater, the metre = 39·37079 inches.
According to Clarke, it = 39·37043 ,,

Whence

Kater's yard = 914·38348 mm.
Clarke's ,, = 914·39180 ,,

These determinations differ from one another by nine parts in a million, or by nearly one part in 100,000. Hence an error of one part in 100,000 in such comparisons cannot be *with certainty* detected even with the help of the appliances used by these observers, and with the extreme care taken by them. This one part in 100,000 is about half the amount by which standards of length (of brass or gunmetal) expand for 1° C. of temperature.

Of the two determinations Captain Clarke's is the more recent, and is also entitled to most confidence. Adopting it—

The metre = 39·370432 inches,
= 39·37 (1 + ·000,011),
and the yard = 914·39180 millimetres,
= 914·4 (1 − ·000,009).

Hence the error of taking 39·37 inches as the length of the metre, and 914·4 mm. as the length of the yard, amounts in the first case to but little more than one part in 100,000, and in the second case to somewhat less than that amount.

These are errors which may be legitimately neglected in all engineering work and in all scientific work done 'with care,' and could only be detected with those elaborate appliances and precautions, and the lavish expenditure of time and money necessary for 'great care': conditions fulfilled only once or twice in a century.

Next as to weights.

Professor Miller's comparison between the imperial lb. and the kilogramme was made 'with great care.' According to him the

$$\text{lb.} = 453{\cdot}59265 \text{ grammes,}$$
$$= 453{\cdot}6\,(1 - {\cdot}000{,}016{,}2).$$

Hence the error of taking 453·6 grammes as equal to the imperial lb. amounts to exactly one-quarter of an imperial grain in the kilogramme, or to a little more than one-tenth of a grain in a pound. This is the weight of a little more than a third of a cubic inch of air; and moreover, it does not come into account except in the rare cases where it is absolute and not relative weights that are in question. Accordingly, for all mercantile, and almost all scientific work, it may legitimately be neglected, and the convenient number 453·6 used for the number of grammes in the imperial lb.

Next as to standards of liquid measure.

The standard gallon is defined by law as containing 10lbs. of distilled water weighed against brass weights, in air, at the temperature of 62° F., the barometer being at 30 inches (see the Acts of 1824 and 1878).

The Royal Commission appointed in 1816, on whose report this definition was founded (of which Commission Kater was a member), determined the weight of a cubic inch of water, weighed as above, to be 252·458 grains; whence it follows that the number of cubic inches in a gallon is 277·2738.[1]

---

[1] This determination was made with 'great care.' Another determination, which however does not appear to be entitled to more authority, has since been made with 'great care,' and according to it the number of cubic inches in a gallon is 277·123. Hence between two determinations made with 'great care' the difference is more than five parts in 10,000. In fact, *the determination is of such a kind that the probable error must necessarily be large.* Nor need this surprise us when we consider the definition which the Acts of Parliament lay down. Water, if exposed to air, absorbs gas: this renders its density indefinite. The temperature to be determined, 62° F., is one which cannot be determined with such accuracy as to avoid a sensible variation in

Combining this datum with Clarke's value for the yard, viz.:

yard = 914·39180 mm.,

and Miller's value for the lb. avoirdupois, viz.:

lb. = 453·59265 grammes,

we find

gallon = 4543·58 cubic centimetres.

= 4544 (1 – ·000,09),

so that the error involved in taking 4544 as the number of cc. in a gallon is less than one part in 10,000. Now the density of water is not known to this degree of accuracy, and accordingly no experimental determinations that have been made are competent to detect the difference. It is, accordingly, legitimate to neglect it and to use the convenient number 4544 as the number of cubic centimetres in a gallon.

We thus find that we may take as our fundamental units—

	Authority.
Yard = 914·4 millimetres, with an error which is less than a fifth-metret[1] in a metre, ...	*Clarke.*
Lb. = 453·6 grammes, with an error of about 7 milligrammes, *i.e.* a little more than the tenth of a grain in the lb., .	*Miller.*
Gallon = 4544 cc., with an error that is less than a cubic centimetre in ten litres.	*Clarke, Miller, Royal Commission of* 1816.

Now the first of these numbers happens to be divisible in succession by 3, by 12, and by 2; the second by 7 and by 8; and the

---

the density of water within the limits of the probable error. And, finally, the volume of the solid must be determined which has to be weighed successively in water and air. This determination is a very difficult one, and probably would not admit with the utmost care of a smaller probable error than one or two parts in 10,000.

The solid used in the later determination was a round cylinder with flat ends. I would suggest as a better form a cube or tetrahedron, the faces of which could be polished flat, and the flatness tested optically. This would ascertain that they had the intended flatness within about two seventh-metrets. (The seventh-metret is the ten-millionth of a metre.)

[1] The fifth-metret is the hundred-thousandth of a metre.

last by 64! This extraordinary concourse of fortunate circumstances makes it possible to base on these numbers the following exceedingly simple tables for the conversion of imperial and metrical measures into one another.

MEASURES OF LENGTH.	Correction,[1] in cases which require the last degree of refinement.
yard = 914·4 mm.	Subtract 9 from every million.
foot = 304·8 ,,	
inch = 25·4 ,,	
½ inch = 12·7 ,,	
metre = 39·37 inches.	Add 11 to every million.
WEIGHTS.	
lb. = 453·6 grammes.	Subtract 16 from every million.
½ lb. = 226·8 ,,	
¼ lb. = 113·4 ,,	
2 oz. = 56·7 ,,	
oz. = 28·35 ,,	
grain = ·0648 ,,	
gramme = 15·4321 grains.	Add 16 to every million.
LIQUID MEASURE.	
gallon = 4544 cc.	Subtract 1 from every 10,000.[2]
½ gallon = 2272 ,,	
quart = 1136 ,,	
pint = 568 ,,	
½ pint = 284 ,,	
naggin = 142 ,,	
½ naggin = 71 ,,	
fluid oz. = 28·4[3] ,,	

[1] All the corrections are subtractive when British is being converted into metric measure, and are, consequently, additive when converting metric into British.

[2] This is the correction to make the result accord with the weight of a cubic inch of distilled water, weighed in air against brass weights, at the temperature of 62° F., and barometer pressure of 30 inches, as determined by the Royal Commission appointed in 1816. To make the result conform to the more recent determination, the correction to be subtracted is six parts in every 10,000. Neither correction is beyond the limits of uncertainty in the determinations.

[3] The number of cubic centimetres in a British fluid oz. exceeds the number of grammes in an oz. weight, because of the expansion of water between the temperature of its greatest condensation and 62° F.

The very simple numbers in the left-hand column of these tables are sufficient for all mercantile and engineering, and for nearly all scientific purposes; and if on some rare occasion any person should need to bring his computation into *full* accordance with Clarke and Miller's determinations, he may do so by making his reductions with the simple numbers, and then applying to his results the corrections indicated in the last column.

It is very desirable, in the interests of all British subjects who use metric measures, that these remarkably simple numbers shall be legalized for the conversion of imperial and metrical measures into one another, whenever next there is a Weights and Measures Bill before Parliament.

Meanwhile, they may be adopted in scientific laboratories.

XXXVI.

ON THIOCAMF: A NEW DISINFECTANT MATERIAL. By J. EMERSON REYNOLDS, M.D., F.R.S., Professor of Chemistry in the University of Dublin.

[Read May 22, 1889.]

Every practical physician is asked from time to time "How can I most easily disinfect that room?" after infectious illness or death has occurred in a household: and the answer is by no means simple. The difficulty is to recommend anything sufficiently easy of application in which confidence can be placed.

Chloride of lime, Condy's fluid, carbolic acid, &c., are all more or less good if they can be brought into direct contact with the things to be disinfected; but that is just the difficulty in the case of a room, for mere exposure of the above-named substances in solution or otherwise in a chamber is useless. If carefully *sprayed* they—especially carbolic acid—can do effective work; but thorough spraying involves the presence of the operator in the room, to his discomfort and possible danger, or the use of costly and troublesome apparatus.

It is evident then that apartments can only be disinfected in any real sense by gases or vapours of very volatile substances which are known to possess the requisite power of destroying the vitality of various bacteria. We are therefore practically reduced to chlorine gas, nitrous fumes, or sulphur dioxide gas; but all the common methods for the production of these in sufficient quantity are more or less dangerous, and disinfection by them can only be properly carried out by skilled persons, since there is risk of corrosion by powerful acids, or of setting fire to woodwork, &c.

Since writing the chapter on "Disinfection and Contagion" in the "Manual of Public Health," I have sought some simpler means than is there recommended for disinfection of rooms, so that any intelligent person could attain the end in view without risk of fire, without the use of corrosive materials, or of large quantities of any agents, and without involving the presence of the operator in the room, or the employment of special apparatus.

This search has been successful, and I have now the pleasure of bringing under your notice the singular liquid which fulfils the conditions I have just specified, and to which the name of Thiocamf has been given.

The basis of this novel disinfectant is a very curious liquid which results when sulphur dioxide gas is brought in contact with camphor. At ordinary temperatures the gas alone requires a pressure of more than two atmospheres to liquefy it; but camphor, owing to chemical attraction, can liquefy the sulphur dioxide gas without any pressure whatever. In this liquid are dissolved several known bactericides, therefore Thiocamf is *all* disinfectant; but I am not free to enter into further particulars as the patent specification has not yet been published.

A quantity of the liquid has been preserved in my laboratory for nearly two years in a corked bottle, and has not undergone sensible alteration during that time.

Thiocamf possesses almost unique properties; for, while it can be preserved *without* pressure in bottles at mean temperature, mere exposure of the liquid in a thin layer to the air determines the steady evolution of relatively enormous volumes of sulphur dioxide gas from it, charged with the vapours of other powerful disinfectants. These gases and vapours diffuse through the whole of the air of a well-closed room, and therefore must reach everything in the room if given reasonable time.

The question then arises whether the sulphur dioxide gas can destroy the bacteria—particularly the infective forms—when it reaches them. The evidence on this point has hitherto been of a rather loose kind, though the results led to the conclusion that sulphur dioxide gas is a powerful bactericide. Happily the truth of this conclusion has now been placed beyond doubt by a critical investigation of the subject, aided by modern methods of bacteriological study. This examination has been carried out in Paris by MM. Dubief and Bruhl, under the direction of Dr. Dujardin-Baumetz, and the results have been recently communicated to the Academy of Sciences. (*Comptes rendus*, t. cviii., 324.)

Starting with air rich in germs of various kinds, and combining Miquel's method of numbering the bacteria with alkaline culture, Dubief and Bruhl found that the germs were always reduced in number after the action of diluted sulphur dioxide gas; therefore the latter destroyed the vitality of bacteria. It was further found that the number destroyed increased with the duration of the action of the gas, and that this destructive action was accelerated when the humidity of the air was increased.

In all the experiments with the rather dilute sulphur dioxide gas used the *latter proved particularly fatal to micrococci* and allied bacteria, whether diffused through the air of a chamber or attached to its walls. As these are organisms of the class which true disinfection seeks to destroy, this testimony to the value of sulphur dioxide is of exceptional importance.

Lastly, those investigations have shown that sulphur dioxide gas is a true bactericide even in a dry state, though longer time is then required for the production of its full effect.

The bearing of these results on the value of Thiocamf is obvious, for if simple sulphur dioxide gas be the powerful bactericide MM. Dubief and Bruhl have proved, the mixture of sulphur dioxide with vapours of other disinfectants of acknowledged value should be a reliable combination. Moreover, there is no material that I know of save Thiocamf which can give off so large a relative volume of sulphur dioxide gas (the contents of a small six ounce bottle can afford over 20,000 cubic centimeters) without any special treatment, save exposure in a very thin layer on an old tray or dish to the air of a room to be disinfected. Further, one ounce of Thiocamf shaken up with a quart of water forms a powerful disinfectant for ordinary purposes, such as sprinkling over various matters, purifying drains, &c.; while a still more dilute solution (one ounce to a gallon) can be used for soaking clothes in which have been in contact with infected persons. The residue of Thiocamf has a pleasant aromatic odour.

This concentrated disinfectant can now be obtained at a cheap rate, as a company, formed for its manufacture, can produce several hundred weight of Thiocamf per week.

XXXVII.

ON THE CONSTITUTION OF ELECTRIC SPARKS.

By W. N. HARTLEY, F.R.S., Royal College of Science, Dublin.

[Read March 20, 1889.]

In the course of my researches on the ultra-violet spark spectra of the elements, a number of isolated observations have from time to time been made, and it is these which I propose to lay before the Society.

An induction coil and a condenser, consisting of a pane of glass coated on two sides with tin-foil, in place of a Leyden jar, is used for the purpose of obtaining brilliant sparks at the highest possible temperature.

Introduction.—Numerous memoirs on the subject of the electric spark have been published, and the following may be quoted as dealing with matters treated of in this communication. Masson's "Études de Photometrie Electrique" (*Ann. de Chimie et de Physique*, 3, xlv., pp. 385–454, 1855) describes the use of the Ruhmkorff coil, and its application to the production of metallic spectra. These are considered to be caused by the incandescence of vapour derived from particles of metal torn off the electrodes. As early as 1853 this author employed a condenser with the coil, for the purpose of increasing the brilliancy of the rays. The action of the spark upon gases was studied. One of the most important conclusions arrived at was the co-existence of two opposite electric currents in the same circuit.

Perrot minutely studied the decomposition of water by the electric spark, and found that two actions occurred side by side: the spark decomposed the vapour of water by reason of its intense heat, and thus yielded the bulk of the mixed gases obtained; but there was also a slight voltaic action. He further caused oxygen and nitrogen to combine by means of the spark, and two well-known lecture experiments illustrating these points are adaptations of his demonstration—"Recherches sur l'action chimique, de étincelle d'induction de l'appareil Ruhmkorff" (*Ann. de Chim. et* *de Phys.* lxi. p. 161, 1861). Theodore du Moncel discovered that the glowing part of the discharge, or aureole which surrounds the fiery path, could be blown aside by a current of air driven into the spark (*Comptes rendus*, xl. p. 313). Perrot, in a later publication, "Sur la nature de l'étincelle d'induction de l'appareil Ruhmkorff" (*Ann. de Chim. et de Phys.* lxi. p. 200, 1861), deals with the nature of the discharge, and proves by a series of ingenious and interesting experiments, that the spark is composed of two parts, of which the fiery track, or central portion, is a statical discharge; the aureole, or flame, is dynamical, and capable of electrolytic action. The two were separated, and their actions studied apart. Lissajous, by means of his well-known method of experimenting, showed that the luminous flame, or aureole, continues to glow for the fraction of a second, whereas the more brilliant fiery track appeared to him to be instantaneous in its passage. This latter he suggested is composed of incandescent particles, torn off the electrodes, which form an incandescent and conducting arc. Perrot confirmed this latter view, and stated that, with a condenser in circuit, the path of the spark is intensely brilliant, but there is little or no flame.

An elaborate paper by Feddersen (*Ann. de Chim. et de Phys.* lxix. p. 178, 1863) established the principles of the mechanism of the Leyden jar discharge. By direct photographs he showed the nature of the discharge, and with the aid of a rotating concave mirror he proved that the apparently simple spark was exceedingly complex, being composed of an initial discharge, followed by as many as 100,000 or 1,000,000 sparks, oscillating between the electrodes in a second of time. These oscillations were rendered visible on a photographic plate, and his paper is illustrated by drawings copied from photographs. Kirchoff showed that Feddersen's result could be deduced mathematically; without demonstration in fact (Poggendorff's *Ann.* cxxi. pp. 551–566, 1864). Von Helmholtz, Sir William Thomson, and Riess have also dealt with this matter. Poggendorff, in his *Annalen* (cxxxii. pp. 107–134), proved that in induction coils the *negative* is the hotter pole. It is the reverse with currents, continuous discharges, and with the brush discharge. The temperature varies with the form, the nature, and the distance between the electrodes. Dewar measured the temperature of the electric spark, and found it to range between 10,000 and 15,000° C. These measurements are based upon the thermal value of each spark, together with the volume of the same (*Proc. Roy. Soc. Edinburgh*, vol. vii. p. 699, 1872). Sir William Thomson calculated the temperature of the sun to be 16,000° C.; it is therefore, comparatively speaking, not much hotter than the spark.

The Relation between the Properties of the Metals and their Spectra.—Sparks which yield the most characteristic spectra may be described as follows:—

I. Sparks from metals which are good conductors:
- (*a*) Metals easily vapourized.
- (*b*) Metals difficult to vapourize.

II. Sparks from bad conductors:
- (*c*) Metals easily vapourized.
- (*d*) Metals vapourized with difficulty.

I. Sparks from good conductors yield spectra with long lines, usually isolated, or distributed in definite groups. The lines are generally strong and continuous from point to point. If the metals are easily vapourized, the lines extend above and below the points of metal to a distance which not infrequently is quite the length of the line which occupies the distance between the points. When the metals are difficult to vapourize, the extension of the lines is very slight, and a number of lines are so short as not even to stretch from point to point.

II. Sparks from bad conductors show few long lines, but many short ones. The lines are generally of feeble intensity, and they are not extended above and below the extremities of the points of metal. If they are easily volatilized, a band of continuous rays is seen at the extremities, and this joins lines of different wave-lengths.

Metals which are bad conductors, and are difficult to vapourize, show lines which are short and of feeble intensity. As the points get heated, the lines lose their intensity unless they are cooled by immersion in water. Under this latter condition these lines are prolonged, but never extended, beyond the upper and lower points.

The Appearance of Impurities in Spectra.—As a general rule it is best for the negative electrode to be placed below, so that sparks pass upwards, carrying a charge of metallic vapour. The direction of the current should not be reversed. Under these circumstances those metals which are present in very minute proportions, such as traces of impurities, are recognized by their longest lines becoming visible at the position of the negative electrode only.

Silver has thus been detected in what was supposed, from its mode of preparation, to be pure copper, zinc in cadmium, cadmium in zinc, copper in aluminium, and magnesium in graphite. It might be supposed that the negative supplies vapour at the highest temperature, and that a portion of this becomes dissipated or oxidized, perhaps even condensed, before the spark touches the upper electrode; but this is not the explanation of the fact which I propose to give. It will be dealt with later on in connexion with the oscillation of the electric discharge. I have elsewhere proved that photographs produced under similar conditions always yield the same metallic spectrum.

On the Path of the Sparks.—Sparks of great intensity, which pass from one metallic point to another, are distinguished by their brightness and the loud noise produced during their passage. A rapid succession of sparks causes a noise which is sometimes almost deafening, and the light is apparently continuous and very brilliant. When single sparks are photographed, there are seen on or below the edges of the electrodes minute bright points, and joining the electrodes is an irregular path described by the incandescent vapour. Two sparks in rapid succession do not take the same path, though they may pass from and to the same points. The most curious effect is caused by a short succession of sparks; they form a brush or bundle of what has the appearance of threads twisting round each other, much in the same way as the fibres from an untwisted piece of twine. Each of these is a stream of metallic vapour, and between and around them is the air heated to incandescence.

The Shape of the Sparks.—It has been stated that the sparks are irregular in their course, and that they seldom, if ever, pass from and to the same point; accordingly it is a matter of interest to ascertain whether the shape of their section is flat, square, circular, or irregular. In order to prove this, sparks were passed through paper, tin-foil, and very thin films of mica, the electrodes being gold. The perforation caused by a single spark in mica or tin-foil is circular. Under the action of a rapid succession of sparks this form is generally maintained, but occasionally the perforation is irregular, but never angular, the mica being fused. The fused mica forms a lip round the hole, which sometimes resembles a little crater when examined by the microscope. Sparks passed through paper form a circular perforation as far as the fibres will admit of this. The fibres are torn up at the surface, and below these the perforation is seen. The edges of tin-foil through which the spark has passed are fused and thickened; in the centre is a dark spot but no *visible* perforation.

The Size of the Sparks.—On measuring the area covered by the inner portion of metal, supposed to be gold deposited on tin-foil by single sparks, it was found to be generally 0·016 of an inch in diameter, and the exterior diameter of the surrounding annular raised portion of metal was 0·04 inch. They have been seen as large as 0·02 and 0·048, though the majority appeared to measure no more than 0·002 and 0·006 inch.

The Rapidity of Passage.—In estimating the rapidity with which a succession of sparks pass when spectra are being photographed, two methods have been employed on different occasions. In 1878 I used a vibrating spring as a commutator, and, from the number of times the circuit was broken, the number of sparks necessary to yield satisfactory results was found to be not less than 600 per minute. Latterly the number has been estimated by drawing pieces of paper and tin-foil between the electrodes, and counting the sparks in spaces which have passed in one second of time. These were found to average 23; they were as many as 27, and occasionally as few as 16. Paper, however, somewhat interferes with the freedom in passage of the sparks, and we may safely say that fairly long sparks are generally as numerous as 1500 per minute. Short sparks, calculated from the musical note of the commutator, must be very considerably greater in number than this; but it is not possible to make sure of a spark discharge occurring at each making of contact; and indeed it is almost a certainty, though this has not been proved, that several contacts occur before the passage of the spark.

On the Chemical Constitution of Electric Sparks.—We are aware from the spectrum of condensed sparks that they are composed of a mixture of air and the vapour of the electrodes. It is possible, however, to condense the vapour and examine the metal which it deposits, and recognize certain metals by the colour and other appearances of the very attenuated films of metal and of metallic oxides which the spark deposits.

The elements examined so far have been—*Gold*, *Silver*, *Platinum*, *Palladium*, *Iridium*, *Copper*, *Lead*, *Tin*, *Arsenic*, *Antimony*, *Bismuth*, *Thallium*, *Magnesium*, *Zinc*, *Cadmium*, *Iron*, *Cobalt*, *Nickel*.

Gold.—Faraday's deposits of thin films of gold are of two colours, ruby-red and purple; gold leaf is green.

Now as the vapour taken from a point of gold by an electric spark must be extremely attenuated, and very minute in quantity, the only chance of recognizing it is to cause it to deposit on some transparent surface. Sparks passed over thin films of mica deposit on the surface faint bluish streaks of extreme beauty, like the bloom on a grape. Occasionally the palest possible rose-colour is spread over the surface. The appearances, which at first sight are not easily discernible, are plainly visible even when caused by a single spark, when the eye is familiar with them. To increase their visibility, they were made to strike the polished surface of a piece of platinum foil, which was supported horizontally between the points, the path of the spark being vertical. After five minutes the appearance of the metal was altered so that the polish was destroyed on both surfaces, but there was no evidence by its colour of a deposit of gold, but minute globules of metal were visible. It seemed probable that the roughness on the under surface was caused by the vapour of gold being condensed on the under surface, and that the platinum melted and volatilized when the sparks sprang off at the other side. The metal was not perforated, as was the case with tin-foil. By using a very thin film of mica the sparks at first traversed the surface horizontally in every direction, sometimes springing over the edges; but they soon perforated the film, and a succession of sparks during four minutes deposited on the under surface a very beautiful film. The hole is rounded, and the mica is fused: around this a circular deposit, from half an inch to an inch in diameter, is seen of an exquisite blue colour, verging near the outer edge upon green (pl. VI.). The part towards the centre is more or less opaque, but a fine ruby or rose-red is visible. Just around the perforation reflected light shows a fine deposit of gold of a beautiful reddish colour with metallic lustre ; slightly removed from this a greenish tinge, irregularly disposed, is seen, while here and there yellow and brilliant films spread till their tenuity does not admit of light being reflected. The appearance is most beautiful when viewed under the microscope with a power of 100 diameters. Around the perforation and at a slight distance, or even upon its edge, the mica is encrusted with globules of gold. The faint bluish tinge may be traced over an area equal to at least a square inch, but it is circular in form. There is no evidence to show why the thinnest films are sometimes red, and at other times blue. The same differences in colour are to be observed even where the gold is thickest. All cracks and fissures in the mica are filled with gold, even in places where none is condensed upon the smooth surface.

Silver.—Silver forms a film which is of varying shades of yellow, amber, and even rose-coloured or violet, the rose tint appearing in patches where the film is very thin. At the edge of the perforation a deposit of frosted silver is seen by reflected light, and this is either brown or quite opaque. The microscope reveals that the opaque incrustation consists of minute globules of silver. The area covered by the incrustation and film is similar in size to that formed by the gold, though the colour of the gold, being much stronger and more peculiar, can be traced over a larger area (pl. VI.).

Platinum.—Platinum yields a smaller sublimate of an intensely deep rich-brown colour, showing that it is less volatile. By reflected light its metallic lustre and characteristic colour appear, and the microscopic appearance is that of an aggregate of minute globules of the metal.

Palladium.—Palladium yields a film very similar to that of platinum as to colour, but it covers a much larger area, the diameter of the outer circular sublimate being at least twice as great as that of platinum.

Iridium.—Iridium condenses in a manner very similar to that of platinum, but the colour is strikingly different, being of a beautiful grey. The deposit of metal is smaller, but the difference is not very marked.

Copper.—Copper forms a black, and at the edges a brown, film, but there is no metallic lustre visible except on using the microscope; the globules, which are very minute and sparsely distributed, alone display this lustre. The deposit is comparatively small in area.

Lead.—Lead forms a larger deposit, consisting entirely of oxide. It is white at the outer edge, yellow and brown as it approaches the perforation, and at the centre occasionally vermilion-red in colour.

The lips of the perforation are quite smooth and rounded in shape, never jagged, and the perforation is much larger than with other metals. These effects are caused by the great fusibility of the slag formed by the action of the lead oxide on the mica. In every direction around the hole drops of slag are projected, and are seen on the mica.

Tin.—Tin forms a deposit of white oxide similar in size to that of copper.

Arsenic.—Arsenic forms a very large deposit of white oxide. Round the perforation a brown to black deposit of the substance, in an unoxidized form, is visible by transmitted light, and a small ring by reflected light.

Antimony.—Antimony forms a large deposit, smaller, however, than that of arsenic. It is bluish at the edges, and becomes denser and whiter towards the centre; around the perforation it is yellow. It is composed entirely of oxide.

Bismuth.—Bismuth gives a fine brown deposit, which is stronger and larger than that of antimony. Its appearance is very striking. No metal present. Slag is very fusible, as with lead.

Thallium.—Thallium yields a dark-brown deposit of large size, presumably all oxide. It is very striking and characteristic.

Magnesium.—This metal yields a white deposit.

Zinc.—The deposit of zinc is fairly large, and varying in colour from white at the edges to yellow at and towards the centre. Probably, if it contained no *trace* of cadmium, the deposit would be entirely white.

Cadmium.—Cadmium gives a fine large deposit of a rich brown tint, verging on yellow, when the film is very thin. It appears to be entirely composed of oxide.

Graphite.—This substance yields a black deposit of carbon.

Iron.—Pure iron forms a dense brown to black deposit, confined to a small area round the perforation. In the thinnest part of the film the transmitted light is reddish, varying from a chestnutbrown to foxy-red. It was observed that the iron punctured a smaller point than most other metals.

Cobalt.—Cobalt gives a dark-brown deposit, quite different from that of iron, both in colour and general appearance, being much larger around the perforations. The fluxed mica is sometimes coloured pale blue.

Nickel.—Nickel is deposited as oxide of the same colour as that of cobalt, but the quantity is smaller, and not distributed over so large a space.

In every case the negative electrode was below, and the discharge took place in one direction, namely, from below upwards; so that it is evident from the deposits being always very much more abundant on the under surface of the mica, that—(1) each spark carries from the negative electrode a charge of metallic vapour; (2) that the vapour is most abundant in the centre of the spark; (3) that where the vapour condenses the quantity of vapour decreases as the distance from the centre increases; but that the vapours of a metal like gold, which is not oxidized, is carried to a considerable distance over a circular area surrounding the body of the spark; (4) that the vapour of an oxidizable metal is oxidized by the surrounding air.

In the case of arsenic, the abundance of the vapour was greater than the air in the spark was capable of oxidizing, but such vapour as escaped outside was oxidized. There is, however, good reason for believing that the column of incandescent matter is a mixture of metallic vapour and air, and not an arc of metallic vapour surrounded by incandescent air.

The Reason why Sparks ultimately take a definite Direction when discharged over the Surface of a Non-conductor.—It has been observed that when electric sparks are discharged at the surface of a film of glass or of mica, that the discharge for a time takes no definite direction, but is in all directions round a central point distributed in minute flashes. After an interval a dense spark flashes along two or three times consecutively in one direction; it then either passes over the edge of the film, and so traversing the opposite side reaches the positive electrode, or it perforates the non-conductor at some point in its path. Each spark deposits some metallic vapour, and if several sparks intersect the path of some other spark, then a deposit of metallic particles is formed, sufficiently thick to become a less imperfect conductor than the film of mica. Successive sparks traversing this path deposit more and more metal, until the conducting surface is sufficiently good for the current to traverse it continuously, then at some point where an inequality in the surface, or an imperfection in the material of the non-conductor, admits of a perforation, and the spark passes once and continues to pass subsequently.

Effects caused by the Oscillation of the Electric Spark.[1]— According to Feddersen, in the Paper already quoted in the Introduction, the number of oscillations is estimated to be over 100,000, and often more than a million per second. The inertia of the discharge causes it to overshoot the mark first in one direction and then in another. This is quite in accordance with certain facts which I have long since observed; and recent experiments of mine have shown that another proof of these oscillations is easily obtainable.

When photographs of the spectrum of the sparks from a good conducting and easily-volatile metal, like zinc or cadmium, are carefully examined, the negative electrode exhibits a series of long lines, with a nimbus and an extension below the point of metal. The positive electrode which is uppermost shows the same extension and nimbus, nothwithstanding that the spark is supposed to pass from the negative to the positive only. If the positive electrode is of some other metal the negative does not yield lines which stretch quite across from point to point, or if so, the lines have only one nimbus around the negative point. This nimbus has always been attributed to the silent discharge which takes place at every little roughness and irregularity on the electrode. If, however, there is a nimbus at the upper or positive electrode, this must be due also to a silent discharge of an opposite character.

---

[1] Professor Oliver Lodge, in a lecture delivered at the Royal Institution, has quite recently (March 9th) demonstrated the character of the Leyden jar discharge. In *Nature* (vol. xxxix. p. 471) he attributes the discovery to Joseph Henry, of Washington, and quotes from his writings, published as early as 1842, from which the following extract is taken:—"The discharge, whatever may be its nature, is not correctly represented (employing for simplicity the theory of Franklin) by the single transfer of an imponderable fluid from one side of a jar to the other; the phenomenon requires us to admit *the existence of a principal discharge in one direction, and then several reflex actions backward and forward, each more feeble than the preceding, until the equilibrium is obtained.*"

Now we know that there is no alternation of the current, and that the passage of the spark is from below upwards; accordingly, the spark to produce this effect must oscillate. Obviously, however, if the spark is passing upwards from below, and the oscillations are very numerous, the aggregate effect will be to make the lower electrode more largely contribute vapour to the spark. Photographs of lines in the spectrum indicate this. To this is to be attributed the fact that lines of impurities present in minute proportions, and likewise the lines of metals present in very dilute solutions, are seen only at the lower or negative electrode, that is to say, they proceed from the point at which the initial discharge takes place.

If now this view cannot be accepted without further proof, it is to be obtained by placing a thin film of mica in the path of the spark. The mica, after it has been perforated, and the spark has passed for an interval of about four minutes, has a much larger deposit upon its lower than on its upper surface, though the electrodes are of the same metal. If the spark is reversed the positions of the larger and smaller deposits are reversed. To put this proof to a still more rigid test the lower electrode should be of graphite, and the upper one of gold. Under these circumstances, the graphite being the negative, gold is found to be deposited upon the upper surface of the mica, and carbon only upon the lower. Reverse the current and much more gold is deposited upon the upper surface of the mica, and little or nothing on the lower, because the carbon is combustible and but slightly volatile. Now in the former instance the deposit of gold could only be formed by the rebound, so to speak, of the electrically-charged vapour.

It will thus be seen that the oscillations of the spark discharge can fully account for the following facts:—

1st. The occurrence of lines in the spectra of the metals with a nimbus surrounding each electrode.

2nd. The extension of the lines of both electrodes.

3rd. The formation of deposits on both surfaces of a non-conductor interposed in the path of the spark; the deposit being more copious on the surface nearest the negative electrode.

4th. The appearance of lines due to impurities or traces of metals in the spectrum of the negative electrode only.

On the Cause of a continuous Spectrum accompanying that of Metallic Lines.—A careful examination of my series of photographs has shown that certain spectra show more of a continuous spectrum than others (pl. VII.). These are characteristic of those metals which are readily vapourized, and which are oxidizable—in fact those which yield the most copious deposits of oxide on the mica films. Without entering into any elaborate explanation to account for a metal like magnesium, which is both volatile and oxidizable, yielding only a feeble continuous spectrum, it may be remarked that the chemical action of the rays emitted by this element is much more powerful than is the case with other metals, and therefore the requisite quantity of metal volatilized and capable of oxidation is less than with other elements, and consequently there is a smaller quantity of oxide to render incandescent. But comparing the spectra of gold and silver, which are largely volatilized, with tin, lead, and cadmium, we see that the former, which yield no oxide, give little or no continuous spectrum, while the latter yield a rich one. Tellurium, arsenic, and antimony, are also similar in this respect. Accordingly, the continuous spectrum is generally to be attributed to the incandescent solid particles of oxide which are formed from the vapour.

DESCRIPTION OF PLATES VI. AND VII.

PLATE VI.

Films deposited upon mica—Silver, brown; Gold, blue.

PLATE VII.

a. Continuous line in the Photographed Spectrum of Cadmium reaching from point to point of metal.

b. b. Two lines of lead occurring as an impurity in the Cadmium appearing at the negative electrode only.

c. One of the principal lines of Cadmium, showing a nimbus, and an extension above and below the position of the point of metal. It will be seen that the extension is greatest at the negative electrode, as if the discharge started from this point. From left to right a continuous spectrum is seen.

XXXVIII.

ON THE PERCENTAGE RELATIONS TO ABSOLUTE ALCOHOL AND PROOF SPIRIT OF THE ALCOHOLIC BEVERAGES IN ORDINARY USE. By HARRY NAPIER DRAPER, F.C.S., F.I.C. (Plate VIII.)

[Read November 20, 1889.]

The accompanying table (Plate VIII.) has been designed with the view of presenting graphically the alcoholic strength of alcoholic liquids commonly used as beverages or stimulants. The information which it gives is to be obtained in books, but certainly not all in any one book or anywhere concisely. Even among medical men and chemists the conception of such relations is anything but precise. Therefore the primary idea in constructing the table was that it should show at once centesimally, and by the simplest calculation relatively, what these relations actually are. That the information thus conveyed cannot but be useful to the physician, who has at one time to administer alcohol, or at another to control its use, I cannot doubt. Nor can I question that there are many of the general public who will feel interested in being easily able to find out for themselves how much *alcohol* is actually present in an ordinary alcohol-containing fluid. And it is not perhaps necessary to point out that to those who, on the one hand, are interested in the cause of temperance, and to those who, on the other, indifferent to this question, have direct business interest in some one or other form of alcoholic beverage, such a table can hardly fail to be directly useful. The pharmaceutical chemist, for example, will find the columns which express the relations of *rectified spirit* and of *proof spirit* to absolute alcohol, and to each other, not without importance. The brewer may take note of the small alcoholic distance which separates the results of fermentation by the German system, from those obtained by English methods; and the manufacturer of mineral waters may observe that only 5 per cent. of alcohol added to one of his beverages would give it the alcoholic content of Lager beer.

The data from which the table has been constructed will be found to coincide with those given by the best authorities, but, as regards wines, have really been obtained in every instance from the mean results of an extended series of original determinations.

Represented in figures, they would stand thus:—

Column.	Denomination.	Percentage of Alcohol by Volume	Percentage of Proof Spirit by Volume.	Percentage of Spirit at 10 Under Proof by Volume.	Factor for Alcohol.	Factor for Proof Spirit.	Factor for Spirit at 10 Under Proof.
1	Absolute Alcohol, .	100	177·2	194·92	—	—	—
2	"Rectified Spirits," .	88	156·0	171·60	—	—	—
3	Proof Spirit, . .	57	100·0	110·00	—	—	—
4	Whiskey, Brandy, Rum, at 10 U. P.,	51	90·0	100·00	0·51	0·900	—
5	Hollands, . . .	49	86·0	94·60	0·49	0·860	0·946
6	London Gin, . .	47	82·40	90·64	0·47	0·824	0·906
7	Port, Sherry, Madeira, 2/6 duty,	21	37·13	40·84	0·21	0·371	0·408
8	Port, Sherry, Marsala, 1/- duty,	15	26·66	29·32	0·15	0·266	0·293
9	Burgundy, Sauterne, Hungarian Wines,	14	25·01	27·51	0·14	0·250	0·275
10	Champagne and other Sparkling Wines,	12	21·08	23·18	0·12	0·210	0·231
11	Clarets and Hocks, .	10	17·56	19·31	0·10	0·175	0·193
12	Strong Ales, . .	10	17·56	19·31	0·10	0·175	0·193
13	Guinness's Stout and Bass's Ale,	6	10·55	11·60	0·06	0·105	0·116
14	Lager and Pilsener Beer,	5	8·81	9·69	0·05	0·081	0·070

Explanation and Application of the Table, Plate VIII.

The first column represents *absolute alcohol*, and is coloured *red*. The third,[1] *proof spirit* (that is, alcohol of specific gravity, ·920), and

[1] Column 2 represents what is commonly called *rectified spirit*, that is, spirit containing 88 per cent. of absolute alcohol; and its introduction, though not necessary for other purposes of comparison, will be seen to have a not unimportant technical value.

at its upper end is coloured *blue.* The fourth column, terminating in *yellow*, represents spirit containing 90 per cent. of proof spirit, the strength at which whiskey, rum, and brandy are (or are supposed to be) generally sold.

These are the standard or reference columns; and to obtain the alcoholic percentage of the liquid in any other column in terms of these standards, it is only necessary to note what marginal figures are intersected by a straight-edged rule laid across the upper terminations of either red, blue, or yellow :—

Red	indicating	*Absolute Alcohol.*
Blue	,,	*Proof Spirit.*
Yellow	,,	*Spirit of* 10 *Under Proof.*

For example: 100 parts of London gin are equal to 47 parts absolute alcohol, 82·40 of proof spirit, and 90·64 of whiskey, brandy, or rum, at 10 per cent. under proof. Therefore, by multiplying any given quantity of London gin by 0·47 we obtain the alcoholic equivalent of that quantity in absolute alcohol, by 0·824 in proof spirit, and by 0·906 in terms of whiskey. The same method of calculation is applicable throughout.

But that the table shall be of practical use, it is necessary that the volume contents of the "glasses" from which alcoholic beverages are most ordinarily consumed shall be known. These of course vary, but the following figures may be considered as giving a close approximation to the mean contents of the "glasses" and "bottles" in common use. The standard of measure employed is the fluid ounce or one-twentieth part of the imperial pint.

Whiskey, sherry, or port,	glass	=	2·5	ounces.
Claret or Champagne,	,,	=	4·0	,,
"Dock,"	,,	=	5·0	,,
Ale,	,,	=	10·0	,,
Small bottle, beer or wine		=	12·5	,,
Large bottle, beer or wine		=	25·0	,,

In order to illustrate the use of the table, a hypothetical case may be taken, in which it is desired to ascertain the quantity of *absolute alcohol* ingested by a person who in the course of a day has taken a glass of sherry, a small bottle of Lager beer, and a glass of whiskey. The absolute alcohol factors are first obtained by dividing the percentages by 100, thus :—

Sherry, . .	21 ÷ 100	= 0·21,
Lager beer, .	5 ÷ 100	= 0·05,
Whiskey, . .	51 ÷ 100	= 0·51 ;

and these factors are then multiplied by the quantities taken—

Sherry, . .	2·5 × 0·21	= 0·525,
Lager beer, .	12·5 × 0·05	= 0·625,
Whiskey, . .	2·5 × 0·51	= 1·275 ;

thus giving a total of 2·425 fluid ounces of absolute alcohol. The equivalents in either the proof spirit or the whiskey standard may be similarly obtained. If objection be taken to the very slight trouble involved in obtaining the factors, they will be found stated to the third decimal place in the three last columns of the figure table, which, like the coloured plate, is based upon the nearest whole numbers in terms of absolute alcohol. Finally, the practical deduction from the most generally useful of the above data may be summed up as follows :—

Quantity and Kind of Alcoholic Liquid.	Equivalent in Ounces of Absolute Alcohol.
"Glass" of Whiskey, Rum, or Brandy, .	1·27
,, of Hollands, ...	1·22
,, of London Gin, ...	1·17
,, of Port, Sherry, or Madeira, 2/6 duty,	0·52
,, of ,, ,, ,, 1/- ,,	0·37
"Pint" bottle of Burgundy or Sauterne, .	1·75
,, ,, of Champagne, . . .	1·50
,, ,, of Claret or Hock, . . .	1·25
,, ,, of Stout or Ale, . . .	0·75
,, ,, of Lager Beer, . . .	0·62

XXXIX.

NOTE ON THE CONJUNCTION OF SATURN AND MARS ON 19TH SEPTEMBER, 1889. By ARTHUR A. RAMBAUT, M.A.

[Read November 20, 1889.]

On the morning of the 19th September, although there were large masses of clouds scattered over the sky which more than once seemed about to hide all, yet the region of the sky containing the bright stars, Regulus, Saturn, and Mars, remained unobscured until within a few minutes of sunrise.

At about half-past three, mean Dublin time, the group rose above the mists of the horizon sufficiently to be well seen; and at this time the two planets presented very much the appearance of θ Tauri, which was then high in the heavens. Perhaps the most striking feature at about this time was the insignificant appearance of the planets themselves. Unconsciously one was inclined to expect that Mars would present the brilliant aspect with which we are familiar at opposition, whereas Mars, Saturn, and Regulus, all appeared of nearly the same brightness. In this respect Venus, which stood a few degrees above and to the south, presented a remarkable contrast, being much more on a level with the waning moon which, in the shape of a thin crescent, hung a little way above.

The comparative faintness of Mars was, of course, due to its being not very far from conjunction with the sun, and in consequence nearly at its greatest distance at the time.

The apparent diameter of this planet varies from about 3″ at conjunction to about 26″ at opposition. On the morning of the 19th its diameter was 4″·8; so that the amount of light we received from it was only about the $\frac{1}{25}$th of what we receive at opposition.

At this time too, before daylight became too strong, the colours were very strikingly contrasted. That of Mars was a ruddy orange, that of Saturn a pale yellow, while Venus shone like polished silver.

Very soon after the planets rose it became evident from their distance apart, and the sluggish pace at which they approached, that no apparent occultation would take place before daylight obliterated the group, and the greater part of this interval was utilized in taking micrometric measures of the distance between the planets with the Pistor and Martins micrometer, described in Part I. of the Dunsink Observations. The first three measures were made by me, the remainder being obtained by Sir R. Ball, each of us in turn writing down the other's observations so as to save time, as dawn was rapidly coming on. For this reason the observations were made in a somewhat more hurried manner than we could have wished; and it is possible that the number of complete revolutions of the screw may be erroneous, as the scale on which the number of revolutions is read is exceedingly small, and an error of a complete revolution is very easily made. But it is most unlikely that an error of this sort remains in the results given below. I have, however, given the actual readings, as well as the results derived from them, lest such an error should exist.

We first measured the distance between the inner limbs, then the distance between the outer limbs, and then again that between the inner limbs. By applying the value 9″·65 for the sum of the semi-diameters, we obtain the results in the last column for the distance between the centres. It is, of course, possible to obtain two measures of the distance from the series without assuming a knowledge of the semi-diameters; for if we take the mean of the first and third measures, and again the mean of this and the second, we obtain the distance between the centres at $17^h\ 15^m·7$ G.M.T. Similarly Sir Robert Ball's first three measures give an independent result.

The atmosphere was unsteady, and the discs very ill defined at the time of observation. The ordinary working power of 300 was employed, temperature 44°.

No.	G. M. T.	Screw I.	Screw II.	Distance.
1	h. m. 17 11·7	4(9)·236 71·866	21·811 4(6)·913	″ 226·96
2	17 15·7	73·438 47·011	4(6)·912 21·245	224·78
3	17 19·7	47·011 71·156	23·320 45·451	217·90
4	17 43·6	70·888 50·078	43·722 25·227	186·53
5	17 50·6	4(7)·253 68·722	25·227 46·474	182·58
6	18 0·6	65·130 48·648	46·474 29·213	161·51
7	18 8·6	49·932 64·738	29·286 45·646	140·26

The time was taken from a chronometer recording sidereal time, and was read only to the nearest minute. In the case of the last two observations a good deal of time elapsed between the two settings, before and after reversal, owing to interruptions by clouds, and it is possible that the exact time corresponding to the setting may not be very reliable.

With regard to the brightness of the planets it is worthy of remark, that whereas Saturn appeared to the unassisted eye the brighter of the two, the reverse was the case in the telescope. Thus I find in my note-book that, at 17^h 35^m, it was only just possible to glimpse Mars with steady gazing, while Saturn remained an easy enough object to see; but still the two planets were distinctly separated. At the same hour Sir Robert Ball notes:—“Mars ceased to be visible to the naked eye, and Regulus could still be glimpsed. The two planets never coalesced; indeed I was struck by the nearness and smallness of the discs. This was especially noticeable in the opera-glass.” At 18^h 9^m, however, he remarks:—“Further observations of Saturn became impossible owing to daylight, though Mars was still visible.”

XL.

NOTE ON THE MAGNETIC PROPERTIES OF COLUMNAR BASALT. By PROFESSOR W. F. BARRETT.

[Read December 18, 1889.]

Professor Hull having brought under my notice the interesting fact that blocks of basalt from the Giant's Causeway were not only magnetic but magnetized in a definite direction, I thought it would be of interest to submit them to a more careful examination by means of a mirror magnetometer, and at the same time to determine their intensity of magnetization in absolute measure. Examination showed that the blocks had, in general, a strongly marked north and south pole, the magnetic axis running diagonally through the block. The magnetic distribution was, in fact, similar to that of all magnetic bodies submitted to the earth's magnetism in northern latitudes; the magnetic axis being inclined to the horizon approximately at the angle of dip. The concave or less convex side of the blocks was, in each of those examined, a north pole, *i.e.* it repelled a north-seeking pole, and must, therefore, have been downwards when *in situ* at the Causeway: this is, assuming the blocks to have been magnetized by the action of the earth, as was probably the case.

Three blocks, *A*, *B*, and *C*, were now weighed, their respective weights being 27,600, 24,100, and 37,000 grammes. The specific gravity of a fragment of one of the blocks was found to be 2·86. The magnetic moment of each of the blocks was determined by placing it on a turn-table at a given distance from the magnetometer. The deflection produced in one direction having been read, the block was turned round by means of the turn-table, the distance of its centre from the magnetometer remaining unchanged. The deflection in the opposite direction was now read. The moment was then calculated from the formula[1]

[1] This formula can only be regarded as approximately true of the large masses, with feeble subsidiary poles, with which we are here dealing.

$\frac{1}{2}r^3 \tan \theta H$, where r is the distance of the centre of the block from the magnetometer, θ the angle of deflection made by one pole (that is, half the total scale reading), and H the horizontal intensity of the earth's magnetism in C. G. S. units. The total moment of each block, being divided by its weight in grammes, gives the moment per gramme of the basalt. The centre of the blocks was in each case 60 centims. from the magnetometer, the scale of which was 100 centims. distant from the mirror; the total deflection produced by A was 1·2 centim.; by B was 1 centim.; and by C was 1·56 centim. The value of H, determined for the place of observation, was found to be 0·16 C. G. S.; whence we have the moment per gramme of—

Block A = 0·00188 C. G. S. units,
,, B = 0·00179 ,,
,, C = 0·00182 ,,

or a mean of 0·00186.

A small, feebly magnetized steel bar magnet at the same distance gave a moment per gramme of 10 C. G. S. units. Highly magnetized steel runs up to 95 units per gramme, a moment 50,000 times greater than that of the basalt. Dividing the total moment by the volume in C. C., instead of by the weight, gives the intensity of magnetization. In the case of the basalt this is 0·0054. Now, if the earth be regarded as a uniformly magnetized body its intensity of magnetization is 0·079[1], or nearly fifteen times greater than the basalt. Hence, although basaltic masses must cause a considerable local deviation of the compass over a wide area, they cannot be regarded, even if they encompassed the earth, as the source of terrestrial magnetism.

[1] Everett's "Physical Constants."

XLI.

OBSERVATIONS OF THE LATE CONJUNCTION OF MARS AND SATURN. By MAJOR SOMERSET MAXWELL, F.R.A.S.

[Read December 18, 1889.]

On the 20th September, 1889, I was fortunate enough to be enabled to observe the conjunction of the planets Mars and Saturn, under tolerably favourable conditions, at my Observatory in the Co. Cavan,

Lat. 53° 49′ 30″,

Long. W. 0^h 29^m 13^s.

Although clouds were frequent they were not continuous; and the intervals of brightness were of sufficient duration to admit of a fairly satisfactory series of micrometrical determinations of position and distance.

The instrument used was a 6-inch refractor, with bifilar micrometer by Sir Howard Grubb, and the time was taken (with the help of an assistant) from a watch which was compared, both before and after the observations, with a chronometer, the error of which latter was obtained the same day at 3.30 p.m. by a mean of five sextant altitudes of the sun.

Taking into consideration the unfavourable position of the planets (their altitude being from 20° to 30°), the rapidity with which the change, both in position angle and distance, took place, and the frequent interruption by clouds, I deemed it advisable not to attempt the precautions usually taken to secure an accurate result: such, for instance, as measuring on different sides of the central wire, and on alternate limbs of the planets, but to content myself with single measurements whenever I could get them.

The measurements thus obtained, corrected for semi-diameter, are shown in the third and fourth columns of the following table, the fifth of which represents the value of the distance measures corrected for parallax and refraction :—

TABLE OF OBSERVATIONS OF ANGLE AND DISTANCE.

No.	G. M. T.	Pos. Ang.	App. Dist.	Corr. Dist.	Observations.
	h. m. s.	°	″	″	
1	17 17 4	304·0	222·7	225·5	These measurements were taken on the outside limbs of the planets, a correction of 9·6″ (Mars 2·3″, and Saturn 7·3″) applied for semi-diameter.
2	17 19 34	304·5	218·4	221·2	
3	17 22 9	305·0	214·1	216·9	
4	17 31 41	305·8	203·5	206·3	
5	17 35 32	306·0	198·8	201·6	Definition good until about sunrise, when the atmosphere became very unsteady.
6	17 41 51	307·0	191·0	193·8	
7	17 53 49	308·0	176·9	179·6	
8	17 57 37	309·0	171·0	173·7	
9	18 4 7	309·5	162·9	165·6	
10	18 7 56	310·2	157·6	160·2	
11	18 12 39	310·8	153·3	155·9	
12	18 18 47	312·0	145·4	148·0	
13	18 31 46	315·5	130·6	131·1	Saturn very faint; very unsteady.
14	18 41 56	318·5	120·0	122·5	Saturn barely visible; very unsteady.

If the results of these observations are plotted out in a pair of curves, taking the epochs for the line of abscissæ, and the angles and distances respectively as ordinates, we shall find the following interpolated values for each :—

Epoch.	Position.	Distance.
h.	°	″
17·10	303·6	233·5
17·20	304·6	221·0
17·30	305·6	208·5
17·40	306·6	196·0
17·50	307·7	183·0
18·0	309·0	170·5
18·10	310·4	158·8
18·20	312·2	146·5
18·30	314·9	135·0
18·40	318·5	124·0

With the exception of the last two of these, we shall find that the positions are in fair agreement with the computed places; and even in the case of those two, when we take into consideration the extreme difficulty of observation, owing to increasing unsteadiness and faintness of the objects, we shall see that there is no discrepancy which is not well within the limits of probable errors of measurement.

XLII.

FORMULÆ FOR THE EASY DETERMINATION OF GASEOUS VOLUMES AND WEIGHTS. By G. JOHNSTONE STONEY, VICE-PRESIDENT, M.A., D.Sc., F.R.S.

[Read April 10, 1889.]

I HAVE used the following approximate formulæ for several years and found them convenient. They are proved below.

Call the barometric pressure of 760 mm. of mercury at Paris and at freezing temperature the standard pressure. [For most laboratory purposes the usual British standard of 30″ of mercury, at 62° F., may be used anywhere instead of it.]

Then, under standard pressure, and at a temperature of 21° C.,

$$W \text{ (the weight of a litre of any gas)} = \frac{D}{12} \text{ grammes,}$$

and $$V \text{ (the volume of a gramme of the gas)} = \frac{12}{D} \text{ litres,}$$

where D is the density of the gas when compared with that of hydrogen as unit.

At any other temperatures and pressures, not too far removed from the foregoing,

$$W = \frac{D}{12} \pm \textit{a temperature correction,} \pm \textit{a barometric correction,} \quad (1)$$

and

$$V = \frac{12}{D} \pm \textit{a temperature correction,} \pm \textit{a barometric correction,} \quad (2)$$

where the temperature correction is one per cent. for every 3° C. that the temperature deviates from 21°, and the barometric correction is one *per cent. for every $7\frac{1}{2}$ mm., or three-tenths of an inch, that the barometer deviates from its standard height.*

Another very convenient formula—formula (3)—is given in the Appendix. (See page 390.)

These approximate formulæ give results within a few thousandths of the truth under atmospheric changes of the barometer and at atmospheric temperatures, say between − 5° and + 30°. They are therefore quite sufficient for *most* laboratory purposes.

They are easily proved. The weight of a litre of dry air at freezing temperature, and under the pressure of 760 mm. of mercury at Paris, was determined by Regnault to be,

1·2932 grammes.

Using this determination, and Boyle and Mariotte's formula, viz.:—

$$p = k\rho \frac{T}{T_0},$$

we find that the weight of a litre of air under the above standard pressure becomes exactly,

1·2 grammes.

when its temperature is brought to 21°·2 C. This temperature may be taken as 21° in most laboratory work. Next, taking the relative density of air to hydrogen as 14·4, we deduce from the above that at the same pressure and temperature,

the weight of a litre of hydrogen $= \frac{1}{12}$ gramme,

and the volume of a gramme of hydrogen = 12 litres;

whence, for any other gas,

W (the weight of a litre of the gas) $= \frac{D}{12}$ grammes,

V (the volume of a gramme of the gas) $= \frac{12}{D}$ litres,

where D is the relative density of the gas compared with that of hydrogen as unit.

These formulæ refer to standard pressure and 21° temperature.

At other pressures or temperatures a correction has to be applied.

This for variations of pressure evidently amounts approximately to one per cent. for every $7\frac{1}{2}$ mm. [more exactly 7·6 mm.], or ·3 of an inch, that the barometer deviates from its standard height.

To find the temperature correction we must use Boyle and Mariotte's formula, remembering that 294 is the Absolute Temperature of 21° C. Whence

$$\frac{\text{The weight of a litre of the gas at } (21 + \tau)^\circ}{\text{Its weight at } 21^\circ} = \frac{294}{294 + \tau},$$

and

$$\frac{\text{The volume of a gramme of the gas at } (21 + \tau)^\circ}{\text{Its volume at } 21^\circ} = \frac{294 + \tau}{294}.$$

It appears from these formulæ that the correction will amount to one per cent. in the first formula when τ is such that

$$\frac{294}{294 + \tau} = 1 - \frac{1}{100},$$

and, in the second formula, when τ is such that

$$\frac{294 + \tau}{294} = 1 + \frac{1}{100},$$

i.e. when $\tau = 2^\circ{\cdot}97$ in the first formula,

and $\tau = 2^\circ{\cdot}94$ in the second.

In ordinary laboratory determinations it is legitimate to use 3° instead of either of these; by doing which we obtain the very simple rule given in the beginning of this Paper.

APPENDIX.

As an example, apply the formulæ to determine how much zinc is consumed in displacing 7 litres of hydrogen from acidulated water at a temperature of 15° when the barometer reads 31 inches.

The following is a very convenient modification of our formulæ which is applicable to all such cases:—

$$\frac{G_2}{B_2}\left[=\frac{G_1}{B_1}\right]=\frac{D_1}{B_1}\cdot\frac{L_1}{12}, \qquad (3)$$

where

G_2 is the weight in grammes of the reagent,

G_1 the weight of the gas evolved,

B_2 the bond-weight of the reagent as defined below,[1]

B_1 the bond-weight[2] of the gas evolved,

D_1 its density[2] compared with hydrogen,

and L_1 the number of litres evolved.

This formula will find L_1 when G_2 is given, and G_2 when L_1 is given: *i. e.* it will find either the volume of gas which a given weight of the reagent will furnish, or the weight which is consumed in disengaging a given volume of gas, *all at standard pressure and* 21° *temperature.*

To the result so obtained the corrections for temperature and pressure given on p. 387 *may be applied.*

In the present case we are to make L_1 equal to 7, and we know that D_1 is 1; B_1 is 1; and B_2 is $32\frac{1}{2}$. Introducing these numbers we find

$$G_2 = 32\tfrac{1}{2} \times \tfrac{7}{12} = 19, \text{ very nearly.}$$

This accordingly is the number of grammes of zinc that would evolve 7 litres of the gas *at the temperature of* 21° *and at standard pressure.*

To get the result at 15° of temperature, and under 31″ of pressure, we have to correct for 6° deviation in temperature, and 1″ deviation in pressure. Now we found above that the

temperature correction for 6° = 2 per cent.,
barometric correction for 1″ = $3\frac{1}{3}$ per cent.

---

[1] The bond-weight means the part of the atomic weight to be allotted to each bond engaged in the reaction. Thus, the bond-weight of H is 1, and the bond weight of Zn is half its atomic weight, since there are two bonds of zinc engaged in the reaction that occurs in this case.

[2] D_1 and B_1 are usually the same number.

Both of these corrections are additive, for more zinc is required to produce 7 litres of gas at 15° than at 21°, and again more to produce 7 litres of gas under a barometric pressure of 31″ than under 30″, the standard pressure.

Hence our former result has to be increased by $5\frac{1}{3}$ per cent., which brings it up to 20·01 grammes for the weight of zinc that will evolve 7 litres of gas at 15° under a barometric pressure of 31″.

19·00
19
19
19
19
19
6
20·01

This is very nearly identical with the result that would be furnished by the usual much more complicated formulæ.

XLIII.

ON TEXTURE IN MEDIA, AND ON THE NON-EXISTENCE OF DENSITY IN THE ELEMENTAL ETHER. By G. JOHNSTONE STONEY, a Vice-President of the Royal Dublin Society, M. A., D. Sc., F.R.S.

[Read February 19, 1890.]

In the investigations of ordinary dynamics—the dynamics of secondary (*a*) motion—integrations have to be extended throughout the bodies with which we are dealing, or over their surfaces. Now whenever we employ this operation assumptions are tacitly made which do not accord with what exists in real objective nature.

Suppose that the problem is to obtain the pressure of water against a sluice; to ascertain the amount and distribution of the

---

(*a*) In the computations of ordinary dynamics, we conceive the portion of space occupied by the body with which we are dealing to be divided into elements of volume (the $dx\,dy\,dz$'s), which elements of volume we regard as movable. Each of these we multiply by a coefficient called the density, and call the product the element of mass ($dm = \rho \, . \, dx\,dy\,dz$). These elements of mass we picture to ourselves as acting on one another, or as being acted upon by external forces; and from the laws of these actions we endeavour to deduce the motion of the element of volume, carrying its contents with it, and in some cases changing its form or volume.

In this process we take no notice of any motions which may be going on within the element of volume, except so far as that some imperfect account may perhaps be indirectly taken of them when we multiply the element of volume by a density. Nevertheless, in all the real cases that occur in nature, there are, as a matter of fact, *very active* motions of various kinds going on within the element of volume—motions of the molecules which it contains, and still more deep-seated motions within the portion of the element of volume occupied by those molecules, or in the interspaces between them.

Accordingly, the motions with which we deal in our ordinary dynamical investigations are merely drifting motions—the drifting about of elements of volume, within each of which, as events really occur in nature, there are elaborate subsidiary motions going on. Now, *secondary motion* is to be defined as the motion which consists in the drifting about, with or without changes of size and form, of elements of volume, *within each of which there are subsidiary motions.*

If the subsidiary motions consist exclusively of irrotational motions in an incompressible and perfectly fluid medium, they cannot contribute to the density by which the element of volume in which they occur is to be multiplied. It is, however, otherwise if there are any rotational motions present.

pressure, we integrate over the surface between the water and the sluice, and in doing so assume—

1° that the boundary is a surface; and

2° that the elements into which we conceive this surface divided for the purposes of the integration, may be made as small as we please without ceasing to be subjected to the law in heavy liquids of pressure proportional to the depth below the upper surface of the water, plus that due to the superincumbent atmosphere.

Both these assumptions continue approximately true when the elements into which we suppose the surface divided are diminished till they are as small as, or even a good deal smaller than, the smallest spec that can be distinguished with the most powerful microscope; but they utterly break down if we suppose the subdivision carried so much farther as to reach or even approach the scale of molecular magnitudes. If, for instance, the elements into which we suppose the surface divided were reduced to a square tenth-metret (*b*) in size, a patch of surface which is the millionth part of the utmost a microscopist can see, we should have got well within the range (*c*) of molecular differences. The boundary between the water and sluice would cease to be a surface: it would be the continually shifting boundary between molecules on both sides in energetic motion, acting individually on each other in their own special ways; which happen to be such that when immense numbers of these individual operations are lumped together, they produce approximately, as the outcome of all that is going on, that law of pressure proportional to depth with which we are familiar.

Thus, what we regard as a physical property of the medium—

(*b*) The decimetre is the first of the metrets (*i.e.* decimal subdivisions of the metre), the centimetre is the second, the millimetre is the third. The tenth-metret is the tenth of this series. It is a metre divided by 10^{10}. The waves of visible light have lengths varying from 3900 to 7600 of these tenth-metrets.

(*c*) According to Professor Loschmidt, who first published an estimate of the interval within which the centres of two molecules must approach to act sensibly on one another, this interval is about a ninth-metret (Proceedings of the Mathematical Section of the Academy of Vienna, October, 1865, p. 404). The mean of such intervals may, perhaps with more probability, be taken as lying nearer to the tenth-metret. It is very improbable that it is as small as the eleventh-metret. In the present paper I assume it to be about the tenth-metret. If, however, it lies nearer the ninth-metret, we shall have to change 80,000 into 800 on p. 398.

in this case the law of pressure in a heavy liquid—is in reality a statement of what is the drift of a vast number of individual events, grouped together by a kind of statistical process. This we may briefly describe by saying that the dynamical properties of the medium are due to its *texture*, meaning by the texture of a medium whatever is going on in it at close quarters.

It is the same with the other recognised physical properties of media, such as what are called gaseous laws—the laws connecting the density, temperature, and pressure of gases, the laws of their diffusion, the law of viscosity, and so on. Similarly with the properties of solid bodies: all are the outcome of vast numbers of very diverse individual events that occur between or within the molecules of the bodies, or between them and the luminiferous ether.

In order to penetrate to this world of individual actions, we must not only descend to magnitudes that are comparable to the intervals at which the centres of molecules are spaced from one another, but we must also consider periods of time that are not too vast in reference to the motions that go on among them. A second of time is "out of all whooping" too long;(*d*) but a period which is definite and of suitable brevity is that for which I have elsewhere proposed the symbol τ—viz., the time that light takes to advance one millimetre *in vacuo*. The velocity of light being 30 quadrants per second, and the quadrant (the length of a meridian from the Earth's equator to the pole) being 10^{10} millimetres, we find that

$$\tau = \frac{1}{3} \cdot \frac{\text{one second}}{10^{11}},$$

(*d*) See the Philosophical Magazine for August, 1868, p. 140, footnote. Readers of the Paper here referred to are requested to change the square of 16 in the second paragraph into the square root of 16. In that Paper, p. 141, I estimated the number of molecules in a cubic millimetre of a gas, at atmospheric temperatures and pressures, as about a uno-eighteen (10^{18}), without being aware that a similar estimate had been obtained for solids and liquids by Professor Loschmidt in 1865 (Proceedings of the Mathematical Section of the Academy of Vienna for October, 1865, p. 405). In March, 1870, Sir William Thomson, doubtless also without knowing of what had been done before, published a paper in *Nature* on the "size of atoms," and arrives at substantially the same estimates as Professor Loschmidt and myself.

The earliest determination of a molecular magnitude, so far as I am aware, was that made by Professor Clerk Maxwell of the mean length of the "free paths" of the *i. e.* it is one-third of the eleventhet (*e*) of a second of time. In this fragment of time, visible light makes from 1300 to 2600 vibrations according to its colour, so that the mean frequency of vibration of light is about 2000 vibrations during each τ.(*f*) [This mean is the actual frequency of that green ray whose wave length *in vacuo* is 5000 tenth-metrets.]

We may now get some insight into the physical events that occur in the world into which we have passed. The pressure of the air in this room against the walls is, according to the kinetic theory of gases, due to the walls being bombarded by molecules of the air as they fly about like missiles. It is an elementary proposition (*g*) in the kinetic theory of gases that the momentum communicated to the wall is substantially the same when, as actually happens, the molecules frequently encounter one another throughout the room, as it would be if the aerial missiles could be divided into three equal squadrons, one of which should travel uninterruptedly up and down between the floor and ceiling, another squadron travelling horizontally from side to side, and the third squadron from end to end of the room: and all moving with a velocity whose square is the mean of the squares of all the actual velocities of molecules in the room. This "velocity of mean square," as it has been called, depends on the molecular mass and on the temperature of the gas; and in the case of the air in this room it is about 500 metres per second. (*h*) Let us then suppose the wall to be struck by one-third of the molecules in this room, rushing backwards and forwards between it and the opposite wall at this pace; and let us endeavour to form an estimate of how often one of the superficial molecules of the wall will be subjected to an encounter.

The number of molecules in a cubic millimetre of the air is

---

molecules of certain gases in their excursions between their encounters. See Philosophical Magazine for January, 1860, p. 32, and for July, 1860, p. 31. See also Philosophical Transactions for 1866, p. 258.

(*e*) The eleventhet means a unit in the eleventh place of decimals. It accordingly is a name for the fraction 0·000, 000, 000, 01, or $\frac{1}{10^{11}}$.

(*f*) See British Association Tables of Oscillation-frequency, B. A. Report for 1878, p. 40.

(*g*) See Maxwell's "Heat."

(*h*) Phil. Mag., 1857, vol. xiv., p. 124; or Maxwell's "Heat."

known to be about a uno-eighteen (10^{18}),(*i*) and there are of course 500,000 times this number in a column 500 metres long, and a square mm. in section; *i. e.* there are 5 uno-twentythrees in this column. One-third of all the molecules in the column are the squadron that we are to regard as travelling lengthwise—half of these advancing towards one end, and the other half retiring from it. It thus appears that the number of molecules within the column to be taken as travelling at any instant *towards* one end is $\frac{5}{6} \cdot 10^{23}$. This, accordingly, is the number that will strike against a square millimetre of the wall in one second. Now the time τ being, as we have found, $\frac{1}{3}$ of an eleventhet of a second $\left(\frac{1}{3} \times \frac{1}{10^{11}}\right.$ of a second$\left.\right)$, it follows that $\frac{5}{18} \times 10^{12}$ is the number of downright blows that would be delivered by these molecules upon one square millimetre of the wall in the time τ.

This is on the supposition that the molecules are divided into three squadrons. They are not so divided in reality, and accordingly all the strokes delivered against the square millimetre of the wall are not downright blows, but are many of them oblique. An easy computation shows that this will increase the number of blows in the ratio of 3 to 2 : (*j*) so that the real number of blows delivered upon the square millimetre is about $\frac{5}{12} \times 10^{12}$.

(*i*) See footnote (*d*), above. The uno-eighteen means the number represented by 1 with eighteen cyphers after it. It accordingly is the same as 10^{18}.

(*j*) If N be the number of downright blows delivered on a surface s in the time T, and if α be the momentum communicated by each blow; then the pressure they will occasion

$$= \frac{N\alpha}{sT}. \qquad (1)$$

If, on the other hand, the blows arrive from all quarters indifferently, and if dn' be the number reaching s from inclinations between θ and $\theta + d\theta$, θ being measured from the normal, then will

$$dn' = k \,.\, s \cos\theta \,.\, 2\pi d \cos\theta, \qquad (2)$$

where k is such that $k \,.\, d\sigma$ is the number of blows coming from directions lying within an element $d\sigma$ of solid angle, that would be received in the time T, by a unit of surface presented perpendicularly to the shower.

These dn' molecules communicate to s a momentum

$$= \alpha \operatorname{co}\theta \,.\, 2\pi ks \cos\theta d \cos\theta.$$

Next consider the distance within which the centres of two molecules, one a molecule of the air and the other a molecule of the wall, must approach in order that they may sensibly act on one another. A circular disc, with this distance as radius, may be considered as a target towards which the centre of a molecule of the air must be directed in order that this particular molecule of the wall may be reached. Now the distance within which the centres of the molecules must approach lies more probably in the neighbourhood of a tenth-metret than in the neighbourhood of either a ninth-metret or an eleventh-metret.(*k*) Let us for the purpose of an estimate assume that it is a tenth-metret. The size of the target, supposed flat, will then be about three square tenth-metrets. This is 3 fourteenthets of a square millimetre ($3 \times \frac{1}{10^{14}}$ of a square millimetre). Accordingly the number of encounters this molecule will receive in the time τ will be approximately $\frac{5}{12} \cdot 10^{12} \times 3 \cdot \frac{1}{10^{14}} = \frac{1}{80}$. This is on the supposition that the target to be struck is a disc, whereas it is in reality a sphere. This will double (*l*) the number of blows it will be subjected to in the time τ :

Therefore the whole momentum communicated in this way from all inclinations

$$= 2\pi k s a \int_0^1 \cos^2\theta d \cos\theta = \frac{2}{3}\pi k s a\,;$$

and the pressure thus caused

$$= \frac{2}{3}\frac{\pi k a}{T}. \tag{3}$$

This is to be equal to the pressure produced by N downright blows ; whence, equating (1) and (3),

$$N = \frac{2}{3}\pi s k. \tag{4}$$

Again N', the number of blows that reach s, when molecules fly in all directions—

$$= \int dn' = 2\pi s k \,.\int_0^1 \cos\theta d\cos\theta:$$

whence

$$N' = \pi s k. \tag{5}$$

Comparing (4) and (5), we find that

$$\frac{N'}{N} = \frac{3}{2}$$

as in the text.

(*k*) See footnote (*c*), above.

(*l*) N', the number of blows that reach a circular disc of radius a, is, according to equation (5) of footnote (*j*),

$$N' = \pi^2 a^2 k. \tag{6}$$

whence, finally, we may take this number to be about $\frac{1}{40}$: in other words, this molecule of the wall is struck on the average at intervals of about 40 times τ. If the colour of the wall be green, the molecular motions which occasion this colour are repeated in the molecule 2000 each τ, and therefore something like 80,000 in the intervals between the shots to which the molecule is subjected by the aërial artillery. This serves to explain why the incessant bombardment by the air does not alter the colour of the wall. Between the encounters long intervals elapse: intervals so long compared with the motions of light, that any small (*m*) disturbance in the periodic time which may be caused by the encounter probably lasts for but a very trivial part of the long intervals of respite.

Thus in both liquids and gases, what are called the dynamical properties of the medium do not exist when we come to close quarters; and, accordingly, investigations based on these dynamical properties, and carried out by integrations, will yield results that are valuable only when the integration ($\iiint \phi(x, y, z)\, dx\,dy\,dz$) furnishes a result nearly identical with that which would be furnished by a summation ($\Sigma\,\phi(x, y, z)\,\Delta x\,\Delta y\,\Delta z$), where each of the

---

Again, proceeding as in equation (2) of footnote (*j*), we find that the number N'' which would reach a sphere with radius a,

$$N'' = \int_0^1 k\,.\,\pi a^2\,.\,2\pi d\cos\theta$$

$$= 2\pi^2 a^2 k. \qquad (7)$$

Comparing (6) and (7), we find that

$$N'' = 2N'.$$

(*m*) Probably but small: since the periodic time seems to depend much more on the relation which subsists (and acts without intermission) between ponderable matter and the luminiferous ether, than upon the occasional events which occur in the grappling of molecules with one another.

This view is borne out by observations made by the author on the absorption spectrum of the vapour of chlorochromic anhydride (CrO_2Cl_2), the lines of which were found to have sensibly the same appearance whether air was or was not present with the vapour. It was expected that the spectrum might exhibit an appreciable difference in these two cases, since when air is present the molecules of the vapour are subjected to a largely multiplied number of encounters—notwithstanding which no alteration in the appearance of the lines of the spectrum could be detected.

For an account of the *very* remarkable spectrum of this vapour, see a paper by Professor Emerson Reynolds, F. R. S., and the Author, in the Philosophical Magazine for July, 1871, p. 41.

blocks $\Delta x\,\Delta y\,\Delta z$ is sufficiently large to include an *enormous* number of the individual operations that are in reality what actually go on in the medium.

We come upon the same result when we make a similar inquiry with regard to solids. But I forbear going into numerical details in this branch of our subject until I can publish investigations on which I was engaged some years ago, by which it appears that the form and dynamical properties of many crystals can be connected with their chemical constitution. When this subject is gone into it becomes plain that the dynamical properties of solids also, such as their power of propagating shearing stresses, are, like those of liquids and gases, due to events of an utterly different kind that occur between parts so close, and in periods of time so brief, that enormous shoals of these events occur in a very small fraction of a second, within elements of volume many times smaller than the most tiny spec the microscope can show. Accordingly, what we regard as dynamical properties of solids, such as their power of propagating tensile, compressive, shearing, and twisting stresses, are an outcome of what I have called the *texture* of the medium; and only appear between blocks so large that in considering the effect of one of these large blocks upon its neighbours, we need only take account of the general outcome that emerges when vast numbers of the individual events that are actually going on are combined, and their general drift obtained by a statistical method.

It is especially instructive in this connexion to consider the problems of that branch of dynamics which is called Rigid Dynamics—such as the investigation of the motions of a top, or hoop, or of the precessional motion of the Earth. In these inquiries the integral calculus is employed. But the integrations are all such that the calculated motions of such bodies would come out almost precisely the same, whether the absolute limit, as furnished by the integrals, be taken, or a summation for which the volume of the rigid body is regarded as divided into blocks as large as the smallest specs visible in the microscope. It is desirable, however, that we should bear in mind that *there is the widest difference between the physical assumptions underlying these two methods of procedure.*

If we proceed by integration it is tacitly assumed that the stresses characteristic of a solid body prevail between elements of the volume *however small,* and differ, according to the law laid down as the law prevailing in the medium, at situations in the body *however near.* This is not true.

On the other hand, if we proceed by summation, it is assumed that the forces acting on each little block are distributed equally and without any variation of direction to the several equal portions into which its little mass may be conceived to be divided, however minute this subdivision may be. If this were the case, *the internal stresses of a rigid body would be powerless to induce rotation in any one of these blocks, or to alter any rotation that may have pre-existed in it.* Accordingly, each of these blocks would not *rotate* round the instantaneous axis: it would merely revolve round it.(*n*) These, which are the real physical meanings of the assumptions made in the two cases respectively, are specially instructive.

About fifty years ago Professor MacCullagh announced his great discovery that the phenomena of light could be accounted for, if we suppose light to be an undulation in an *incompressible* medium of uniform density, endowed with those dynamical properties which are embodied in his fundamental equations. These properties are not very unlike the properties attributed to an ordinary solid body; and the question now arises, whether these properties (or whatever are the real dynamical properties of the medium in which are propagated light, radiant heat, and other waves of electro-magnetic stress) are fundamental properties of the medium, or whether, like the properties of solids, liquids, or gases, they *are the outcome of events of a wholly different character* happening at intervals so short that the elements of volume (the $dx\,dy\,dz$'s of MacCullagh's formulæ) contain *vast* numbers of them. Now the dynamical properties of the luminiferous medium—whether we use MacCullagh's or Cauchy's fundamental equations—sufficiently resemble those of media which we know to be "textured", to make the latter supposition the more probable, after what we have found to be the real nature of solid liquid and gaseous media. And this probability is

(*n*) The proper inference from this is that our equations have only taken into account a part of the forces that are really acting. This is true.

very much strengthened by the discovery made by Helmholtz about a quarter of a century ago, of the persistence and dynamical behaviour of vortex rings and other vortex filaments in a *perfect* incompressible fluid, and by the investigations to which this discovery has led.

One result of these investigations has been to suggest to Sir William Thomson that the chemical atoms of which ponderable matter consists may be simply vortex tangles in such a medium; and to suggest to Professor FitzGerald that the luminiferous ether may be a medium of this kind permeated by straight vortex filaments in all directions. Investigations are being actively pushed forward with a view to ascertaining how far these suppositions can be corroborated. Other hypotheses which may be classed with these have been advanced by Professor Hicks and others, but I select Professor FitzGerald's and Sir William Thomson's, both because they seem, in our present imperfect state of information, the best of their class, and in order to give definiteness to what further I have to say.

Let us then imagine this room to be permeated by three systems of wires. Let the first be a set of vertical wires from the ceiling to the floor in rows parallel to the walls, and at intervals from one another of one inch. Let a similar system cross the room from side to side, passing midway between the wires of the first set: and let a third system of wires run from end to end of the room threading their way along the middle of the clear passages that lie between the wires of the other two systems. Let these wires represent straight vortex filaments in a uniform incompressible medium devoid of stress resisting change of form, and let the alternate vortex filaments of each row rotate in the same direction, while the intermediate ones rotate in the opposite direction, but let the vortex filaments be in other respects similar.

Such would be the simplest case of a medium of the kind that Professor FitzGerald has conceived.(*o*) Let us next imagine the whole space within the room to be divided into large blocks of a cubic yard in size. One of these blocks will include a great number of the vortex filaments, and all the large blocks will closely resemble one another; insomuch that if an undulation

(*o*) *Nature*, May, 1889, vol. xl., p. 32.

consisting of shallow waves each a quarter of a mile long, were to traverse the medium, the blocks would appear to act on one another in a certain definite way. This corresponds to the way in which Professor Mac Cullagh's elements of volume, his $dx\,dy\,dz$'s, are in his formulæ assumed to act. But if the whole space were divided into much smaller blocks, suppose into cubes of half an inch, great differences would be found to prevail between these small blocks, and equally great differences in the way they act on one another: and the difference would become more striking if the subdivision were carried so far as to render the blocks small in comparison with the thickness of the wires that represent vortex filaments.

If now we further conceive small vortex tangles travelling about in this medium, the long vortex filaments opening to let them pass, and acting in front sideways and behind upon them in such a way as to urge them equally forwards and backwards, so long as their journey is along a *straight* path with *uniform* speed—we shall have a first sketch of what constitutes ponderable matter and the luminiferous ether, according to these speculations.

The particular hypotheses which are here described may perhaps not have quite hit the mark; but, though we have as yet only a glimmering of this great subject, it is pretty certain that either these hypotheses, or something like them, are the true ultimate account of material Nature.

We must, therefore, carefully distinguish between the elemental and the luminiferous ethers. The elemental ether, until motions create differences in it, is *absolutely* alike and undistinguishable in *all* its parts, and in the mathematical investigation of motions in it, wherever in any of the equations of dynamics an element of mass appears, we must write everywhere the element of volume instead. It is itself the integral of these elements of volume; in other words, it is space under a new aspect. In the geometrical way of conceiving space, the parts into which it may be conceived to be divided are thought of as they would be if at rest relatively to one another. In the kinematical way of conceiving space, *which alone is in accordance with what objectively exists*, we are to recognise that each portion of volume is pervaded by the motions that actually subsist within it, and that it can travel about carrying those motions with it. In fact the volume occupied by a block of iron differs from an equal volume occupied by air, *only* by the motions that are going on within the one volume being different from those that pervade the other. In every other respect they are as exactly alike as one stationary portion of space is to another. One such portion of space is not another; but it is *exactly* like it: and *there is no limit* to this resemblance, however small the portions compared may be. There is no "texture" until there is motion.

On the other hand, when, in investigating the motions of ponderable matter, we have occasion to conceive the bodies we are dealing with divided into small portions, it is only *if we stop short* in our division so that the blocks we form do not fall below a certain size, that we are justified in treating them as resembling one another. When we thus stop short, the blocks are in reality accumulations of more minute internal motions; and if we do not stop short, but carry the division sufficiently far, we shall come down upon the individual motions themselves, between which of course the most marked differences would be found.

It appears to be the same in regard to the luminiferous ether. It is only when we do not subdivide too far, that we are justified in speaking of the blocks as resembling one another. The luminiferous ether seems to be a textured medium like ponderable matter. But in the elemental ether—in space itself regarded as movable—there are no such limits. Its portions, however small, resemble one another with mathematical exactness;(*p*) except so far as there may be different motions prevailing within those portions.

It thus appears that *the distinction* between different parts,

---

(*p*) Empty coreless vortices involve the hypothesis of a medium that is discontinuous and has boundaries; or else (in the case of some coreless vortices) of a medium which obeys two laws of motion, one for the part of the medium that is interned on one side of a closed vortex sheet, and another for the rest of the medium. Now, it seems very improbable that the objectively existing elemental ether—space under its kinematical aspect—is of either of these kinds; and, accordingly, it is improbable that empty coreless vortices can be any part of real nature. This is a kind of objection which may raise an improbability, even a great improbability; but we should be rash to rely on it as finally decisive, for the reality of things is not limited by our way of conceiving them.

The objection, such as it is, would not lie against the presence in nature of coreless vortices lined with a vortex-sheet and filled in with a part of the medium devoid of rotational motion; but such vortices would, in some respects, behave differently from empty coreless vortices.

which is implied by the term density, *does not exist*(*q*) in the elemental ether, and that in it the element of volume *is* the element of mass. There is, accordingly, no such physical quantity as density in the dynamics of the ultimate motions of the elemental ether. It is only when accumulations of these primary motions are lumped together, and where what we are investigating is merely *the drifting about* of these accumulations—it is only in this branch of dynamics that we find the need and the advantage of the conception of density *as a substitute for having to take separately into consideration some of the motions that are really going on.* In fact, if any such hypothesis as Sir William Thomson's is true, the density of a lump of iron, *i.e.* the coefficient by which the elements of its volume have to be multiplied in order to get their masses, is nothing but *a mere function of the primary or elemental motions prevailing in that portion of space*,(*r*) and which alone make that portion of space differ from one in which other elemental motions are going on.

(*q*) This conclusion is confirmed by an important ontological proposition which is susceptible of demonstration, viz. that nothing that we suppose to exist in nature can be "real," unless *it is a syntheton of perceptions* actual, potential, or conceivable. Thus, motions and space relations may be "real," for they are such syntheta; but a "thing to move" is not real *except* in those cases in which the motion we are considering is the drifting motion of volumes within which subsidiary motions prevail. In such cases the subsidiary motions are often thought of, and may perhaps without objection be spoken of, as a thing that moves.

(*r*) That is, on the supposition that the luminiferous ether is of uniform texture throughout its whole extent, as seems to be the case. If, however, the fact be otherwise, we must regard the density of the iron as a function both of the elemental motions pervading its volume and of the elemental motions in the *adjoining* part of the luminiferous ether. The density of the iron would then depend on its situation in the material universe.

XLIV.

ON SOME EPI-DIORITES OF NORTH-WEST IRELAND. By J. SHEARSON HYLAND, Ph. D., M.A. (Communicated by permission of the Director-General of the Geological Survey).

[Read February 10, 1890.]

In an appendix to the explanatory memoir on sheet 17 of the Map of the Geological Survey of Ireland (Dublin, 1889), I have furnished a description of the petrographical characters of the epidiorites of the district. Some of the facts elicited by an examination of these rocks are sufficiently interesting to deserve a wider circulation.

The rocks occur as sheets and dykes, intrusive into the altered sediments (quartzites, mica-schists, &c.[1]), and at St. Johnstown and Raphoe they are seen to break through the stratified deposits transversely to the bedding.[2] In the field a strong foliation is often to be recognized; but this structure is at times little developed and hardly perceptible. Still, the absence of this macroscopic feature does not preclude the possibility of reconstruction having occurred; for it has been abundantly demonstrated that molecular re-arrangement can ensue without the development of such a structural modification.[3]

The specimens examined are greenish in hue, and vary in

---

[1] The dark, bluish-grey mica-schist is seen under the microscope to consist of a plexus of light green, uniaxial mica and minute grains of quartz : calcite, hematite, tourmaline, rutile, are also present. Strain-slip-cleavage is well developed. Iron-pyrites is to be observed macroscopically; also *rutile*, according to Giesecke.

[2] Prof. E. Hull, in Memoir to Sheet 17, p. 7.

[3] Teall, The Metamorphosis of Dolerite into Hornblende-Schist, Q. J. G. S. Lon., 1885, p. 139; and The Metamorphosis of the Lizard Gabbros, Geol. Mag. iii. vol. i. p. 487.

grain from coarse to fine. The petrographical description is mainly based upon a collection made from the following localities:—

One mile N. of Raphoe,	Co. Donegal.
Half mile N. of Raphoe,	Co. Donegal.
Half mile N. of Convoy,	Co. Donegal.
Half mile S. E. of Drumahoe Bridge, two miles S. E. of Derry,	Co. Londonderry.
One mile and a-half W. of St. Johnstown (Dooish Mountain),	Co. Londonderry.
One mile and a-half S. S. W. of New Buildings, and four miles S. S. W. of Derry,	Co. Londonderry.

All these rocks are plagioclase-pyroxene rocks, which have undergone alteration under the influence of dynamic metamorphism. Most of them were originally dolerites (Ger. *Diabase*); but it is not improbable that the masses at one mile N. of Raphoe and half mile N. of Convoy represent altered Gabbros.

As a result of the metamorphism, the pyroxene has been completely altered into a greenish monoclinic hornblende, which possesses the characters of "uralite." This mineral occurs in ragged patches, which, in most cases, still preserve the ophitic structure of the pyroxene which it has replaced. Where there has been movement coincident with, or subsequently to, this uralitisation, the hornblende becomes split up into innumerable fibres which partake in the general movement. A sort of lenticular structure is thus produced, the margins of the lenticles consisting of a felted hornblendic mass in a state of fine division. In the much altered varieties, the hornblende becomes decidedly actinolitic in character, forming long green or bluish-green prisms. As the actinolitic nature becomes the more evident, the more decided the foliation, it is not surprising that planes of movement are coated with amianthus-like actinolite (one mile S. S. W. of New Buildings, Co. Derry). Liebe [1] has described the presence of primary hornblende in rocks of this type; but there is no evidence of an occurrence of this nature in those under examination. A colourless,

---

[1] Uebersicht ueber den Schichtenaufbau Ostthüringens. Abhandl. zur geol. Spezialkarte von Preussen u. d. Thüring. Staaten. Bd. v.; heft 4, p. 83.

tremolite-looking hornblende is sometimes apparent, but is not a constant accessory.[1]

Intergrown with, and embedded in, the hornblende there are to be observed numerous patches and flakes of biotite. This mineral is singularly devoid of inclusions and appears to stand in a genetical relation to the hornblende. The pleochroism is:

α = pale straw-yellow,

β and γ = brownish-yellow to dark-brown.

Epidote and zoisite[2] are very common, whilst secondary quartz is not infrequent. There is also a little calcite present.

The quantity of felspar varies more or less, but is always subordinate to that of the hornblende. It can eventually become very small, as the hornblende appears to displace the felspathic constituent. This almost entire disappearance of the felspar may possibly account for the statement made over fifty years ago by G. Rose, that "uralite" was only to be found in those greenstones in which felspar was absent or little apparent.[3] Still, notwithstanding this opinion, put forth shortly after his discovery of the mineral, mention is especially made in his work on the Urals of the constant association of uralite and oligoclase.[4]

The metamorphism of the felspar leads to its "granulation," and the consequent formation of new products. This granulation is referred to a "crystallising process going on under the influence and control of powerful mechanical stresses."[5] The original

---

[1] Tremolite occurs in the district comprised in Sheet 17, viz. near Curley Hill, Co. Tyrone, but in limestone. (C. L. Giesecke, Minerals of the Royal Dublin Society, to which is added an Irish Mineralogy: Dublin, 1832, p. 227.)

[2] For crystallographic details see Memoir, Sheet 17, pp. 35 and 36. The occurrence of zoisite in this district at Holly Hill, near Strabane Co. Tyrone, was known to Portlock (Report of the Geology of the Co. Londonderry, &c.: Dublin, 1843, p. 209); also to Giesecke (*l. c.* p. 208).

[3] Pogg. Ann. d. Ph., 1833, 1 St., p. 103. "Immer haben sie (Uralite) sich nach den gemachten Erfahrungen nur in den Grünsteinen gefunden, in welchen Albit oder Feldspath nicht vorkommen oder wenigstens nicht deutlich ausgeschieden vorkommen; mit der Bildung dieser Mineralien scheint die Bildung des Uralits aufzuhören und statt dessen *Hornblende* an seine Stelle zu treten." The term "Uralite" is used in a strict sense as applying to a mineral possessing the outer form of augite and the cleavage planes of hornblende. (V. Pogg. Ann. 1831, xxii., p. 321; and Jahrbuch f. Min., 1832, p 237).

[4] Reise nach d. Ural, Bd. ii. 575.

[5] Judd, On the Processes by which a Plagioclase Felspar is converted into a Scapolite, Min. Mag. viii., No. 39, p. 186 (13.)

felspathic constituent was a Labradorite. Some few well-developed, lath-shaped sections, parallel to the M-face, give an extinction of $-30°$: this denotes the presence of a felspar allied to $Ab_1\ An_3$. Such sections show the albitic lamellation. The mass of the felspar is, however, particularly striking owing to the want of this striated appearance, to its occurrence in a granular condition, and to its association with quartz and epidote. This combination of minerals forms, under crossed Nicols, the so-called quartz-felspar-(epidote)-mosaic: it bears every aspect of being secondary, and recalls the metamorphism of labradorite ($Ab_1\ An_2$ according to Schilling[1]) into albite with bye-products, as has been described by Lossen in the case of the Hartz diabases[2]. The similarity being so strong, we may, therefore, assume that a like alteration has been effected in the felspar of our Irish Epi-diorites.

The albitic character of the secondary felspar has been inferred from the analyses of the vein-felspars so frequently observed in rocks of this class. Gümbel[3] supplies, for instance, an analysis of a vein-"albite" from the Fichtelgebirge, whilst Teall[4] gives the composition of the vein-felspar in the Scourie Dyke in Sutherlandshire as that of andesine. From his analysis I have calculated the admixture of orthoclase, albite, and anorthite, to be as follows:—

			orthoclase 10·40 °/o		albite 59·06 °/o		anorthite 28·78 °/o
SiO_2	58·16	=	6·72	+	40·54	+	12·42
Al_2O_3	26·66		1·92		11·53		10·57
CaO	5·79		—		—		5·79
MgO	·65		—		—		—
Na_2O	6·99		—		6·99		—
K_2O	1·76		1·76		—		—
	100·01		10·40		59·06		28·78
			2.4				1

[1] Grünsteine des Harzes: Göttingen, 1869.

[2] Studien an metamorphischen Eruptiv-und Sedimentgest. Jahrbuch d. k. preuss. geol. Landesanstalt für 1883: Berlin, pp. 619–640; also Erläuterungen zur geol. Specialkarte von Preussen. Blatt Wippra, 1883, pp. 50 and 83.

[3] Die paläolithischen Eruptivgesteine des Fichtelgebirges, 1874, p. 14.

[4] British Petrography, p. 155.

The 10.40 °/₀ of orthoclase is presumably not present as an independent felspar; hence, the analysis represents a felspar of the constitution An_1 $Ab_{2.4}$, *i. e.* a felspar intermediate between andesine and oligoclase. It would manifestly be more accurate to analyse the felspar which occurs in the ground-mass of the rock itself; but no attempt has apparently been made in this direction, owing to the difficulties the isolation presents. In order to do this, the rock from Convoy was taken, and, after being powdered, treated with weak acid in order to remove the small quantity of calcite present. The secondary felspar was then separated by means of the Sonstadt-solution: its specific gravity was found to be 2.645. The analysis gave the following result:—

					orthoclase 2·11 °/₀		albite 71·49 °/₀		anorthite 22·31 °/₀
SiO_2	62·86	=	62·74	=	1·36	+	49·07	+	9·63
Al_2O_3	20·1		20·06		0·39		13·96		8·19
Fe_2O_3	2·6[1]		2·59						
CaO	4·5		4·49		—		—		4·49
Na_2O	8·48		8·46		—		8·46		—
K_2O	0·36		0·36		0·36		—		—
H_2O	1·3		1·3		—		—		—
	100·20		100·00		2·11		71·49		22·31
					3·3				1

The constitution of the secondary felspar is, therefore, An_1 $Ab_{3.3}$—in fact, the rearrangement of the original labradorite Ab_1 An_3 has resulted in the formation of an oligoclase. We have, accordingly, the association of uralite and oligoclase in these rocks, and it is, hence, interesting to recall G. Rose's observations upon the subject (*vide supra*). Owing to the metamorphism of the felspar, a large amount of lime was set free, which induced the formation of epidote and zoisite. The aggregates of these two minerals are sometimes found piercing the bi-silicates in continuous lines, and thus preserve the ophitic structure so characteristic of dolerites.

[1] The Fe_2O_3 was estimated by titration: the amount is certainly high; but the sp. g. of the powder (2.645) shows that it cannot be ascribed to the presence of epidote. 2.59°/₀ of Fe_2O_3 would be equivalent to an admixture of about 5.8°/₀ of epidote, which would demand a sp. g. of about 2.9. (V. Cathrein "Ueber Saussurit," Zeits. f. Kryst. vii. 241, 242.

Iron-pyrites and ilmenite are present: the latter is mostly altered into granular aggregates of sphene. The amount of chlorite and quartz is naturally in direct proportion to the degree of alteration the rock has undergone. The chlorite is to be regarded as the final product of the alteration of the hornblende. A quantity of iron and lime, liberated by this chloritisation, led also to the formation of epidote and zoisite. Apatite is rare. There is no trace of either scapolite or sahlite in the specimens examined. It is, however, highly probable that both these minerals are to be met with in the greenstones of this district, as Sir Charles Giesecke records their occurrence at the old lead mine in the vicinity of Strabane, Co. Tyrone.[1] The scapolite shows a "four-sided prism;" whilst the sahlite is described under the old name "baikalite." The same mineralogist calls attention to the presence of a "silver-white, pearly mica, resembling lepidolite," at Hollyhill, Co. Tyrone, where he also observed lievrite.

[1] *l. c.* pp. 208, 219.

XLV.

ON THE MESOLITE (GALACTITE) OF KENBANE HEAD, CO. ANTRIM. By J. SHEARSON HYLAND, Ph.D., M.A., of the Geological Survey of Ireland.

[Read February 10, 1890.]

The basaltic rocks of the North of Ireland have long been noted for their richness in zeolites, and the publications of Jameson,[1] Giesecke,[2] Thomson,[3] Tamnau,[4] Portlock and others,[5] testify to the interest these minerals excited amongst the collectors of that time. To Thomson's enthusiasm for mineralogical investigations we owe most of our present knowledge of their chemical composition. The researches of this chemist have enriched our nomenclature with such names as Lehuntite, Harringtonite, Erinite,[6] &c.; but, as the right of some of these minerals to be regarded as distinct species is open to considerable doubt, it seems desirable to re-determine their chemical characters. Since Thomson's time little, if any, inquiry has been made into the subject.

Along the cliff near Kenbane Head, about two miles W. of Ballycastle, Co. Antrim, the decomposed basalt is seamed with veins of white needle-like zeolite. At times it is associated with analcime, showing the form 2O2 (211). Analcime is not very common in Ireland; but its occurrence "near Fairhead" is already recorded by Giesecke.[7]

---

[1] A System of Mineralogy, 3rd edn., 3 vols.: Edin. 1820.

[2] A Descriptive Catalogue of a New Collection of Minerals in the Museum of the Royal Dublin Society, to which is added an Irish Mineralogy. Dublin: 1832.

[3] Outlines of Mineralogy, Geology, and Mineral Analysis. 2 vols., London: 1836.

[4] Monographie des Chabasits. Neues Jahrbuch: 1836, p. 633.

[5] Report on the Geology of the County of Londonderry, and of parts of Tyrone and Fermanagh. Dublin: 1843. Also, Manual of the Mineralogy of Great Britain and Ireland, by Greg and Lettsom. London: 1858.

[6] This is not to be confounded with Haidinger's Erinite, which is $Cu^3(AsO^4)^2 + 2Cu(OH)^2$, and occurs at Limerick.

[7] *l. c.*, p. 215.

*

To prepare the mineral for chemical analysis, it was removed from the mother-rock, powdered, and then inserted into a "Thoulet-solution" in order to separate it from all adherent foreign matter. Success attended this process, and the powder was observed under the microscope to be free from all impurities. The specific gravity was determined to be 2·26 at a temperature of 11° C. The analyses were conducted with the usual care, and the purity of the precipitates was tested in all cases. A small quantity of alumina was found to remain with the silica, and an almost equal quantity of silica was detected with the alumina. The difference between these two quantities, 0·08°/₀, had to be deducted from the silica and added to the alumina. The mineral is easily dissolved by acids with gelatinization. The amount of H_2O was estimated three times.

Under I. is given the mean of my two almost identical analyses.

Under II. a natrolite-analysis made by Thomson, the locality being given as "Antrim". He states that the mineral was "full of holes, through which water containing iron seems to have filtered."[1]

	I.	II.
SiO_2	46·50	47·56
Al_2O_3	27·55	26·42
FeO	tr.	0·58
CaO	2·59	1·40
Na_2O	13·28	14·93
K_2O	nil	
H_2O	10·10	10·44
	100·02	101·33
Sp. g. =	2·26	Sp. g. = 2·139

Divided by the atomic weights of the substances, my analysis would give—

0·776	or	7·76	SiO_2		= 3
0·27	,,	2·7	Al_2O_3		= 1
0·046	,,	0·46	CaO	} 2·60	Na_2O = 1
0·214	,,	2·14	Na_2O		
0·562	,,	5·62	H_2O		= 2·16

[1] *l. c.* vol., i., p. 317.

or the relation $Na_2O \cdot Al_2O_3 \cdot 3SiO_2 \cdot 2H_2O$, when the lime is considered as replacing the soda.

This formula demands as is well known—

SiO_2	47·20
Al_2O_3	27·00
Na_2O	16·30
H_2O	9·50
	100·00

It seems, however, more rational to consider the analysis as expressing a mixture of natrolite and scolezite, such as is represented by the variety of natrolite called galactite. Reckoning the formula of natrolite as $Na_2(Al_2)Si_3O_{10} + 2H_2O$, that of scolezite as $Ca(Al_2)Si_3O_{10} + 3H_2O$, the mineral from Kenbane Head may be said to contain—

	Scolezite-substance.		Natrolite-substance.		Reckoned.	Found.
SiO_2	8·34	+	38·53	=	46·87	46·50
Al_2O_3, FeO	4·73	+	21·86	=	26·59	27·55
CaO	2·59	+	—	=	2·59	2·59
Na_2O	—	+	13·28	=	13·28	13·28
H_2O	2·49	+	7·69	=	10·18	10·10
	18·15	+	81·36	=	99·51	100·02

This is equal to—

$$\left\{ \begin{array}{llll} (4·5 & \text{or} & 9 & Na_2(Al_2)Si_3O_{10} + 2H_2O) \\ (\ 1 & \text{or} & 2 & Ca\ (Al_2)Si_3O_{10} + 3H_2O) \end{array} \right\}$$

Heddle[1] gives the following analysis of the galactite of Bishopstown :—

SiO_2	48·03	=	48·03[2]
Al_2O_3	25·26		25·26
Fe_2O_3	0·86		—
CaO	2·31		2·87
MgO	0·40		—
Na_2O	13·97		13·97
H_2O	9·72		9·72
	100·55		99·85

[1] Phil. Mag., 4th ser., vol. xi., 1856, p. 272. Behaves optically like Mesotype (Descloizeaux).

[2] Handbuch der Mineralchemie. Ergänzungsheft zur 2ten Aufl. Leipzig: 1886, p. 164.

This affords the formula—

$$\left\{\begin{array}{ll} 4\cdot3 & (Na_2(Al_2)Si_3O_{10} + 2H_2O) \\ 1 & (Ca\ (Al_2)Si_3O_{10} + 3H_2O) \end{array}\right\};$$

or, according to Rammelsberg—

$$\left\{\begin{array}{l} (9\ Na_2(Al_2)Si_3O_{10} + 2H_2O) \\ (2\ Ca\ (Al_2)Si_3O_{10} + 3H_2O) \end{array}\right\}.$$

But the amount of H_2O required for this formula does not agree with that found upon analysis. Hauer,[1] who has investigated several of the Scottish lime-bearing natrolites, gives an analysis of a zeolite from Campsie Hills, which we can compare with that from Kenbane Head. The quantity of H_2O found is very nearly identical with that demanded by the empirical formula.

Locality.	SiO_2.	Al_2O_3.	CaO.	Na_2O.	H_2O.	Totals.	$Na_2(Al_2)Si_3O_{10}$ $+2H_2O$.	$Ca(Al_2)Si_3O_{10}$ $+3H_2O$.
C. Hill,	47·32	27·36	2·63	13·35	10·39	101·05	4·4	1
K. Hd.	46·50	27·55	2·59	13·28	10·10	100·02	4·5	1

It should be especially brought under notice at this juncture that, as scolezite contains $3H_2O$, whilst natrolite has only two, it is very necessary to an accurate analysis of a mineral representing an isomorphous mixture of these two substances that the H_2O found be in agreement with the calculated formula.

It is manifest from the foregoing that the zeolite from Kenbane Head must be regarded as no true natrolite. It is rather an isomorphous mixture of natrolite and scolezite, such as that described under the name of galactite. The amount of lime, however small it may appear, cannot but be considered as forming an integral portion of the mineral. As the powder does not effervesce with acids, it cannot be ascribed to the presence of foreign calcareous matter; optically, also, there is no evidence to show that the mineral is merely natrolite, with an *accidental* admixture of scolezite. Neither does it appear that the lime arises from the presence

[1] Wien. Ak. Ber.: 1854.

of phillipsite—an explanation offered by Stock[1] for the occurrence of 4·46°/₀ of this element in a zeolitic mineral, which is found in the cavities of the nepheline-dolerite of Löbauer Berg in Saxony.[2]

The analyses of galactite furnished by Heddle show that the amount of CaO may become very trifling: a transition to true natrolite is thus effected. According to the same writer, it is the small portion of lime which gives to these zeolites "their whiteness and opacity, and doubtless prevents their assuming the definite crystalline form which the pure mineral under favourable circumstances adopts."[3]

All zeolites are decomposition-products, and seem to owe their origin to the alteration of minerals such as plagioclase, nepheline, &c.[4] Chemically, these minerals may be said to represent the silicates of the nepheline and felspar group, combined with water. In fact, many zeolites seem to be *hydrated* plagioclases;[5] a comparison of the formulæ will render the probability of this apparent.

From the circumstance of finding zeolites disseminated through the minutest cavities of the mass of volcanic rocks, it was formerly believed that these minerals were formed by segregation in the mass of the rock, and that they were enabled to retain their water at a high temperature, under the influence of pressure. The results of subsequent observations, however, have led to the belief that the deposition of zeolites is a direct consequence of the infiltration of water through the mass of the rock. This water, reacting upon the constituents, will give rise to various species of minerals. The first effect will be that of decomposition, and subsequently of reconstruction, with the formation of new compounds. Zeolitic minerals may therefore be considered a kind of "extract" of the rocks so subjected to continued lixiviation—a view that is borne out by the more or less altered condition usually observed in the rocks most abounding in this class of mineral—the

---

1 J. Stock, Die Basaltgesteine des Löbauer Berges. Tschermak's Mitt.: 1888, Bd. ix., Heft. 6, p. 453.

2 Schneider, Geogn. Beschreibung d. Löbauer Berges. Abh. der naturf. Ges. zu Görlitz.: 1868, Bd. xiii., p. 42.

3 Heddle, l. c., p. 274.

4 Whitman Cross and W. F. Hildebrand, "Contributions to the Mineralogy of the Rocky Mountains." Bull. of the U. S. Geol. Survey, 1885, No. 20.

5 Tschermak, Lehrbuch der Mineralogie. Wien: 1889, 3te. Aufl., p. 495.

alteration resulting, in many cases, in the production of an earthy state; and chemical examination proves that in such cases the rocks are hydrated.[1] Highly instructive, as bearing upon the formation of minerals of this class, are the researches of Daubrée[2] upon the production of zeolites, during the historic period, by the action of thermal waters, at a temperature not above 70° C., upon the masonry of the ancient Roman baths at Plombières.

Water containing CO_2 is not considered by F. Senft[3] to play a part in the production of zeolitic minerals out of Labrador-felspar, &c. The evidence, he holds, suggests rather the action of pure water, which, saturating atom by atom the substance of the pre-existing minerals, causes their complete hydration. The zeolitic mass thus formed may either remain undisturbed, or it may gradually become dissolved, and thus travel until evaporation or other causes invokes crystallization. A remarkable fact in the history of zeolites, has lately been made known by the researches of Messrs. Murray and Renard.[4] They found that the decomposition of volcanic detrital material goes on at low temperatures in the depths of the ocean, transforming a basic silicate into a crystalline zeolite on the one hand, and the characteristic red clay of deep sea-deposits on the other. The temperature at which this alteration proceeds is approximately 0° C. The investigations of Friedel and Sarrasin are also remarkable as bearing not only upon the production of felspars in the wet way, but also upon the production at will, under similar conditions, of a felspar or a zeolite.[5]

The properties of minerals of this class were first studied by Cronstedt, who applied the general term "zeolite" on account of the fretting and swelling they exhibited before the blowpipe.[6] But it was Bergmann who first observed another characteristic

---

[1] A. Daubrée, "On Points of Similarity between Zeolitic and Siliceous Incrustations of Recent Formation by Thermal Springs, and those observed in Amygdaloids and other altered Volcanic Rocks." Quart. J. Geol. Soc. Lon., vol. 34, 1878, p. 80.

[2] A. Daubrée, Études synthétiques de Géologie expérimentale. Paris: 1879, p. 180.

[3] Die krystallinischen Felsgemengtheile. Berlin: 1868, p. 622.

[4] Les caractères microscopiques des cendres volcaniques et des poussières cosmiques et leur rôle dans les sédiments de mer profonde. Bull. Musée Roy. d'hist. nat. de Belgique iii., Bruxelles: 1884; also "Volcanic Ashes and Cosmic Dust," Nature, xxix., p. 585 (1883–4).

[5] Cf. Michel-Lévy et Fouqué, Synthèse des minéraux et des roches. Paris: 1882.

[6] Kong, Vet. Acad. Handl., 1756, p. 120; and an Essay towards a System of

feature—the gelatinization with acids. The water all such minerals possess is now separated into water of constitution and water of crystallization. Under water of constitution is understood that water which is in chemical, *i.e.* atomistic combination with the atoms of the substance, and which is present, not as H_2O, but as H . O . H; whilst water of crystallization is considered as water, which, owing to the action of molecular influences, is stored in a condensed condition between the molecules of the substance.[1] It is present in a definite chemical proportion, but is not an essential portion of the compound, although, according to old Haüy, "it is necessary to its crystallization".[2] Still, though the difference in theory is quite clear, it is often very difficult to decide whether the water given off upon the application of heat is water of crystallization, or whether it is produced by the combination of the hydrogen and oxygen of the compound—a difficulty to which Fr. v. Kobell has particularly called attention.[3] It seems, however, certain that the water which is driven off only upon ignition (Glühhitze) is chemically combined; on the other hand, it is not yet established whether the water of crystallization is completely expelled at 100° or 120° C. Experiments upon the quantity of H_2O expelled at various temperatures have been made by A. Damour;[4] but the question of the relation of the water was not attacked. Rammelsberg,[5] in his *Handbuch der Mineralchemie,* makes allusion to the subject, and considers as water of crystallization that water which is lost at low temperatures and taken up again upon exposure to free air. Very interesting work has recently been executed in

Mineralogy, 2nd edn., by J. Hyacinth de Magellan. London: 1788, vol. i., p. 244. To p. 252 the Editor adds the following foot-note, which is not without interest:—

"Mr. Pazumot thinks that the zeolites cannot be a volcanic production, but only a secondary production formed by the decomposition of volcanic earths. Certainly pure basaltes and volcanic lavas have the same component parts as those of the zeolites; and these last have not yet been found but among volcanic matters; but as Mr. Faujas observes, there are many instances of the true zeolites being quite buried within the bodies of solid basaltes, some being only fragments of zeolites, and some having a complete form; which prove that they have been already formed before these volcanic masses were produced by subterraneous fires (!)."

1 Naumann—Zirkel, Mineralogie, 1885, 12te. Aufl., p. 225.

2 Traité de Minéralogie. Paris: 1801, ii., p. 122.

3 Sitzungsbericht der bayr. Akademie d. Wiss. 11 Juni, 1870.

4 Recherches sur les propriétés hygroscopiques des minéraux de la famille des zéolites; Annales de chimie et physique. 3me. série, tome 53, p. 438.

5 Handbuch der Mineralchemie. Leipzig: 1875; 2te. Aufl., i., p. 123.

this department by Carl Hersch,[1] and it is to be regretted that his death, immediately after the completion of the experiments, prevented a continuation of his labours. His experiments and analyses were conducted upon material which was previously dried with air. This is a point of considerable importance. If it be remembered that $Si \begin{smallmatrix} \nearrow O \\ - OH \\ \searrow OH \end{smallmatrix}$ loses its water at 100° C., it will be seen that hydrated silicates—if the H_2O is combined with the SiO_2, which in most cases cannot be otherwise—must lose a portion of their water at this temperature. Hence the analysis would no longer give the exact constitution of the mineral, if the powder were previously dried at a temperature of 100°.

At 100°, H_2SiO_3 commences to lose its water. $Al_2(OH)_6$, (or $Al_2O_3.3H_2O$), which occurs in nature as a monoclinic crystallizing mineral, Hydrargillite, loses, according to Mitscherlich,[2] two molecules of H_2O at a temperature a few degrees over 280°, and then passes into the rhombic Diaspore $Al_2O_3.H_2O$. The latter remains unaltered at 450°, the remaining molecule being expelled only after lengthy ignition. Therefore, when the water is expelled from aluminous silicates at a temperature under 280° C., Hersch concludes it is combined with the silicium, and not with the aluminium. His experiments upon natrolite and scolezite are as follows:—

Hours.	Temp.	Loss expressed in molecules of H_2O.	
		Natrolite.[3]	Scolezite.[4]
2	105°	0·03	—
2	130°	0·03	0·03
2	160°	0·04	0·25
2	195°	0·06	0·86
2	225°	0·07	0·95
2	290°	0·50	1·05
	Red heat.	2·—	3·—

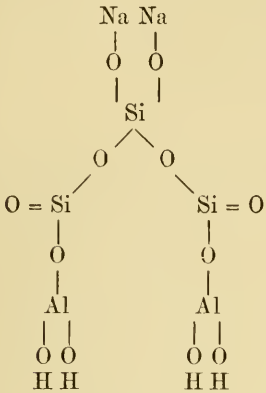
[1] Der Wassergehalt der Zeolithe. Zurich: 1887.

[2] Fortsetzung der Beiträge zur analyt. Chemie—Untersuchung des Alaunsteines, &c. Journal für praktische Chemie. Bd. 83, p. 468.

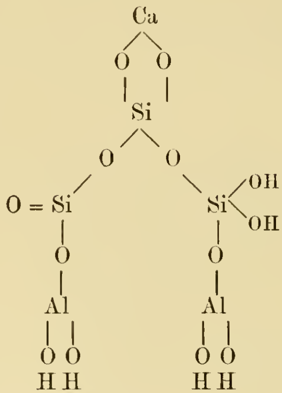
[3] From Jakuben in Bohemia, Hersch, l. c., p. 34.

[4] From Bulandstindr in Iceland.

In the case of the natrolite, as 0·5 molecule H_2O is not expelled until the temperature rises to 290°, the two molecules of H_2O must be considered as attached to the aluminium. On the other hand, the scolezite loses one molecule under 250°; this must belong to the silicium; the other two to the aluminium. The Constitution-formulæ will therefore be—



Natrolite.



Scolezite.

XLVI.

ON SOME SPHERULITIC ROCKS FROM CO. DOWN. By J. SHEARSON HYLAND, Ph. D., M.A., of the Geological Survey of Ireland.

[Read February 10, 1890.]

The district of the Mourne Mountains has attracted the attention of numerous observers, including Berger,[1] Bryce,[2] Griffith,[3] Haughton,[4] and Hull.[5] Both in its physical features and geological structure it bears a striking resemblance to those of the Island of Arran in Scotland. In petrographical characters there is also the closest possible relation between the granites of the two districts. This petrographical similarity may possibly be considered an indication of contemporaneity. In both cases the geological age of the granite is a point of conjecture, and is incapable of actual demonstration.[6]

The granite of the Mourne Mountains is composed of two felspars, quartz, and a dark mica.[7] It is, accordingly, a granitite in Rosenbusch's sense. It often contains drusy cavities, in which the constituents occur in a well crystallized form, and attain considerable dimensions. The minerals observed in these cavities are white orthoclase, albite, smoky quartz, beryl, chryso-beryl,

---

[1] On the Geological features of the N. E. Counties of Ireland, &c., Trans. Geol. Soc., Lon., 1st series, vol. iii., p. 121.

[2] On the Geological Structure of the Counties of Down and Antrim, Rep. Brit. Ass., 1852, p. 42.

[3] Geological Map of Ireland, 1839.

[4] Experimental Researches on Granites of Ireland, Q. J. G. S., Lon., vols. xii. and xiv.

[5] Report Brit. Ass. 1871, Trans. of Sections, p. 102 (with Traill.)

[6] E. Hull, in Memoir to accompany sheets 60, 61, and part of 71 of the Maps of the Geological Survey of Ireland: Dublin, 1881, p. 9.

[7] Berger, *l. c.*, p. 135, mentions amongst the "accidental ingredients" of the Mourne granite crystallised hornblende and reddish garnet. The hornblende is chiefly abundant in the porphyritic variety of the granite; the garnet in the granular variety.

octahedral fluor, topaz, and peridote (Haughton); whilst Lacroix has recently added the Yttrium-silicate, Gadolinite,[1] to the list. The presence of drusy cavities, containing white orthoclase and smoky quartz, is another feature which the granites of Mourne and Arran have in common. Intercrystallisation of the quartz and felspars, so as to produce micro-pegmatite, is often to be observed in the Mourne granite.

The occurrence of the spherulitic rocks now to be described is of interest, and brings the two districts into even closer relationship. Spherulitic "felsites" are, we know, very abundant in Arran, and have received considerable attention at the hands of Allport[2] and Bonney.[3]

I have found spherulitic rocks at three localities in Co. Down, viz. near Newcastle, Hilltown and Slieve Bearnagh. As the most interesting type of this rock occurs at the first locality, I will describe it in full, and content myself with making a short reference to the others at the conclusion of the paper.

I am indebted to Professor J. P. O'Reilly, of the Royal College of Science, Dublin, for kindly bringing the Newcastle rock under my notice, and supplying me with specimens. It occurs—as a dyke (?)—amongst the Lower Silurian slates, in proximity to the granite of Slieve Donard, near Newcastle, the label reading: "In Lady Annesley's demesne: bed of stream: 200 yds. above bridge near mansion." The direction of the dyke was calculated in 1874 to be N. 38° E. The rock is of a grey colour, with greenish hue; the surface is often marked with ferruginous stainings. With the naked eye the following constituents may be recognised:—

1. Felspar: Up to $\frac{1}{2}$ inch in length; colour, pinkish (orthoclase) and white (albite); at times glassy in appearance; tabular form.
2. Quartz: Up to $\frac{1}{4}$ inch; smoky and globular; pitted with minute holes full of a whitish substance.
3. Chlorite: Mostly as specks.[4]

---

[1] Sur un nouveau gisement de Gadolinite. Bull. de la société française de Minéralogie, 1888, xi., p. 68. (See Note added in the Press, p. 436.)

[2] On the Microscopic Structure of the Pitchstones and Felsites of Arran: Geol. Mag. vol. ix., 1872, p. 536 *et seq.*

[3] On certain Rock-structures, as illustrated by Pitchstones and Felsites in Arran: Geol. Mag. ii., vol. iv., 1877, p. 499.

[4] Amongst the most remarkable dykes which occur traversing both the granite and

Upon the polished face of the rock the greenish-grey matrix is observed to be studded with small globules of a whitish material. The quartzes are also seen to be surrounded by a film of the same substance. Under the microscope these globules are seen to be spherulites. A crystal of quartz often forms a nucleus; at other times no nucleus is apparent. The porphyritic felspars are frequently encircled by tufts of this radiating crystalline matter. The spherulites consist of alternating brown and colourless streaks of crystalline material; a radial structure is apparent and is usually made apparent by disseminated brown, dust-like matter, which is arranged along certain lines. The radiation from a common centre is not always uniform, and a sheaf or bundle of "fibres" often stands across others which possess one and the same centre. The form is not always that of a well-defined circle. Further, it often happens that the spherulites have been developed side by side, in which case the spherical form of the individuals is more or less destroyed by mutual interference. Still, a polygonal network does not often result from this interference. The radiating portion of the spherulites is surrounded by an almost colourless ring, the particles of which possess the same optical orientation as that of those composing the inner portion. Hence, under crossed nicols, these bodies show a four-armed black cross, which is continuous through the outer ring. Following upon this colourless ring, a further development of radiating matter is sometimes to be observed. The black cross is fan-shaped towards the circumference of these bodies, and the arms may not lie parallel to the vibration planes of the nicols. The cross is not infrequently disturbed upon rotation of the nicols. It may either "open" to a small extent, or it may almost entirely disappear. In the latter case we obtain

---

slate, Lieutenant James describes "one visible in the large crater-shaped hollow above Tullamore Park; on the western side of Corra it is about 50 feet thick, and is composed of cream-coloured porphyry, containing globular smoked quartz, with crystals of felspar." This is possibly a similar rock to that which I am now describing. (On the Mourne Mountains: Paper read before Geol. Soc., Dublin, Jan. 14, 1835; see also Presidential Address by Griffith, Feb. 11, 1835, pp. 21–28.) G. A. J. Cole has mentioned the occurrence, and studied the characters, of a spherulitic tachylyte which is found as the selvage of a basalt dyke at an elevated point of the high-road from Newcastle, Co. Down, west of Bryansford, and near the afore-mentioned Tullamore Park. (On some Additional Occurrences of Tachylyte, Q. J. G. S., Lon., May, 1888, xliv., p. 305, and Pl. xi., fig. 4.)

a sphere polarising in low tints, and showing two dark spots in the centre. Upon further rotation of the nicols these spots enlargen until the black cross becomes once more visible and normal in aspect. Some of the smaller spherules show a modified form of this phenomenon. In their case, the outer portion of a sphere becomes light, the black cross remaining confined to the centre portion. Further rotation of the nicols restores the original aspect of a continuous black cross.

The larger spherulites immediately attract the attention of the observer by the manner in which they project from the field of vision, and by the brown colour which a finely disseminated "ferritic"[1] pigment imparts to them. They are to some extent porphyritic in their occurrence, and represent the globules to be observed on the polished face of the rock. But the large quantity of spherulitic matter in the rock only becomes apparent when a section is studied under crossed nicols. The ground-mass, or matrix, is then seen to consist of innumerable small spherules, cemented together, so to say, by crypto-crystalline (sometimes micro-crystalline) matter in a state of fine subdivision.

At first sight, these spherulites appear to be identical with those so often observed in glassy rocks; but a more exact examination reveals that, whereas the latter are homogeneous bodies, those we are now describing are decidedly heterogeneous, and appear to consist partly of felspar, partly of quartz. The felspathic portions would be those which are turbid and ferritic; whilst we would consider as quartz those lines or streaks which are pellucid and free from such brownish substance. The colourless ring, which surrounds the radial portions, may at times be seen to show traces of micro-pegmatitic structure. Again, the fan-shaped black cross, which most of the spherules present under crossed nicols, is not normal in character—the arms not lying parallel to the vibration planes of the nicols. These observations prove that we are dealing with those structures which Rosenbusch calls pseudo-spherulites.[2] They probably answer in composition to

[1] "Ferrite" = yellowish, reddish, or brownish amorphous substances or particles, probably consisting of peroxide of iron, either hydrous or anhydrous, but not certainly referable to any mineral.

[2] Mikroskopische Physiographie der massigen Gesteine: Stuttgart, 1887, p. 384.

micro-pegmatite. Rosenbusch suggests, in the last edition of his work,[1] that they may be formed of a definite chemical compound —micro-felsite—in which the ratio of alkalies to alumina is the same as in the felspars, the silica being in excess of that required to form an alkali-felspar; whilst Teall[2] "is inclined to regard the spherulites as due to the simultaneous crystallisation of quartz and felspar."

We have referred to the crypto-crystalline matter present in the groundmass of the rock. It seems well to mention its characters before entering upon the general description of the rock, especially seeing that it stands in such close relation to the spherulitic masses. It is noticed, under cross nicols, to consist of ill-defined flecks and granules, which polarise in low tints. In only rare instances are the boundaries of the grains, constituting the double-refracting substance, recognizable. There are then faint indications of micro-pegmatitic structure to be sometimes observed; but the intergrowth of felspar and quartz is not very definite in character. There is, therefore, both crypto-crystalline and micro-crystalline matter in the rock. It is quite possible that superposition may have something to do with the production of the indefinite aspect which crypto-crystalline matter gives under crossed nicols. We can easily imagine the case of double refracting particles—small in comparison with the thickness of the slide—so overlapping each other as to interfere with the successfull differentiation into individual grains.

Orthoclase is the predominating felspar in the rock. Its form is generally well preserved; but rounding of the angles, through the corrosive action of the acid magma, is often apparent. In fact, the greater part of a crystal may be destroyed by this influence. Still, such an extreme degree of corrosion is rare in this rock. This corrosion of porphyritic crystals is due to chemical and physical changes during consolidation. Lagorio[3] has shown that mere relief of pressure will cause corrosion. But it is still more probable that corrosion is largely due to the changes in the chemical

---

[1] p. 190.

[2] British Petrography, p. 402.

[3] Ueber der Natur der Glasbasis, &c., Tschermak's Min. u. petr. Mitt., 1887, viii., p. 510.

composition of the magma, which the separation of minerals must produce, and to the rise in temperature which must suddenly ensue upon the transition from the amorphous to the crystallised condition.[1]

The orthoclase is frequently twinned according to the Carlsbad law. The normal orthoclase gives an extinction upon the M-surface of $5\frac{1}{2} - 7°$. The intergrowth of orthoclase and plagioclase, known as micro-perthite, is sometimes apparent. Sections of such crystals show a number of narrow and irregular strips and patches, arranged with their longest axes parallel to the vertical axis of the crystal. These patches extinguish at a different angle to the main mass of the crystal, and appear to be albite.

In appearance the orthoclase often reminds the observer of the sanidine of trachytic rocks. Its alteration is accompanied by the development of that scaly, granular matter which is generally referred to kaolin. But some of these scales may be recognized as a white micaceous mineral, possessing high double refraction. A certain amount of free silica is set free by this process, and is to be found again as quartz, minute grains of which are seen to be embedded in such altered orthoclases. The decomposition proceeds along the cleavage planes.

In one of the slides there occurs, lying in the micro-perthite, a colourless mineral, which shows traces of a hexagonal form. It remains almost isotropic under crossed nicols. In its occurrence and general appearance it reminds one of trydimite. Unfortunately the mineral is very infrequent, having been only observed three times in the rock: hence, its identity with tridymite cannot be satisfactorily established. The fact, however, that Lagorio has observed the occurrence of this mineral as an alteration product of an "acid" orthoclase, confirms my conclusions upon the point. The rock in which Lagorio made this discovery is the "black Porphyry" of Wällikallio, a locality situated in the East Baltic provinces. The felspars he describes are altered into quartz

---

[1] Lagorio, *l. c.*, pp. 462, 463. See also Kopp: Lieb. Annalen, 1855, 93, 125. Scacchi, Palmieri, and Guarini observed this rise of temperature upon crystallisation at the eruption of Vesuvius in 1855; the lavas upon which this was noticed were those in the Fosso della Vetrana, (Roth. "Der Vesuv und die Umgegend von Neapel." Berlin, 1857, 293, 304.)

and epidote, and a portion of the silica set free by the decomposition has crystallised as trydimite.[1] We have seen above that the alteration of our felspar also necessitated the liberation of a definite quantity of silica: hence, it is quite possible that the two modifications, quartz and tridymite, have been produced in the case before us. The researches of Friedel and Sarasin prove that both these modifications or forms of silica may be produced in the wet way; but tridymite requires a higher temperature than quartz.

Tridymite was recognised by Von Lasaulx[2] in the liparite of Tardree, Co. Antrim; and this remains at present the only recorded instance of the occurrence of this mineral in the British Isles. It is probable that we now have a second locality, and that also in Ireland; but the infrequency of its occurrence in the rock we are describing does not permit us to express a decided opinion.

Triclinic felspar is present, but is mostly represented by the micro-perthitic interlaminations. When it occurs separately, it is seen to be albite or oligoclase-albite. Periclinic twinning is visible in addition to the albitic. It undergoes the same alteration as the orthoclase; but calcite seems to be a bye-product.

The quartz is corroded: it contains the liquid inclusions, which possess the geometric form of the quartz (so-called "negative crystals") and enclosures of gas. The inclusions are far behind the granites in quantity. Portions of the groundmass are also to be found in the mineral.

A greenish hornblende represents the ferro-magnesian constituent. It is not of frequent occurrence, but was one of the first minerals to consolidate, having been enclosed by the felspar, the formation of which was a later proceeding. The hornblende is mostly altered into chlorite, thin threads and streaks of which are also to be met with in the felsitic-looking groundmass. Yellowish epidote was a bye-product of this alteration. The pleochroism of the hornblende is from deep grass-green to light-yellow. A

---

[1] Microscopische Analyse ostbaltischer Gebirgsarten: Archiv für die Naturkunde Liv—, Est—, und Kurlands, serie 1; Bd. viii.; heft 2, p. 66.

[2] Jour. Roy. Geol. Soc., Ireland; new series, vol. iv., 1876, p. 227; also Min. u. petr. Mitt. (Tschermak's) N. F., vol. i., p. 410.

little granular sphene is to be observed. Oxides of iron are infrequent. The occurrence of prismatic apatite could also be established.

The specific gravity of the rocks varies. Three estimations gave 2·586, 2·595, 2·605 at a temperature of 20° C. The mean sp. g. is therefore 2·589. The variation is presumably due to the fact that the amount of free quartz varies in each specimen. The SiO_2 is not a constant quantity. It was found upon estimation of portions taken from different hand specimens to vary from a little under 74 °/₀ to 70 °/₀. Two complete analyses of the rock were executed.

Under I. and II. are given two analyses of the rock from near Newcastle.

Under III. the mean.

Under IV. Liparite (Quartz-Trachyte) from the Chiaja di Luna, Ponza Island.[1]

Under V. an analysis furnished by Peach and Horne of the spherulitic felsite from Papa Stour, Shetland Isles. Of the microscopic characters of this rock the authors say :—

"Instead of presenting a marked crystalline aspect, it shows a felsitic groundmass . . . in which few felspar crystals are discernible. . . . The characteristic feature of the rock is the well-marked spherulitic structure which it presents under the microscope. . . . We are inclined to believe that the felsite originally possessed a vitreous character, which has, to a large extent, disappeared through devitrification."[2]

Under VI. "Claystone," Arran, analysis by M. M. Tait, quoted from Bryce's "Geology of Arran," p. 203.[3] The rock is presumably a felsite.

Under VII. Felsite-porphyry with spherulites from Felsenkeller, near Ilmenau in Thuringia.[4]

---

[1] Kalkowsky, Elemente der Lithologie: Heidelberg, 1886, p. 75.

[2] The old Red Volcanic Rocks of Shetland: Transactions of the Roy. Soc. of Edinburgh, vol. xxxii. Part ii., p. 383 (1884).

[3] Teall, British Petrography, p. 347.

[4] E. Kalkowsky, Op. cit. p. 68.

	I.	II.		III.	IV.	V.	VI.	VII.
SiO_2	[70·01]	[70·12]	=	70·07	71.12	69·12	72·50	71·97
Al_2O_3	13·79			13·86	14·58	14·55	11·53	12·47
Fe_2O_3	1·88	16·36 (Al₂O₃, Fe₂O₃, FeO, P₂O₅)		1·89	1·69 [1] (Fe₂O₃ + FeO)	1·70	2·06 (Fe₂O₃ + FeO)	3·68
FeO	·51			·52		·14		—
P_2O_5	tr.			tr.	—	·05	—	tr.[1]
CaO	1·43.	1·45		1·44	1·50	1·57	1·79	tr.
MgO	·72	·69		·70	0·15	·52	2·72	0·26
K_2O	6·9009	6·9007 [2]		6·90	6·01	10·17	5·24	8·52
Na_2O	3·69	3·41		3·55	3·26	1·27	3·37	1·17
H_2O [3]	1·07	[1·07]		1·07	0·95	·79	·70	0·95
	100·00	100·00		100·00	99·26	99·88	99.91	99·02
			Sp. g.	2·589	2·540			

If we calculate the whole of the potash as orthoclase from the formula $K_2O \cdot Al_2O_3 \cdot (SiO_2)_6$, and the soda as albite from the formula $Na_2O \cdot Al_2O_3 \cdot (SiO_2)_6$, we will find my analysis of the Newcastle rock (III.) equal to :

Percentage of orthoclase-substance	40·78
Percentage of albite substance	30·00
	70·78

It should, however, not be inferred from these calculations that the rock actually contains 40·78 °/₀ of orthoclase-felspar as against 30 °/₀ of albite. The percentages only express the probable relations which would exist were the whole of the potash and soda present as orthoclase and albite. Past researches have shown that the spherulites contain both potash *and* soda—in fact, the quantity of alkalies in these bodies may become so large as to render worthless such a calculation, and obscure the estimation of the relationship between the felspars. Still, in some instances, the inference from the calculation is permissible.

Professor E. Hull, Director of the Geological Survey of Ireland, has very kindly drawn my attention to the felstone dyke in the

---

[1] A trace of MnO.

[2] This is another testimony to the wonderful accuracy of the chloride of platinum process. No TiO_2 was found, the amount of sphene being too small to give a reaction.

[3] Loss on ignition.

Silurian rocks at Leitrim River, Hilltown[1] (Sheet 60 (1 inch) of Geol. Survey of Ireland.) Upon examination of this rock, under the microscope, I find it to be spherulitic, and almost identical in character with the rock from near Newcastle. The spherules are here more apparent in ordinary light, owing to the excessive amount of ferruginous dust with which they are besprinkled. The contrast between the radiating nucleus and the only slightly coloured peripheral portion is thus very marked. The globular character of the spherules is very decided at times. Orthoclase is often present as Carlsbad twins; but little plagioclase is apparent. The quartz frequently shows excellent crystallographic boundaries, the prism being not an uncommon face to be observed. Secondary quartz is found encircling many of the spherules, and is constantly observed throughout the matrix of the rock. A dark mica (biotite) is also present in small quantity. Its pleochroism is between golden-yellow and dark-brown. It is also found as thin threads, scattered sporadically through the groundmass. This latter is, at places, decidedly micro-crystalline.

The third locality for rocks of this description is Slieve Bearnagh. The rock is the central dyke, traversing the Mourne granite at the summit of the mountain in an E.S.E. direction. "It is of a light-brown or gray colour, consisting of a felsitic paste enclosing crystals of felspar (often decomposed) and speckled by a greenish mineral."[2] This rock is also spherulitic, but not to the same degree as that from Newcastle. Both orthoclase and plagioclase are present. Carlsbad twinning is frequent. The plagioclase shows both the albitic and periclinic striae. This rock presents an excellent example of growth of crystalline material *after* consolidation.[3] For instance, a felspar crystal which

---

[1] The "reddish granitoid dyke, projecting S. from the Newry Granite at Hilltown," is seen upon microscopic examination to be a granophyre (Rosenbusch): the groundmass is micropegmatitic. The felspar of the micropegmatite surrounding a porphyritic felspar crystal mostly extinguishes the light simultaneously with the crystal, and where the latter is a Carlsbad twin, the trace of the twinning plane may be followed into the micropegmatite. The felspar crystals are generally unstriated, and Carlsbad twins are very frequent. A greenish or bluish-green micaceous mineral is present, also a white radiating mica (muscovite).

[2] Prof. Hull, in Memoir to Sheets 60, 61, &c., 1881, p. 36.

[3] Cf. Judd, in Q. J. G. S., Lon., vol. xlii. (1886) pp. 72, 73, pl. vii. fig. 8; also *ibid.* for May 1889, p. 175 *et seqq.*; further, E. Haworth, The Archaean Geology of Missouri: Minneapolis, Minn., 1888, pp. 16, 17, and Amer. Geologist, May and June, 1888.

shows a perfect external form is seen under crossed nicols to be partly fringed by a secondary growth, possessing an irregular and ragged outline. In ordinary light there is, however, no trace of a development of this nature; and the contours of the crystal stand out in sharp relief from the surrounding matrix. It is only under crossed nicols that the outgrowth becomes visible. We are then able to observe that the material composing this fringe is largely felspar, with minute fibres of intercalated quartz —in fact, its constitution is identical with that of the spherulites. The felspathic substance extinguishes coincidently with the felspar to which it is attached. As yet I have only observed the growth upon the faces P and x. But one of these faces sometimes shows an attachment of pseudo-spherulites, whilst the other will then present the outgrowth described above; so we have the two structures developed side by side upon one and the same crystal. It is a very significant circumstance that such crystals have only undergone enlargement where they would be in contact with a glassy matrix, and that where other crystals lie against them all growth upon the contact surfaces is suspended. I will refer to this interesting subject later on. Some serpentinous masses point to the original presence of a non-aluminous silicate. Epidote is very common; but porphyritic quartz is not apparent. There is a goodly quantity of quartz in the groundmass, but it seems to be for the most part of a secondary nature. The groundmass of the rock is distinctly micro-crystalline; but this aspect may possibly be due to some extent to the infiltration of secondary silica.

It may not unreasonably be asked whether we are not dealing with glassy rocks which have undergone devitrification. The question would be a natural one, seeing that many felsites and felsite-porphyries are now judged to be nothing else than devitrified obsidians, pitchstones, and vitrophyres; but the subject presents numerous and serious difficulties. Our present knowledge does not permit us to distinguish these from those rocks in which the double refraction of the felsitic matter is a consequence of primary devitrification, or that which is the consequence of actions accompanying solidification.[1] In micro-granites and granophyres the double refraction of the matrix, due to the fact that the

---

[1] Teall, Op. cit., p. 293.

groundmass consists of definite minerals, quartz and felspar, may be an original feature. Still, Professor Judd, in his recent paper "On the Growth of Crystals in Igneous Rocks after Consolidation,"[1] promises to show in a future communication every gradation from a glassy groundmass to one characteristic of the so-called granophyric rocks, and to prove that the characteristic structures of these rocks must be attributed to secondary rather than to primary causes.[2] The double-refraction of the matrix, which felsites and felsite-porphyries exhibit, may be either original or secondary; but we cannot as yet dogmatise upon the point. Where perlitic structure is present, we may conclude with Allport[3] and others that the rocks which show this structure were originally in the glassy condition. So far as we know, this structure can only arise during the consolidation of a glass. In the absence of perlite or some other feature equally characteristic of glass, we have no test by which we can distinguish an original micro- or crypto-crystalline groundmass from one which has been produced by subsequent devitrification.[4] A special type of devitrification is the spherulite which Rutley has described as occurring in a perlitic felsite from the Long Sleddale Valley in the Lake District of England.[5] The same author has, in conjunction with Hermann, studied the microscopical characters of glass devitrified by artificial means, and drawn attention to the conditions under which such devitrification has taken place.[6] We may assume with considerable safety that within certain limits there will be a more or less close analogy between the results of the natural and artificial devitrification,

---

[1] Q. J. G. S., Lon., May, 1889, p. 175, *et seq.*

[2] *l. c.*, p. 184.

[3] On Devitrified Pitchstones and Perlites of Shropshire, Q. J. G. S., Lon., xxxiii., p. 449.

[4] Teall, on Some Quartz-felsites and Augite-granites from the Cheviot District, Geol Mag. iii., vol. ii., 3, p. 110.

[5] Q. J. G. S., Lon., 1884, xl., p. 340.

[6] Herman and Rutley, On the Microscopic Characters of some Specimens of devitrified Glass; with Notes on Certain Analogous Structures in Rocks: Proc. Roy. Soc., London, vol. xxxix., 1886, p. 87.

See also Meunier Stan.: Expériences et observations sur les roches vitreuses. Comptes rend. tome lxxxiii. 616–619; Recherches sur la devitrification des roches vitreuses. Compt. rend. lxxxiii., 1083–1085; Michel-Lévy: Observations sur l'origine des roches éruptives, vitreuses et cristallines. Compt rend. lxxxiii. 749–752.

allowing, of course, a margin for certain natural conditions, which it would be difficult, if not impossible, to reproduce experimentally. Mixtures of fused silicates, such as those from which artificial glasses, slags, and igneous rocks are formed, may be regarded as solutions. Such silicate solutions have a strong tendency to form an amorphous glass when cooled rapidly—a feature which appears to be connected with the fact that they may be readily over-cooled, and a rapid approach of the molecules prevented. A glass results, therefore, from the solidification of an over-cooled solution. All kinds of glass may be devitrified—that is to say, may be converted into a crystalline aggregate. The process consists in maintaining the glass for a long time at a temperature sufficiently high to render it plastic without actual fusion. Now, if an over-cooled silicate solution, capable of producing crystalline bodies, solidifies as a glass, owing to the resistance the viscosity of the mass offers to rapid crystallization, it cannot be said to possess molecular stability. It may contain porphyritic crystals; but the capability of producing crystalline material will still remain an inherent quality of the vitreous matrix or base. Perpetual strain will be present—in short, there will be an effort on the part of the glass to come to a condition of molecular equilibrium. This, aided by other causes, must eventually conduce to some rude sort of crystallization. The tendency of a stable body like a porphyritic crystal of felspar will be to attract to itself particles of similar constitution, and to surround itself with a fringe of secondary material. It will grow at the expense of the vitreous matrix. Now, in the rocks before us there is no reason why they should not be supposed to have originally been vitreous in character. There is certainly no conclusive evidence such as that of perlitic structure. Fluidal structure is only slightly apparent; but they have the structure known as petrosiliceous.

Professor Bonney,[1] a high authority upon questions of this nature, considers that "we may safely affirm that the majority of the petrosiliceous rocks owe their structure to a peculiar form of subsequent devitrification, and so, as *altered* rhyolites, obsidians, and pitchstones, belong more properly to the metamorphic rocks (of igneous origin.)" Reference should be made to his suggestive

---

[1] Presidential Address to the Lon. Geol. Soc., vol. xli., 1885, p. 95.

address for particulars of the crystalline aggregates and spherulitic bodies formed in artificial glasses by the action of heat short of fusion.

Before concluding this portion of the Paper, it seems well to recall once more the experiments of Daubrée [1] on common glass. These were performed in closed tubes in the presence of water. They are remarkable as showing the powerful solvent action which water at high temperatures, and under considerable pressure, may have upon many substances which are not affected by it under ordinary temperatures and pressure. He found, that a glass representing a homogeneous silicate of soda and lime was converted into crystallized quartz and pyroxene with spherulitic growths at a comparatively low temperature. The process which has taken place in nature must, according to Professor Bonney, have been analogous to this experiment—that is to say, when "devitrification," in the strict sense of the word, has been produced in a rock once glassy "the agents of change have been pressure, water, heat—the elevation of temperatures being probably, in most cases, very moderate." [2]

A brief reference will now be made to the question of the age of the outbursts of acid material in the Mourne Mountains. In a paper read before the British Association, Messrs. Hull and Traill recorded their opinion that the granite of Mourne is of Mesozoic Age.[3] On the other hand, the late Professor Harkness suggested that it was irrupted during the interval between the Carboniferous and Permian period. All that can be confidently affirmed from the available evidence is, that the Mourne Granite is Post-Carboniferous on the one hand, and older than the Miocene Period on the other.[4] To the latter period of volcanic activity are referred the numerous basaltic dykes by which it is penetrated. On the other hand, the basaltic dykes, which terminate at the margin of the granite, are more ancient than it. The order of succession has therefore been in the Mourne Mountains :—1, basic materials ; 2, acid ; and 3, again basic.

---

[1] Etudes Synthétiques de Géologie Expérimentale, tome i., pp. 159–171.

[2] *l. c.*, p. 93.

[3] Brit. Ass. Rep., 1871 ; Trans. of Sections, p. 102.

[4] Prof. E. Hull, in Memoir to Sheets 60, &c., p. 29.

The actual epoch of irruption is, therefore, very uncertain, and cannot yet be conclusively established. The same uncertainty also exists about the Arran Granites and spherulitic felsites. Touching the age of the latter, Allport writes: "So far as is yet known with certainty, they may have been intruded at any time between the close of the Carboniferous and the close of the Tertiary Periods.[1] Both at Newcastle and Hilltown the spherulitic rocks break through the Silurian slates, but nothing more definite as to their age can be stated. But at the summit of Slieve Bearnagh the dyke pierces the Mourne Granite, and may possibly be of Tertiary age, according to Professor Hull.[2] This fact upsets the idea that the dykes are apophyses of the granite, but brings them, on the other hand, into relationship with the trachytes of Co. Antrim.

This brings us to the question of nomenclature. Spherulitic felsite-porphyry would accord very well with the microscopic characters of the rock; but the employment of such a name would imply something as to their age. They might, with equal propriety, be called quartz-trachytes or Liparites, and they would certainly be placed in the trachytic group, were they definitely known to be of Tertiary age. Allport is of the same opinion as regards the Arran spherulitic rocks, and especially mentions that there is no mineralogical or structural difference between them and the recent trachytes; there is also, on the other hand, nothing to distinguish them from much older rocks.[3] But, even if we consider the pre-Tertiary age of the rocks established, there seems little reason in pursuing the unphilosophical system of making geological age, *per se*, a factor in petrographical nomenclature. The older rocks are, of course, more liable to undergo mineral changes during the vicissitudes of their longer history. The less stable minerals will have disappeared, and more stable forms will be substituted. In short, an ancient rock, like a living creature (to quote the words of Professor Bonney), can hardly fail to exhibit signs of old age. Teall, in his series of excellent papers on the Cheviot rocks, has shown that, except for alterations which can only be attributed to the effect of time, some of the porphyrites

---

[1] *l. c.*, p. 544. [2] *l. c.*, p. 36 (Memoir). [3] *l. c.*, p. 544.

of that region are *chemically* and *mineralogically* undistinguishable from the hypersthene andesites of Tertiary and yet more recent age.[1] The volcanic eruptions which gave rise to these rocks must have taken place in Lower Old Red Sandstone times. S. Allport[2] has shown that the devitrified perlitic rock of the Wrekin, which is indubitably older than the Lingula Flags, and in all probability is one of the later pre-Cambrian lavas, is as nearly as possible identical, chemically, mineralogically, and structurally (except for devitrification) with the perlitic obsidian of Hlinik, near Schemnitz, and corresponds very closely with another post-secondary obsidian from Hungary. The red felsite, which in North Wales is found below the base of the Cambrian series, exhibits, in some localities, a fluidal structure, and every indication of having once been a true glass, and is *chemically* identical with the above rock from Schemnitz; while several of the lavas of the Ordovician series in Wales are, except in this one regard of devitrification, not to be distinguished chemically and microscopically from ancient rhyolites, exhibiting fluidal or perlitic spherulitic structures.[3] Zirkel was long ago impressed by the same similarity, when he stated that many ancient felsite-porphyries cannot be distinguished microscopically from recent quartz-trachytes;[4] whilst Vogelsang[5] expressed himself inclined to the opinion that the felsitic groundmass represented the result of secondary devitrification.

In the light of these considerations, and remembering (if we still wish to make geological age a factor in nomenclature) that the rocks may possibly be of Tertiary age, we may, with safety, propose the name "Spherulitic Quartz-Trachyte" to denote the rocks from Co. Down.

---

[1] Notes on the Cheviot Andesites and Porphyrites, Geol. Mag. 1883, vol. x., pp. 100, 145, 252.

[2] On Certain Ancient Devitrified Pitchstones and Perlites from the Lower Silurian District of Shropshire, Q. J. G. S., Lon., May 23, 1877.

[3] Bonney, T. G., On the Quartz-felsite and Associated Rocks of the base of the Cambrian Series in N. W. Carnarvonshire, Q. J. G. S., Lon., 1879, xxxv., 309: also Presidential Address to Geol. Soc. 1885.

[4] Lehrbuch der Petrographie: Bonn, 1866 ii. p. 381.

[5] Philosophie der Geologie, &c.: Bonn, 1867, 144, *et seq.*, 153, 194; also Archives Neérlandaises, tome vii., 1872.

The following comparison will prove worthy of attention :—

	Mourne Granite, Slieve Corragh (Haughton).[1]	Spherulitic Rock, Newcastle, Co. Down (Hyland).	Quartz-Trachyte, Tardree, Co. Antrim (Player).[3]
SiO_2	75·00	70·07[2]	76·4
Al_2O_3	13·24	13·86	14·2
Fe_2O_3	2·52	2·41	1·6
CaO	·69	1·44	·6
MgO	—	·70	—
K_2O	4·33	6·90	4·2
Na_2O	3·07	3·55	1·8
H_2O	0·80	1·07	1·5
	99·65	100·00	100·3
	Sp. g. 2·595	Sp. g. 2·589	

Professor O'Reilly has kindly drawn my attention to the fact that traces of gold have been found by M. Baudin in the pyritous trachytes of Cantal (Puy-de-Dôme). It would be interesting to find similar evidence of the presence of the noble metal in the Newcastle Rock, and I hope at a future date to supply a communication upon the subject.

NOTE ADDED IN THE PRESS.

Since the above list of minerals occurring in the geodes of the Mourne Mountains granite was compiled, Professor Sollas, F.R.S., has added still another in the shape of a lithium-mica of the species Zinnwaldite. Most of the crystals possess an exqui-

---

[1] Experimental Researches on the Granites of Ireland, Q. J. G. S., Lon., xii., p. 192.

[2] The silica varies from 70 to 74 °/₀.

[3] Teall, British Petrography, p. 348. This analysis agrees exactly with Hardman's (J. Geol. Soc. Ireland, xiii. 29) so far as the alkalies are concerned. Hardman's analysis is exceptional as regards the amount of alumina and lime; but Player' agrees with the quantities usually present in a rock of this nature. Hardman's analysis is as follows :—SiO_2 76·96; Al_2O_3 5·1; Fe_2O_3 2·344; CaO 7·06; MgO 0·29; K_2O 4·26; Na_2O 1·8; H_2O 2·1; P_2O_5 tr.

[4] Résultats principaux des expériences faites dans le laboratoire de Clermont pendant l'année 1841. Trachytes pyriteux aurifères de Mandailles (Cantal. " Ann. d. Mines, 1842, tome i., p. 100.

sitely defined zonal structure. (Paper read before the Royal Irish Academy, March 15, 1890. See also *Nature*, March 20, 1890, vol. xli., p. 469.)

A "chalcedony, constituting sphericles in a felspar porphyry from the Mourne Mountains," was analysed by Thomas Thomson, with the following result:—

Silica	95·15
Alumina, with a little peroxide of iron	1·95
Lime	2·25
Water	1·00
Sp. G. = 2·641	100·35

(Outlines of Mineralogy, Geology, &c., London, 1836, vol. i., p. 68.)

XLVII.

ON SOME SPECIMENS FROM WADY HALFA, UPPER EGYPT.

By J. SHEARSON HYLAND, Ph. D., M.A., of the Geological Survey of Ireland.

[Read February 10, 1890.]

During the recent Soudan Campaign Wady Halfa was occupied by the English Expeditionary Force, and became one of their principal stations on the Nile—a large hospital being established there. Surgeon-Major S. Archer, of the Army Medical Department, seized the opportunity afforded him in his leisure hours of searching the immediate vicinity for remains of the stone age. He was successful in discovering an immense number of flakes and hammerstones; but more finished implements appeared to be scarce, and only a few were found.

Whilst in England in 1888, I had occasion to examine the collection, which is now in the possession of Mr. F. Archer of Liverpool, and was particularly struck by the igneous aspect presented by the material composing some of the more rudely fashioned flakes. As may be inferred from the long-known occurrence of jaspers, &c., upon the Egyptian desert, the mass of the collection consists of siliceous pebbles. I had sections cut from the igneous-looking material, and was not disappointed in my expectations. But, before entering upon a microscopical description of this rock, a short account of the other specimens may be given.

The hammerstones consist of silicified wood, masses of which are found upon the surface of the country. The material is hornstone-like in appearance, highly siliceous, and, accordingly, very suitable for hammers. A thin section shows, under the microscope, a well-defined organic structure. The wood is converted into chalcedony, more or less discoloured by ferruginous matter. Sometimes there is an alternation of chalcedony and crystalline quartz; the latter is then arranged parallel to the organic fibres, and presents, under crossed nicols, a mosaic-like structure. Where crystalline quartz occurs, the organic structure is obliterated. A certain amount of carbonate of lime is present—a fact that Russegger long ago remarked when visiting the locality.[1]

The fossil wood, which covers the desert to the East of Cairo, has long filled the passing traveller with surprise. At Jebel Ahmar, or the Red Mountain, near Cairo, it occurs, according to Sir W. Dawson, "in prostrate trunks, sometimes flattened, and imperfectly preserved, and sometimes perfectly silicified, and occasionally lying in disintegrated cuboidal fragments, showing that the wood was imbedded in its natural state, and in a decayed condition, and afterwards silicified."[2] The fossil wood of the Jebel Ahmar and the "petrified forests" has been examined and described by various authors.[3] It includes several species of *Nicolia*, also conifers and a Palm.

The collection also contains "scrapers" of varying shape. They are made of jasper, do not exceed four inches in length, and are almost all fabricated upon a plan which has been noticed elsewhere in Egypt, viz. by taking a rather flat stone and chipping away upon one surface only so as to leave the whole of the flatter side, whilst but a small central portion of the upper surface was left. Many of the flakes are trimmed articles with carefully worked edges: the material selected for these was a bright and yellow cornelian. There are also very fine pebbles, consisting of fibrous chalcedony, streaked with parallel lines of iron oxide, and presenting a beautiful picture under crossed nicols. One section shows the line of growth or infiltration, and inclined to this, at an angle of nearly 60°, the chalcedonic fibres have formed. The iron oxide exhibits a tendency to develop a sort of oolitic structure—in fact, at times the reddish layers consist almost entirely of such

---

[1] Neues Jahrbuch für Mineralogie, etc., 1836, p. 688. (Letter to v. Leonhard, dated Alexandria, April 17, 1836).

[2] Notes on the Geology of Egypt, Geol. Mag. 1884, iii. vol. i., p. 385; also, Newbold, On the Geological Position of the Silicified Wood of the Egyptian and Libyan Deserts, with a Description of the "Petrified Forest," near Cairo, Q. J. G. S., Lon., 1848, vol. iv., pp. 349–357.

[3] R. Brown, Q. J. G. S., Lon., iv., p. 354; W. Carruthers, Petrified Forest near Cairo, Geol. Mag., vol. vii. (1870), p. 306; Zittel, Ueber den Geol. Bau der Libyschen Wüste: München, 1880.

globular or spherulitic bodies. The ruder flakes are mostly made of a material which has the following microscopical aspect:—Imbedded in a dark-brown, non-transparent matrix lie numerous fragments of quartz and a few of felspar. Rounding of the edges by attrition is not visible; on the contrary, the minerals have preserved their fracture-lines remarkably well. Their bizarre forms remind the observer of fragmental rocks, like tuffs or breccias, rather than of sandstones. The "burnt Sienna" coloured matrix appears to be formed of highly siliceous limonite; it is, so to say, the cement which binds the fragments together. Such siliceous limonites are not at all uncommon; and Walchner has described an occurrence at Kandern, in Baden, with as much as 21 °/₀ of silica.[1] The quartz is mostly the quartz characteristic of granitic rocks, and contains numerous fluid cavities, also inclusions of zircon and dark mica (biotite.) But some of the quartzes are evidently derived from the metamorphic areas; for they show the phenomenon of granulation in its early stages and the optical anomaly due to compression known as undulose extinction. The little felspar present is mostly orthoclase; but traces of plagioclase are observable, though very infrequent. All the fragments are remarkably fresh; but the geological bearing of this feature will be shown at the end of the paper.

Rocks similar to this are very common in East Africa. I possess, and have previously described,[2] some specimens from Kahe-Aruscha (a locality situated between the Kilima-Ndjaro *massif* and Pangani upon the East Coast), which are practically identical with those referred to above. The similarity is, in fact, so striking that we are compelled to conclude that they are derived from one and the same formation.

Flakes bearing evidence of human workmanship are not uncommon in the Nile valley. The mode of occurrence, and the relations of the flint implements, are well discussed by A. Jukes-Browne in his papers in the Cambridge Antiquarian Society's Communications, and in the Journal of the Anthropological Insti-

---

[1] Naumann-Zirkel, Mineralogie, 1885, p. 415.

[2] J. S. Hyland, Ueber die Gesteine des Kilimandscharo und dessen Umgebung, Tschermak's Min. u. petr. Mitt. x., Heft iii., p. 266.

tute.[1] A remarkably fine palaeolithic stone implement of the true river-drift type has been described by H. Stopes.[2] The locality given is half-a-mile from the Spring of Moses, near Cairo; the greatest length is 5·5 in, width 3·8, and thickness 1·5. It is made of "conglomerate" precisely similar to that found at Jebel Ahmar. Sir W. Dawson[3] holds, however, that all such remains of man are superficial and modern, and considers that there is no certainty as to the human origin of the implements stated to have been discovered by General Pitt Rivers in the old indurated gravels near Thebes.

Many of the implements before me are highly polished and unevenly corroded. The agency to which this is generally ascribed is Eolian. It is, in fact, a well-known observation in Egypt that this action goes on upon the large scale—strata being deeply grooved and ploughed by the sand-charged blasts of the desert.[4] The unevenness in the corrosion is due to differences in the composition and hardness of the various layers. Professor V. Ball[5] has recently suggested that the appearance is probably due to the solvent action of a supersaturated solution of carbonate of soda upon the silica. Incrustations of sodium carbonate are abundant in India, whilst in Nubia the soil is impregnated with salts. In Equatorial Africa nitrate of soda makes its appearance, and covers huge plains to the N.W. and S. of the Kilima-Ndjaro.[6] Hence, considering the known solvent action of such alkaline salts, it seems necessary for us to ascribe to this agent a part in the process of corrosion—though a minor one as compared with that of blowing sand. A. Irving[7] regards the humus-acids furnished by the desert-scrub as the more likely solvent.

---

[1] Dawson, *l. c.*, p. 483; also, *inter alia*, Haynes, Silex acheuléens de l'Egypte, Bull. Soc. Anthrop. Paris, sér. 3, tome i., 1878, p. 339; E. Desor: Notice sur les silex préhistoriques des bords du Nil. Bull. Soc. Sci. Nat. Neuchâtel, vol. xii., 1882, pp. 435–438; 1 pl.

[2] On a Palaeolithic Stone Implement from Egypt. Rep. Brit. Ass., 1880, p. 624.

[3] Transactions of the Victoria Institute, 1884.

[4] Cf. J. D. Enys, "On Sand-worn Stones from N. Z.," Q. J. G. S., Lon., xxxiv., p. 86.

[5] On some Eroded Agate Pebbles from the Soudan, *ibid.*, March 28, 1888, p. 368.

[6] Hyland, *l. c.*, p. 211.

[7] Metamorphism of Rocks: London, 1889, p. 104.

The lower beds of the nummulitic limestone seem to be largely the home of the cherts, jaspers, and agates. (Russegger and Newbold.)

The igneous rock, to which I have referred above, is dioritic in appearance, and is found, upon microscopic examination, to be a Lamprophyre. It probably comes from an area of crystalline rocks, similar to those which make their appearance, for instance, near the First Cataract (Assouan), where "we pass from the unaltered and nearly flat Nubian sandstones to rocks highly crystalline, greatly disturbed and penetrated with multitudes of igneous veins."[1] The latter are dykes of granite, felsite, diorite, and basalt. Sir W. Dawson observed that one of the diorites exhibited a porphyritic character, induced by crystalline patches of white felspar. Now, the rock I have before me has a tendency to develope the same structure—the porphyritic constituent being a pinkish felspar. Still, the structure is generally evenly crystalline, with a grain which allows the constituent minerals to be recognised with the aid of the lens. The colour of the rock is very dark green.

Under the microscope the felspar is seen to be mostly an unstriated variety. Striated felspar is very rare, but the striæ are always very fine. The non-lamellated felspar does not always give straight extinction. In section this constituent is lath-shaped, being from 3 to 5 times as long as broad. The outline is generally well-defined. Still, at times it is irregular in appearance. It is usually considerably altered; but the decomposition is always confined to the centre, and a thin external zone then remains quite fresh and adular-like in appearance. This would lead us to expect some difference in the chemical constitution of the two zones. The alteration consists in the formation of cloudy granular products, some of which belong to the mineral epidote, while others appear to be micaceous in character. There is, unfortunately, not sufficient material for a chemical analysis; so no definite conclusions can be drawn as to the nature of the unstriated felspar. Where straight extinction occurs, it is, no doubt, an orthoclase; but

---

[1] Dawson, *l. c.*, p. 439; *cf.* also Lord Talbot de Malahide, Notes on the Geology of Egypt, Journ. of the Geol. Soc. of Dublin, v. 1850–53, pp. 277–279; and C. B. Klunzinger, Upper Egypt, &c., London (Notes on Rocks of Desert Mts., pp. 229–235.)

whether we are dealing with a felspar of the anorthoclase series it is impossible to say.

Both mica and hornblende are present. The inclination is to develope a rod-shaped form. The colour of the two minerals is practically the same, being green to greenish yellow. The directions of extinction and the degrees of pleochroism serve to distinguish the one from the other. The maximum extinction angle of the hornblende ($\mathfrak{c}$: c) was found to be 14°, and the pleochroism deep green to rich yellow. There is twinning parallel to 100. Chlorite is present, and appears to be due to the alteration of the mica or hornblende. A vein of epidote runs through the rock, and secondary quartz can also be observed. Primary quartz is also to be noticed, and contains inclusions of a colourless, needle-like mineral, probably apatite. The amount of quartz, both primary and secondary, is not inconsiderable. Carbonates, sphene, and iron ores are not absent.

The microscopic structure is that of a holo-crystalline rock. There is no trace of foliation; and the dykes of this series are evidently posterior to the earth-movements which have affected the crystalline schist area. We have applied the term Lamprophyre to denote the rock. This name was first introduced by Gümbel,[1] to define rocks which occur as a series of dykes (usually running N. & S.), in the Palaeozoic strata of the Fichtelgebirge, Thüringerwald, and Voigtland in Germany. They occur as high as the Culm Measures, are mostly dark-coloured, and bear a strong resemblance to "diabase," though they differ from that rock in containing much dark mica. Manifestly, Gümbel's Lamprophyres are similar in composition, geological age, and mode of occurrence, to the mica-traps of Cornwall and Devon.[2] Rosenbusch[3] extends, however, the signification of Gümbel's term, and distinguishes between the *syenitic* and *dioritic* Lamprophyres according as orthoclase or plagioclase is the dominant felspar. The general name, "Lamprophyre," he applies to rocks which occur as dykes in disturbed regions, and which so far as the composition is concerned, have affinities on the one hand with syenites,

---

[1] Geognostische Beschreibung des Fichtelgebirges, p. 189.

[2] Teall, British Petrography, p. 351.

[3] Mikroskopische Physiographie der massigen Gesteine, 1887, p. 308.

and on the other with diorites. The syenitic Lamprophyres he separates into two groups, the Minettes and the Vogesites, whilst the dioritic are divided into Kersantites and Camptonites:—

Lamprophyre	*Syenitic*	orthoclase +	biotite[1]	= Minette
		orthoclase +	hornblende or augite	= Vogesite
	Dioritic	plagioclase +	biotite	= Kersantite
		plagioclase +	hornblende or augite	= Camptonite.

The dominant felspar in our rock appears to be an orthoclase. Hence, as hornblende is the dominant ferro-magnesian constituent, the rock is a Vogesite; on the other hand, a dark mica (biotite) is also present, but in minor quantity. The rock must, therefore, be allotted an intermediate place between the two types, and receive the name "mica-bearing Vogesite."

It is interesting to note that Professor Bonney[2] who microscopically examined the series of rocks brought from Upper Egypt by Sir William Dawson, found amongst them a holo-crystalline trap, which he has described as a quartziferous Kersantite. The constituents are given as biotite, hornblende, felspar (commonly plagioclase), quartz, apatite, iron ores, and sphene; the locality being Biggeh (Assouan).

The distance between the cataract at Wady-Halfa (the second) and that at Assouan (the first) is about 214 miles. As the average fall of the Nile between these two points is, according to L. Horner,[3] not 9 inches in a mile, it is not to be expected that much coarse gravel can be carried forward. The greater portion of the heavier detritus thus falls down in the higher parts of Upper Egypt. It is a well-known fact that the

---

[1] Biotite is used as synonymous with dark mica.

[2] Notes on the Microscopic Structure of some Rocks from the Neighbourhood of Assouan, &c., Geol. Mag., 1886, vol. iii., p. 106.

[3] An Account of some Recent Researches near Cairo, undertaken with a view of throwing light upon the Geol. History of the Alluvial Land of Egypt. (Philosophical Transactions of the Roy. Soc. Lon., 1855, vol. cxlv., p. 117.)

surface of the Nile valleys is, for the most part, covered with drifted gravel, composed not only of the detritus of rocks in the vicinity, but of rolled pebbles of other formations transported from great distances. For the presence of many of these, the action of existing streams is not adequate to account. The limestone valley of Kossier, near the Red Sea, is covered with a gravel—great part of which consists, according to Newbold, of pebbles from the plutonic and metamorphic rocks of the interior. Few of these pebbles, he adds, are found near the Nile west of the sites of the parent rocks —a fact which indicates the easterly direction of the transporting agency.[1]

There are before me some loose grains which bear the description "the so-called Nile rubies, Wady-Halfa." The "rubies" are reddish garnets, some of which show a remarkably well-preserved form (211). Cyanite can also be microscopically determined. Both minerals are evidently derived from the crystalline schist areas.

Through the kindness of Mr. F. W. Rudler, F.G.S., I am enabled to add a description of the microscopical characters of the desert sand of Korti on the Nile. My best thanks are due to him for permitting me to examine the slides in his possession. As regards the delta-deposits, these consist of admixtures, in varying proportions, of blown sand and alluvial mud. The microscopical characters of these deposits have been carefully investigated by Professor J. W. Judd, and described in a Report to the Royal Society.[2]

The sand[3] at Korti differs but slightly from that described by Professor Judd. It is seen upon microscopical examination to be

[1] Newbold, "On the Geology of Egypt," Q. J. G. S., Lon., iv., 1848, p. 326.

[2] Report on a Series of Specimens of the Deposits of the Nile Delta, obtained by the recent Boring Operations. (Communicated by desire of the Delta Committee, Proc. of the Royal Society of London, 1885, xxxix., p. 214 *et seq.*) In a footnote to this Paper additional interest is given to the results of the boring at Rosetta by the reported discovery, at a depth of 79 ft. 4 in., of a fragment of red granite possessing undoubted marks of human workmanship upon it.

[3] The sands and muds of the Nile deposits have been subjected by Johnson and Brazier to careful analyses, performed under the superintendence of Hofmann. The results are published in Horner's Paper already quoted. The mud has been also investigated by earlier chemists; but of all these, Regnault seems to have executed the most minute analysis. (Mémoires sur l'Egypte, tome i., pp. 348, 382.)

made up of two kinds of grains, the larger being perfectly rounded and polished, whilst the smaller are often sub-angular or angular. The grains often exhibit traces of deposits of iron oxides upon their surfaces. The material constituting the sand is quartz—felspar being extremely rare. The quartz shows every evidence of having been derived from granitic rocks: it is very full of gas- and fluid-cavities, and is often traversed by fine, hair-like needles of a mineral which is presumably rutile. These are arranged along definite planes, and cross each other at an angle of about 60°. The latter phenomenon is a very characteristic and constant feature of the quartz of granitic rocks.[1] Evidence of the presence of quartz, such as finds its home amongst metamorphic rocks, is not wanting. In such cases the quartz is seen under crossed nicols, to consist of aggregates of small grains—in short, the quartz has undergone granulation. Zircon is to be observed amongst the sand, but is not of frequent occurrence. There are also some dark-coloured opaque grains which are presumably of a siliceous nature. But a few of the almost perfectly spherical grains appear to be of calcareous origin.

It is to be concluded that the desert sand had been formed by the breaking up of granitic or metamorphic rocks, or of sedimentary deposits directly derived from these rocks. Of still greater interest is, however, the fact, enunciated so ably by Professor Judd, that the fragments of felspars and other compound silicates of the delta-deposits exhibit but slight evidence of kaolinization or other chemical alteration. This is also true of the few felspars in the Korti sands. The fact points to the conclusion that, in the arid districts drained by the Nile, the disintegration of rocks is effected by mechanical rather than by chemical agencies.[2] The most potent of these agencies of disintegration are, according to

[1] H. C. Sorby has also described the sand of the Egyptian desert in his Paper entitled "The Application of the Microscope to Geology: Micro. Journ., xvii. pp. 113–136.

[2] It is a well-known fact that rocks are singularly well preserved in Egypt. According to Newbold (*l. c.*, p. 340), the granite of Egypt, for instance, is freer from the decay, the "maladie du granite," than that of India. This probably arises from the peculiarly dry atmosphere of Egypt, which has been mainly instrumental in preserving, almost in their original freshness, its magnificent sculptures and vivid frescoes. (See also E. Hull, On building and Ornamental Stones: London, 1872.)

the same writer, the heat of the sun, causing the unequal expansion of the minerals which build up the rocks, the force of the wind producing constant attrition of the disjoined particles, and torrential rains. A very striking confirmation of this conclusion is afforded by a study of the composition of the Nile waters. In spite of the enormous evaporation and constant concentration the waters of the Nile must undergo during its passage of 1400 miles through regions of exceptional heat and drought, it is shown that these waters actually contain far less dissolved matter than the Thames, the Lea, the Severn, or the Shannon.[1] The chemical disintegration of rocks being so largely due to the action of rain and vegetation, it is not surprising to find that, where these kinds of action are almost entirely absent, but little evidence of chemical change is exhibited by their mineral-constituents. It is therefore to be expected that the waters which traverse such regions will be characterised by a deficiency in the proportion of solids in solution, and by anomalies in the degrees of temporary and permanent hardness. As a matter of fact, the waters of the Nile really hold in solution little more than one-half the per-centage of mineral matter which is present in the river waters of temperate and rainy regions.

---

[1] C. M. Tidy, River Water. Journal of the Chemical Society, 1880, vol. xxxvii. pp. 268–327.

XLVIII.

NOTES ON A SUCKING-FISH (*Liparis vulgaris*, Flem.), NEW TO IRELAND. By R. F. SCHARFF, Ph. D., B. Sc.

[Read February 10, 1890.]

The occurrence of this little fish on the Irish Coast was first recorded in the Ordnance Survey Memoir of the County of Londonderry (vol. i., Notices, p. 14). The locality given for it is simply "Lough Foyle and Larne."

Thomson, in his Natural History of Ireland (vol. iv. p. 221), mentions having examined eight specimens in the Ordnance Collection labelled *Liparis vulgaris*, but he found them all to belong to *L. montagui*, a closely allied species.

Having recently had an opportunity of critically examining and cataloguing the collections of Irish fishes in the Dublin Museum, in which the Ordnance Survey collections have been incorporated, I found among the latter a jar of specimens labelled "*Liparis montagui*." Seven of these specimens undoubtedly belong to *L. vulgaris*, Flem., which species may now figure on the list of Irish Fishes, though recorded by Thomson as doubtfully present, for he says: "it would be desirable if the other specimens alluded to from these different quarters were closely examined; but until this be done, and *L. vulgaris* be positively found among them, or be obtained elsewhere, it had better be omitted from our Catalogue."

Both these species of sucking-fish have a small circular disc on the under side of the body, by means of which they are able to attach themselves to stones or sea-weeds. Apart from a slight difference in the respective sizes of the two species, the nature of the disc seems to be the only safe criterion by which they may be distinguished. In *L. vulgaris* the disc is more oval than in *L. montagui*, and is composed of eleven flat papillae, while in the latter species it has thirteen. *L. vulgaris* moreover has a number of irregular, narrow dark bands distributed over the surface of the skin, which are absent in *L. montagui*, though this character, according to Yarrell, is not always to be met with.

Both forms occur between tide marks, *L. montagui* being often found concealed beneath stones, where, when at rest, the body is bent, so that the tail is brought close to the head. The two species have a wide range; but they are decidedly northern forms, having been recorded from the Polar Regions to the Shores of France, and also on the North American Coast. In Greenland *L. vulgaris* is said to be used as food, and it seems to be more common there than the other species, which becomes more numerous as we proceed to temperate climes.

As regards their distribution on the Irish Coast, I have mentioned the only recorded localities of *L. vulgaris*, viz. "Lough Foyle and Larne." *L. montagui*, on the other hand, has been recorded by Thomson from Carrickfergus and Portpatrick in the North; by the late Dr. Ball from Tramore and Youghal in the South, and Roundstone in the West; while the Rev. Father Davis recently obtained some specimens in Baltimore Bay (Co. Cork) for the Museum Collections.

XLIX.

NOTES ON SOME ASSAYS FOR GOLD OF ROCKS OCCURRING IN THE NEIGHBOURHOOD OF DUBLIN. By Professor JOSEPH P. O'REILLY, Royal College of Science, Dublin.

[Read February 10, 1890.]

The existence of gold in this country, the conditions under which it has been found, as well as the localities where it has been met with, are matters which have been detailed in different well-known works—one of the most remarkable circumstances connected with the occurrence of the metal in Ireland being the rarity of its appearance in the rock *in situ*, in any appreciable quantity capable of giving rise to mining operations. Considering, however, the varied nature of the geological formations of this Island, the remarkable development of crystalline rocks, and of the older sedimentary strata, the frequency of disturbances such as faults, dykes, &c., it might reasonably be expected that gold-bearing rocks should be met with in Ireland, and have been discovered long ago. Nothing, however, can be collected from the historical records of the country pointing to the knowledge of such rocks, and it is generally assumed that the gold which certainly was worked in different districts of Ireland in former ages, was of placer origin—that is, it was collected by washing sands or the detritus of rocks accumulated by the action of streams and rivers. Yet, no fact is more distinctly established scientifically than the extent to which gold is dispersed throughout the rocks and minerals forming the surface of the earth. Some facts in this respect are worth citation. Landrin, in his work on gold (Traité de l'or) makes the following statement (p. 49): "Gold is one of the most generally disseminated of metals; there is no earth nor sand which does not contain some of it." It is found even in the ashes of vegetables. Berthollet was able to extract 40 grains from a cwt. of ashes (= 0, 000054.) Sage went farther and obtained the following results for the gold present in certain soils and ashes:—

Vegetable Mould (terreaux), . . .	0, 0000138
Heather Soil (Terre de Bruyère), . .	0, 0000195
Beachwood Ashes, ...	0, 0000195
Vineshoot Ashes (sarments), . . .	0, 0000325
Garden Soil, ...	0, 0000390
Manured Vegetable Soil, . . .	0, 0001520

As a distinct proof of this general dispersion may be cited the fact of the existence of gold in sea-water, as ascertained by Sontag, and estimated at 0, gr. 05 p. ton (Proceed. R. S. Lon., 1872)—a much smaller quantity, no doubt, than the silver or copper present in the ocean, but sufficiently distinct to be determinable chemically—its presence being naturally accounted for by the salts carried in solution by rivers—these receiving the products of the decomposition of strata containing gold in some one or other mineralized state. It is further presumed that the gold is held in solution by the sea-water in virtue of the chlorides, iodides, and bromides present.

Taking it, therefore, as ascertained that gold is very generally dispersed in rocks, and more particularly in the older rock formations, that dispersion may be either uniform or varied, so that certain rocks and localities should show much more gold than others.

Thus, quartz has always been considered as the mother rock of gold, and, as a consequence, the formations in which quartz veins occur most markedly have generally been recognized as the richest in that metal, with the result that the Cambrian and Silurian formations have long been reputed the richest in gold-bearing reefs, and the countries wherein these formations show themselves have become the fields of exploration for that metal.

The extraordinary development of gold mining, since the Californian discovery of 1848, in every quarter of the world, and the number of facts observed and recorded in connection with the associations of gold, and as regards the encasing rocks and accompanying minerals, have considerably modified the views held in this respect. Thus A. G. Lock, in "Gold: Its Occurrence and Extraction," 1882 (p. v. Introduction), says:—"Recent geological explorations have shown that gold is abundantly present in formations which it was authoritatively stated could never prove to be auriferous, and in the light of our present knowledge it would not be safe to exclude any geological series from the possibility of being gold-bearing. Gold reveals its presence in the earth's crust far less readily than other useful minerals, and many a gold-field has been passed over by generations of men before its riches were discovered. Hence the necessity for intelligent search"; and the summary given in this remarkable work on gold, p. 803, merits being cited. He says:—

1st. "Gold exists in the oldest known rocks, and has been thence distributed throughout all the strata derived from them.

2nd. "In the metamorphosis of these derived rocks it has been reconstructed in segregated quartz-veins by some process not yet understood.

3rd. "It is a constituent of fissure-veins of all geological ages, where it has been deposited from hot chemical solutions, which have leached deeply-buried rocks of various kinds, gathering from them gold with other metallic minerals.

4th. "By the erosion of strata containing auriferous veins segregated or fissure gold has been accumulated by mechanical agents in placer deposits, economically the most important of all the sources, of gold."

He then passes in review the different formations from the Laurentian upwards, and shows that gold has been found in connection with them all, and points out the important rôle played by the igneous rocks, (diorites, &c.) At p. 835 he cites the later conclusions of Forbes as to the existence of two epochs of auriferous impregnations throughout the world:—

(1.) The Older or Granitic outburst.

(2.) The Younger or Dioritic outburst.

From the consideration of the facts brought forward by Lock, and those continually appearing in the Journals specially dedicated to mining and mineral matters, it may be concluded that the search for gold need not necessarily be confined to any one particular class of rock, and that the examination of any given rock, chemically, is the only safe criterion by which to decide whether it contains gold or not. Carefully executed chemical analyses or assays are, therefore, the only sure and safe guides in the determination of the extent to which a rock or a district may be considered auriferous and capable of leading to mining operations. As such analyses or assays are costly, and even tedious in many cases, they are not so often resorted to as is desirable—explorers more generally basing their conclusions on washings or pannings of the ground or rock being examined. This method, excellent in skilful hands, when applied to rock containing free gold, and valuable on account of its simplicity and quickness, cannot give satisfactory results when the gold is in combination with other metals, and therefore it has been found advantageous, in those countries where exploration is being carried on with the greatest activity and intelligence, to facilitate for explorers access to laboratories, wherein careful determinations of the gold and associated metals are made, so that research being continually guided, it can be pushed on with both activity and a clear knowledge of the ground being operated on.

Influenced by considerations of this nature, I was led to examine and to have assayed during the year 1888 and the commencement of 1889, various rocks occurring in the vicinity of Dublin, with a view to ascertaining whether they contain gold, and also in what quantity, so as to be guided as to the existence of rocks which might be found to present points of concentration of the metal capable of being worked profitably—that is, I proposed to proceed from the general to the particular, and, having traced the existence of gold in several rocks, to endeavour to arrive at a conclusion as to the existence of the metal in greater quantity in certain of them, pushing on, then, the inquiry and endeavouring to define localities likely to show gold in paying quantities.

The assays were made by Mr. F. Claudet of Coleman-street, London, who was good enough, at my request, to take particular care in determining traces of gold, since, in nearly every case, the most to be expected from the nature of the rock submitted for assay would be a trace of the metal, if any.

The first rock submitted to him was the stone being used for metalling the streets by the Corporation, and which I had frequent occasion to see laid down between Baggot-street Bridge and Stephen's Green, and in the neighbouring streets. This stone—a greenstone or diorite—comes from the quarries about Montpelier and Bohernabreena; it is very tough, sometimes porphyritic, and nearly always contains iron pyrites. From time to time, during the course of six or eight months, and at various points, I had picked up samples; from the lot a sample was taken, ground, and forwarded for assay. The return was 2 dwts. to the ton of 20 cwt. This, of course, for practical purposes is only a trace, but a very significant one, considering the nature of the rock which had furnished the specimens and their associations. Wishing to render myself an account of the quantity of road metal put down annually by the Corporation of this description, I applied to the Town Clerk, Mr. Beveridge, for such information in this respect as he could afford me. He very courteously communicated the following details:—

The Dublin Improvement Act of 1849 came into operation on the 1st January, 1851, and in that year the quantity of Bohernabreena stone used for macadamizing was 14,365 tons. The average quantity used in the 13 years ended 1863 was 17,006 tons. The work was then undertaken by a contractor, but was again assumed by the Corporation in 1866. Thenceforth, about 15,000 tons on the average were used annually until the extensive paving works commenced in 1879, since when the average has been reduced to about 9,000 tons. The total quantity laid down up to 1888 may therefore be estimated as follows:—

1851 to 1863, . . .	17,006 tons	× 13	=	221,078 tons
1864 ,, 1866, . . .	16,000 ,,	× 3	=	48,000 ,,
1867 ,, 1879, . . .	15,000 ,,	× 13	=	195,000 ,,
1880 ,, 1889, . . .	9,000 ,,	× 9	=	81,000 ,,
Total quantity laid down from 1851 to 1859			=	545,078 tons

This at 2 dwts. per ton would represent a total amount of gold of 54·537 oz., value about £196·224. Of course it may have been a mere chance that the specimens taken by me should assay so much gold; but even supposing one-half or the fourth of the quantity it is interesting to note what even such a small quantity in such a mass of rock may represent. It should furthermore be remarked that many of the worked quartz reefs of South Africa and Australia, show in certain parts of the works as small a yield of gold, and that the miner is guided by the assays of the samples from those parts to others more likely to pay.

There is a further conclusion to be drawn from this assay; it is that the River Dodder traversing these rock masses, and similar ones higher up in its course, and having received the *débris* carried down by the streams in consequence of their decomposition, must have carried in its bed golden sands, and may retain in the lowest stratum of the gravels and sands in contact with the mother rock quantities of gold worthy of serious exploratory works. Some further assays of rock samples from this neighbourhood would seem to support this view.

Thus, the steam tram line to Blessington, which runs along the foot of the Saggart Hills, passes into the Brittas valley across a bridge which I believe is known in the country as the Crookling or Crooked Bridge, and the hill to the east of it is known locally as Crookling Hill. The formation is clay slate of the lower Silurian, containing here and there ribs of quartz, and traversed in several places by lenticular masses of diorite of the same nature as the stone of Bohernabreena, which circumstance led to their being worked for road metal. In one of the old quarries where one of these diorite masses occurs there are parts showing large detached crystals of iron pyrites. A certain quantity of these were separated from the containing rock and a sample submitted for assay, the return being 6 grains to the ton of 20 cwt. At the same time, samples of the rock as it came from the quarry were ground and submitted for assay in three different states of fineness of division. In each of these traces of gold were found, the amount in one of them being 2 grains per ton of 20 cwt.

In respect to these pyrites it may be of interest to cite the observation of the celebrated chemist J. B. Boussingault, which appears in a Memoir by him on "A New Method of Assaying and Treating Auriferous Pyrites," An. d. Mines, 1827, p. 319. At p. 330 he says: "As regards auriferous pyrites it is less important to know exactly the richness of the ore than to determine the presence of gold in it, since once demonstrated that it is auriferous it is quite certain that it is well worth while being worked."

It is of interest to note that this diorite mass is traversed by a vertical vein of quartz, about 12 to 14 inches wide, and having a direction of N. 9° 53 E., a not unfrequent direction of joining in the environs of Dublin. Lastly, on the course of the River Liffey, at a point about one mile to the south of Blessington, there is a bridge in the close vicinity of a ruin known as "Bogey's Castle." The river here bends and gives rise to a small strand, where are thrown up during floods pebbles of different sizes, many of them being quartz, such as occurs in seams in the clay-slates and mica-schists. Having collected, at hazard, some of these quartz pebbles, they were ground, sampled, and submitted for assay. The return showed a distinct trace of gold less than 2 grains to the ton of 20 cwt.

Of the quartz veins which occur in the slate rocks samples were taken. One from the excavation then in course of execution for the inner dock or basin of Greystones: beds of slate-rock, with veins of quartz and chlorite, forming here the rock-mass; another from the cutting made on the roadside just south of Crookling Bridge, where the steam tram line curve required the enlargement of the road. The Greystones sample gave a trace of gold; the Crookling Bridge one nothing.

A locality better known in the vicinity of Dublin is Ballycorus, on account of the Lead Smelting Works which exist there, as well as the old Lead Mine in the immediate vicinity. Having had occasion to learn that the silver found in the ores of that mine contained gold in an appreciable degree, and assuming that it might be found in the rocks in the vicinity of the mine, I took samples of the mica-schists which occurs quite near in contact with the granite. This rock, not usually considered as a gold-bearing one, being submitted to assay showed traces of the metal; and, as a further test, mica-schists from the contact at Killiney were also assayed, the result being also traces. Further assays of this rock would be interesting, since its extent would render it worthy of consideration even although the quantity of gold were small—the softness of the rock and consequent ease in working it being capable of in some way compensating for poverty as regards the contained metal.

This general diffusion of gold through any given stratified rock or rock formation, although not of immediate practical interest, may be of importance at some future period when the methods for the extraction of gold from rocks shall have become so perfected that ores which now present but a mineralogical interest, so far as concerns their yield in gold, may become capable of treatment by these improved processes.

To this class may fairly be assigned rocks such as the old red sandstone, so extensive in its development in the south of Ireland, and boulders of which are not unfrequent in the drift. As this rock is formed of quartz and purple or red clay-slate pebbles, cemented by a red argilaceous indurated clay resulting from the erosion of older formations noted for their auriferous character, it seemed reasonable to assume that the *débris* forming the old red should show traces of the metal. Having collected specimens from the Drift, and from various localities about Dublin, samples were made of them and assayed for traces of gold. Both the assays reported showed traces of the metal, the samples being from localities wide apart. The last assay was in January, 1889.

It is interesting to note in connection with these two assays, the account which appeared in the Mining Journal of September 28, 1889, of the Witswatersrand Gold Field, Johannesburg, Transvaal, and the further notice of this Mineral District read at the Geological Society of London at their Meeting of November 20th last. From these two descriptions it would appear that the "reefs" are in reality the outcrops of a conglomerate bed, associated with red purplish rocks which present themselves stratified and dipping at angles varying between 45° and 80°. As might be expected, the President of the Society considered the occurrence of gold in large quantities in such a conglomerate as "a remarkable and interesting case."[1]

So far as the description of the formation goes it seems to resemble in some degree the old red sandstone of this country; and the discoveries being made in South Africa render such results as those furnished by the assays quoted both interesting and of some practical value as regards the future.

As minerals rich in iron, and particularly those containing pyrites, may generally be looked on as likely to show traces of gold, it occurred to me to put this likelihood to the test in the case of the pyrites which accompanies nearly all coals except those of the very purest classes. For that purpose I collected from time to time, during the winter months, samples of the ashes from the coals as supplied to the College, and which it may be assumed as presenting rather a mean quality than otherwise. The ashes were washed, and the remaining heavy part was assayed by Mr. Wrapson, an Associate Student of the College, under the guidance of the Assistant-Chemist, Mr. Shegog. From Mr. Wrapson's

[1] See also article in the *Pall Mall Gazette* of Monday, February 17, 1890.

Report it appears that an appreciable trace of gold was found corresponding to about 469 milligrams to the ton of washed ash, = 7, grains 22. Considering the enormous yearly production of coal in Great Britain alone, which has reached 170 millions tons for the year 1887, representing a proportion of ash which may be taken at 5 °/₀ or 8·5 millions, taking the heavy part assayed in this case as only the half of the total ash the quantity of gold contained in the ash of a year's production would be about 2125 kilogrammes, value about £377,714.

Here again there is occasion to remark that the assay may have been made on an accidentally exceptional sample; but there are other considerations to be taken into account as well. If gold be generally present in coal ashes, which will be assumed here, evidently there should be a difference in the quantity contained, according to the nature of the ash, and even to the physical conditions of the coal-field; moreover it may be that the most impure varieties of coal, and those carrying the largest quantity of pyrites, contain the largest amount of gold (since the quantity of precious metal contained may be assumed to be proportional to the quantity of ash). Hence the interest there is in having a series of comparative assays of coal ash made with a view to ascertaining those which may contain gold in notable quantity, and allow of an attempt being made to turn to account the ashes which, as a by product, may be taken as of extremely low value in their actual state.

In conclusion it may not be out of place to point out that research is very active at present with a view to discovering better and cheaper methods of extraction of gold from the matrix, and of saving the metal already free and liable to escape with the fine slimes and thus be lost. In this respect Lock's remarks are of importance (*l. c.* Introduction, p. v.) "In the more difficult operations of extracting gold from mineral veins and complex ores, reliable evidence from all parts of the world shows that most of the processes at present in use or the methods of carrying them out, are far from satisfactory, as they entail the loss on the average, of $\frac{1}{4}$ to $\frac{1}{3}$ of the gold present in the material operated on."

These facts point unmistakably to the necessity of studying the conditions under which gold occurs..

As one of the latest examples of this activity may be cited the report of the meeting of "The Economic Gold Extraction Co.," from the *Mining Journal* of December 28, 1889, p. 1484. The Chairman made the following statement:—"Our process does not cost you £4, nor 30*s*., but we claim that by it we can do it for 1*s*. per ton, which will have the effect of making non-paying mines pay." It is evident, therefore, that the tendency will be to reduce by various improvements the cost of treatment of gold ores, so that many rocks, now not workable because of their low grade in metal, may be treated, and thus enable a mine to be developed, so as to give access to richer and more productive parts. The knowledge of the existence of such low grade minerals is, therefore, already of importance, as hereafter they may be found capable of advantageous treatment. Hence, careful assays of all such rocks may be considered as pioneering work of real value for the future mineral interests of the country.

*

L.

ON THE MAGNETIC MOMENT AND OTHER PHYSICAL CONSTANTS OF STEEL CONTAINING FROM ONE TO TWENTY-ONE PER CENT. OF MANGANESE. By Professor W. F. BARRETT.

[Read November 20, and December 18, 1889.]

Having lately received from my friend Mr. R. A. Hadfield, of the Hecla Steel Works, Sheffield, various specimens of his now well-known manganese steel, I submitted the samples to investigation for the purpose of determining the magnetic moment per gramme that could be given to steel containing largely different percentages of manganese. Mr. Bottomley was the first to draw attention to the extremely low susceptibility of manganese steel. In a paper read before the British Association, in 1885, he showed that whilst ordinary steel when magnetised to saturation has a moment, varying according to the steel, from 30 to 90 c. g. s. units per gramme, steel containing 13 per cent. of manganese, when magnetised in a very powerful field, had a moment of only 0·013 units per gramme.

In a previous paper of mine read before this Society,[1] and in a subsequent paper read before the British Association, in 1887,[2] I gave the results of a series of experiments I had made on the remarkable physical properties of this steel, which Mr. Hadfield had, after much difficulty, succeeded in drawing for me into wire. This was accomplished by heating the alloy to a bright white heat and then suddenly cooling it in cold water: a reverse effect to that produced on ordinary steel results; instead of becoming brittle and glass-hard, manganese steel so treated loses some of its hardness and becomes exceedingly tough, so that it can be drawn or bent cold into any shape. It still, however, remains very difficult to drill or work in the lathe owing to its hardness—in fact, it has

[1] Proc. R. D. S., vol. v., 1886, p. 360.

[2] For full report see "Electrician," November, 4, 1887.

a curious combination of properties. When submitted to a stretching force it elongates almost like copper, and yet has a higher tenacity than Siemens' steel. The specimen No. 552, to which we shall refer subsequently, with 13·7 per cent. of manganese had a breaking strain of 63·5 tons per sq. inch, and an elongation of 45 per cent. The *work done* in fracturing this specimen of manganese steel is, according to Professor Kennedy, quite unprecedented in any material, being upwards of double that required for the best steel. The *breaking strain* of the No. 19 *hard* wire, 0.98 mm. dia., I found to be 110 tons per sq. inch, or 1735×10^4 grammes per sq. centim, and of the same wire *annealed* 49 tons per sq. inch or 768×10^4 grammes per sq. centim. The *modulus of elasticity* of the hard wire was found by direct stretching to be 16,800 kilogrammes per sq. millim, or 1680×10^6 grammes per sq. centim, and of the annealed wire 1500×10^6 grammes per sq. centim. The *electric resistance* of this specimen of the wire was found to be 75 microhms per cubic centim, or upwards of 40 times that of pure copper, 6 times that of pure iron, and nearly $3\frac{1}{2}$ times that of German silver. Its increase of resistance for rise of temperature, or *temperature co-efficient*, was found to be considerably less than that of pure iron, being 0·13 per cent. per degree centigrade, but higher than German silver, which is only 0·04 per cent. per degree centigrade. Professor Fleming and Mr. Mordey have subsequently verified these results, the specimen tried by Professor Fleming having a somewhat lower, but still very high, specific resistance, namely 68 microhms per cubic centim. I have also determined the *co-efficient of expansion* of manganese steel between 0 and 100° C, and find it to be 0·000015—for this range of temperature ordinary steel is 0·0000117. All these experiments were made on an alloy containing from 13 to 14 per cent. of manganese.[1]

[1] Since the foregoing was written, Professor Le Chatelier in an official report of a Committee of the "Société d'Encouragement pour l'Industrie" has stated his experiments have completely confirmed all the remarkable mechanical properties which Mr. Hadfield has found in this new alloy. Tempering, he states, produces the unique effect of imparting great tensile strength, increased resistance to shock, and an elongation of over 50 per cent. before rupture. The French Committee, therefore, suggests its use in a forged and tempered state for agricultural implements, wheels, axles, &c. The co-efficient of expansion for 1° C. between 0 and 1000° C. Professor Le Chatelier finds to be 0·0000245, ordinary carbon steel for the same range being much less, viz 0·000015.

The *specific heat* of two forged bars of manganese steel, marked 6 A and 552, containing respectively 9·4 and 13·7 °/₀ of manganese I determined by the method of mixtures. Both were found to have a higher specific heat than iron, the 9½ per cent. specimen being 0·1238 and the 13½ per cent. specimen being 0·1264—iron having a specific heat of 0·114. Since these experiments were made I have learned that Mr. Crichton Mitchell has determined with great care both the specific heat and thermal conductivity of manganese steel.[1] The specific heat of a 10 per cent. specimen of manganese steel Mr. Mitchell finds, by the method of cooling, to be 0·124 (1 + ·0014 t), being 1·087 times that of iron; this closely agrees with my own result. The thermometric conductivity of the same specimen at 100° C. Mr. Mitchell finds to be .00272, whilst iron at the same temperature is ·01274, so that the presence of 10 per cent. of manganese in iron or steel lowers its thermal conductivity one-fifth.

The experiments about to be described were made on samples containing from 1·10 to 21·69 per cent. of manganese. Some of the specimens were in the form of ingots just as they were broken after casting, others were test bars that had been forged and then tested for breaking strain. The ingots were nearly cubical blocks, on an average measuring three inches along the edge; the test bars were cylindrical rods, some ¾ inch in diameter, and from 6 to 9 inches long; the ends had been enlarged for holding them in the jaws of the testing machine, and as all the bars had been broken in testing, the experiments were made on a broken half of each bar.

The method of experiment was as follows:—A magnetising helix was constructed of sufficiently large diameter to contain the ingots, and about twice their length, and another longer helix was employed for the forged bars. Through the helix a powerful current from a storage battery was passed for a definite number of seconds, the strength of the current being measured by a Thomson's graded galvanometer. The current was repeatedly flashed on and off—a process that facilitates magnetisation—then, interrupting the current, the sample was at once carried to a magnetometer in an adjoining room and there tested.

---

[1] Trans. Royal Soc. Edin., vol. xxxv., part 4, 1890.

The magnetometer consisted of a short fragment of magnetised watch spring, with attached mirror, suspended by a silk fibre in a glass shade—the deflection being read on a millimeter scale placed 100 centims from the mirror. The specimen to be tested was placed on a level with the needle, and its centre at a given distance (varying from 20 to 60 centims) due east behind the magnetometer. After reading the deflection the specimen was reversed end for end, and the deflection in the opposite direction read. Half the difference of the scale readings gives the deflection produced by a single pole. As the length of the magnetometer needle may be neglected, the magnetic moment M is :—

$$M = \frac{(r^2 - l^2)^2}{2\,r} \tan \theta .\, H.$$

where r is the distance of the magnetometer needle from the centre of the specimen under trial, l, half the distance between the poles of the specimen (practically its semi-length) θ, the angle of deflection produced by the specimen, and H, the horizontal force of the earth's magnetism in C. G. S. units, this was determined for the place of observation and found to be 0·16. θ is equal to $\frac{d}{2\,D}$ (the angular displacement of the needle being doubled by reflection) where d is the scale reading, and D the distance of the scale from the mirror, in the same units.

When the specimen is placed at some distance from the magnetometer its length may be neglected, and the moment is then given by the approximate formula

$$M = \tfrac{1}{2}\, r^3 \tan \theta \,.\, H$$

r being as before the distance of the specimen from the magnetometer.

The magnetizing force, F, of the field to which the specimens were subjected was calculated for each helix employed from the formula

$$F = \frac{4\pi n C}{l}$$

where n is the number of turns of the current of strength C (in C. G. S. units), and l the total length of the helix in centims.

In order to ascertain the effect of the duration and strength of the current on the saturation of the specimen under trial the following experiments were made :—Ingot No. 43, with 1·93 °/₀ of manganese, was submitted to a current of 20 ampères, equal to a field of 260 C. G. S. units, for 5 seconds, and then tested by the magnetometer again for three successive 10 seconds, the magnetizing force was applied, and the magnetometer deflection each time taken. Here are the results—the moment is proportional to the magnetometer deflection :—

TABLE I.

	Magnetizing Force.	Duration of Current.	Magnetometer Deflection.
Ingot No. 43, . .	260 units	5 seconds	28
	,,	+ 10 ,,	54
	,,	+ 10 ,,	146
	,,	+ 10 ,,	146

Hence, in magnetizing this specimen 25 seconds is as effective as 35 for the current employed. In another specimen with 9·65 °/₀ of manganese the effect of a still stronger field was tried.

TABLE II.

	Magnetizing Force.	Duration of Current.	Magnetometer Deflection.
Ingot No. 8, . .	260 units	5 seconds	145
	,, ,,	+ 10 ,,	190
	930 ,,	+ 10 ,,	310

A similar experiment was made with one of the forged test bars, No. 596, containing 14·48 °/₀ of manganese.

TABLE III.

	Magnetizing Force.	Duration of Current.	Magnetometer Deflection.
Test Bar No. 596, .	147 units	10 seconds	113
	265 ,,	+ ,, ,,	145
	646 ,,	+ ,, ,,	188
	882 ,,	+ ,, ,,	190
	1030 ,,	+ ,, ,,	191

A body is said to be magnetized to saturation when no increase of the magnetic force can increase its magnetization any farther. In this particular case a field rising to 700 units applied for 30 seconds magnetizes the specimen to saturation.[1]

[1] With a similar bar of ordinary magnet steel a field of 300 units applied for 10 seconds magnetized it to saturation.

In order to construct a curve of magnetization with increasing magnetizing force a more extensive series of experiments were made on one of the virgin test bars, No. 598, containing 18·4 per cent. of manganese. The weight of this bar was 467 grammes, its specific gravity 7·8, its length 16 centimetres, and diameter 2 centims. The scale of the magnetometer was 100 centims. distant = D, and the scale reading of the magnetometer is given as before in millims. In each case the specimen, as before, was first magnetized in the helix, then removed and brought to the magnetometer, the reading taken, and then the sample reversed end for end: hence the deflection due to one pole is one-half of that read.

A series of comparative experiments were made with a bar of ordinary steel glass hard and a bar of ordinary mild steel. In each case the specimen is magnetized with a current of definite strength, removed from the helix, and its moment tested in an adjoining room. The following are the results:—

TABLE IV.

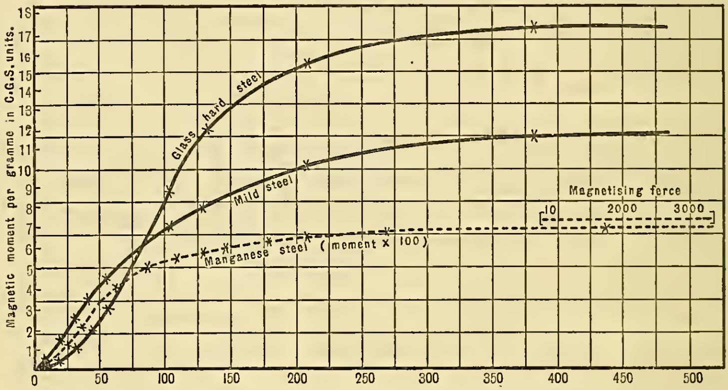
Effect of increasing strength of field on the Magnetic Moment of Manganese Steel.

TEST BAR No. 598, containing 18·4 per cent of manganese.

Current in Ampères.	Magnetizing Force.	Magnetometer Deflection. = $2d$
1	29·4 C. G. S. units	73 millims
2	58·8 ,,	164 ,,
3	88.2 ,,	202 ,,
4	117.6 ,,	218 ,,
5	147 ,,	230 ,,
6	176 ,,	236 ,,
7	206 ,,	240 ,,
9	265 ,,	259 ,,
15	441 ,,	265 ,,
22	647 ,,	280 ,,
44	1294 ,,	290 ,,
80	2352 ,,	292 ,,

We thus see that even with the enormous magnetizing force of 1300 units saturation is not reached with this specimen. The actual magnetic moment per gramme produced by this field is 0·0701 C. G. S. units.

In the accompanying diagram, Fig. 1, the foregoing table is plotted in a curve, the abscissæ being magnetizing force, and the



MAGNETISING FORCE IN C. G. S. UNITS.

FIG. 1.

ordinates one hundred times the corresponding magnetic moment. This exaggeration of the moment is necessary in order to show on the same diagram the curve resulting from similar experiments with ordinary steel and glass-hard steel.

A series of comparative experiments were now made with the different ingots, though the field employed, 260 C. G. S. units, was probably not large enough to raise them to saturation; a larger current was impracticable, being found to heat the helix unduly. The current was flushed on and off for 30 seconds in each case.

The following table gives the results of the experiments:—

TABLE V.

Magnetic Moment of Ingots of Manganese Steel.

Mark.	Percentage of Manganese.	Weight in grammes.	Total moment in C.G.S. units.	Moment per gramme.	Appearance of Ingot.
46	1·10	2582	66	0·0257*	granular.
44	1·22	2896	77	·0262*	,,
43	1·93	2336	40	·0173*	,,
40	3·50	2886	92	·0320*	crystalline.
6	9·20	2642	2830	1·072	,,
8	9·65	2554	53	·0213*	,,
14	10·56	3124	553	·177	,,
13	10·60	3018	151	·0501*	,,
29	16·49	2562	66	·0259*	granular.

* The numbers marked with an asterisk require to be reduced nearly 5 per cent. when the length of the ingot is taken into account, as in those cases the distance from the magnetometer needle was small. Thus the moment per gramme of the first and last ingots instead of being ·0257 would be ·0245 units.

This table at once reveals the striking fact that the magnetic moment does *not* decrease as the amount of manganese increases; on the contrary, the specimens having the smallest and the largest per-centage of manganese had practically the same magnetic moment. One specimen, No. 6, had an abnormally high magnetic moment. This may be due to some accidental cause in the casting—several experiments with this ingot giving perfectly coincident magnetic moments, as did further experiments with No. 8, with almost the same per-centage of manganese, and yet having a magnetic moment fifty times smaller. In fact there appears to be no relation between the magnetic character of the alloy and the amount of manganese present; nor does the appearance of the fraction give any clue to the differences observed.

Another striking fact revealed in Table V. is the extraordinary difference in magnetic character of specimens having almost identical composition. Thus, not only ingots marked 6 and 8 already referred to, but ingots 13 and 14 have each practically the same amount of manganese, and yet the magnetic moment of one is upwards of three times that of the other. This difference is probably due to the different state of aggregation of the particles after casting. In forging the material becomes throughout of uniform texture, and hence we must turn to the subsequent experiments on the test bars for further information on this point.

It would be extremely interesting to ascertain the magnetic permeability of this specimen, that is, the ratio of the *induction* produced to the magnetizing force producing it. But for this purpose it would be necessary to have rings forged, and this was out of the question, in fact many of the ingots would not forge. What the Table shows is the general magnetic character of the specimens, or if the moment be divided by the volume, the permanent intensity of magnetization that can be conferred on the ingots. This power of retaining magnetism when the inducing force ceases is attributed to the so-called "coercive force," the harder the steel the higher being the coercive force. But manganese steel is intensely hard, and, as might be expected, has a very high coercive force, no loss of magnetism being observed in those specimens again tested, without re-magnetizing some weeks later.

Some of the specimens were harder than others, and accordingly experiments were made to determine *their relative hardness*. The scale of hardness used by mineralogists is judged by one material scratching another. Thus the softest in the scale No. 1 is mica; No. 2 is gypsum; No. 3, calcspar; No. 4, fluorspar; No. 5, apatite; No. 6, orthofelspar; No. 7, quartz; No. 8, topaz; No. 9, sapphire; No. 10, diamond. At best this is an unsatisfactory means of estimation, and when we find the different varieties of steel lying between No. 5 and No. 6, it will be seen how extremely imperfect such a scale is. Ferromanganese containing 82 °/₀ of manganese is nearly as hard as quartz, but the ingots were softer lying near to No. 6 on the scale. The best mode of testing their relative hardness was to use a new glass-hard file, and judge by the touch in filing. In this way two of my assistants, both of whom were expert in the use of the file, arranged the ingots, according to hardness, independently of each other; neither of them at the time knowing the composition of the blocks. They found the order as follows:—No. 29 the hardest; Nos. 6, 14, 8, and 13, next; No. 40, next; and Nos. 46, 44, and 43, next, being the softest. It will be seen by reference to Table V. that this order is practically the order of the quantities of manganese in each ingot, No. 29 containing 16½ per cent., and the Nos. 46–43 from 1 to 2 per cent. The magnetic moment, therefore, does not follow the order of hardness in the ingots.

In some of the ingots a most beautiful quasi-crystalline appearance was presented. The molten metal cooling down from the outside of the mould, the needles or fibres of cooler steel started from each cool face, and so arranged themselves geometrically in

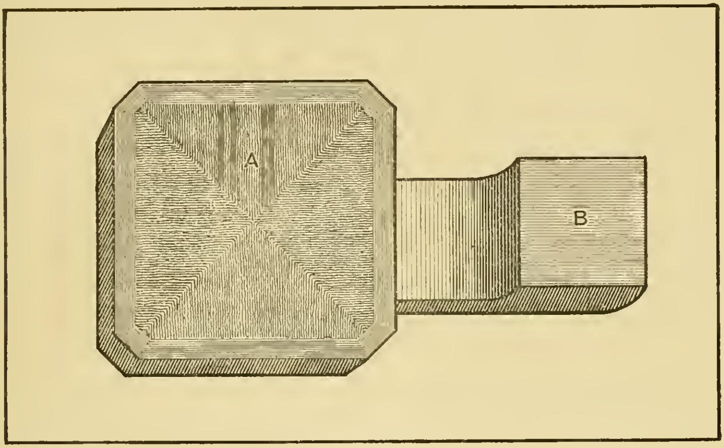


Fig. 2.

groups at right angles to the four cool surfaces. The appearance is shown at A, fig. 2, engraved from a photograph, of half a link made of manganese steel. The peculiar structure disappears in forging, as is shown in the other end of the link B, which has been forged, and is evenly granular in texture.

But whilst the molecular structure of the material is an important factor in determining its magnetic character, there can be little doubt that the extraordinary reduction in magnetic moment produced by the presence of manganese in steel points to a *chemical combination* of the manganese with the iron. A mere admixture of 2 or 20 per cent. of manganese with iron would not lower the magnetic moment so enormously. Hence it may well be that at certain per-centages a definite chemical union has occurred, and this would doubtless be indicated in those specimens where the magnetic moment is lowest.

The study of this question is best followed by an examination of the forged test-bars which were now tried. These bars were treated in a similar way to the ingots, being magnetized in a suitable helix in a field of 700 C. G. S. units, the current being maintained for half a minute, and then immediately each bar was tested with the mirror magnetometer. The fracture of the test bars was in all cases granular. Their relative hardness was tested by a file in the same way as the ingots, and found to be precisely in the order of the per-centages of manganese contained. To the composition per cent. of each specimen, kindly supplied to me by Mr. Hadfield, I have added the breaking strain of each test bar taken from Mr. Hadfield's admirable paper on manganese steel,[1] and also how each bar was treated after forging.

It will be seen that, as with the ingots, additional per-centages of manganese do not produce a corresponding decrease of magnetic moment. In fact the moment appears to rise pretty regularly with increasing per-centages of manganese up to 13·7 per cent., and then to decrease again from this point.

TABLE VI.

Magnetic Moment of forged test bars of Manganese Steel.

Composition per cent., remainder being Iron.						Magnetic moment per gramme.	Breaking strain in tons per sq. in.	Treatment after heating.
Mark.	Mn.	C.	Si.	S.	P.			
5 D	7·2	0.47	0·44	0·06	0·09	·0328	27·4	as forged.
6 A	9·4	·61	·30	·07	·09	·0161	38·2	cooled in oil.
13 D	10·6	·85	·28	—	·11	·0488	33·6	as forged.
547	12·3	·85	·37	·06	·09	·0691	62·6	cooled in water.
552	13·75	·85	·23	·08	·09	.1408	63·5	,,
596	14·5	1·1	·32	·07	·07	·0422	39·4	
30 A	15·2	1·5	·14	·06	·09	·0449	40·3	cooled in oil.
598	18·4	1·54	·16	·06	·08	·0701	51·0	cooled in air.
291	20·0	1·9	·32	·03	·10	·0250	22·8	cooled in oil.
235 D	21·7	2·1	·46	·08	·10	·0316	36·0	as forged.

The presence of foreign substances in the alloy, such as silicon, or the variable amounts of carbon, have doubtless a considerable influence on the magnetic character of the different specimens; but these do not account for the wide divergence in the magnetic moment. Thus Nos. 547 and 552 have almost an identical com-

[1] See Proceedings of the Institute of Civil Engineers, February, 1888.

position, with the exception that one has 12·3 °/₀ of manganese, and the other 13·75 of manganese; yet the magnetic moment of No. 552, with 1·4 °/₀ more manganese, is double that of 547. It will further be noticed that a nearly similar composition of the alloy, in the form of ingot and of forged bar, have different magnetic characters: this, as already remarked, is no doubt due to the mechanical treatment the test bars have received. Looking over Table VI. it will be seen that the specimens 6*A* and 291 have very low magnetic moments, corresponding to 9·4 and 20 per cent. of manganese respectively. It is possible that we have here a chemical union of the manganese and iron; in fact these alloys would correspond to a compound having the formulæ $MnFe_8$ and $MnFe_4$. Further information on this point can be obtained by a careful determination of the specific heat of the different specimens. Unfortunately the different treatment the bars received after forging confuses the results. By Mr. Hadfield's permission I cut off from each of the bars similar cylindrical portions. Each of these smaller rods were raised to a white heat, and then dropped in water. The result of this, in manganese steel, is to soften the alloy: hence by diminishing the coercive force to lessen the magnetic retentivity. Each of these portions was re-magnetized in a similar and powerful field, and the magnetic moment per gramme of each again determined. The moment found in each case was extremely small: nevertheless No. 552 still retained its pre-eminence, having far higher moment than any other specimen, and many of the irregularities in the curve, showing the relationship of the magnetic moment to the composition, were smoothed away; *the magnetic moment rising up to* 13·7 *per cent. of manganese, and then falling from this point to the* 21·7 *per cent. specimen.* The following experiment will illustrate the magnetic change produced by the different treatment of the same specimen:—Two similar portions, each 8 centims long, were cut off the bar No. 552. One portion was heated to whiteness, and then dropped in cold water; the other was left untouched. Both were then magnetised in the same field. The untouched portion had a moment per gramme of 0·1398 (practically the same as the test bar from which it was cut, as shown in Table VI., viz. 0·1408); the other portion, annealed by sudden cooling, had a moment per gramme of 0·0456, or one-third less. The specific gravity of the two portions were not quite the same:

the annealed part had a specific gravity of 7·77, and the untouched part of 7·81.

In Table VI. I have added the *breaking strain* in tons per square inch of each of the test bars; and it will be observed that those specimens having a high breaking strain have a higher magnetic moment than the others. In the accompanying diagram

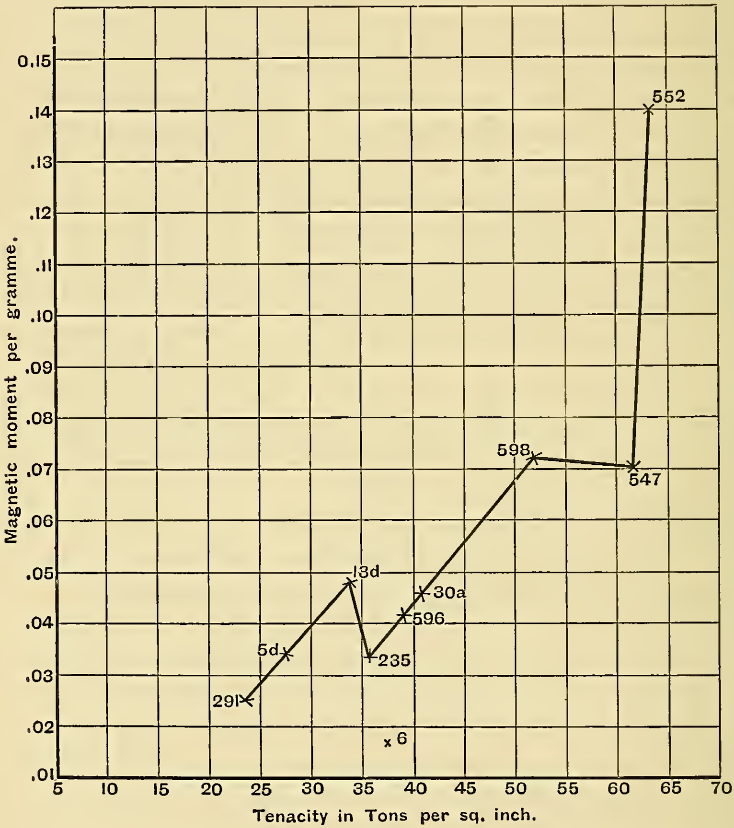


FIG. 3.

(Fig. 3) the magnetic moment of the different specimens is plotted against their breaking strain. The diagram shows that some such relationship exists, though the number of experiments are too few to found upon them any definite conclusion. It will be seen that 6*A* is the only specimen that does not fall within the curve. I hope before long to have a larger collection of rods of different kinds of steel with known breaking strain, when I will pursue the interesting point further.

The very high coercive force of manganese steel rendered it interesting to ascertain the effect of increasing temperature on its magnetic moment. Accordingly the portion of No. 552, which had not been annealed, was magnetized in a powerful field, and having been placed in an oil bath at a fixed distance from the magnetometer, it was gradually raised in temperature, and the magnetometer deflections noted every 10° Cent. up to 250° C.; a similar series of observations were made during the cooling of the bar. For the sake of comparison, a bar of ordinary magnet steel was magnetized in the same field, and then submitted to similar heating and cooling. The result was that the magnetic moment

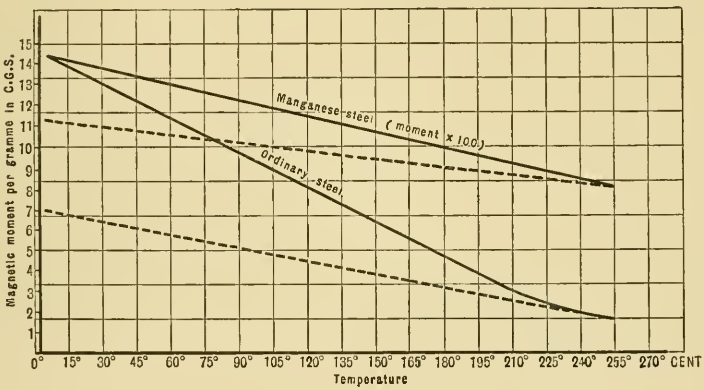


FIG. 4.

per gramme of the manganese steel fell from 0·14 at 18° Cent. down to 0·082 at 250° Cent., or a fall of 40 per cent., and in cooling back to the temperature of the air it rose to 0·111. The ordinary steel magnet, on the other hand, had a moment per gramme of 14·1 at 18° C., and it fell to 1·75 at 250° Cent., or a fall of 87 per cent.; in cooling back to the air it regained a moment of 6·5. In the accompanying diagram (Fig. 4) the moments per gramme are plotted against the corresponding temperatures. In order to bring the manganese steel in the same diagram, its vertical scale has been multiplied 100 times. The dotted line in each case shows the magnetic moment regained in cooling. It will be noticed that the permanent magnetic loss by heating to 250° and then cooling is much greater with ordinary than with manganese steel. If the latter could have a high moment conferred upon it, it would be incomparably the best material for the construction of magnets and compass needles. Dr. Hopkinson (*Phil. Trans.*, May, 1889) has treated a 12 per cent. specimen of manganese steel to a temperature of upwards of 800° C., and finds that even at this temperature, when ordinary steel has entirely lost all magnetic properties, manganese steel still remains slightly magnetic. But the most remarkable effect of temperature on the magnetic state of a body is that which Dr. Hopkinson has lately discovered in an alloy of iron and nickel containing 25 per cent. of the latter metal. At the ordinary temperature this alloy is practically non-magnetic, but on being cooled to a little below the freezing point it becomes magnetic, and remains in this condition even when heated up to a temperature of 580° Cent. Then it suddenly ceases to be magnetic, and remains non-magnetic until cooled again below the freezing point. This nickel alloy has therefore two stable conditions, one magnetic, and the other non-magnetic; its state being determined by the high or low temperatures to which it was last exposed. Facts of this kind show the great importance of a fuller magnetic study of the different alloys of the magnetic metals: thus slowly may we hope to throw more light on the outstanding enigma of why magnetic properties are confined to the three elements—iron, nickel, and cobalt.

NOTE ADDED IN PRESS.

M. Osmond's admirable researches throw considerable light on the nature of manganese steel, which probably owes its non-magnetic character to its heterogeneousness.

M. Du Bois in a recent Paper (*Phil. Mag.*, 1890) has confirmed this view by a magneto-optic method of investigation. Chemical and microscopic examination also exhibit its heterogeneous structure.

LI.

STUDIES IN ONTOLOGY, FROM THE STANDPOINT OF THE SCIENTIFIC STUDENT OF NATURE.

By G. JOHNSTONE STONEY, M.A., D.Sc., F.R.S., a Vice-President of the Royal Dublin Society.

I.—THE FIRST STEP, IN WHICH AN ATTEMPT IS MADE TO FIND OUT IN WHAT WAY THE SCIENTIFIC STUDY OF NATURE IS RELATED TO THE ACTUAL EXISTENCES AND EVENTS OF THE UNIVERSE.

[Read May 21, 1890.]

CONTENTS.

	PAGE.
Part I.—Introduction: Method and Postulates of the Inquiry,	475
Part II.—Outline of the Argument,	478
Part III.—Illustrative Diagrams,	484
Part IV.—The Essay,	488
Part V.—Glossary of Terms,	520

[*It is, perhaps, best to begin by reading Part IV., p.* 488.]

Part I.—Introduction: Method and Postulates of the Inquiry.

Progress in ontology by reasoning, as in other subjects of human study, *must* start from the existing beliefs in the mind of the inquirer, or from some of them.

If the beliefs thus made the basis of a first investigation have been chosen with judgment, the inquirer will find himself, after he has traced their legitimate consequences, in a better position to review all his ontological beliefs and to amend them, before proceeding to take a further step of a like kind. This is the *only* process whereby, when repeated as often as may be necessary, any individual human mind can make sound progress.

The following are the beliefs which are treated as fundamental in the present essay. The reader is requested to accept them as postulates while he is occupied with it. He may afterwards make any or all of them the subject of a further inquiry, with the advantage of knowing what consequences they involve. If they stand this scrutiny, and if the scrutiny is a sufficient one, they will become related to the present inquiry as lemmas and will cease to be postulates.

Postulates.

First Belief.—That my present thoughts exist.

Definition 1.—The term thought is taken in its widest extension. It is to be understood as embracing *everything* of which we are conscious.

Second Belief.—That my remembered thoughts have existed.

These two beliefs involve a third, viz. :—

Third Belief.—That time relations exist.

Definition 2.—I, my mind, or the ego, is that varying group of associated and interacting thoughts which includes my present thoughts; and included my remembered thoughts, with others that are but partly remembered and some that are now forgotten.

Fourth Belief.—That minds more or less resembling mine exist in my fellow-men and in some other animals.

Observation.—By intercourse between my mind and the minds of my fellow-men I learn that they experience sensations which are closely related to those that present themselves as a part of my mind. Whence, and from much other evidence, I infer—

Fifth Belief.—That my sensations and theirs have their source in some existing thing or things which are not any part of my own present or past thoughts.

Bishop Berkeley entertained this belief as emphatically as other men. He held that sensations are produced in human minds by acts of will of a "governing spirit."

Sixth Supposition.—Another belief is freely made use of in the Essay, viz. that my organs of sense and parts of my brain are instrumental in introducing sensations into my group of thoughts.[1]

This belief is, however, not a necessary postulate of the investigation. The argument can be stated in language which does not include it; but the supposition is true, and therefore unobjectionable, and it is introduced thus early, because without it we should be obliged to use unfamiliar forms of expression which would be less perspicuous.

With the same end in view, viz. to attain lucidity, the language of causation is freely used throughout the Essay, but will be found not to involve anything beyond what is included in the fifth of our postulates, until we reach paragraph 22 in the Outline, or p. 510 in the Essay.

Caution.—It should be distinctly borne in mind that it is not legitimate to infer that causes resemble their effects. As a general rule the presumption is *very strongly* the other way. When men are forming ontological judgments, they often tacitly assume that causes are like their effects, or suppose that the relations between the causes are of the same kind as those which they find prevailing among the effects. We should be carefully on our guard against these errors.

The importance of the investigation lies in this, that it enables us to correct other ontological beliefs which are usually entertained with the five enumerated above, but which are found to be no longer tenable along with them; especially the beliefs that space or space relations have an autic existence (see § 12, p. 480), and that the existing things which are the sources of our sensations are situated in space. The dismissing of these errors and the substitution of correct beliefs for them are an important correction of those ontological beliefs which are commonly accepted by scientific men, and place the inquirer in a much better position for taking his next step in the study of ontology.

---

[1] In this sentence the terms "brain" and "organs of sense" are to be understood in their autic, not their phenomenal sense. See Diagram III., p. 486.

Part II.—Outline of the Argument.

1. Man is concerned with what may be provisionally regarded as two kinds of **auta** (*τά ὄντα αὐτά*, real existences), viz. *egoistic auta* and *sense-compelling auta*. (Essay, p. 488.)

2. **Definition.**—By **egoistic auta** are to be understood the thoughts that are my own mind, and those which are the minds of my fellow-men and of other animals. See Postulates 1, 2, 4, and Definitions 1 and 2. (Essay, p. 489).

3. **Definition.**—By **sense-compelling auta** are to be understood the sources of my perceptions, which by Postulate 5 are auta which are *not* within the little group of auta constituting my mind. (Essay, p. 489.)

4. **Definition.**—The **Universe** is the totality of auta. (Essay, p. 489.) It accordingly includes both the egoistic and the sense-compelling auta.

5. Sense-compelling auta communicate with us—human minds —by signalling to us along certain channels of telegraphic communication which consist of our senses and the synergos. See the 6th Supposition, p. 477, and the next paragraph: *see* also Diagram I., p. 484 (Essay, p. 490.)

6. Let us use the term onto-brain to designate the whole of that real existence—an auto, or rather a group of associated auta—which, as the result of one branch of its activity, can produce in us the various perceptions that when built together constitute the phenomenal object usually called the brain. This onto-brain is more than the mind. (Foot-note, p. 492.) What more there is in it may be appropriately called the **synergos**—*συνεργός*, a fellow-labourer—because (along with other activities) it renders help to the mind. Accordingly the onto-brain (of a man who is alive and awake) consists of—

1. The mind.
2. The synergos.

Similarly, if the rest of the *onto-body* of a man be called the **doulos** (δοῦλος, a servant), the entire of the onto-man—the really existing man, in the wider[1] significance of the word man—consists of—

1. His mind, } Making together his onto-brain.
2. The synergos, }
3. The doulos, making up the rest of his onto-body.

His organs of sense, *i. e.* the onto-organs, are a part of the doulos. In illustration of the use of the prefix onto, see Diagram III. The phenomenal object which we are accustomed also to call a man, is not any part of the onto-man, the really existing man. It is merely a **syntheton**—σύνθετον, the structure resulting from synthesis—of certain *effects* which the onto-man can, through organs of sense, produce within the man's own mind or in the minds of his fellow-men. See § 13, below. (Essay. p. 499.)

It is better to treat Part II. as a Recapitulation, and to read it *after* the Essay, p. 488.

we are to understand [illegible]
relations to one another. They are entitled to be called tekmeria, inasmuch as they are proofs to me that other operations are going on in the universe beside those going on in my mind. See Diagram I. (Essay, pp. 491 and 504.)

9. The messages undergo profound change in their transit from the sense-compelling auto to me, so that the tekmerion, the message in the form in which it reaches me, is utterly unlike what the originating auto sent abroad. *A fortiori* there is no trace of ground for supposing it like that auto, or that a structure made by compacting tekmeria together (§ 13, below) is like that auto. See the warning on p. 477. (Essay, p. 499.)

10. It is possible to trace with considerable probability, how, by reason of what we inherit from our ancestors, the tekmeria have come in modern human minds to be perceptions (see definition in § 8) and not mere sensations. (Essay, pp. 503 and 492.)

---

[1] In the narrower significance of the word a man is his mind only.

Part II.—Outline of the Argument.

1. Man is concerned with what may be provisionally regarded as two kinds of **auta** (τά ὄντα αὐτά, real existences), viz. *egoistic auta* and *sense-compelling auta*. (Essay, p. 488.)

2. **Definition.**—By **egoistic auta** are to be understood the thoughts that are my own mind, and those which are the minds of my fellow-men and of other animals. See Postulates 1, 2, 4, and Definitions 1 and 2. (Essay, p. 489).

3. **Definition.**—By **sense-compelling auta** are to be understood the sources of my perceptions, which by Postulate 5 are auta which are *not* within the little group of auta constituting my mind. (Essay, p. 489.)

4. **Definition.**—The [illegible]

[illegible] existence—an auto, or rather a group of associated auta—which, as the result of one branch of its activity, can produce in us the various perceptions that when built together constitute the phenomenal object usually called the brain. This onto-brain is more than the mind. (Foot-note, p. 492.) What more there is in it may be appropriately called the **synergos**—συνεργός, a fellow-labourer—because (along with other activities) it renders help to the mind. Accordingly the onto-brain (of a man who is alive and awake) consists of—

1. The mind.
2. The synergos.

Similarly, if the rest of the *onto-body* of a man be called the **doulos** (δοῦλος, a servant), the entire of the onto-man—the really existing man, in the wider[1] significance of the word man—consists of—

1. His mind, } Making together his onto-brain.
2. The synergos, }
3. The doulos, making up the rest of his onto-body.

His organs of sense, *i. e.* the onto-organs, are a part of the doulos. In illustration of the use of the prefix onto, see Diagram III. The phenomenal object which we are accustomed also to call a man, is not any part of the onto-man, the really existing man. It is merely a **syntheton**—σύνθετον, the structure resulting from synthesis—of certain *effects* which the onto-man can, through organs of sense, produce within the man's own mind or in the minds of his fellow-men. See § 13, below. (Essay. p. 499.)

7. Several of the items of the description given in the last two paragraphs rest on Supposition 6, p 477. These details are not essential to the argument of the Essay, but they make the argument more easily stated and more easily understood.

8. The **tekmeria** (τεχμήριον, a sign which is at the same time a proof of something), *i. e.* the signals or messages (§ 5) *in their final form* as they reach the minds of modern men, are more than sensations: they are **perceptions**, [definition] by which term we are to understand *sensations which appear to us to have space relations to one another.* They are entitled to be called tekmeria, inasmuch as they are proofs to me that other operations are going on in the universe beside those going on in my mind. See Diagram I. (Essay, pp. 491 and 504.)

9. The messages undergo profound change in their transit from the sense-compelling auto to me, so that the tekmerion, the message in the form in which it reaches me, is utterly unlike what the originating auto sent abroad. *A fortiori* there is no trace of ground for supposing it like that auto, or that a structure made by compacting tekmeria together (§ 13, below) is like that auto. See the warning on p. 477. (Essay, p. 499.)

10. It is possible to trace with considerable probability, how, by reason of what we inherit from our ancestors, the tekmeria have come in modern human minds to be perceptions (see definition in § 8) and not mere sensations. (Essay, pp. 503 and 492.)

---

[1] In the narrower significance of the word a man is his mind only.

11. **Definition.**—An **object** is a *supposed non-egoistic existence.* The supposition, being a thought in the mind, is an auto—one of the egoistic class of auta; but the object of that thought has not necessarily an autic existence. It is, in fact, an hypotheton. (Essay, pp. 497 and 498.)

12. Accordingly **objective existence** is to be carefully distinguished from **autic existence.** Objective existence is hypothetical, and is usually not autic (or real) existence. It will be autic only under the very exceptional circumstance that the hypothesis made has been the true theory of existence. (Essay, p. 506.)

13. The **phenomenal objects** which seem to us to be situated about in space are in reality syntheta of perceptions, *i. e.* of the tekmeria or messages sent to us by sense-compelling auta. Of the perceptions which are built together to form a phenomenal object, those only exist at any one time which we experience at that time, and even they have an egoistic, not the supposed non-egoistic, existence; the rest are potential, that is, they are not then in existence, but will come intc egoistic existence if certain conditions are fulfilled. (Essay, p. 498.)

All these perceptions, whenever they arise, are *additions made to my mind* by the sense-compelling part of the universe. The supposition that the syntheton formed by putting them together has a non-egoistic existence is only a hypothesis, most useful to me, and therefore legitimate as an hypothesis, but not to be mistaken for a part of the true theory of existence. (Essay, p. 499.)

14. **Definition.**—**Nature** is the totality of phenomenal objects. (Essay, p. 501.)

15. **Definition.**—The **phenomenon** is man's thought about the phenomenal object. (Essay, p. 500.) Accordingly it is an auto; it exists, but only while we are thinking about the phenomenal object. It is transitory, imperfect, and fluctuating, whereas—

16. The phenomenal object, though only an hypotheton, is perfectly definite and has in it nothing unstable or arbitrary, including, *as it must, all* the tekmeria which a certain part of the sense-compelling universe does or can legitimately produce in human minds through human senses. (Essay, p. 501.)

17. In the sense of being *derived by this definite process* from what is in actual existence in the sense-compelling part of the

universe, the phenomenal object is fully entitled to be called **real**, as opposed to illusory or imaginary. (Essay, pp. 502 and 506).

18. We may liken the sense-compelling part of the universe to a great machine in motion, and the perceptions it produces within the human mind to shadows cast by it. The laws of the movements of the machine are the real laws of the universe; the laws of Nature are but the laws of the changes which the shadows in consequence undergo. (Essay, p. 502.)

19. (*a*) Natural objects ⎫ Have only an objective existence,
(*b*) Space relations ⎬ not an autic existence. See § 12,
(*c*) Motions ⎭ above. (Essay, p. 507.)

They are, however, *real* in the sense in which that term is used in § 17. (Essay, p. 508.)

20. The exigencies of scientific inquiry have led to the conception of parts of phenomenal objects, and of motions, which are smaller than any that are built up of perceptions that man's senses can convey to him (Essay, p. 509); so that the phenomenal object of the scientific man consists of—

1. Actual perceptions;
2. Potential perceptions; and of
3. Certain other conceived perceptions.

21. Furthermore, in substitution for the phenomenal objects of Nature, scientific investigation has led inquirers to conceive space as peopled with objects that consist exclusively of motions. These may be called **diacrinomenal objects** to distinguish them from the phenomenal objects for which they are substituted; and the totality of them may be called Diacrinomenal Nature. See Diagram I. (Essay, p. 509.)

22. It is obvious that **causation**, *when that term is understood to include efficiency in the cause*, can only prevail among auta. It has no place in the study of phenomenal or of diacrinomenal nature, *i.e.*, in the domain of physical science. (Essay, p. 510.)

23. The assumption that material "substances" and that forces exist, and that the former occupy positions in space the same as or near to those which the phenomenal objects appear to occupy, is the commonly received **noümenal hypothesis**. (By a noümenal hypothesis is to be understood an hypothesis as to what the auta of the sense-compelling universe are.) (Essay, p. 515.)

This view of existence was instilled into all of us in our childhood, and is embedded in the language we must all use.

24. However erroneous (see § 9, and the warning given on p. 477) this crude noümenal hypothesis may be, each of the two parts of which it consists appears to have a partial basis in truth. We have already embodied in the fifth of our postulates the fragment of truth that may be extracted (mixed with error) from the conception of *material substances* (see that postulate and the last paragraph of the Introduction). The second part of the hypothesis has reference to *forces* supposed to surround and act on these substances, and a study of these is instructive. The conception of **force** as commonly entertained by scientific men contains this important element of truth, that a true causal connexion does exist which determines the concomitant events that take place in Nature—the changes which will simultaneously occur among the shadows cast by the great machine.

25. This causal connection is represented in Diagram IV. If true causation operates between two auta, A and B, when they stand in a suitable relation, R, to one another, they and their causal relations to one another and to other auta undergo change; and an event will thus have taken place in the Autic Universe. Should the auta that are concerned be sense-compelling auta, the effects they can produce in human minds, the α's and β's of the diagram, will be different after the change from what they were before; and the syntheta that these effects will form when compacted together, the phenomenal objects, will be different before the event and after it, i. e. a, b, and r of the diagram will undergo change, and become a', b', and r'. Thus the true causal connection between the antecedent state of Nature, and that which follows it, passes, as it were, over the bridge of the diagram. Accordingly, a force, which is usually regarded as a cause of dynamical change in Nature, is in reality **of the nature of a symbol**, a symbol which *stands for*[1] the indirect causal connection described above.

[1] In the science of dynamics it is immaterial what it stands for, since in that science we are only concerned with the *direction and amount of the change which a certain shadow undergoes* when the cause symbolized by the force has been operating in the autic universe, and has altered that part of it which casts this shadow. As to the meaning of a shadow and of casting a shadow, see foot-note 2, p. 510, and Part V., p. 522. See also Diagram IV., p. 487.

The great machine has moved, and the shadows which it casts have undergone change. But the cause of this change is to be sought, not in any power which the shadows have to operate on one another, but in whatever has brought about the motion of the machine. *Physical causes* are but causes conceived of as operating between the shadows, and are but symbols in their relation to the *true causes* that have operated between the auta of the sense-compelling Universe. They are, nevertheless, entitled to be pronounced *real* (as being based on reality and a legitimate supplement of the phenomenal hypotheton) whenever the indirect causal connection represented in the diagram actually exists.

26. The commonly received noümenal hypothesis that material substances exist and have space relations to one another is discredited by the investigation. The author has elsewhere put forward in substitution for it the noümenal hypothesis that all auta are thoughts, sense-compelling auta as well as egoistic. The evidence for this monistic hypothesis is glanced at, but not fully discussed, in the essay of which this is an abstract, since neither the argument nor the conclusions of the essay depend on it.

27. The main steps of the argument are presented in a diagrammatic form in the first of the following diagrams.

28. The conclusion is stated in the paragraph which begins at the middle of p. 519 of the essay.

Part III.—Illustrative Diagrams.

DIAGRAM I.

Illustrating the relation of Hypotheta to Auta.

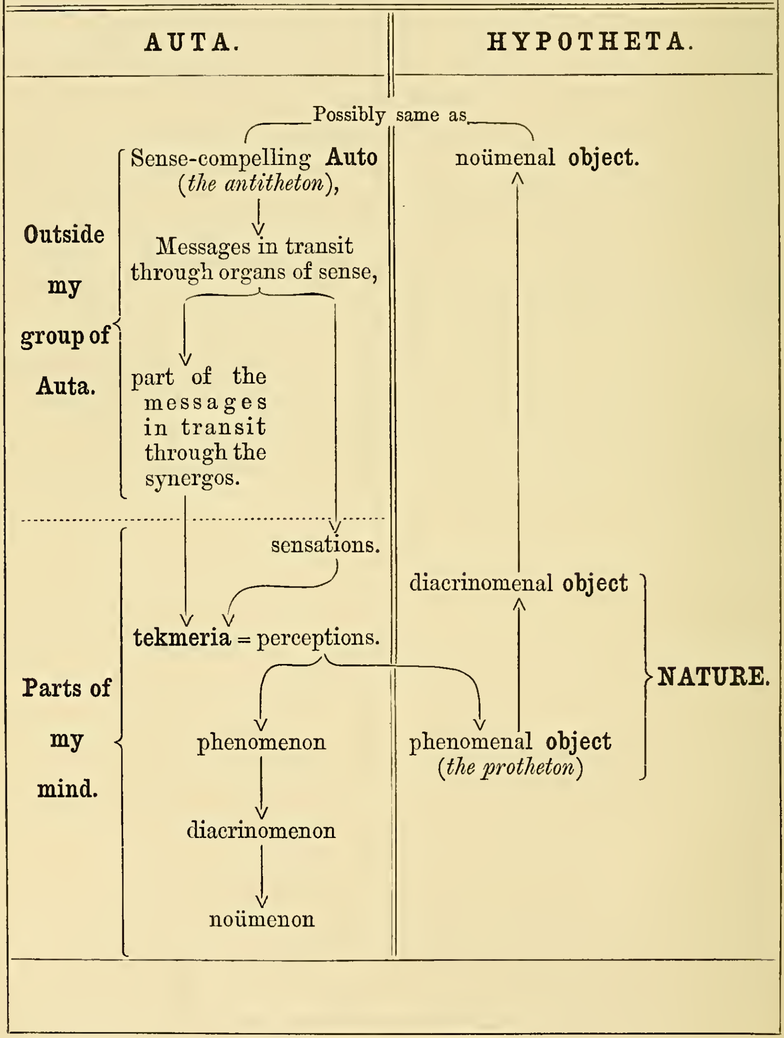


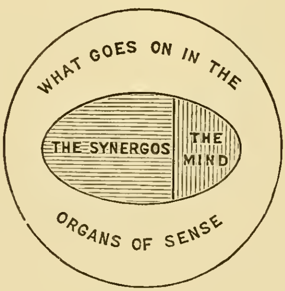
DIAGRAM II.

Illustrating the relation of the minds of Men and other Animals to the rest of the Universe.

[The onto-brain of a man who is alive and awake consists of his mind and its synergos.]

THE

SENSE- COMPELLING



PART OF THE

UNIVERSE.

DIAGRAM III.

Illustrating the Ambiguity of the names of Objects, Relations, and Events.

The word **fire** may mean

either {the aitio-fire, / the onto-fire,} viz.:

The **Antitheton** — an Auto, or real existence, or rather a group of Auta, in the sense-compelling Universe,

[which cause to come into existence]

operations in my organs of sense, and in the synergos,

[which cause to come into existence]

tekmeria, or perceptions, in my mind

[which, by synthesis, furnish]

the **Protheton**—the Phenomenal, or Natural, object.

or {the syntheto-fire, / the skio-fire,} viz.:

The word fire in its two meanings may, appropriately, be called the aitio-fire and the syntheto-fire, in their relation to our perceptions: the one being the aition or source of our perceptions of the fire, the other the syntheton or structure formed by building these perceptions together.

Or, they may be called the onto-fire and the skio-fire in their relation to one another: the one being the reality, the other a shadow cast by it in a particular way.

DIAGRAM IV.

Illustrating the causal connection between Man's perception of the Antecedents and his perception of the Consequents when "a change is observed to take place in Nature."

Antecedents				Consequents		
Sense-compelling **Auto.**	Relation between them.	Sense-compelling **Auto.**	[become, if they operate on one another,]	Altered **Auto.**	Altered relation.	Altered **Auto.**
A	**[R]**	**B**		**A′**	**[R′]**	**B′**

[can produce tekmeria in men's minds through their senses, viz. :—]

Either α_1 $[\rho_1]$ β_1

or α_2 $[\rho_2]$ β_2

or α_3 $[\rho_3]$ β_3

or &c. &c.

[which, when synthesised together, furnish the phenomenal objects]

a [r] **b**

[which produce as their tekmeria]

α_1' $[\rho_1']$ β_1'

α_2' $[\rho_2']$ β_2'

α_3' $[\rho_3']$ β_3'

&c. &c.

[and these furnish by synthesis]

a′ [r′] **b′**

Part IV.—The Essay.

An Inquiry into the Relation between the Scientific Study of Nature and the Actual Events of the Universe.

Hitherto every attempt to ascertain the events that are actually happening in the universe of real existences, and to determine what those existences are—in other words, the study of ontology—has been pursued almost exclusively from the standpoint of the metaphysician. This mode of treatment has led to a few negative results which are chiefly of value by helping to dispel some popular errors, but it has established little that is positive, or that can be of much service to the scientific student of nature. And yet the scientific investigation of nature has been pushed in more than one direction into contact with problems of ontology, and is there arrested[1] owing to the wholly different levels at which these two fields of investigation lie. It appears therefore to be in an eminent degree desirable that an attempt should be made to bring them into line by carrying on the ontological investigation from the standpoint of the scientific student of nature.

Such an investigation will necessarily be extensive; but the present essay[2] only aims at endeavouring to lay its foundation by seeking to ascertain in what way the scientific study of nature (with which the human mind is fitted to cope) stands related to the real events and real existences of which the universe actually consists.

Let us for convenience call these real existences **auta** (*τά ὄντα αὐτά*)—the very things themselves. An auto then is a thing that really exists, and in no wise depends on the way we, human minds, may happen to regard it. Our impressions or beliefs about it may be correct or may be erroneous, but the term auto means the thing *itself*.

---

[1] Notably in physiology, in which science we are brought to a stand when we come face to face with the problem of the interdependence between the thoughts of animals and changes in their brains; and generally throughout physics, when we make any attempt to penetrate to the causes of the events that occur.

[2] For convenience of reference, the postulates upon which the reasoning of this essay is founded are set out explicitly in the Introduction (p. 476); and definitions of most of the terms used will be found in the Outline (p. 478). (A complete Glossary of the Terms is given at p. 520.) Some Diagrams are added (p. 484), the first of which represents, in a graphical form, the general plan of the argument.

I also use the term **universe** to mean the *totality* of all existing things, of all these auta. It is to be noted that here and elsewhere the word totality is to be understood as having a more comprehensive meaning than the word aggregate. Any collection of auta, however disorderly, would be an aggregate of them. By their **totality** I mean the auta under one definite set of conditions, viz.: under those conditions that actually prevail—with those mutual relations, performing those operations, undergoing those changes that actually occur.

My own thoughts are, at all events, things that exist: they at least are auta so long as they last. They are, accordingly, while they last, a part of the universe of existing things. But they are not the whole of that universe. In the first place, the thoughts of other men and the thoughts of the lower animals are also things that exist. And beside all these auta, there are also auta of the kind that produce effects within men's minds through their senses. This is a complete enumeration of auta—things that exist—so far as known to man.

In the last paragraph I have used the term **thought** in its widest extension, to embrace *everything* of which I or my fellow-men or the lower animals are conscious, whether they be sensations, perceptions, conceptions, beliefs, feelings, memories, emotions, sentiments, judgments, acts of will, or any others. I also use the term *I*, the *ego*, or **my mind**, to mean the totality (not the mere aggregate) of a certain group of these thoughts.

The minds of my fellow-men and the minds of the lower animals may conveniently be classed along with my mind as *the egoistic part* of the universe—being the part of the universe which I am already in a position to know consists of auta of the same kind as those that make up the ego.

Auta of the other kind we may provisionally speak of as *sense-compelling* auta, in contradistinction to my mind and the minds of other men and animals which are groups of auta that receive certain definite additions when and so long as our organs of sense are forced into action by sense-compelling auta. The totality of these sense-compelling auta we may for brevity designate the sense-compelling universe, which will accordingly mean the same as the sense-compelling part of the universe.

The whole universe then, as known to man, consists of this sense-compelling universe, and of the thoughts of men and animals. This division is convenient, although faulty from a logical point of view, since we shall find that the parts of which it consists overlap. We shall, nevertheless, make use of the distinction provisionally for the sake of its convenience.

Now, when I open my eyes or exercise any of my other senses, sense-compelling auta transmit messages to me through my senses. These messages present themselves as parts of my mind, of my group of thoughts; and, in the actual form in which they arise within my mind, I propose to call them **tekmeria** — signs within my mind that events are happening in a part of the universe that is distinct from my mind. Thus, when I look towards the fire in the room in which I sit, the actual existence, the sense-compelling auto, which for distinctness sake we may call *the onto-fire*,[1] (τά ὄντα, things which actually exist), transmits one message or signal to me through my eyes, viz. the visual appearance of the fire. This is one tekmerion made to be a part of my mind by the onto-fire so long as it is acting upon me. When, at the same time, I hold out my hands, it transmits a second message to me, the perception of warmth, through another of my senses. And it sends another tekmerion to me, another witness that it is in existence and producing effects, through my sense of hearing, viz. the sound of the flame playing over the coals.

Thus, so long as I am employing my senses upon the fire, the onto-fire, a cause which is distinct from my mind, *i. e.* which is not a part of my little group of thoughts, is in three different ways, and each of them a very indirect way, sending me what may well

---

[1] All names of objects, relations, events, or operations in nature are ambiguous, and in some contexts mean the natural object, &c., and in other contexts, that auto or collections of auta in the sense-compelling universe, which is the aition or source from which our perceptions come. See Diagram III., p. 486. (*το αἴτιον*, that part of the entire body of causes leading up to the existence of a thing or of a group of things, to which we may *attribute* the presence of that thing or group of things.)

The autic source of our perceptions, and the phenomenal object which is the outcome of building the perceptions together, stand so much in contrast to one another, that each might appropriately be called the antitheton of the other. Of each pair of antitheta, one would then be a portion of the autic universe, the other an object of nature. But in order to mark as emphatically as possible the distinction between these, it is better to confine the designation **antitheton** to the former of them, and to speak of its correlative in the phenomenal world as its **protheton.**

be called telegraphic signals; and these three tekmeria become, for the time, a part of that fluctuating group of thoughts which is my mind. The advent of these perceptions within that group implies that events competent to cause them have occurred in the universe beyond.

What has really happened is, that some of the auta of the sense-compelling universe have been operating upon one another and have produced extensive changes—changes which may have affected the auta themselves or their relations and operations. Of a very wide-spread effect some small outlying portions have filtered as far as to my mind—to my little group of auta—through certain narrow and tortuous channels, my senses. They are thus tekmeria, signs to me that events are occurring beyond myself.

Now, the tekmeria, as I experience them when an auto acts on me through my senses, are more than mere sensations. To enable me to see this, it is only necessary for me to direct my attention to the remarkable judgments about space relations which have annexed themselves to my sensations. When I hurt my foot and when I hurt my elbow there is a difference in the sensations; and this difference my trained and assisted[1] mind has come to translate into the perception of a space relation between these two sensations and between them and others. Thus, the first pain is felt as a pain in the foot, i.e. *in or about a certain position in space;* the second pain I similarly *localise.* So, also, with other sensations when they have come to be transformed into perceptions. The red which I now see in each coal of the fire is a sensation of colour which seems to me of a certain shape and size, and at a certain distance from muscular sensations which I feel at the same time, viz. the sensation of turning my head towards the fire, of converging my eyes in succession upon different parts of it, the sensation of now and then winking,[2] and the sensation of making and maintaining the focal adjustment of my eyes: all of which latter sensations appear to me to be located elsewhere, viz.

---

[1] Assisted by that part of the activity of the onto-brain which goes on without my being conscious of it. (See foot-note, p. 492.)

[2] I mention winking, because in my own case, and probably in the case of other men, the sensations which I experience when winking, and for a brief time afterwards, are a conspicuous element in the totality of sensations which furnish me with the distinction between here and there in space.

at or near the centre of **space as I apprehend it**. So, also, with the sensation of warmth, which seems to me to be *on the surface of my hands* when I hold them to the fire. Now, [definition of the term perception] sensations which thus appear to occupy positions in space are **perceptions**.

In such cases the perception is far from being a mere co-existence of sensations. It is the result of a very subtile synthesis, a synthesis usually of many sensations, and of the mind's present and past experience, with probably other materials. My mind assisted by its synergos[1] could not have effected this synthesis in its present complex form but for their inherited tendency to make it and their inherited capacity for doing so.

By the synthesis which results in my visual perceptions, a very remarkable co-ordination has been effected between the muscular, the tactual, and the visual sensations produced in me by sense-compelling auta; an equally remarkable co-ordination between the perceptions of my own mind and the perceptions of my fellow-men and of other animals; above all, a co-ordination between my own perceptions, past, present and future: which co-ordinations enable me promptly to form correct predictions, and are *of the greatest service to me in regulating my acts.* Natural Selection has probably helped to develop them. Of all the syntheses by which my mind assisted by its synergos succeeds in translating sensations into perceptions, this one appears to accomplish the greatest and most useful transformation. The intense tendency to make this particular synthesis and the extraordinary facility with which I

---

[1] Without anticipating too much what would more naturally be dealt with further on, it may be observed here that my onto-brain (that **real existence,** that body of closely-related and inter-acting auta, which is the autic *antitheton* of the phenomenal object commonly called my brain) may be distinguished into two parts, the my-thought part, and the part not directly concerned when I am conscious. These two parts act on each other; so that the thoughts that are my mind are affected from outside themselves in *two* ways, viz.:—1°. By sense-compelling auta acting directly on the first part of the onto-brain (*i. e.* on my mind) through my senses; and 2°. By the second part of the onto-brain acting on the first, whether when stimulated thereto by sense-compelling auta operating on it through my organs of sense, or at other times. (See Diagram II., p. 485.) As the second part of the onto-brain behaves as associate and helpmate to the first, it may be called the **synergos;** and the whole onto-brain of a man while he is alive and awake will then consist of two parts—the mind and the synergos. If the rest of the onto-body requires to be spoken of it will be convenient to call it the **doulos.** (See § 6, p. 478).

can effect it, are no doubt due to the frequent repetition of the process by each member of an immense series of progenitors: and in fact there is evidence to show that the co-ordination, substantially as my synergos and I now make it, had been effected in my ancestors at a very remote period.[1]

The transformation of sensations into perceptions is now so complete in modern human minds, that it is very difficult to unravel perceptions and successfully analyse them into the elements of which, nevertheless, they really consist. Thus, in the visual perception of the newspaper which lies on the table before me, some of the visual sensations are not much transformed, and are accordingly felt by the mind predominantly as **sensations**. The general colour of the paper and print are so felt, as is also the mere visual sensation of form and position in the field of view—that which would be different if the newspaper were round instead of square, or if one of its corners were turned towards me instead of one of its sides. On the other hand, *the difference of* the visual sensations conveyed by the two eyes is not felt as sensation, but as a **perception** of stereoscopic effect, that is, it is *quite* transformed. The same has happened in a considerable degree to the delicate differences of shade, which, co-operating with the binocular vision, are chiefly felt by my mind as space perceptions—the perception that the paper is somewhat crumpled—and are only obscurely felt as colour sensations.[2] And

[1] *E. g.* Before birds were differentiated from other vertebrates. See the truly wonderful design on the feathers of the Argus pheasant referred to in the next foot-note.

[2] A careful scrutiny of works of art will be found to be very suggestive in this connexion. If a painter wants to represent on his flat canvas such an object as, for example, a brown ball supported on a white pillow, he finds it necessary to bring out the appearance of the rotundity of the sphere and of the depression in the pillow by the skilful application of delicate touches of an astonishing number of different tints. Few of these strike the beholder as colours. The impression he receives through their instrumentality is that he is beholding two objects *standing out in relief*, each of which is of one uniform colour. In cases of this kind the sensations of colour are so much transformed into a judgment about space relations that what remains to be taken notice of as colour is but a small residue.

A similar variety of colours, laid on as though with the brush of an artist, and with the same resultant effect, will be found on a close examination of that truly marvellous representation of beans sunk into the recesses of a pod which is pourtrayed on the feathers of the Argus pheasant.

Now, over the natural objects that surround us on all sides in nature there is this same profusion of tints, helping, along with muscular and binocular sensations to enable my synergos to supply me with **instinctive** judgments (*i. e.* judgments again, a nearly complete translation into judgments about space relations has so transformed the many delicate muscular sensations which accompany vision, that unless I direct special attention to them I am not conscious of them as sensation at all. Instead of being felt as sensations, they are another of the factors acting on a part of the onto-brain which is wholly or partly outside my consciousness, and inciting it to produce within my consciousness those judgments about space relations that accompany vision. That we, modern men, are endowed with such brains is part of the great inheritance that has come down to us from our ancestors; and the course of events in the universe is such, that we in our turn can somewhat augment the store by judiciously exercising our faculties, and so transmit a still greater possession to our posterity.[1]

But we need not pursue this inquiry farther: the fact is enough for our present purpose. The tekmeria, the telegraphic messages which reach me from the sense-compelling universe along the several channels of telegraphic communication, present themselves in my mind *in the very much modified form* of perceptions. Such I experience to be the fact.

It is very instructive to follow out the simile of a telegraph somewhat further, with a view to our more clearly understanding what has really occurred. Along a line of telegraphic communica-

---

formed unconsciously so far as *I* am concerned) about space relations; and in many, perhaps in most, cases those tints are not appreciated by me as colour sensations at all, unless I expressly scrutinise them under this special aspect.

This remarkable transformation of sensations *into something quite different from sensation* may be observed under circumstances which make it conspicuous, whenever an extensive scene among mountains is viewed, especially in sunshine, first in the ordinary erect posture, and then after inclining the head sideways, or, still better, after turning it partly upside down. Under these latter circumstances a surprising amount of colour, chiefly consisting of purples and greens, will seem to spring into existence, which had been unseen as colour when the prospect was viewed from the erect position; and at the same time all the minor undulations of the surface, which were conspicuous in the erect position, are now lost. In fact the wonderful instinct we possess, by which we (with the co-operation of our synergos) effect the transformation of sensations of colour into a judgment about form, is at fault when our eyes are brought into a position markedly different from that in which they were when we underwent the training which developed that instinct in us; and accordingly the sensation in its unaltered state is what then reaches us.

[1] Observe, in this connexion, the greater power of observation possessed by the members of some families than of others, and especially by some individuals of those families who have sedulously cultivated their powers of observation.

tion there may be intermediate repeating stations at which the message is received and then transmitted forward. This I find to be also the case with the messages that come to me from sense-compelling auta. The fire that I am looking at acts upon the æther,[1] and thereby originates and maintains in it an extensive undulation of rapidly alternating electro-magnetic stresses. This is the form in which the message was despatched from the transmitting station. A very little of the enormous effect produced by the originating auto gets into my eyes through the pupils. This is the fragment of the message which the intermediate station—my eye—succeeds in catching. Here the small portion of this fragment of the undulation which falls between certain limiting wave-lengths is supposed to act on photo-sensitive matter in the pigment cells at the back of the eye, and produces there chemical changes. This is the way the message is recorded at the intermediate station: in being recorded *it is translated into an entirely new language.* It has next to be transmitted forwards. This is accomplished by the new chemical compounds that have been called into existence being such as stimulate the outer end of the optic nerve, which is part of the telegraphic conductor between the eye and the mind. Ultimately the message reaches the onto-brain, the terminal receiving station, and is here worked up with other materials and transformed from crude sensations into perceptions. The message in its final form[2] is, as it

---

[1] That is, the onto-fire, not the phenomenal object, acts on the onto-æther, and maintains in it whatever is the autic antitheton of the objective undulation. In fact, throughout the entire paragraph it is of the autic antitheta and their behaviour that we are speaking, and the reader is requested to understand such names as eye, wave-length, photo-sensitive matter, new chemical compound, optic nerve, in their autic not their phenomenal (or objective) meaning. (See foot-note, p. 490, and Diagram III., p. 486.)

[2] It appears then that what reaches the mind is only *a message from* the originating auto; and not even the direct message, but a message which takes its final form quite as much, or perhaps more, from what has happened to it in transmission than from anything that the originating auto did. It is very plain then that I am not justified in regarding the tekmerion which is called into existence within my mind as being in any sense an image or copy of the originating auto. And yet this is so generally assumed to be the case, that the supposition underlies many common forms of speech. The source of the error is that the phenomenal object (*which our perceptions do resemble*) has in the popular apprehension been, by a natural confusion, identified with the originating auto, to which, on the contrary, it really bears a relation somewhat similar to that between an effect and its cause—a relation of antithesis, not of resemblance.

were, written out from the telegraphic symbols into the handwriting of the clerk at the receiving station.

Another tekmerion reaches me from the onto-fire through my sense of warmth, and another through my ears. These messages travel to me by other and very different lines of telegraphic communication between that auto and me. They also undergo complete transformation before they reach their destination. This is in fact true of all the communications made to me by sense-compelling auta.

The tekmerion being the ultimate form of the message, any change which it undergoes indicates that a change has taken place either in the sense-compelling auto, or somewhere along the line of communication. If, for example, I am looking at a building, the tekmerion which thereupon comes into existence, viz.: my visual perception of the building, will change—1°, if a window be thrown open. Here the change in the tekmerion is caused by a change in the auto.[1] Or 2°, if the building is seen by a red strontium light, instead of by daylight. Here the change has been in the way the sense-compelling auto has been affected by other sense-compelling auta. Or 3°, if I direct my eyes in succession to different parts of the building. Here the change has been in the channel of communication. Or 4°, if I walk round the building and view it from different sides. Here again the change has been in the channel of communication. Or 5°, if by drugging myself with santonin I become temporarily colour-blind. Here the change has again been in the channel of communication, the repeating station, my eye, having been so altered that it now translates the message it receives differently before sending it forward.

The enumeration of these particulars is chiefly of use here in order to lead up to the remark that, owing to past experience and an inherited aptitude, my mind, aided by its synergos, has become extraordinarily expert in distinguishing in such cases; so much so that I can usually tell instinctively, *i. e.* at once and without any effort (that falls within *my* consciousness), which of the perceived changes in the tekmerion indicate changes in the originating auto,

[1] Throughout this paragraph, as in the paragraph on p. 495, it is in their autic significations that the names used are to be understood. (See Diagram III., p. 486.)

and which are to be attributed to mere changes in the channel of communication.

This remarkable power of discrimination, so easy to me now, is intimately associated with the transformation spoken of above, of sensations and other materials into perceptions; and, however easy I now find it, must have been acquired by my ancestors gradually, and after the correction of many mistakes.

Synthesis does not mean merely the act of collecting materials together. It means that and much more, viz. the building up of a definite structure [συντίθημι includes the meaning of the Latin verb *construere* as well as of *colligere*]. The completed structure may be conveniently called the **syntheton** [σύνθετον, the structure resulting from synthesis]. Moreover, in the cases we are concerned with the syntheta have not been formed by merely fitting the materials themselves together: they consist of some of these materials brought into combination, not directly with the rest of the materials, but with effects produced by them. For example, all the perceptions which come into existence within my mind while sense-compelling auta are acting on me through my senses, are syntheta of this more complex kind.

It is to be noted that these syntheta, my perceptions, while they last, are auta, real existences: they are thoughts, parts of my mind. In fact up to the present we have been dealing exclusively with auta, things that really exist, some of them non-egoistic, others of them parts of my own little group of thoughts.

But in the next step which the mind takes—a very important step—it transcends these limits. It forms a further syntheton, namely, the **phenomenal object**. By an object is to be understood a *supposed* non-egoistic existence. The supposition that the phenomenal object has a non-egoistic existence, if confidently believed in, as it is by men untrained in inquiries relating to the mind, may be correct or may be an error; and on careful scrutiny is found to be an error. By persons trained in mental philosophy, the supposition is usually put clearly before their own minds as **an hypothesis**; *i. e.* it is entertained with good reason and for useful purposes, but in so guarded a way that the mind is not misled into concluding that in dealing with the phenomenal object it is dealing with an auto. (See Diagram I., p. 484.)

Perceptions—*i. e.* **sensations which appear to me to be planted out in space**—are the tekmeria or messages which I receive from sense-compelling auta, and arise within me whenever and so long as a real auto is acting on my mind and my synergos through my senses. But the perceptions which it creates within me at any one time are but a small part of all the tekmeria that it can send me. Which of all the possible tekmeria shall exist at any one instant depends on the particular line of communication which is at that time open between the sense-compelling auto and me; and whenever I make those changes which are popularly described as "looking at the object from a different side," "touching it in a different place," and so on, what I do is simply to change the channel of communication without altering the sense-compelling auto. But I thereby alter the perceptions, the tekmeria which it sends me. Now, the **phenomenal object**—which persons untrained in mental philosophy are apt to mistake for the cause of their sensations—is simply *the result of my mind's effecting a synthesis of all these tekmeria.* They cannot actually exist except in succession,[1] but my mind has the power of conceiving them as existing—

1. Simultaneously,
2. Persistently, and
3. Without being any part of itself.

In this power of conception consists its power of effecting this most useful synthesis.

While I am what is called "looking at the object," one of the tekmeria, my visual perception at that time, is **actual**—that is, is in existence; the rest are **potential**—that is, they are not at present in existence, but they can be brought into existence. When I "turn my eyes away," none of the tekmeria are actual: they are all potential. Meanwhile the originating auto continues in existence during all this performance, and will, with certainty, reproduce the first-mentioned tekmerion if "I turn my eyes back,"

[1] That is, not more than *one of each kind* can exist at once. Of course a sense-compelling auto or group of auta may simultaneously produce two or more perceptions in my mind through *different* senses; *e.g.*, one of the innumerable visual perceptions which it can produce, and one of the innumerable tactual, may coexist in my mind; but the other visual and the other tactual perceptions which that auto or group of auta is competent to produce within my mind can only be in actual existence at other times.

i.e. if the channel of communication between the sense-compelling auto and me is reopened.

It thus appears that the phenomenal object is not at all made up of any of the parts of which the sense-compelling auto consists, but only of certain very minute outlying portions of the wide-spread effects of its great activity, viz. those effects which, by its activity, it can produce within me, through a few very narrow and tortuous passages, at the same time that most of its activity is being expended in other directions. This clearly shows (1°) that the phenomenal object is not the auto, and (2°) that for all human purposes my attaining a knowledge of this hypothetical existence is as useful to me as if I knew what the auto is. It tells me, *in a direct and in the most compendious form*, what effects the auto, under every variety of circumstances, **will** produce within me, for it is itself a structure **built up of these very effects put together.**

It is to be observed that ordinary language is throughout built upon the popular belief that the objects of the phenomenal world are non-egoistic *existences*, and moreover that they are the cause of the perceptions which come into existence when we exercise our senses. This is "to put the car before the horse": it is to imagine that a structure built up out of the effects of a thing can be the cause of those effects. The phenomenal object is built up of perceptions instead of being the cause of them. Their cause is to be sought in the sense-compelling universe of *auta*, not in the phenomenal world of *objects*. Ordinary language is accordingly apt to mislead us very much; and we must be constantly on our guard against illusions into which we may but too easily be led by the common usages of language, and by associations which have grown up round familiar forms of expression.

Illusions will be found to lurk in what are apparently the most harmless forms of expression, such as "I perceive a cloud moving across the sky"—and to get at what we are really justified in believing, it is well diligently to practise ourselves in converting such expressions into less misleading equivalent forms *until we do so with facility*. Thus the foregoing statement is equivalent to—

1°. I am a fluctuating group of associated thoughts, and the perception of a moving cloud is for a short time one of *this* group.

2°. The perception of a moving cloud is also a part of *another* group, a very useful hypothetical group, in which it is joined, not with the other thoughts at present in my mind, but with all the other perceptions that the onto-cloud *could successively* produce in my mind.

3°. This useful hypothetical group, which may be called the objective cloud, is not the cause of my perceptions. The true cause must be sought elsewhere, and to give it a name we call it the onto-cloud.

We have passed successively under review two acts of synthesis —the *synthesis of the first order*, whereby sensations are transformed into perceptions; and the further synthesis which may be called a *synthesis of the second order*, whereby certain perceptions are built together into the phenomenal object, which is a kind of synopton or collected view of materials, only a small part of which are in existence at any one time. But in reality these two acts of synthesis are now carried on by my mind and its synergos simultaneously and with equal ease and promptitude, and it is probable that the gradually acquired power to make them was developed *pari passu* in my ancestors.

For the sake of completeness it is well here to assign a name to my thought about the phenomenal object. This we may call the **phenomenon**,[1] or phenomenal thought. The phenomenon at any particular time consists of all or some of the following:—

1. The actual perceptions which at that time the sense-compelling auto is producing in me, if there are any such perceptions existing at that time.

2. My memory of the perceptions which that auto has on other occasions produced in me.

3. My anticipation of such perceptions as I suppose it would produce in me under other circumstances.

4. Certain suppositions with respect to this group of perceptions.

[1] The word phenomenon has three established meanings: 1°. It is used by metaphysicians, as in the text, to mean thought in the mind. This is the original meaning of the term: the other two meanings are of recent date. 2°. It is used to mean an extraordinary occurrence. This is the popular acceptation of the word. 3°. It is used to mean any natural object or event in nature. This is the meaning attributed to it in works on Natural Science.

This phenomenon, or phenomenal thought, is itself an auto, an internal auto, a part of my group of thoughts; while, in contrast to this, it is only as an hypothesis that *the object of this thought*, the phenomenal object, can as a whole be regarded as in existence. Part of it no doubt may be temporarily in existence, viz. so long as the sense-compelling auto which is the source of the perceptions happens to be acting on me through my senses. During this time some of the perceptions that go to make up the phenomenal object *are in actual existence*, but only as a part of my group of thoughts. None are in existence independently of the mind, nor are any of the rest of the perceptions that go to make up the phenomenal object in existence at that time either in or out of the mind. That the whole phenomenal object is supposed to be in existence and to be distinct from the mind is therefore an hypothesis; most useful, but not to be entertained as the *true* theory. On the other hand, the phenomenon, *i. e.* my thought about the phenomenal object, while it has the advantage of being an auto, is transitory, imperfect, very variable, and almost always erroneous in some respects, depending as it does on the extent of my information and the amount of attention I give to it: while the phenomenal object, though an hypotheton, has in it nothing in the least shifting or arbitrary. *It is perfectly definite*—including *as it must* all the tekmeria which its antitheton, the sense-compelling auto, actually does, or can legitimately [1] create in human minds through human organs of sense.

We are now in a position to give a useful meaning to the word Nature, and one which is in accordance with its usual acceptation. To each auto which can act on man through his senses, we have found that there corresponds a phenomenal object, viz. the syntheton of all the perceptions which that auto can produce in human minds through human senses. Let then the term **Nature**—the phenomenal world—mean *the totality of all such phenomenal objects*, *i.e.* of the phenomenal objects which correspond to *all* the auta which can act on man through his senses. This may also be called the great Phenomenal Hypotheton; and it is very important to take notice that the objects of which it consists, and the changes they

[1] It is intended by the word "legitimately" to exclude cases of illusion. Legitimately means—when every part of the line of communication is working normally and satisfactorily.

undergo, are entitled to be designated **REAL**, using the word real to mean that they are *the legitimate outcome* of auta which actually exist in the sense-compelling universe, and of what is going on there. (See foot of p. 506 ; see also § 17, p. 480.)

We here reach the point at which the scientific study of Nature may begin. Phenomenal nature is the totality of phenomenal objects, and therefore includes all the materials of which phenomenal objects are made up, viz. *all* the tekmeria which the autic universe does *or could* send through human senses into human minds. Nature is much better than an aggregate of these perceptions, for it is the totality of them : it is these perceptions not merely brought together, but brought together with the relations between them made clear.

When that occurs which in popular language is described by saying that "a change has been observed to take place in nature," what has really happened is that the tekmeria which can be aroused within human minds by the autic sense-compelling universe are found to be now different from what they used to be. This is an autic change within men's minds, consequent upon a change in the causes that produce tekmeria in human minds, viz. a change in the sense-compelling autic universe. Accordingly, every so-called "observed event in nature" corresponds to a real event which has taken place in the sense-compelling part of the universe. In other words, some change which has actually occurred in the autic universe, is the real cause of the appearance of change in nature. Now experience tells us that the appearances of change in nature succeed one another in conformity with definite laws. This can only be because the changes in that part of the universe which produces these appearances accord with laws. **It is these latter which are the real laws of the universe**.

We may liken the sense-compelling universe to a great machine in motion, and the tekmeria which it produces within our minds to shadows cast by it. The laws of the movements of the machine are the real laws of the universe—laws of nature are but the laws of the changes which the shadows in consequence undergo. It is these shadow laws alone which Natural Science can reach : the real laws of the universe of which these are shadows are beyond its grasp.

This is another of those similes which it is instructive to follow up. If the shadow of the machine be caught upon a sufficiently large flat screen placed perpendicularly to the direction in which the light comes, it will assume the form which gives most information: that in which the outline of each part of the shadow is most simply related to the form of the part of the machine by which it is cast, and that in which the motions apparent among the shadows are most intelligibly related to the real motions of the machine. But if the shadow is formed upon a screen crumpled up into hills and hollows there will be no such intimate connection. The forms and motions visible in the shadow will, no doubt, still possess *some* reference to what exists and is going on in the object which cast the shadow, but it will be obscure; and to get at the simple relations the irregularities introduced into the shadow by the ruggedness of the surface must be allowed for.

Now, the telegraphic messages sent to me through my organs of sense by the auta of the sense-compelling universe are such complex shadows. But in me, a modern man, a great part of this message is worked up with other materials and transformed. The crude materials as they originally reached my ancestors appear to have consisted of sensations and acts of will—the sensations produced by the sense-compelling auto, a multitude of other slight sensations from the muscles directing and adjusting the organs of sense, and, in addition to these, acts of will setting these muscles in action. Along with these, there probably appeared in my remote ancestors memories of similar sensations and acts of will previously experienced, and the reflections to which all these sensations, acts of will, and memories would give rise in their minds: issuing on subsequent occasions in the further guidance which these thoughts would more and more exercise over their acts of will. By a law, the existence of which is known to us by experience, though the cause is unknown, the very frequent repetition of such a process would cause it to be more and more carried on outside their consciousness, in the synergos, *i. e.* by operations in the onto-brain of which they were not conscious, the general result only appearing within their consciousness. Thus seems to have slowly evolved that most remarkable *instinct*, which I as a modern man possess, viz. the instinctive judgments of space relations, which in me take the place of a multitude of obscure sensations. These dim sensations I can now perceive as sensations only by close attention, and then but partially; by, as it were, dragging them out of that part of my onto-brain which carries on its operations wholly or partly outside my consciousness.

The general outcome of the whole process is that the tekmerion as it appears within my consciousness is a **perception** which includes a portion of the original group of sensations, but *profoundly* modified by instinctive judgments about space relations that come directly from the synergos and only indirectly from sources more remote. Instead of the complicated shadow which fell on a very broken surface, I have by synthesis, and by the transformation of what was due to irregularities in the surface, got instead a much simpler shadow, which may be likened to the shadow which would fall on a *flat* screen.

Again, if the screen I can use is a small one, and can at any one time catch only a part of the shadow, it would be possible, by combining into one picture what is thus successively presented, to come at what the shadow would appear on a screen of adequate size. This may be taken as an illustration of what I gain by the important further synthesis by which perceptions are conceived as built together into the objects of phenomenal nature.

Thus, by the synthesis of the first order, which results in perceptions, and still more by the synthesis of the second order, which results in the phenomenal world, everything which is due to the fluctuations and irregularities of the channels through which information from the autic universe comes to me, or to their limited scope whereby they can only convey a small portion of the message at one time, is as much as possible eliminated; while all that has relation to what is going on in the part of the universe from which the message comes, is simplified and freed as much as possible from extraneous matter. It has become, as it were, the complete shadow on a screen that is both flat and of adequate size. But it must not be forgotten that the world of natural objects is after all only the shadow of a greater reality.

It is impossible to overrate the importance of the transformation which has taken place through synthesis. *In virtue of it the sensations that present themselves in our modern minds seem to be located about in space.* They become perceptions, that is, they are sensations which have acquired the appearance of having space relations to one another. Our sensations have become endowed with this appearance in various degrees, or at least with different degrees of precision. The colour sensations which come into existence when I look out of the window into the park which is before my house, appear to me to be at different distances from the sensations that accompany the act of looking, viz. those caused by the occasional winking of my eyes, and by my adjusting them upon the several objects. These latter may be called my central sensations, as they are those which fix the centre of *space as I apprehend it.* The colour sensations appear also at different distances and in different directions from one another, the green of the grass appearing in a different situation from the sensation of the white blossoms of a cherry tree in flower, from the sensation of blue in the sky, or of the grey pebbles of the gravelled walks. Now, this localising of sensations has arisen through synthesis, and is accomplished instinctively by our modern developed and trained minds, or rather partly by our minds and partly for them by the unconscious[1] cerebration which is associated with them.

The instinct which impels us to assign a position in space to sensations affects our visual and tactual sensations most, including under the latter term our muscular sensations as well as sensations of roughness, smoothness, resistance, hardness, softness, and some others. We also perceive it conspicuously in the allied sensations of tickling, warmth, coolness, pain, and several others. We localise with somewhat less precision our sensations of taste and smell: and of all our more conspicuous sensations sound is that which we least refer to a definite position. We have less power of doing so than many other animals who are furnished with ears which can be turned so as to distinguish the direction of sound, and far less power than some nocturnal insects who by their feathery antennæ, which are their auditory apparatus, are able to determine the direction of a sound with a precision approaching that of eyesight. In man there are but slender materials for the synthesis.

In order to apprehend clearly how much has been accomplished by synthesis, it is advisable that we should scrutinise more closely space relations, and man's instinctive judgments about them: and as these judgments are a more conspicuous factor of my visual and tactual perceptions than of others, it will be instructive to treat

---

[1] That is, cerebration that is not within *my* consciousness.

specially of them. Many slight muscular and other feeble sensations accompany the use of my visual and tactual organs of sense. These obscure sensations are constantly changing while I am using those senses, and in an excessively complicated way. That out of such tangled materials synthesis has been able to evolve so simple a result as my judgments about space relations, is because, amid all the apparent disorder, there *do exist real relations* between those much varying sensations ; and the syntheton which can be produced depends on what these relations are. They in turn depend on what relations exist between my organs of sense [1] and the various parts of the auto I am examining : for it is while varying these that the sensations in question arise. Hence, finally, the synthesis which can be effected depends on what relations prevail between my organs of sense [1] and other parts of the autic universe. We have no reason to suppose that these onto-relations are in the least like space relations, these being syntheta constructed out of all the obscure sensations that are indirectly occasioned by the onto-relations. But whatever the onto-relations may actually be, **they are at all events a part of the conditions which determine in the sense-compelling universe whether auta can act on auta**. I have to adapt my organs of sense to them in order to get tekmeria; and *it is in doing this* that I experience the complicated sensations which have come, by reason of what has occurred in my long line of ancestors, to be synthesised for me into instinctive judgments of space relations between my sensations. It is evident then that *my judgments about space relations are the result of a synthesis of materials which are themselves consequences of the onto-relations*—of relations that prevail in the sense-compelling part of the universe.

These *judgments* about space relations are thoughts, a part of my little group of thoughts. They are accordingly auta, so long as they last. But the space relations to which they seem to refer have *only an objective* existence, *i. e.* their essence is to be the object of these thoughts, not to be themselves auta. They are, in fact, a part of Nature, the great Phenomenal Hypotheton ; and like other parts of that hypotheton are entitled to be regarded as **real**, as

---

[1] Here the term "organs of sense" is to be understood in its autic, not its objective sense. See Diagram III., p. 486.

distinguished from illusory and imaginary, if they are *the legitimate* outcome of actually-existing onto-relations, that outcome which emerges when the crude sensations primarily sent to us have been worked up by the two definite acts of synthesis[1] described above.

Every space relation therefore in Nature—for instance, that my foot is at present three yards from the fender—has a real autic relation in the sense-compelling universe, which is its antitheton: a relation between what may be called the onto-foot and the onto-fender, meaning by these terms the auta which send men the tekmeria which, when synthesised, furnish those two phenomenal objects. It is, however, in all such cases, the auta of the sense-compelling universe and the relations of these auta to one another that are what really exist. Space relations are but a simplification of shadows: of the shadows cast by the autic relations within the minds of men and some other animals.

We are now in a position to deal with the important subject of motion. The *appearance* of motion is an auto, a perception in my mind; and the existence in my mind of this perception is a tekmerion, a proof to me that an event capable of producing this appearance has occurred in the sense-compelling autic universe. This event could send different tekmeria to me according to the way I employ my senses upon it; and the syntheton formed by putting all these together is what is meant by the term motion. It is accordingly a part of the great Phenomenal Hypotheton which we call Nature. If we want to indicate the real occurrence in the sense-compelling universe we may speak of it as the onto-motion, meaning by this term the autic existence or event which corresponds to the syntheto-motion in the phenomenal world. It is the antitheton of that syntheto-motion. The word motion, like all other similar terms, is ambiguous, and in some contexts means the onto-motion, and in others the objective or syntheto-motion, which latter is a kind of conjoint view, a synopton, of the actual effects that are at the time being produced, and of the possible effects that might have been produced, within modern men's minds,

[1] Viz.: By the synthesis of the first order, which transforms sensations and other materials into perceptions; and by the synthesis of the second order, which combines perceptions into the phenomenal object, and attributes to the latter a persistent and non-egoistic existence.

by its antitheton the onto-motion. It is well, therefore, to use the prefixes *onto-* and *syntheto-* (or the equivalent adjectives *autic* and *objective*) when there is any risk of mistake.[1]

It is in accordance with the signification we have hitherto given to the word **real** that motion in the phenomenal world shall be deemed real when it is a syntheton of the actual perceptions which an onto-motion does, and of the potential perceptions which it could produce by acting on human minds through human senses. But Science, in its progress, has found this definition too cramped. The definition would limit the stamp of being real to those cases in which man's senses are competent to act as channels of communication between the sense-compelling universe and him. Now, scientific investigation has penetrated much further than this—even the flimsy appreciation of what goes on in Nature, which is necessary for man's every-day work, renders essential some extension of the meaning of the word *real*—and accordingly the exigencies of common life, but more especially of scientific inquiry, have made a very marked extension inevitable, so that a motion or other part of the Phenomenal Hypotheton is still to be regarded as real, although too small, or in some other way unfitted, to be a syntheton of human perceptions, *whenever justification for this extension exists.* It would, however, draw us too much aside from the main topic of this essay to deal adequately on the present occasion with this most interesting extension, so that I must content myself here with a bare reference to it. The phenomenal object of the scientific student of Nature is accordingly a syntheton of—

1°. Actual perceptions,

2°. Potential perceptions, and of

3°. Certain conceived perceptions, viz. those others beside actual and potential, which scientific investigation does or can warrant.

---

[1] In the text the word motion is used in the two possible senses pointed out in the foot-note on p. 490, and these two meanings of the word are distinguished as the onto-motion and the syntheto-motion. It will usually be found more convenient to confine the meaning of the word motion to the latter sense, *i. e.* to use it *only* for phenomenal, objective, or syntheto-motion. The other meaning may then be indicated by the word anti-motion, which will then mean the same as the antitheton of this phenomenal motion. The two events will then be distinguished as *motion*, the apparent event in the phenomenal world, and *anti-motion*, that which has actually occurred in the autic universe.

Now, motions are by far the most important part of the phenomenal hypotheton; for scientific investigation has brought to light the significant facts which are described in common language by saying that men and animals receive their sensations of sound from motion in the air, of light from motion in the æther, and in the same way their other sensations from motions somewhere in Nature. This, put into less objectionable language, is equivalent to the statement that the auta or autic events of the sense-compelling universe which produce in me the sensation of sound through one channel of communication, viz. through my sense of hearing, are such as are also competent to produce in me through other channels, namely, through my senses of sight and touch, another tekmerion, viz. the perception of motion; or, at least, differ only from those autic causes which are capable of producing an actual perception of motion through those senses, in the way that the autic cause of the perception of a small motion differs from the autic cause of the perception of a similar motion on a larger scale.

These remarkable discoveries have led scientific men to entertain a new and very important view of Nature, in which it is regarded as made up of objects each of which consists of almost inconceivably minute and swift motions. These and the drifting about in space of some objects, *i. e.* of some masses of internal motions, are the whole of this hypotheton. It may be regarded as the utmost simplification of which the shadows cast within the human mind by the sense-compelling autic universe are susceptible. If the phenomenal hypothesis is to be likened to reducing the shadows of the great machine to order by providing a screen that is flat and of adequate size, we may continue the metaphor and regard the new hypothesis as making the further improvement —the utmost possible—which is effected by condensing the source of light into a point, and by bringing it and the screen which receives the shadows into the very best available positions.

The remarkable hypothesis described in the last paragraph may appropriately be called the **Diacrinomenal** Hypothesis, as it has discriminated between the various tekmeria produced within us by the autic universe, and has selected for further synthesis one out of the number—our perception of motion—on the ground that it, and that it alone, is able *by itself and without being mixed up with other tekmeria* to people Nature with objects which are *complete* as bodying forth in a collected form the information sent us by the real auta of the actual sense-compelling universe, and which, owing to their simplicity, stand in a closer[1] relation to those auta than the more complex objects of Phenomenal Nature. Phenomenal objects are bright, warm, hard or soft, coloured, sweet or bitter, and so on; as well as moving or at rest. In Diacrinomenal Nature motions take the place of all these. I attempted to give a summary of the results of this hypothesis in a Friday Evening Discourse, delivered before the Royal Institution in 1885, and printed in the Journal of that Society, so that it is the less necessary to dilate upon them here, even if it had been appropriate to do so. We may therefore pass on at once to the consideration of the last circumstance which it seems necessary to make clear in order that we may at length be in a position to understand how the scientific study of Nature stands related to the real existences of which the universe actually consists, which is the problem we proposed to investigate.

For we have now reached the point at which the very important observation obtrudes itself upon our attention, that **causation** in the *full* sense of that term implying efficiency in the cause **can only prevail in the operations of auta.**

When a change takes place in the sense-compelling universe owing to some cause having operated in its own definite way, the sense-compelling universe, the mighty machine, will produce one shadow before the change and another after.[2] The second shadow will accordingly succeed the first in orderly sequence, but *the relation between the shadows is not the relation of cause and effect.* Accordingly, in the laws of Nature which have been discovered by scientific investigation, we find abundant instances of unfailingly concomitant events and of uniformities of sequence, but not one single instance

[1] The Phenomenal Hypotheton is but a blurred shadow of the Autic Universe, when compared with the much more searching Diacrinomenal Hypotheton. All molecular motions, and motions finer than molecular motions are blurred together in the objects of Phenomenal Nature (which hereby acquire their appearance of being rigid), or are equally lost to view in the apparently empty spaces between. These omissions are supplied in the Diacrinomenal Hypotheton.

[2] That is, the sense-compelling universe is capable of producing one set of effects within human minds before the change, and becomes such as to be capable of producing another set of effects after. The syntheton made by putting together all the former set of possible effects is Nature, as it exists (objectively) before the change; and the syntheton of all the latter set of possible effects is Nature as it exists after the change. These are the two shadows of the great machine.

of cause and effect. There is nothing in Nature competent to *cause* one body to exclude another from the space it occupies. A statement of the fact is one of the laws of Nature. If a stone be allowed to drop in the vicinity of the earth, its downward speed is accelerated by a perfectly definite law. This law is one of the Uniformities of Nature[1] which scientific inquiry has brought to light. But *within the domain of Physics* there is no *cause* of the acceleration. (See § 25, p. 482, and Diagram IV., p. 487.) The facts as to what occurs in Nature can be observed; the circumstances under which they occur can be investigated; similar cases can be compared; and the laws to which the simultaneous or successive events conform may be brought to light. But here our knowledge ends: Physical Science has said its utmost.

Now all this is changed when we turn to the only field of observation accessible to us in which we are dealing directly with auta. The thoughts of which I consist, the thoughts that are my mind, are auta: a very small group of auta no doubt in the mighty universe of auta, but still *an actual sample*, although a very special and one-sided sample of what auta are. Now in the operations that go on in my mind I do find instances, some few instances, of causes producing effects. The familiar case of a geometrical demonstration producing in a man's mind a belief in the truth of the conclusion is a case in point. Here the understanding of the proof is the *efficient* cause of the belief in the conclusion which accompanies that understanding. A wish to accomplish something, and a knowledge of how to go about it, both of which are thoughts in the mind, are a part of the efficient cause of subsequent events, unless counteracted by other causes. A few other examples can be obtained from the same small field of investigation; and this is all that man, in his isolated position, has any right to expect; for the bulk of his thoughts are due, at least in large part, to autic causes which lie outside his mind, and it is there also that those of his thoughts that are known to be causes, usually exhibit their effects. When perceptions arise in my mind, the effect is indeed within my mind, but the cause lies beyond it; and when I move my muscles the cause is within my mind, but it is outside the mind that it operates. The instances are indeed few where the causes and the effects are *both* within

[1] In this case the vicinity of the earth to the stone and the acceleration of the stone's vertical velocity are the two "unfailingly concomitant events."

my tiny group of auta, and it is only in these few cases that I can have the process of causes producing effects under my inspection.

But since cases can be cited, however few, **they suffice to establish the fact** that the relation of cause and effect, *in its full sense*, does exist in some instances in the autic universe; whereas it has nowhere any place within the domain of physical science. I am even under the impression that every event which has occurred in the real universe, every change that has taken place there, has been, as a matter of fact, brought about by true, adequate causes; although I am bound to admit that man lives too secluded[1] from the rest of the universe, and with channels for communicating with it that are far too indirect, for me to be entitled to dogmatize and to say to myself or to my fellow-men that I absolutely know this to be so. At the same time it recommends itself to my mind as intrinsically probable; and it is besides supported by direct evidence *which makes it probable in a high degree*—

1°. Since there are some instances in which the whole process of causation operating among auta can be observed.

2°. Since no instance can be found in which observation is possible, and in which it does not prevail; and

3°. Since the alternative supposition appears to be very improbable. The only alternative is that, while the few changes among auta which can be investigated are found to be due to adequate causes, the rest which we cannot investigate are uncaused.

The ontological inquiry on which we have entered may be approached either in the sceptical or in the scientific frame of mind. These are not only different but opposed. The motive which rouses the scientific man to exertion is his earnest desire for the increase of knowledge. For this he is willing to do his utmost in any and every direction that is open to him. The motive which controls the philosophical sceptic is his fear of a false step. He is indisposed to stir at all until secure of his footing. The mind when in a scientific attitude is patient even of known error, if only it can be made the basis of a really good working hypo-

[1] According to Bacon, the mind of man is, as it were, a prisoner in a cave with his back to the light, who sees only shadows of the events passing outside.

thesis that will help the inquirer forward, and which may then become susceptible of revision and correction. Numberless instances can be given in which this process has led to valuable results. In fact, most of man's scientific knowledge of Nature is owing to it. But such a method is repugnant to the philosophical sceptic, whose attitude damps all advance unless it can be carried on from the beginning under conditions of perfection—in other words, under conditions which are impossible in the early stages of almost every inquiry.[1]

Accordingly I shall venture to adopt as a postulate in the rest of this essay, the premiss that every event that occurs in the autic universe is caused—since this fertile postulate is eminently fitted to enable us to push forward in our inquiry, since also its truth is already probable, and since the evidence for it will receive great (I had almost said abundant) confirmation as we advance. If, however, anyone prefers, he need go no further than admit

---

[1] This statement may be carried farther. I know of no justification (of the kind demanded by the philosophical sceptic) for my relying on memory as showing that past states of my mind existed. What the sceptic permits himself to believe should accordingly, if he is consistent, go on shrinking till nothing is left but the *present* phase of his own *ego*—if even that remains.

The philosophical sceptic begins by refusing to venture in company with any of his beliefs in reference to which he does not at once see justification for his mind being in the attitude called philosophical certitude. He then attempts to make such petty excursions as he can within the narrow limits thus laid down.

The scientific method of investigating the validity of our beliefs is entirely different. In it our existing beliefs are taken as our starting point, or a careful selection from them is made with a view to our employing only those that involve the least onerous assumptions, *and which at the same time are fitted to enable us to advance.* After the legitimate consequences of these have been worked out, the inquirer finds himself in a better position to return and test the validity of the bases on which he had proceeded. After this revision, and such corrections as he finds possible, he makes a step of a like kind farther forward; after which another revision and another advance. Thus real progress is accomplished. Probabilities acquire strength and accumulate; and in the end a state of mind is attained replete with knowledge of the realities within and around us.

The sea of knowledge on which man makes his brief voyage is for the most part unfathomable. He cannot hope except near shore to measure the *whole* depth, and thus attain philosophical certainty. But the scientific student may diligently use such a sounding line as he possesses—that of probability—and with it explore wide expanses under which there are no rocks or shoals within the utmost depth that he can plumb, and over which he may securely sail.

Compare this with the situation of the philosophical sceptic, groping among rocks along the shore, and not venturing beyond the shallow margin which he can probe with his little pole.

that the same kind of uniformity in the sequence and in the concomitance of events occurs in the autic universe as that with which we are familiar in the world of phenomenal objects. Of this, as a matter of fact, we have clear evidence, since the orderly sequence which we observe to prevail among the varying shadows, that is, in the changes that take place in phenomenal nature, necessarily implies that the real events of the autic universe which cast these shadows succeed one another in accordance with laws as regular as those of nature, and which might be ascertained like them if it were within our power to observe the past. But it is one thing to be familiar with facts, and it is another thing to contemplate them under that aspect *which most justifies us in using the past as our guide in judging what the future will be.* From this point of view **it is really a less assumption** to regard a change that has occurred in the autic universe as having come about because it was caused, than to suppose that it merely arose; and the divergence of the two assumptions becomes greater, if instead of a single event, an orderly sequence of events is contemplated. The subject of causation, however, requires so much fuller treatment than can be given to it here, that I hope to devote a separate essay to it.

We have found that whenever a change takes place in Nature, it is because a change has occurred in the autic universe—in other words, every change in Nature has as its antitheton some event which has happened in the autic universe. So much seems certain; but is the converse true? Is *every* event in the autic universe shadowed? Does every change which takes place in the autic universe involve a change in Nature? To this question we shall find that probably an affirmative answer is to be given. For

1°. The labours of physiologists lead to the conclusion that no thought becomes a part of the mind of any animal without being accompanied by some change in its brain, using the word brain here to mean, not the onto-brain, but the objective brain, which is a part of Nature. These objective changes are motions of some kind. Hence, here are cases in which the autic antitheta of certain motions are thoughts.[1]

---

[1] This relation is often so stated as to imply that the change in the brain is in some way the cause of the thought. This is to mistake the weathercock for the

2°. The labours of the mathematician and physical inquirer have reduced phenomenal nature into the simpler form of diacrinomenal nature, which consists of motions; and the investigations of the student of dynamics seem to justify our believing that *every* change in the motions of Nature has a "physical cause," *i. e.* that it occurs *only* when the conditions of concomitant events required by dynamics are fulfilled; so that if we take under our view the totality of all diacrinomenal objects there is no event occurring without its dynamical cause: Nature is a *complete* concatenation of events.

Now, if Nature be such a complete dynamical concatenation, the autic antitheton to which it is due must be correspondingly complete, the concatenation here being one of actual causation. Hence it appears that the events occurring throughout this antitheton are all of them due to causes *lying within itself*—in other words, it is the *whole* autic universe.[1] This conclusion seems to be entitled to whatever authority attaches to the premiss from which it is derived, viz. that the motions of nature are complete in their dynamical relations to one another, the probability of which is certainly great.

If we distinguish, when considering the autic universe, between the auta themselves and the relations between them which determine whether, in what way, and in what degree, they will act on one another, it is of importance to observe that it is with the changes and relations, not with the auta themselves, that we are primarily concerned; for it is these—the conditions of causation in the autic universe—that are the direct autic antitheta of the motions and space relations of diacrinomenal nature—in other words, it is not what an auto is but what it does that we have to consider.

We have hitherto made no supposition as to what the auta of the sense-compelling universe are. An hypothesis about them may be called a **noümenal** hypothesis (νοέω, to think about an

---

wind. What occurs in the autic universe is the cause of the appearance of change in Nature, not *vice versâ*.

[1] Another way of enunciating this conclusion is that *the sense-compelling universe* is the whole of the Universe.

object which is an object of reflection, not of sense). It is not *essential* to adopt any noümenal hypothesis, so far as the purposes of this essay are concerned, and none such is involved in anything that is said in the preceding pages. But it will give definiteness to our thoughts to have provisionally before our minds a noümenal hypothesis which is probably true; and it is of use to dispel errors which are apt tacitly to creep into our ways of thinking, from the circumstance that we and all men have had instilled into us in our childhood the noümenal hypothesis that material substances and forces exist, and even that they occupy positions in space the same as or close to those which seem to be occupied by human perceptions. All this is embodied, too, in the ordinary forms of speech which everyone has daily to use; and under these circumstances men, for the most part, unhesitatingly believe this crude noümenal hypothesis to be the true theory of that part of the universe which acts on us through our senses. It is manifest that this is a somewhat gross error (see § 9, p. 479); but even careful thinkers are entrapped into mistakes by it in consequence of the forms of speech they are forced to employ.

We have found that in one very remarkable instance[1] the autic antitheta of certain motions in Nature are thoughts—that if a bystander were armed with adequate appliances for ascertaining what is going on in my brain while I am thinking, then what I should experience to be thought is the remote cause with several intermediate causes of a complex effect within his mind which he would call observing motions in my brain.

Perhaps it is better to endeavour to consider the *causal relations* of my thoughts apart from the thoughts themselves, and to describe the process more in detail as follows. My thoughts stand in certain causal relations to one another, to parts of the synergos,

---

[1] Every change in Nature may, from the diacrinomenal standpoint, be described as motion; and that motion of the brain, which is the protheton of human thought, is part of the change which is going on in the brain while we are awake, and which does not go on when we fall asleep.

So also in regard to particular thoughts. So long as "I am looking at the door" some change is taking place in my brain, which is, or a part of which is, the protheton of the perception that I then have. The perception is what really exists; the change in the brain has only an objective existence (§ 12, p. 480); and these two are related to one another as antitheton and protheton. See Diagram III., p. 486.

In this case the antitheta of some motions going on in the brain are thoughts. Are the antitheta of all the other motions thoughts?

and to other parts of the autic universe. These causal relations change while I am thinking; and it is to what these causal relations are, and to changes they are undergoing, that we are to attribute the advent into the bystander's mind of the perception of motion. In other words, that perception is the tekmerion sent to him by my thoughts in virtue of their being themselves links in some of the illimitable chains of causes and effects which make up the universe of real existences.

Turn now to such known facts as that my brain is undergoing wear and tear while I am thinking, and has been replenished by the food I ate yesterday.

This in the common language of mankind is equivalent to the statement that the oxygen I breathed yesterday, and the vegetables and meat that I ate (or parts of them) *are to-day thinking* in the same sense in which it can be said that my brain thinks.

The description which a chemist would give of these events would have an appearance of precision, but would cover but a part of what has happened. He would say—My brain as it existed yesterday consisted of certain chemical atoms variously combined, and going through certain changes of arrangement which are in uninterrupted progress so long as life lasts. Some of these changes are different while I am thinking from what they are when I am not thinking. Part of the change that has taken place since yesterday has consisted in the removal from my brain of many chemical atoms. These have been replaced by other chemical atoms of the same kind, which have been taken in, and which yesterday were in the food I ate, but to-day are in my brain, and are now combined very nearly in the same way as their predecessors in the brain, and possibly in a different way from the way in which they were combined in the food.

The account of the same sequence of events which would be given by the student of diacrinomenal nature would be less precise, but at the same time more nearly complete. It would be somewhat as follows:—The oxygen, meat, and vegetables I consumed yesterday consisted of motions. Some of these motions have been followed in true dynamical sequence by motions now going on in my brain, which motions in my brain are the events in diacrinomenal nature that are directly associated with some of the thoughts at present in my mind.

But the only satisfactory account is that which is couched in the language of the student who tries to describe what it is that has actually occurred in the universe of real existences. He would say—The food I consumed yesterday consisted from the diacrinomenal standpoint of certain motions. These motions had only an objective existence; what were in real existence yesterday were their antitheta. These antitheta were auta and autic events which were part of the universe as it existed yesterday. The auta and autic events of the universe are causes acting upon and effecting changes in one another, and the changes which those particular auta have in consequence undergone since yesterday have made them become to-day thoughts in my mind, have altered them and their causal relations, so that they have now taken the form of being a part of a certain very special little group of auta, viz. my mind as it exists to-day.

When to facts of this kind (of which many of great weight can be brought together) we add considerations pressed upon us by the relations between the mind and its synergos, and by the fluctuations of the boundary between them which are brought prominently to light in cases where we are more or less *imperfectly* conscious of what is going on; and when with these we combine the further fact that thought to exist need not be any part of my thought:[1] we are led to see that the most probable hypothesis *that can be made* is that what we have found to be true in some cases is always true, and that in every case it is **thought** (or rather a change in the causal relation in which thought stands to thought) which is the antitheton of motion; so that the totality of all actual existences, the universe, is in fact identical with the totality of existing thoughts. Of course all this thought, with the exception of the tiny group that is my mind, is as much outside my consciousness, as are the thoughts of my fellow-men and of the lower animals.

Under this view the minds of men and of other animals are specialised specks, as it were, in a vast ocean of thought, to which they bear a like inconspicuous proportion as that borne by the few brain motions of which they are the antitheta, to the totality of

---

[1] As is evidenced by the fact that the thoughts of all my fellow-men and of other animals are in this predicament.

motions throughout Nature. Even of the motions going on in my brain, these special motions are but a small part; from which we may perhaps justly infer that my mind is but a small thing even when compared with the synergos that acts as its coadjutor.

If this noümenal hypothesis is the true theory of autic existence, it will follow that the laws of the universe are the laws of thought. *This is a very different thing from saying that they are the laws of human thought.* The laws of human thought bear to them the same small proportion which the laws of the action of the wheels of a watch upon one another bear to the entire science of dynamics. The science of dynamics could never be evolved from a study of these laws. But perhaps it may not be hopeless for man to attain to some sound knowledge of the laws of cosmic thought, inasmuch as we have some few instances of the way thought acts upon thought open to our investigation in our own minds, and since this is supplemented by our knowledge of the physical laws of nature, which are a shadow, *a probably complete shadow*, of all the laws of causation which operate throughout the universe, throughout the all-embracing mind of the great Autos.

The real *laws of the universe* are those which govern the advance of events throughout the autic universe. And it appears as the issue of our inquiry that *the study of Nature* in ultimate analysis is the study of the changes which that great progress induces within certain very special and very secluded portions of the universe, viz. within the minds of animals, our little groups of auta. Natural Science is thus, as it were, the study of an ever-changing shadow cast in a special and very indirect way by the mighty march of actual events.

This then is the relation in which the knowledge we acquire by the scientific study of Nature stands to the real laws of the universe: and although, in order to give definiteness to our treatment of the subject, I have ventured to use that particular noümenal hypothesis which, as I think, we are entitled to regard as probably the true theory of existence, nevertheless the relationship we have been led to recognise is quite independent of that particular hypothesis, and can easily be stated in terms that do not involve it. To do this it is only necessary to substitute the word auto for thought throughout the last few pages—the name auto being one which avoids involving any hypothesis.

I cannot refrain from adding that, whether we accept the noümenal hypothesis which is presented above or not, the study of our subject has partly lifted the veil from a spectacle of unsurpassed sublimity. If Nature, the mere shadow, is wonderful past all searching out, WHAT MUST THE GREAT ORIGINAL BE!

PART V.—GLOSSARY OF TERMS.

Actual, in existence, autic. [Sometimes in contrast with *potential*, which means, not at present in existence but that can be brought into existence; at other times in contrast with *hypothetical* or *objective*, which see.]

Aition (plural *aitia*). For definition see foot-note, p. 490 (see also Diagram III., p. 486). [The aition of a perception, or group of perceptions, is that part of the sense-compelling universe which is the source of those perceptions.]

Antitheton (plural *antitheta*). For definition see foot-note, p. 490. When we are considering a group of our perceptions which we can build together into a phenomenal object, their *antitheton* means the aition (the source in the sense-compelling universe) which has produced, or can produce, these perceptions in us: their *protheton* means the phenomenal object made by compacting them together, and by attributing to this structure a non-egoistic existence.

[Thus, 1° the antitheton, 2° the perceptions in the mind, and 3° the protheton, are three terms of a series in which the perceptions in the mind stand *between* the other two. Each of these perceptions also has its place *in another series* of a like kind: a perception in my mind, being itself an auto, can act as antitheton if there be any human mind so circumstanced as to be able to receive tekmeria from it; in other words, if an observer is so placed as to be able to perceive what is going on in my brain while that perception is part of my mind. Here the perception in my mind is an antitheton, the perception in the bystander's mind of what is going on in my brain is the intermediate term, and what objectively occurs in my brain is the protheton.]

Auto (plural *auta*, adjective form *autic*), what actually exists, in contradistinction to what only apparently exists (see p. 488).

Cause. In the latter part of the essay, from p. 510 to the end, cause means *efficient cause*. In this meaning of the word, causation can only prevail among auta (see p. 510).

Physical causes are causes conceived of as acting between shadows. They are merely the uniformities of coexistence or of sequence in the events of Nature which can be brought to light by observation combined with the assumption that the future will resemble the past (see § 25, p. 482).

Cerebration, the autic antitheta of the motions or changes of the brain.

[Our thoughts are some of these antitheta, the rest of them may be spoken of as "unconscious cerebration," meaning by unconscious, not falling within *our* consciousness.]

Diacrinomenal nature } Nature and the objects of Nature regarded as
Diacrinomenal object } consisting exclusively of motions (see pp. 508 and 509).

Doulos. For definition see p. 478.

Ego. For definition see p. 476.

Egoistic. For definition see p. 489.

Hypothesis, the act of treating a supposed thing as an existing thing for some useful purpose.

Hypotheton, the thing which is in this way supposed to exist.

I. For definition see p. 476.

Instinct (*instinctive*). [When the materials which come in through the senses are dealt with by the synergos, and appear in the mind with alterations and additions made by the synergos, these alterations and additions are said to be *instinctive*. The most conspicuous of these instincts are our judgments about space relations.]

Legitimate. For definition see foot-note, p. 501.

Mind. For definition see pp. 476 and 489.

Noümenal. For definition see pp. 481 and 515.

Object (*objective*). For definition see § 11, p. 480, and p. 501; and for the contrast in which objective existence stands to autic existence see § 12, p. 480.

Onto, used as a prefix (see Diagram III., p. 486).

Perceptions. For definition see p. 492 (see also under *tekmerion* below).

Phenomenal Nature } , the totality of phenomenal objects.
Phenomenal World }

Phenomenal object. For definition see p. 498.

Phenomenon, the thought in my mind about the phenomenal object (see p. 500).

Physical cause. (*Dynamical cause.*) See above, under *cause.*
Potential. See above under *actual.*

Protheton. See above under *antitheton.* [The relation of a protheton to its antitheton is a perfectly definite one. The *antitheton* is either an auto or an event in the sense-compelling universe, the *protheton* is the object or event in Nature derived from it by the two following steps:—1°, the synthesis of the first order which transforms the sensations produced by the antitheton and other materials into perceptions; 2°, the further synthesis of the second order which combines the perceptions into a phenomenal object.]

Real (*reality*). This important word has two meanings depending on the subject-matter to which it is applied.

Real, applied to existence, means actual or autic, in contradistinction to either objective or apparent.

Real applied to objects or events in Nature means *based in one particular way* on what is actually going on in the sense-compelling universe, viz. by standing to some actual auto operation or event of the universe in the definite relation of a protheton to its antitheton (see above under *protheton*). In this sense of the word real, it is opposed to either imaginary or illusory.

Sense-compelling. For definition see p. 489. [If the monistic theory of existence (p. 518) is correct, it is probable that *all* auta are sense-compelling auta.]

Shadow. The perceptions produced in my mind by an auto or autic event of the sense-compelling universe, may be spoken of as shadows cast by it. But the *phenomenal object* formed by combining *all* the perceptions to which it could possibly, under every variety of circumstances either now or at other times, give rise in my mind, is a much more complete shadow: and the *diacrinomenal object* (p. 509) is a further improvement on this. [In this sense of the word, the auto or autic event and its shadow are an antitheton and its protheton, and stand in a perfectly definite relation to one another (see above under *protheton, see* also foot-note 2, p. 510).]

Skio (from σκιά, a shadow, also a phantom), used as a prefix (see Diagram III., p. 486). [The phenomenal object is at some times partly the actual shadow which is at that time being cast by the originating auto, and partly a phantom; at other times it is wholly a phantom. So far as it consists of my perceptions at any particular time, it is an actually existing shadow; so far as it consists of perceptions that are only potential, it is a phantom shadow.]

Space, a syntheton of all space relations, both *real* and conceivable. [It is plain that only a portion of the materials which go to form this syntheton have an ascertainable basis in what actually exists.] See above under *real.*

Synergos. For definition see p. 478, and foot-note, p. 492. [The synergos is the whole of the onto-brain while we sleep without dreaming. The synergos and the thoughts that are our mind are the whole onto-brain at other times.]

Synopsis, the act of conceiving a collected view of materials which cannot be actually viewed except in succession.

Synopton, the structure which by synopsis we conceive.

Synthesis, the act of bringing materials together and forming a structure out of them or by their help. (See p. 497.)

Syntheton (plural *syntheta*), the structure resulting from synthesis. [The syntheta treated of in the essay are either *perceptions,* which are syntheta of the first order formed by working up sensations in the way described on pp. 493 and 494, or *natural objects*, which are syntheta of the second order formed by compacting certain groups of actual and possible perceptions together, and attributing (by a most useful act of hypothesis) a non-egoistic existence to the structures so formed.]

Tekmerion (plural *tekmeria*). For definition see pp. 479 and 490. [In *modern human* minds the tekmerion is a *perception* (see p. 491, also Diagram I., p. 484.) The term *perception* does well enough when we need only to consider it in its relation to the phenomenal object made up of it and other perceptions, but the term *tekmerion* is to be preferred whenever we want to bring into prominence the relation in which it stands to its *cause.*]

Thought. For definition see p. 489.

Totality. For definition see p. 489.

Universe. For definition see p. 489. [For the definition of *sense-compelling universe* see lower down on the same page.]

POSTSCRIPT.

The further inquiry in regard to causation which is suggested on p. 514 should,[1] if sufficiently complete, involve an examination of time relations with a view to ascertaining, if possible, what they actually are. One episode in this inquiry has been attempted by the Author in a paper on "Curious consequences of a well-known Dynamical Theorem," published in these *Proceedings* (vol. v., p. 448), and reprinted in the *Philosophical Magazine* for June, 1887, p. 544.

A study of memory bears directly on this inquiry, and a great step will be gained if it ever becomes possible to ascertain the protheta of human memory—the changes of the brain which accompany the revival of thoughts recollected, and how these differ from the protheton of the original thought, as also the condition of the brain during the interval between the original

---

[1] Since simultaneity is one of the *conditions of causation.*

thought and its revival. It is probably hopeless to find this out directly: but there may be instances in which it would not be impossible to detect that which in *external*[1] nature is the protheton of what may be called cosmic memory, and if this clue can be obtained, other discoveries are likely to be brought by it within man's reach.

[1] That is, exclusive of the brain and similar structures.

ERRATUM IN A PAPER ON "TEXTURE IN MEDIA" BY DR. STONEY.

Page 393 of this volume, last line of foot-note (*c*), *change* 800 *into* 800,000.

LII.

AN IMPROVED METHOD OF USING ANNULAR LENSES FOR LIGHTHOUSE ILLUMINATION. By JOHN R. WIGHAM. (Plates IX. and X.)

[Read April 16, 1890.]

On a previous occasion I brought under the notice of this Society an arrangement which I had just devised for superposing the lenticular apparatus used in lighthouses, so as to obtain a greater light than could be derived from the apparatus in its original form. Since then, that arrangement has been adopted both in England and Ireland in several important lighthouses, and has given great satisfaction to shipowners and seamen.

I have now to describe a still further improvement in lighthouse illumination, involving a still greater departure from the old system. That this description may be intelligible, I must briefly recapitulate and explain the steps which have led up to this improvement. I have here a complete segment of the lenticular apparatus used in lighthouses of the first order, such as Howth Baily. It will be seen, when I light one of my lighthouse gas burners in its focus, that the light proceeds from the whole of its surface. The apparatus is divided into three parts, the great central belt from which 75 per cent. of the light is transmitted, and the top prisms and bottom prisms which transmit the remaining 25 per cent.

It was because this central portion of the apparatus is so much more powerful in the transmission of light than the top and bottom prisms combined, that I conceived the idea of discarding these prisms altogether, using instead the central parts only, superposed; say two, three, or four of them, giving respectively 50 per cent., 125 per cent., and 200 per cent. more light than in the old system. This increased light is of course only obtained when the two, three, or four burners are lighted. Contrary to what might be supposed, there is no great increase of annual cost by the use of these extra lights; for during the greater portion of the year the weather is clear, and one burner is then sufficient; showing to the horizon a good well-individualized light. In such weather the sailor needs nothing more; it is only when the weather thickens that the superposed lights are put into operation, being added one by one or all together according to the density of the mist or fog which may require to be illuminated. While the fog lasts, the extra lights are kept burning; but the moment the fog passes away they are extinguished, and then of course the cost of maintaining them ceases. This system I named biform, triform, and quadriform, according to the number of lights superposed. It has hitherto been employed solely for revolving lights with annular lenses, and of course without any top or bottom prisms. These lenses, because they parallelize the light of the burner vertically as well as horizontally, must of necessity continually revolve, in order that all portions of the sea may receive the powerful beams which they transmit. The complete apparatus at which we were first looking is a fixed light apparatus, the illumination from which is constantly visible from all parts of the horizon, and is therefore much less powerful than the concentrated beam of the revolving light.

It is necessary here to interpose a few words respecting group flashing lights. Groups of flashes are caused by breaking up the beam of the annular lenses by continually extinguishing and re-igniting the gas lights which are in their foci. This is done by the same clock-work which causes the lenses to revolve, and the result is that the sailor sees, instead of a long flash of light recurring at certain intervals, a group of shorter flashes, say about three, four, or five in number, as might be determined upon. It is found that these groups of flashes are better calculated to arrest the attention of the sailor than an unbroken beam, and that their characteristic appearance is also useful in enabling him to identify the lighthouse. Hence it is that this system of group flashing is now employed in the greatest lighthouses of Ireland.

The difficulty of increasing the height of lighthouse lanterns and the tendency of lighthouse engineers to increase the height of lighthouse lenses, seemed to indicate that it was not expedient to go much further in a vertical direction in the multiplication of lights; therefore it occurred to me that the great advantage which had been obtained by placing lenses vertically over each other might also be gained by placing them side by side. This led to an entirely novel arrangement of the lenses: not only their being placed side by side, but formed into a figure having only two great illuminating faces and two dark ends. In another respect also it was novel. Under the old plan the lenses are caused to revolve round a central burner: but in this case it was necessary for the burners as well as the lenses to revolve, so that the precise focal relation between them might be constantly maintained. The use of a lute of water or mercury enabled me to do this, and at the same time to provide a constant flow of gas or oil to the burners or lamps. One of the models on the table shows these arrangements. It also shows that in this new plan there is sufficient space to enable ventilating tubes, gas-pipes, &c., to be so placed as not to obstruct any portion of the light, whereas in the old form of apparatus these tubes present some amount of obstruction to the light in certain bearings.

I tested this form of light practically, first in the workshops of the Company with which I am connected, and subsequently (with the consent of the Commissioners of Irish Lights) in the Experiment House at Howth Baily. The result was precisely what I had anticipated, namely, the illuminating power of the beam was exactly double that of the quadriform. I asked Sir Howard Grubb, whose practical acquaintance with optical science confers such great value upon his opinion, to examine it critically. He kindly acceded to my request; and the sum total of his report was a distinct corroboration of the opinion that it possesses double the power of an ordinary quadriform light. Professor Barrett also favoured me by making repeated observations respecting this double quadriform light. The weather was particularly favourable for his observations, the result of which he conveyed to this Society in the form of an interesting Paper read at one of its scientific meetings, and since printed (*Proceedings*, Vol. v., p. 74). He mentioned specially a most important fact, viz. that while he was looking at the light a fog came on, and yet he was able to see it though six miles distant, while at the same time the full fog power of the Baily lighthouse was invisible. Sir Robert Ball, the Astronomer Royal, also gave me his testimony to the beauty and the splendour of the light when he accompanied the late Earl of Meath and other members of the Irish Lights Board, and looked at it from Salthill.

In parenthesis, I may here say it was this light, thus tested practically and commended by the high authorities I have named, that the Trinity House refused to try at the South Foreland experiments, which experiments were instituted by the Board of Trade for the express purpose of testing all lighthouse lights.

In the year 1885 a question arose as to whether it would be advisable to adopt this double quadriform light at Tory Island lighthouse, then being reconstructed; but Sir Robert Ball, who is scientific adviser to the Commissioners of Irish Lights, pointed out that the light having but two faces would not be suitable for that lighthouse, which it was intended should be a group-flashing light having a considerable number of flashes. I will presently explain this point; but, meanwhile, perhaps you will allow me briefly to refer to what *was* done at Tory Island.

In the year 1872, in this Lecture Theatre, and in subsequent papers read to the British Association and the Institute of Civil Engineers, and on other occasions, I strongly urged that in order to take advantage of the full light to be derived from the large gas-burners then introduced, large long-focus lenses should be constructed specially to suit them, and thus prevent the waste of the light caused by its having to be transmitted by the small lenses designed by Fresnel for the lamps of much less diameter used in his time; and that till this was done the full benefit of the gas system would not be obtained. It was not until the year 1885, through the influence of Messrs. Stevenson, the eminent engineers of the Scottish Lighthouse Board, that the use of one of these lenses, as an experiment, was at last sanctioned by the Board of Trade. It gratified me exceedingly to learn that the trial of that lens had resulted satisfactorily, as I had so long before and so *frequently* predicted. I pressed the Commissioners of Irish Lights to adopt these lenses at Tory Island, certain of the additional illumination they would give (as, indeed, the result has amply proved), and feeling confident that the further step of doubling the great light from these lenses, by the adoption of the double quadriform arrangement, would follow when sufficient attention had been given to the subject.

To return to the construction of the double quadriform as originally devised, and explain Sir Robert Ball's remark as to group-flashing:—Plate IX., elevation and plan A, shows, as I have already said, that the light is emitted from the two sides, and not from the two ends of the apparatus. This diagram, and these other two, represent the ground plan of the apparatus. They are so made that I can revolve them exactly as they would revolve if in actual use. The arrows represent the rays of light forming the beam emitted from each side of the apparatus. I will bring the face which is now illuminating the ship marked on the black-board right round to the opposite side, when the ship will receive the light from the opposite face, and the whole horizon will have been visited by the light, by the complete revolution of the apparatus. In order that the light from one face should be replaced by the light from the other face without too great delay, say within a period not longer than one minute (the longest interval of darkness now allowed in lighthouses), it is necessary to rotate the apparatus rapidly. But this rapid rotation reduces the duration of each flash; that is to say, the light from each face passes the mariner's eye very quickly, say in about seven and a-half seconds. This length of flash is quite long enough to enable him to have a good look at the light and take his bearings from it; but it is hardly long enough to permit of the beam being broken up into the minor beams or groups of flashes which I have described—such as are used in the great lighthouses of Galley Head and Mew Island. In other words, this two-sided apparatus, while it forms the most powerful revolving light ever seen, is not suitable for cases where such group-flashes are required.

And now I come to the last and most important development of the system of lighting which I have the honour of introducing to your notice. Last autumn I had a visit from Professor Sir George Gabriel Stokes, Bart., M.P., President of the Royal Society. He said he had been told by my brother what the double quadriform light meant, and asked to have it fully explained to him. This was done by means of a model which happened to be at hand. After some consideration Sir George said that his conception of the double quadriform light had been somewhat different; and he sketched out with a pencil what had been his idea. On the occasion of a subsequent visit I was able to show him an arrangement which I had worked out from his idea: Plate IX., elevation and plan B, explains it. It will be seen that this form of double-revolving light is perfectly applicable to group-flashing lights; for, by the arrangement which Sir George suggested, the apparatus, instead of being two-sided, is made four-sided; and thus its speed of rotation is reduced by one-half, and the duration of its flash increased in the same proportion. Instead of the lenses being placed side by side in the same plane as in A, Plate IX., they are placed in the position shown in B, Plate IX. This model will further assist in explaining this form of light. By the diagram shown, the light proceeding from lens I. unites with that of lens III., that from II. with that from IV., that from V. with that from VII., and that from VI. with that from VIII., making, as I have just said, a four-sided optical apparatus. This apparatus will not only convey to the mariner a light of double the power possessed by any other lighthouse light, but linger in his eye for a period sufficiently long to admit of its being broken up into minor flashes if required. Besides this, we have in the arrangement a light having a distinctive character of its own; for as the apparatus rotates, it will transmit to the observer two brilliant flashes, succeeding each other at intervals of say half a minute, followed by a period of darkness of say one minute, to be again followed by two brilliant flashes half a minute apart, as before, and so on continuously. It will be perceived that in this arrangement four lenses out of every tier are dispensed with; therefore the first cost of the apparatus is but small in comparison with the enormous amount of light given to the sailor, and it is this suppression of lenses that causes the characteristic appearance of the light, namely, two flashes followed by a given period of darkness. This peculiar arrangement lends itself most admirably to the cases in which it might be thought desirable to use colour as the distinguishing lighthouse characteristic. Under the old system, when red glass is employed, it is necessary to reduce the power of the annular lens through which the white light is shown to one-half its normal power in order to equalise the red and white beam, so that they may always be seen of equal intensity, and thus the actual power of the lighthouse is reduced by one-half. Under this new system there need be no curtailment of the annular lens, but its full power would be utilised, and a brilliant white flash of the full power of the lens, followed by two red flashes each of equal intensity to the white flash, would be the characteristic appearance of the light, and as a further distinctive mark, these flashes, both red and white, might, if required, be broken up into groups. The double barbed arrows in B, Plate IX., show the white beams, and the single barbed arrows, the red beams. In this case the apparatus is six-sided.

As in former cases I tried this hexagonal light *practically* with great care. With the consent of the Commissioners of Irish Lights, I have within the last few weeks placed it at the Howth Baily Experiment House, and critically watched its performance from Salthill, with the result exactly as I have mentioned.

Important as are the features of the light which I have been describing, by far the most important plan which the admirable idea of Sir George Stokes suggested is that of which I *now* come to speak of. In it there is no blank face, all the light is utilised and transmitted evenly to the horizon. It is shown in Plate X. The lenses are placed so as to form squares, not hexagonal figures, as in the previous instance. All the faces of the squares transmit beams of light of equal intensity, following each other at intervals determined by the rate of rotation which may be given to the apparatus, say of 20, 30, 40, 50, or 60 secs., and the light of 1 blending with that of 3, 2 with 4, 5 with 7, and 6 with 8, produce a regular succession of beams with an illuminating power never before attempted in lighthouse practice.

This model will show the details of this particular light which differs from the others in the grouping of its lenses and in having a greater breadth and duration of beam. It must be borne in mind that this light, as also the others which have been under our consideration this evening, may be used as biform, triform, or quadriform, *i. e.* that 4, 6, or 8 burners may be employed conjointly to pour their light through their respective lenses upon the sea, and that it is only necessary to use one burner for ordinary weather, the other 3, 5, or 7 being available at a moment's notice on the occurrence of fog; and although during the continuation of the fog the expense is of course considerable, yet I think it is obvious that during the dangers which fogs involve *no reasonable expense should be considered too great to protect life and property;* and as fortunately the aggregate duration of fog during the year is but very small, the *annual* expense of this great light is not much greater than an ordinary lighthouse light.

The extreme angles of apparatus C, if in actual operation, would be cut off, as shown by the diagram, in order to give room in the lighthouse lantern. The light would be but little diminished by this alteration, for the extreme edges of such large lenses are but feeble in their refracting effect. Indeed, it is this fact which is one of the chief recommendations of the double system. A more powerful beam can be transmitted through two lenses placed side by side than by one lens equal in area, with one central burner, even if it were possible and convenient to double the size of the burner.

My description of the mechanical part of this subject is finished. A very few words on its moral aspect may be allowed. Improvements for lighthouses likely to save life and property may be devised, carefully thought out, and tried practically by practical men, may be approved by eminent men of science, and endorsed by scientific societies such as this; but if the Board of Trade will not even look at them, humanity is none the better. You will ask—What about the shipowners? Are they content that an improvement should be despised and neglected which would save from destruction their ships and the valuable property they contain? What about the sailor? Is it to him a trifle not worth considering, that the lights which guide him in his dark and perilous voyages might be *doubled in illuminating power?* Is not his interest still deeper than that of the shipowners? Is not his very life concerned? Shipowners have indeed spoken out. They have again and again memorialised the Board of Trade, urging that the question should at least be *investigated.* They have even addressed the Prime Minister to that effect. There has been no response. If this wealthy and influential class is thus treated with contempt, what can the poor sailor expect? Who will speak for *him?* He has one friend—the public—whom he serves so well in the discharge of his hazardous calling. Surely the voice of public opinion will demand that justice shall be done to him, and denounce the inaction of the officials who rule the Board of Trade, whether their refusal to give the new system even a *trial* arises merely from the *vis inertiæ* natural to the official mind (which hates any departure from routine), or from any other cause. Let it be clearly understood: the shipowners have not demanded that the system shall be adopted; all that has been asked is that it be tested by experiment. Surely a reasonable request.

LIII.

ON A METHOD OF DETERMINING THE ABSOLUTE DENSITY OF A GAS. By J. JOLY, B.E., M.A. (Plate XI.)

[Read June 18, 1890.]

The method still in general use for the accurate determination of the density of a gas is that of Regnault, improved from the conception of Biot and Arago, by the addition principally of the counterpoising vessel. This method is not free from objections.

The gas is weighed in the vessel in which its volume is measured, and as this is necessarily a large vessel, of considerable weight, the weight of the gas bears but a very small proportion to the total weight observed. Again, from the great bulk and surface of the containing vessel, it is in itself a difficult object to weigh with a high degree of accuracy, more especially when exposed, as it is, between the first and the second weighings, to the manipulation incident in filling it at a known temperature.

Further, in the determination of the volume of this vessel there arises, as Lord Rayleigh has lately shown[1], an error due to the variation of pressure within the vessel when it is weighed, vacuous in the first instance, full in the second. This error, which escaped Regnault, is very considerable in this method.

If, again, there is an object in economising the gas, Regnault's method is wasteful, as the "washing out" of so large a vessel with the gas necessitates a far greater expenditure of gas than is subsequently required for the actual determination. Without referring again to these objections to the method of Regnault, it will be seen that they are either much reduced in importance or eliminated in the method to be described.

In this new method the measurements of the volume and of the weight of the gas are effected in separate vessels. That in

---

[1] *Proc. Roy. Soc.*, vol. 43, p. 356.

which the gas is weighed is small, the gas being under high pressure within it. That in which the volume is subsequently measured may, on the other hand, be as large as may be desired. We are not concerned with its weight.

The vessel which I have in use for holding the gas, when being weighed is of copper, spherical in form, about 6·7 cms. in diameter, made up of two hemispheres, the walls being about 1mm. in thickness. The hemispheres are brazed (not soft-soldered) together within a belt of copper about 4½ mm. wide, and 1 mm. in thickness. The vessel must be quite staunch. Its internal volume is just 160 c.cs. It is closed by a small screw valve, having a side tubulure for attachment to the various apparatus. The valve spindle of steel works through a small stuffing-box to prevent the escape of gas along the shaft of the spindle when the vessel is being filled or emptied.

This vessel is tested hydraulically to 1000 lbs. in the square inch. It may be safely filled to pressures of 20 or 25 atmospheres. I am daily using such vessels in the steam calorimeter in determining the specific heats of gases; here they are raised to the temperature of 100°C. bringing the pressure to near 30 atmospheres in many cases. For the purpose of compressing the gas into this vessel I use a pump of special construction, a description of which I hope shortly to publish. But, obviously, any compression pump which will deliver the gas without contamination of oil or moisture will answer.

A counterpoising sphere of the same bulk and weight approximately is required. Against this, after the required quantity of gas has been inserted in the weighing sphere, the latter is equilibrated. This operation is readily performed in an ordinary chemical balance to an accuracy of one-tenth or one-twentieth of a milligram. The weight of a copper vessel of the strength described will be from 80 to 90 grammes. It will be seen later that one sufficiently strong to hold 2 litres safely need not exceed some 40 grammes in weight.

The vessel in which the volume is determined is next to be considered. It is lettered *g*, in Plate XI., where it is shown connected with the weighing-sphere, the latter screwed to the steel connexion *b*, provided for it, and through the fine bore (1 mm.) of which it delivers its contents into *g*. The volumenometer is of glass, cylindrical, closed at each end by ground stoppers, with tubulures attached. The upper tubulure is of fine bore, hardly 1 mm., the lower tubulure of some 3 or 4 mms. bore. The volumenometer is surrounded by a copper jacket, having two large openings cut in its cover for the admission of broken ice or water, and also a tubulure for admitting a thermometer. A fine mark is etched on the lower tubulure at *f*, and this tubulure is continued by attachment to a smaller vessel *c*, as shown. This again is connected by a rubber tube connexion with the vessel *d*, which can be raised or lowered, as will be understood from the plate. The volume of the volumenometer is best determined with water. If water is subsequently to be used in it the procedure is as follows :—

The coupling *b* is removed and the vessel *g* inverted in the copper jacket. The wide tubulure is now uppermost, the narrow one below. This is attached to *d*, and the upper one to an air pump, and distilled air-free water drawn into *g*, through the lower tubulure till it is quite full. The vessel *d* is now raised, the connexion with the air pump removed, and when *d* is so high that water is just swelling out of the tubulure this is closed with a short pinched rubber tube.

Broken ice is now filled in round the volumenometer and after the lapse of some hours the connection below with *d* is broken and the fine tubulure closed with a little piece of wax. The upper tubulure is now opened, and the level in the tubulure lowered by applying bibulous paper till it sinks to the mark etched upon the glass. It is then closed with rubber tubing as before. The ice being next removed, *g* is lifted out, dried carefully, and weighed. This done it is replaced in the copper cylinder, this time in its normal position, and the water let run out. The ice is now returned to the jacket, and after the lapse of some time the volumenometer is closed as before, when the height H of the barometer is read. Another weighing is now made, and by difference the weight of water at 0°C. which has quitted the vessel is calculated, allowing for the weight of saturated air at 0°C. and H contained in the vessel at the second weighing. One or more such operations may be performed, and from the known density of water at 0°C. the volume at the temperature 0°C. calculated. To this must be added, for the complete volume, the volume at ordinary temperatures of the small steel connection with the sphere. It is obvious that the error arising from the inconstant temperature of this fine tube or of the short tubulure exposed at *f* need not be attended to.

If mercury is subsequently to be employed in the volumenometer the volume should be determined on a slightly different procedure. Water should still be used, however—not mercury, or a distending effect, due to the great weight of the latter, might give rise to error—but the weight of the vessel, when containing air, should be *first* ascertained when the walls within are dry. In this way the capacity of the *dry* volumenometer is obtained, which is that required with the use of mercury. It is evident that the use of mercury is on this account much preferable to water in subsequent work, as the volume of residual water in the vessel from one experiment to another will not be accurately constant. Again, no hygrometric correction on the pressure of the gas contained in the volumenometer will be requisite.

The volume of this vessel (which is but an enlarged sprengel tube) being ascertained once for all at the temperature 0°C., it follows that it will afford a ready means of dealing with a gas contained in the weighing sphere. It is filled with mercury or water, and surrounded by ice. The vessel *d* is then raised till the liquid in the volumenometer has risen to the top of the fine steel tubulure *b*, the weighing sphere removed from the balance, screwed on to *b*, and the vessel *d* lowered. The valve at *a* is next screwed back a little till the mercury is seen to rise in *d*. The right-hand stopcock on *d* is now opened, and the mercury let flow into a tall graduated or marked vessel, so that it may be known about when the operation of filling *g* is approaching completion. Presently, the surface level of the mercury sinks into the vessel *c*. This possesses such capacity as to give time to close the valve of the sphere before any gas is lost; *d* is now raised slowly, till the overflow gas in *c* is compressed back into the volumenometer. All must now be let stand till t_o° is attained (half-an-hour will suffice), and the final adjustment of the mercury level to the mark *f* then effected. By means of a cathetometer the height *h*, the difference of level between the surfaces at *d* and *f*, is read. This will only be some 5 or 6 mms. in general. For this a temperature correction is hardly required; but a capillary correction, ascertained experimentally once for all, must be applied owing to the different areas of the surfaces in the two tubes. This might be eliminated in the construction by conferring an equally small area on d, but it is probably more convenient to make the simple correction required. The barometer is now read, and the pressure of the gas in g computed. Its temperature is 0°C., and its volume that of the vessel = V. The sphere is now returned to the balance, re-weighed, and the weight of gas, subject to a small correction, found by difference.

The correction mentioned is due to the shrinkage of the copper sphere on the relief of pressure, and corresponds to that occurring in the case of Regnault's glass vessel. Experiments (two, closely agreeing, have been made on this sphere) reveal a shrinkage which may be taken as 0·1732 c.cs. on the removal of 4·3525 grammes of air at the temperature 12°C., a fall of pressure of 22·01 atmospheres, closely. At 760 mms. this weight of air occupies about 3·367 litres. This would be a needlessly large volume to confer on the volumenometer, except for very special work. Even in the case of hydrogen (1 litre at 760 and 0°C., weighing 0·0895 grams.) two litres will suffice for a very accurate estimation of the weight of gas dealt with. At the pressure corresponding to the compression of two litres into the sphere of 160 c.cs. capacity, a much lighter weighing sphere than that previously described will suffice. Thus I use one weighing but 41 grammes, which has been tested up to 500 lbs. in the square inch. The thickness of its walls is somewhat less than half a millimetre, its volumes a little greater than 160 c.cs. There is no difficulty in weighing such a vessel to the one-twentieth of a m.gram., or closer. Using the heavier vessel the correction for shrinkage will be the shrinkage due to two litres, *i. e.* 0·1029 c.cs. multiplied into the normal density of air. This gives a displacement effect of 0·000127. This correction is on a weight of 2·5878 grams. of air or the correction on w, which is subtractive, is for air one part in 25,000 g.p. In the case of hydrogen one part in 1790. Assuming the use of the lighter sphere the experimentally determined shrinkage is 0·26359 c.cs. for a lowering of pressure of 12·82 atmospheres, a little more than the pressure due to two litres. The shrinkage is, in fact, closely 0·257 c.cs., and the correction on the weight of gas released is 0·000318. This is higher than with the heavier sphere, but the correction is perfectly definite [and easily ascertained once for all by successive weighings, before and after emptying, in distilled water][1]; and on the other hand the use of the lighter vessel will probably confer still greater accuracy on the weighings.

Turning our attention to the volumenometer it appears possible that a similar correction may arise in the assumption made as to its capacity. For, in the experiments in which its volume is determined, its walls are exposed to the pressure due to the weight of the water contained in it; subsequently, when it is occupied by a gas, this pressure does not obtain. Hence there might be reason to fear some small excess in the value ascribed to its capacity. To make this a matter of experiment, I filled the jacket with water, and provided a wide tube dipping into it, syphon-wise, enabling the water to be all run off within a short space of time. The volumenometer within was filled with air, the upper tubulure was closed, the lower one being arranged to dip into a vessel of water, the water standing some little height in the tube, nearly to the etched mark. Thick baize was now folded round and over the jacket, and after the lapse of some time the cross wire of a cathetometer was brought to read the level of the water in the lower tubulure. A few minutes' observation sufficed to show when this level was stationary. The syphon was now put into operation; and while the water was running out of the jacket the level of the liquid on the tubulure was observed. No movement was perceivable. It is thus, I think, legitimate to conclude that no appreciable error arises from this source, the experiment being a delicate one.

Comparing the previous figures with those obtained in the exact experiments of Lord Rayleigh, using Regnault's method, which experiments may fairly be taken as representative of modern refinement on the method, the following numbers are obtained, assuming the same weight of hydrogen to be dealt with in the present method as was used by Lord Rayleigh, and the lighter sphere to be used.

---

[1] Two experiments on the heavier sphere afforded: (1) a shrinkage of 0·1013 c.cs. for the release of 2·5728 grammes of air at 15°·4; (2) a shrinkage of 0·1732 c.cs. for 4·3525 grammes of air at 12°C.

Two experiments on the lighter sphere gave: (1) 0·1720 c.cs. shrinkage for the release of 1·6046 grammes of air at 16°; and (2) a shrinkage of 0·2636 c.cs. for 2·5284 grammes of air at 14°·3.

Volume of vessel in which the gas is weighed:—

For Regnault's method 1800 c.cs.
,, new ,, 160 ,,

Weight of vessel in which the gas is weighed:—

For Regnault's method 200 grams.
,, new ,, 41 ,,

Error of buoyancy on the weight of gas:—

For Regnault's method 1 in 280.
,, new ,, 1 in 560.

Ratio of weight of gas to weight of vessel in which it is weighed:—

For Regnault's method 1 to 1261.
,, new ,, 1 to 258.

Regarding the last numbers I may observe that the case assumed is unfavourable to the new method. The compression of 1800 c.cs. (at 760 mms.) in the sphere raises the pressure to 12·5 atmospheres, but it may safely be filled to 17, or, it will carry some 36 per cent. more gas than is assumed above.

The volumenometer which I am about to take into use in estimating the density of the samples of gas used in my experiments on the specific heats of gases has only lately been constructed. A first and hasty experiment on the density of dry air may, however, indicate the magnitudes dealt with, and the accuracy obtainable when restricted to the use of water in the volumenometer. The interior volume of the volumenometer determined by weighing it filled with water at 15°·67, and again filled with air, but wet on the walls, was found to be 1751·0 c.cs. This is with great probability correct to unity, the first place of decimals being perhaps open to small error.

The data in the experiment on air density are as follows: Weight of air inserted = 2·1092 less 0·0001 for error of buoyancy = 2.1091. Temp. of water jacket = 15°·70. Bar. 7760·32 reduced to 0°C. Head of water 0·388 inches (= h) + 0·120 inches correction for capillarity (by subsequent experiment). Total press. 76·032 + 0·70 mms. = 761·05. Max. vapour tension of water at 15·7 = 13·3 mms.; hence the pressure, finally, is 747·75 mms. The volume for the experiment may be taken as 1751 c.cs., neglecting the temperature effect of 0°·03.

From these data the density of dry air at 747·75 mms., and at the temperature 15·70, is found to be 0·0012046. The last figure is doubtful, as being beyond the limit of accuracy with which the volume is known.

If, for confirmation of this result, reference is made to accepted results from the *Tabellen* of Sandholt and Börnstein, the density of dry air under the same conditions of pressure and temperature is deduced as 0·0012039. From Biedermann's *Chemiker-Kalender* (1888) is deduced the number 0·0012052. The mean of these two closely agrees with the experimental result, absolutely indeed to the fourth significant figure, the last reliable one in the determination.

In conclusion, I may point out that this method leaves the gas finally in a vessel, which, by the addition of a small side way to the connection *b*, may be made a most convenient one for the subsequent transference of the gas into any apparatus for its analysis.

The present method may, as in the case of Regnault's, be by obvious procedures applied to the determination of the variation of the density with change of temperature, or change of pressure. And its application to the determination of vapour densities suggests itself. In this case the temperature of the volumenometer would, perhaps, best be adjusted by the use of a vapour in the jacket, and an arrangement for controlling its pressure.

LIV.

ON AN APPARATUS APPLICABLE FOR GAS ANALYSIS AND OTHER PURPOSES. By W. E. ADENEY, F. I. C. Assoc. R. C. Sc. I., Curator and Examiner in Chemistry in the Royal University, Dublin. (Plate XII.)

[Read June 18, 1890.]

The apparatus which forms the subject of this paper was originally designed to serve the double purpose of collecting and determining the gases incident to water analysis. In practice, however, it has been found applicable for a number of other purposes, including gas analysis by absorption and combustion, the analysis of carbonates, of nitrates, and of organic matter by the permanganate method; it may also be employed as an air-pump and for distillation in vacuo or under reduced pressure.

The form of the apparatus is shown in the Plate XII. It consists of a gas burette A enclosed in a glass cylinder B, 75 mms. in diameter, a barometer tube C, which may also be employed as an open pressure tube, and a laboratory vessel D. The whole apparatus is supported on a wooden stand.

The lower portion of the burette is contracted and passed through a hole cut in the centre of the indiarubber bung E, which closes the lower end of the glass cylinder. It is then bent at right angles and joined to the pressure tube at *a* by a piece of india-rubber tubing, lined with canvas, and firmly wired to the tubes; the joint is protected from the air in the ordinary way by fitting round it a piece of wide glass tubing and filling the annular space formed with glycerine.

The way in which the glass cylinder, burette, and pressure tube are supported and held in upright positions will be understood from the drawing; it need only be mentioned that the wooden block which carries the cylinder, or rather on which the bung E rests, is cut away at the centre and side to allow the cylinder and burette to be placed in position, and that the upper portion of the burette is held in its place by the brass plate *b*, one end of which is bent at right angles and screwed to the stand, and the other end is bent and cut to fit and clamp the upper part of the stopcock as indicated in the drawing. By this means the burette is clamped firmly, but sufficient play is afforded for contraction or expansion of the glass by alteration of temperature.

The supply of mercury to the burette and pressure tube is regulated by means of a reservoir which can be raised or lowered by a pulley and small windlass *c*, fixed to the back of the stand. The flexible tube from the reservoir passes through a hole in the back of the stand at *d*, and is attached to the pressure tube by means of the small side tube *e*. The necessity of attaching the connecting tube from the reservoir to the pressure tube, and not directly to the burette, will be explained later on.

The height of mercury in the pressure tube is read off by means of a millimetre scale etched on the unsilvered surface of the narrow slip of looking-glass *ff*, which is fixed close to the back of the pressure tube and inclined to the vertical plane, as shown in the drawing, so as to reflect the image of the tube from the portion of the glass bearing the scale. To read the height of the mercury in the tube the eye is held a little to the right of the scale, and moved about a little until the scale lines in the immediate vicinity of the reflected image of the mercury meniscus coincide with their images reflected from the silvered surface of the glass. When the eye is in this position the height of the mercury can be accurately read to 0·5 mm. and with aid of a lens to about 0·25 mm.

The burette and pressure tube are each provided with a Friedrich's patent glass stopcock of the pattern shown in the drawing. Two branch tubes, *g*, *h*, spring from the stopcock of the burette; the former is a capillary tube and serves to connect the burette with the laboratory vessel and other purposes, while the latter is of wider bore (2 to 3 mms.) and is intended to connect the vessel containing the substance to be examined with the burette. The two tubes are firmly held against the wooden block *k*, which is grooved to receive them, by a brass plate lined with cork and screwed to the said block. It is necessary to support the two tubes thus to obviate the danger of their being broken off from their junction with the stopcock by a sudden blow or undue pressure. When firmly held in the manner described, the tubes will bear even considerable pressure without any danger of being broken, and, as will be explained afterwards, when the laboratory vessel is fixed in position for working, a decided pressure is exerted against the tube *g*.

The contracted portion of the burette immediately below the stopcock is about 225 mms. long, and has a capacity of 15 c.c.; the wider portion is about 410 mms. long, with a capacity of about 250 c.c. Both portions are graduated, the former at intervals of 1 c.c., and the latter at intervals of 25 c.c.

The pressure tube is 1000 mms. long; and since it can be employed both as an open and closed tube, a volume of a gas may be measured under a pressure equal to 1500 mms. of mercury, or, on the other hand, under as low a pressure as 1 mm. Thus the apparatus is more sensitive than Thomas' (*Chem. Soc. Journ.*, 35, 217).

The laboratory vessel differs in principle and shape from the one employed in Frankland's or Macleod's apparatus. The cylindrical portion *n* is 25 mms. internal diameter, and 55 mms. long, and is furnished with the side tube *o* for connecting the vessel with an independent mercury reservoir: the portion *p* is 45 mms. in diameter and 100 or 190 mms. long, according to the character of the analysis to be made; this portion of the vessel, which is shown in the drawing, has a length of 100 mms., the most useful size for water analysis. The upper part *q*, which has an inverted conical shape, is 55 mms. long, the diameter decreasing from 20 mms. at the mouth to 4 mms. at its narrowest part. Two platinum wires are sealed into the vessel in the positions shown in the drawing.

The particular shape given to the portion *q* allows the laboratory vessel to be easily connected or disconnected with the tube *g*. When the laboratory vessel is placed in position, as represented in the drawing, the tube *g*, the end of which is fitted in an indiarubber collar, tightly closes the narrow part of *q*, while the lower shoulder of the vessel rests upon the shelf F, which, in plan, has somewhat the shape of an inverted U. If the space above the collar be filled with water or mercury, a perfectly air-tight joint is obtained. The joint, in fact, may be made so staunch that, when the vessel is arranged in the manner described below, a torricellian vacuum may be maintained in it. When it is desired to disconnect the laboratory vessel, its lower portion is drawn forward sufficiently to clear the shelf, and is then lowered to detach it from the tube *g*. By reversing these movements the laboratory vessel may be again attached to the apparatus. The shape of the indiarubber collar is of importance; its lower end must be rounded off. It may be conveniently made in the laboratory, from the core obtained by cutting a hole in an ordinary cork, by means of a cork-borer of suitable diameter; one end of the core will generally be found sufficiently rounded to suit the required purpose.

For some problems in gas analysis the laboratory vessel may be employed in the ordinary way. The lower and open end is immersed in a mercury trough, and may be filled from the trough in the following manner. The stopcock is opened to the tube *h*, and the reservoir raised until the burette is full of mercury; the stopcock is then turned to open to the tube *g*, and consequently to the laboratory vessel. The reservoir is now lowered slowly, and as the level of the mercury in the burette sinks, it rises in the laboratory vessel. The reservoir is lowered until the laboratory vessel is full. The air that is drawn into the burette during the operation is driven out into the atmosphere by opening the cock to the tube *h*, and again raising the reservoir. When the burette is full of mercury, the glass cylinder filled with water, and the pressure tube in proper order, the apparatus may be used in a similar manner to that of Frankland or Macleod.

Since the apparatus, however, can be employed as an air-pump similar in principle to Friedrichs' new pump, as well as for measuring and analysing gases, its applicability to a great variety of purposes becomes possible, if the laboratory vessel be furnished with the means of filling it with mercury, as well as of adjusting the level of mercury in it, independently of the burette. This may easily be effected by closing the lower end of the vessel with an indiarubber cork, and connecting it by means of the side tube *o* to an independent adjustable reservoir which is raised and lowered by means of a pulley and windlass *m* fixed to the back of the stand, just as in the case of the reservoir furnished for the burette and pressure tube.

To provide the means for introducing re-agents into the laboratory vessel, when it is modified as here described, the cork which closes the lower end of the vessel is fitted with a glass tube (which for the purpose of reference may be called the re-agent tube) about 10 cms. long, and 2 mms. bore, one end of which is drawn out to a fine point, and the other end is bent at right angles, and has attached to it a piece of stout indiarubber tube about 15 cms. long, and 1 mm. bore. When the cork is fixed in its place, the fine point of the re-agent tube projects into the interior of the vessel for about 2 cms. A small bunsen screw clamp is also provided with which to close the indiarubber tube when necessary.

The apparatus and stand should be permanently set on a small table of such a height that the mercury reservoirs may be lowered some 36 inches below the level of the lowest scale mark on the burette.

The heights of the mercurial columns corresponding to the different divisions of the burette are determined in the ordinary way with the aid of a kathetometer.

To calibrate the burette, it is filled with water in the following way :—The burette and glass tube g are first filled with mercury by raising the reservoir; a beaker containing water is then held under the open end of g, and the reservoir lowered until the burette is filled with water down to the lowest division line. The beaker is now replaced by a small tarred flask, and the reservoir slowly raised until the next division on the burette is reached by the mercury; the water displaced is received into the tarred flask, and weighed; a similar operation is repeated for each division on the scale of the burette. Finally, the capacity of the tube g is measured. During the process of calibration the wide glass cylinder which surrounds the burette is filled with water in order to maintain the water in the burette at a constant and known temperature.

During the analysis of a mixture of gases, all measurements are carried on with the level of the mercury in the burette adjusted to the same division line. The selection of the division line must naturally depend on the volume of the gas to be analysed, and the object of the analysis.

An arrangement for accurately adjusting the level of the mercury in the burette at the division line selected for making measurements may be made thus :—A piece of white paper having a horizontal black line drawn upon it, is gummed to the stand behind the glass cylinder, and at the same level as the division line, an exact adjustment being made with the aid of a kathetometer. A similar arrangement may be made for each division line on the burette, but, generally speaking, it will only be found necessary for the 10, 15, 50, and 100 c.c. lines. With this arrangement the mercury may be adjusted to the level of a division line by the operator, with the naked eye, even more accurately than with the kathetometer, the operator being very much aided by the magnifying effect that the water in the cylinder has upon the burette, and upon the line gummed to the back of the stand.

The method of working the apparatus will be understood from the following description of the analysis of a water residue:—The residue is mixed with copper oxide, and packed in a combustion tube with oxide of copper and metallic copper; and the open end of the combustion tube is drawn out and shaped according to the directions given by Frankland and Armstrong in their method for the determination of the organic carbon and nitrogen in waters. The combustion tube may be directly attached to the tube *h* of the apparatus, but it is more convenient to interpose between them a U shaped connecting tube, in the bend of which a bulb is blown for collecting the water formed during the combustion of a residue. The connections are made with pieces of indiarubber tubing protected with water jackets in the ordinary way, to prevent diffusion of air through them.

The burette and pressure tube, let it be supposed, are full of mercury, the stopcock of the latter closed, and the laboratory vessel detached from the apparatus. If now the cock of the burette be opened to the combustion tube, and the reservoir lowered, air will pass from the combustion tube into the burette as the mercury flows out of the latter; when the mercury has reached the lowest level practicable in the burette, the stopcock is turned to close connection with the combustion tube, and to open to the tube *g*, and the reservoir is raised to refill the burette with mercury and expel the air that has been drawn into it, into the atmosphere. If, when the burette is again full of mercury, connection with the combustion tube be for a second time opened, and the cycle of operations described be repeated, a further quantity of air will be drawn from the combustion tube, and will be expelled from the apparatus. After several such repetitions the quantity of air remaining in the combustion tube will be inappreciable.

The degree to which the exhaustion has been pushed, may be accurately determined by first filling the burette with mercury, and then, the stopcock being closed, lowering the reservoir sufficiently to sink the mercury in the burette to the level of the 100 c.c. division line; a torricellian vacuum will consequently be obtained in the burette. Connection with the combustion tube is now opened, and the tube is gently warmed. After a few minutes the stopcock is again closed, and the reservoir raised; if any air has been drawn from the combustion tube, its presence will be indicated as the mercury rises to fill the burette, and its volume may be accurately determined. With a little care it is quite possible to exhaust so completely the combustion tube, that no residuum of air can be detected in it by the method here described. The time required to exhaust a combustion tube, with the apparatus of the size described in this paper, is about ten minutes. The time, however, will vary somewhat with the dimensions of the combustion tube.

The combustion tube, after being exhausted, is heated to ignite the water residue, the stopcock being closed during the process of heating.

During the combustion the laboratory vessel should be carefully and completely filled with mercury, and attached to the apparatus in the following manner:—The laboratory vessel is held in a slanting position, with its lower shoulder just resting on the front edge of the shelf F, and its upper part *q* *loosely* fitting round the collar at the end of the tube *g*. The reservoir is then adjusted so that the mercury in it, when the laboratory vessel is full, shall be just above the level of the collar. The mercury slowly fills the laboratory vessel, and when it *has risen* a little above the collar, the lower shoulder of the vessel may be pushed into its place. After the laboratory vessel has been properly attached, the re-agent tube must be freed from air. This may be done by unscrewing the bunsen clamp, and allowing a little mercury to flow out of the tube. When the air has been completely driven out, the re-agent tube is again closed by screwing up the clamp. If, after first attaching the laboratory vessel, any traces of air are detected in it (and small bubbles are especially liable to collect under the indiarubber collar attached to the tube *g*), the operator will be able to expel them by drawing the lower part of the vessel forward, and then lowering the vessel slightly to loosen its connection with the tube *g*. If the reservoir has been previously adjusted to the level of the end of the tube *g*, immediately on loosening its connection with the vessel in the manner described, the bubbles of air will escape into the atmosphere. After the laboratory vessel has been finally placed in position, a mercury trough filled with water, and supported on an ordinary table support, is placed under the vessel, and fixed at such a height that the lower end of the vessel is immersed in the water. This arrangement prevents leakage or diffusion of air through the indiarubber cork which closes the end of the vessel.

When the combustion of the water residue has been completed, the combustion tube is again exhausted, and the gases resulting from the combustion are transferred to the laboratory vessel; this operation being completed, the gases are next passed into the burette to be measured.

The method of adjusting the level of the mercury in the burette, after the gases have been passed into it, will require some explanation. The simple plan of closing the stopcock, and then raising and lowering the reservoir, in order to bring the mercury to the level of the division line selected for measurement, cannot be followed, since after transferring the gas, a small bubble of it remains in the laboratory vessel under the indiarubber collar attached to the tube *g*, and cannot be expelled. When therefore the level of the mercury in the burette is being adjusted, the connection between the burette and laboratory vessel must be left open, and the adjustment be made by working the two reservoirs conjointly. To transfer in the first instance the gases into the burette from the laboratory vessel, the reservoir of the former is lowered, and that of the latter raised, until nearly all the gas has passed over, a little however still remaining in the laboratory vessel. The operator at this point must observe whether the gases will require to be compressed or expanded, in order that the mercury in the burette shall stand after final adjustment, at the level of the division line selected for measurement, and in order that, at the same time, the laboratory vessel shall be completely filled with mercury, with the exception, of course, of the space occupied by the small bubble above referred to. With a little practice, the final adjustment may be effected in a few seconds.

An indication that the laboratory vessel has been completely filled, may always be obtained by causing the mercury or water, if the vessel be moist, to rise to a definite height in the capillary tube *g*.

When the necessary adjustments have been made, the height of the mercury in the pressure tube is read off; the difference between the reading and the number corresponding to the height of the division at which the measurement is made, gives the pressure exerted on the gas in millimetres. The temperature of the water in the cylinder C is at the same time observed.

The analysis of the gases is conducted in a manner that is now commonly adopted with this class of apparatus. To absorb the carbon dioxide, a few drops of a strong solution of potash are introduced into the laboratory vessel thus:—The stopcock of the burette is closed, the reservoir of the laboratory vessel is fixed above the level of the re-agent tube, and a small pipette containing the solution of potash is connected with the indiarubber tube attached to the re-agent tube. As the reservoir is above the level of the re-agent tube, on unscrewing the bunsen clamp, there will be a tendency for the mercury to flow into the small pipette; and this may be taken advantage of in order to expel the air that collects in the open end of the indiarubber tube to which the pipette is attached. The air having been completely expelled, the reservoir is dropped to a level slightly below that of the re-agent tube, and after a few drops of potash solution have been drawn into the laboratory vessel, the bunsen clamp is screwed up again. The stopcock may now be opened, and the gas passed from the burette into the vessel. After about ten minutes the carbon dioxide may be considered to have been completely absorbed, and the remaining gases may be transferred to the burette, and again measured, after the mercury has been again adjusted to the levels as before. The remainder of the analysis needs no further description.

When commencing to experiment with the apparatus, it was anticipated that a correction for the error introduced by the bubble of gas being retained in the laboratory vessel, as above described, would be necessary when calculating the volume of the gas. In order to determine the amount of this error, my friend Mr. James Carson very kindly made a number of experiments with the apparatus for me. About 175 c.c. of air were drawn into the burette through the tube *h*, the stopcock was closed, and the air was compressed until the level of the mercury in the burette reached the 100 c.c. division. The pressure exerted by the air was then found to be equal to 410 mms. of mercury plus that of the atmosphere, viz. 759·51, that is a total pressure of 1169·51 mms. of mercury. The air was then passed into the laboratory vessel and back again, the mercury being returned to the same level in the burette; the pressure was read, and found to be exactly the same as before, viz. 1169·51 mms. The experiment was repeated, and a like result obtained. It was then decided to try a similar experiment with a small volume of air under reduced pressure. About 3 c.c. of air was drawn into the burette, as before, the stopcock closed, and the volume expanded until the mercury reached the level of the 14 c.c. division line. The pressure of mercury then indicated by the pressure tube was equal to 161 mms. of mercury; on passing the air into the laboratory vessel, and back again, and adjusting the mercury to the same level as before, the difference of pressure indicated by the pressure tube was found to be less than 0·1 mm. It is hence evident that the bubble of gas retained in the laboratory vessel is too small to introduce any appreciable error when the adjustments of the levels of the mercury in the burette and laboratory vessel are made, before making measurements, in the manner above described.

The following results, taken at random, of analyses of sewage and of air will serve to indicate the degree of accuracy which is ordinarily attainable with the apparatus:—

(I.) Analyses of the gases resulting from the combustion of the residue obtained by evaporating 50 c.c. of the sample of sewage with metaphosphoric acid to dryness.

All measurements made at the 14 *c.c. division line on the burette. Closed pressure tube employed.*

	I.	II.
	mms.	mms.
Height of mercury in pressure tube (moist),	776·5	786·0
,, ,, in burette, . . .	351·0	351·0
Pressure of the gas, ...	425·5	435·0
Temperature, ...	20°C.	20°C.

After absorption with potassium hydrate :—

	I.	II.
	mms.	mms.
Height of mercury in pressure tube, . .	514	512
,, ,, in burette, . . .	351	351
Pressure of gas after absorption of CO_2, .	163	161
Tension of CO_2, ...	262·5	274·0

After absorption with pyrogallic acid :—

	I.	II.
Height of mercury in pressure tube, . .	509·5	511·0
,, ,, in burette, . . .	351·0	351·0
Pressure of nitrogen, ...	158·5	160·0

Capacity of burette at 14 c.c. division line = 14·2267 c.c.

The parts per 100,000 of organic carbon and total nitrogen contained in sewage are calculated from the above determinations in the ordinary way.

Analysis No. I. gives :—

4·9 parts carbon per	100,000
6·96 parts nitrogen per	100,000

Analysis No. II. gives :—

5·1 parts carbon per	100,000
7·02 parts nitrogen per	100,000

(II.) Analyses of air. About 175 c.c. air at ordinary pressure taken.

All measurements made at the 100 *c.c. line on burette. Open pressure tube employed.*

	I.	II.
	mms.	mms.
Height of mercury in pressure tube, . .	628·50	628·5
Atmospheric pressure, ...	755·75	759·1
Total pressure, ...	= 1384·25	1387·6
Height of mercury in burette, . . .	210·00	210·0
Pressure of the gas, ...	= 1174·25	1177·6

After absorption with potassium hydrate :—

	I. mms.	II. mms.
Total pressure, ...	1173·45	1176·80
Tension of CO_2, ...	0·80	0·80

After absorption with pyrogallic acid :—

Total pressure, ...	933·25	936·30
Tension of oxygen, ...	240·20	240·50
Temperature, ...	16·5° C.	18·4 C.
Tension of nitrogen, ...	919·286	920·911

Tension of aqueous vapour at 16·5 = 13·964 mms.
,, ,, ,, at 18·4 = 15·389 mms.

	I. mms.	II. mms.
Percentage of nitrogen, ... =	79·2299	79·2379
,, of oxygen, ... =	20·7001	20·6933
,, of carbon dioxide, . . =	0·0689	0·0683

When explosions are to be made in the apparatus, the gas is first measured as above described; the oxygen or hydrogen is then passed into the laboratory vessel through the re-agent tube, and after the mixed gases have been measured, they are returned to the laboratory vessel and exploded therein under reduced pressure according to the directions given by Thomas (*Chem. Soc. Journ.*, 35, 213).

The hydrogen or oxygen may be passed into the laboratory vessel with great facility. The gas is first collected in a test tube or other suitable vessel over mercury; the indiarubber tube attached to the re-agent tube is then carefully freed from air and filled with mercury in the manner above described, and cautiously inserted into the test tube; then, on lowering the reservoir, the gas will pass from the test tube into the laboratory vessel. The method of employing the apparatus for the analyses of nitrates or carbonates, and for other similar purposes, will be understood from the foregoing descriptions. It need only be mentioned that a known quantity of the substance to be analyzed is placed in a small flask in the solid form or in solution, and the flask is attached to the tube *h* of the apparatus. The flask is exhausted and the necessary re-agent added through the cup and stopcock G.

I trust in a future communication to the Society to give the results of a research on certain methods of water analysis upon which I have been engaged for some time past, and to show how the apparatus may be conveniently employed for determining the dissolved gases, organic carbon, and the nitrogen in waters.

In the early part of this paper it was pointed out that the reservoir supplying mercury to the burette and pressure tube was connected with the latter and not with the former. With this class of apparatus such an arrangement is essential, because, when the reservoir is kept for any length of time at a lower level than that of the bottom of the burette, and this is constantly necessary when working in vacuo or under reduced pressure, air diffuses through the indiarubber connecting tube, and passes into the pressure tube immediately the reservoir is raised again. It would of course pass into the burette, and the experiment would be vitiated if the connecting tube were directly attached to the burette. The air may be expelled from the pressure tube when necessary by opening its stopcock and raising the reservoir sufficiently high to fill the tube with mercury.

It will be noticed that the pressure tube is not provided as in the case of Thomas' or Macleod's apparatus with a water jacket for keeping its contents, when employed as a closed and "wet" pressure tube, at the same temperature as the contents of the burette, nor are means furnished for continually renewing the water in the cylinder C during an analysis. I have found that neither additions are necessary to this class of apparatus for all ordinary purposes. Since the burette is of a considerable length, viz. 640 mms., the measurements may in nearly all cases be made with advantage with an *open* pressure tube; and if the cylinder C be filled with water that has been kept exposed for some time to the temperature of the laboratory in which the apparatus is kept, the water will not, if ordinary care be observed, alter sufficiently to appreciably affect the results of an analysis. When it is necessary to use a closed pressure tube and it is at the same time necessary to work with the utmost degree of accuracy, then it is preferable to employ a "dry" closed tube; but even if it be employed "wet" very good results will be obtained. The additions above referred to have the great disadvantage of rendering the apparatus much more complicated and liable to fracture. I have endeavoured to make the apparatus here described as simple as proper regard for accuracy of result will allow, in the hope that it will supply the want of an effective and simple apparatus, which I have, in common with other chemists, experienced in teaching methods of analysis involving the evolution, collection, and measurement of gases, and that it will be consequently found useful in a laboratory in which advanced students are taught, as well as for the purposes of research work.

With reference to the possibility of maintaining the apparatus in good working order, I may say that I have employed it for a large number of experiments of various kinds during the past six months, and have found no difficulty in maintaining the stopcocks in such good order that a vacuum can be maintained in the burette and pressure tube unimpaired for several days. Some difficulty was at first experienced when attempting to subject a gas in the burette to high pressure, owing to the stopper of the burette being loosened and pressed out. The difficulty was overcome by lubricating the stopper with a mixture of beeswax and vaseline.

Other advantages of the apparatus besides simplicity and wide range of applicability are its comparative freedom from the risk of breakage, and its cheapness. The glass parts,[1] with the exception of the scale at the back of the pressure tube, were obtained at a cost of 45*s.*; the cost of putting the parts together, including time and fittings, was about 40*s.*; and it may be taken that the apparatus cost in all not more than £5.

In conclusion I desire to express my sincere thanks to my old pupil and friend Mr. James Carson, C.E., Assoc. R. C. Sc. I., for the aid he has unsparingly given me in making a large number of laborious experiments with which to test the apparatus. My thanks are also due to John Connolly, the laboratory assistant in the Royal University for the skilful assistance he has rendered me in fitting the apparatus together.

[1] My acknowledgments are due to Messrs. Baird and Tatlock of Glasgow, through whom I obtained the glass parts of the apparatus, for the care and accuracy with which all the directions given to them were carried out.

LV.

ON THE EMPLOYMENT OF THE NAMES PROPOSED FOR GENERA OF *ORTHOPTERA*, PREVIOUS TO 1840. By W. F. KIRBY, F.L.S., F.E.S., Assistant in Zoological Department, British Museum (Natural History), South Kensington. (Communicated by A. G. More, M.R.D.Soc.)

[Read June 18, 1890.]

While engaged in the arrangement of a typical collection of *Orthoptera* for the public Entomological Room of the British Museum, I found it necessary to investigate the proper use of the older generic names; and there proved to be so much confusion and uncertainty in their use that I determined to work out the subject thoroughly, down to 1839, when Serville published his "Histoire Naturelle des Insectes Orthoptères," which forms the basis of all recent works on this Order.

In his earlier works Linné regarded the *Orthoptera* as *Coleoptera*, but subsequently classed them with *Hemiptera*. This is fortunate, because Retzius, in 1783, restricted the term *Hemiptera* to the Order for which Olivier, in 1789, proposed the name *Orthoptera*, by which it is now known. But as the *Cimicidæ* are the original types of the Linnean Order *Hemiptera*, this proceeding of Retzius cannot affect the usual application of that name. *Dermaptera*, a term which Retzius employed to include the genera *Cimex* and *Nepa*, if retained at all, must be employed for the *Hemiptera Heteroptera*, although more recent writers have erroneously applied the term *Dermaptera* sometimes to the *Forficulidæ*, and sometimes to the *Orthoptera* in general. But though we can retain the name *Orthoptera*, we must reject the sectional names misapplied by Latreille; for *Saltatoria* and *Gressoria* are terms which Retzius employed long before to designate the *Pulicidæ* and the Linnean *Aptera* respectively. Many genera proposed by Latreille were originally published by him in a French form, and usually without types. These I only recognize when taken up by subsequent authors in a Latin form.

The chief confusion which has arisen in the *Orthoptera* is in the genus *Gryllus*, which Linné divided into five sub-genera—*Acrida*, *Bulla*, *Acheta*, *Tettigonia*, and *Locusta*. *Bulla*, having been subsequently employed by Linné himself to designate a genus of *Mollusca*, soon dropped out of use; but the Fabrician names for the various sub-genera are as follows:—*Truxalis* (*Acrida*), *Acrydium* (*Bulla*, p.), *Acheta* (*Acheta*), *Locusta* (*Tettigonia*), and *Gryllus* (*Locusta*).

It is true that Fabricius borrowed his use of *Acrydium* and *Locusta* from Geoffroy; but not satisfied with this, he adopted *Tettigonia* as the name of a genus of *Hemiptera Homoptera*. Since his time, the confusion has greatly increased; for instance, the name *Acrida* was used by Curtis for one of the Linnean types of *Tettigonia*, and the migratory Locusts have generally been called *Acrydium* or *Gryllus* almost indiscriminately, while *Acheta* and *Gryllus* have been used with equal uncertainty for the Crickets.

I have, therefore, examined analytically, after the method of Scudder, the use of all the genera proposed for *Orthoptera* previous to 1840, quoting later works occasionally when necessary to fix the use of a name; and although I have no right to assume that my results will be undisputed, they will nevertheless enable anyone to form a clear idea of the merits of each particular case.

The order of the genera is taken in the *Forficulidæ* from Serville; in the *Mantidæ* from De Saussure's synopsis in the "Mémoires de la Soc. Phys. de Genève," vol. xxi.; in the *Phasmidæ* from Westwood's "British Museum Catalogue;" and in the other families from Walker's "British Museum Catalogues of *Blattidæ* and *Dermaptera Saltatoria*." I have thought it better to avoid the use of family names, and therefore distinguish the main groups only by those of the typical genera. Synonyms are placed in brackets, and printed in italics, under the genera to which they belong.

The genera of *Forficulidæ* have already been analyzed by Scudder in the "Proceedings of the Boston Society of Natural History," vol. xviii., but are included here to complete the subject.

All generic names preoccupied in zoology, or which I have come to the conclusion are misapplied, are marked ||. Several of these genera will probably require renaming; but I have abstained from doing so in the present Paper. A Bibliography is appended which will enable entomologists to test the completeness of my work, and possibly to supplement it in case I may have overlooked any genera of *Orthoptera* proposed before 1840.

FORFICULA. Linn.

Pygidicrana.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 30. (Type, *P. v. nigrum.* Serv.)

Labidura.

1815. Leach, "Edinb. Ent.," ix., p. 118. (Type, *Forficula gigantea*, Fabr., = *riparia*, Pall.)

(*Forficesila.*)

1831. Serv., "An. Sci. Nat.," xxii., p. 32. (Type, *Forficula gigantea.*)

Psalis.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 33. (Types, *Forficula americana*, Beauv.; and *Psalis morbida*, Serv.)

1839. Burm., "Handb. Ent.," ii., p, 753. (*P. morbida* proved to be a damaged specimen of *Labidura gigantea*; but Scudder is inclined to follow Burmeister, and accept the genus, with *P. americana* as type.)

Spongiphora.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 31. (Type, *S. croceipennis*, Serv.) Agassiz and Scudder write *Spongophora.*

(*Psalidophora.*)

1839. Serv., "Ins. Orth.," p. 29. (Type, *Spongiphora croceipennis.*)

Pyragra.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 34. (Type, *P. furcata*, Serv.)

Chelisoches.

1877. Scudd., "Proc. Bost. Soc. N. H.," xviii., p. 295.

‖ (*Lobophora.*)

1839. Serv., "Ins. Orth.," p. 32. (Type, *L. rufitarsis*, Serv.)

Echinosoma.

1839. Serv., "Ins. Orth.," p. 34. (Type, *Forficula afra*, Beauv.)

Forficula.

1758. Linn., "Syst. Nat.," ed. x., i., p. 423. (Types, *F. auricularia*, and *minor*, Linn.)

1802. Latreille, "Hist. Nat. Crust. Ins.," iii., p. 268. (Type, *F. auricularia*, Linn.)

Apterygida.

1839. Westwood, "Mod. Class. Ins.," ii., Synopsis, p. 44. (Type, *Forficula pedestris*, Bon.)

‖ (*Chelidura.*)

1835. Steph., "Ill. Brit. Ent., Mand.," vi., p. 6. (Type, *Forficula albipennis*, Charp.) Scudder considers this genus to be synonymous with *Forficula.*

Labia.

1815. Leach, "Edinb. Enc.," ix., p. 118. (Type, *Forficula minor*, Linn.)

Chelidoura.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 36. (Type, *Forficula aptera*, Charp.) (Later authors write *Chelidura.*

Diplatys.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 33. (Type, *Forficula macrocephala*, Beauv.)

Sparatta.

1839. Serv., "Ins. Orth.," p. 51. (Type, *S. pelvimetra*, Serv.)

Mecomera.

1839. Serv., "Ins. Orth.," p. 53. (Type, *M. brunnea*, Serv.)

Apachyus.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 35. (Type, *Forficula depressa*, Beauv.) (This name was subsequently written *Apachys* and *Apachya* by Burmeister and Serville.)

BLATTA. Linn.

Blaberus.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 37. (Types, *Blatta gigantea*, Linn.; *grossa* and *biguttata*, Thunb.)

(*Blabera.*)

1839. Serv., "Ins. Orth.," p. 74.

1865. Brunn. Watt., "Nouv. Syst. Blatt.," p. 371. (Restricted to *B. gigantea* and allies.)

Monachoda.

1839. Burm., "Handb. Ent.," ii., p. 513. (To include *M. dominicana* and *franciscona*, Burm.; *Blatta mouffeti*, Kirb.; *M. biggutata*, Burm.; *B. grossa*, Thunb.; *M. crassimargo* and *laticollis* Burm.)

Polyphaga.

1835. Brullé, "Hist. Nat. Ins.," ix., p. 57. (Type, *Blatta ægyptiaca*, Linn.)

Heterogamia.

1839. Burm., "Handb. Ent.," ii., p. 488. (Types, *H. ursina*, Burm.; and *Blatta ægyptiaca*, Linn.)

Homœogamia.

1839. Burm., "Handb. Ent.," ii., p. 490. (Type, *H. mexicana*, Burm.)

Panesthia.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 38. (Type, *P. javanica*, Serv.)

Panchlora.

1839. Burm., "Handb. Ent.," ii., p. 506. (Includes *Blatta viridis*, Fabr., and allies.)

Nauphoeta.

1839. Burm., "Handb. Ent.," ii., p. 508. (Types, *N. circumvagans*, *grisea*, *bivittata*, and *lyrata*, Burm.)

Proscratea.

1839. Burm., "Handb. Ent.," ii., p. 509. (Types *P. fulviceps*, and *funebris*, Burm., and *Blatta complanata*, Perty.)

Zetobora.

1839. Burm., "Handb. Ent.," ii., p. 509. (To include *Z. conspersata*, Burm.; *Blatta conspersa*, Guér. and Perch.; and *Z. nimbata*, *emarginata*, and *cicatricosa*, Burm.)

1865. Brunn. Watt., "Nouv. Syst. Blatt.," p. 288. (Restricted to *Z. cicatricosa*, *nimbata*, and allies.)

Brachycola.

1839. Serv., "Ins. Orth.," p. 119. (To include *B. robusta* and *lævicollis*, Serv.; and *Blatta sexnotata*, Thunb.)

Probably synonymous with *Hormetica*.

Hormetica.

1839. Burm., "Handb. Ent.," ii., p. 511. (Types, *H. ventralis*, *lævigata*, *scrobiculata*, *monticollis*, and *Blatta tuberculata*, Dalm.)

Corydia.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 42. (Type, *Cassida petiveriana*, Linn.)

Euthyrrhapha.

1839. Burm., "Handb. Ent.," ii., p. 491. (Type *E. biguttata*, Burm.)

Holocompsa.

1839. Burm., "Handb. Ent.," ii., p. 491. (Types, *H. cyanea*, *collaris*, and *fulva*, Burm.)

Phoraspis.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 43. (Types *P. pallens*, Serv.; and *Blatta picta*, Fabr.)

Epilampra.

1839. Burm., "Handb. Ent.," ii., p. 504. (Includes *Blatta brasiliensis*, Fabr.; and *Epilampra conspersa*, *cribrosa*, *nebulosa*, *lurida*, and *verticalis*, Burm.)

Pseudomops.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 41. (Type, *Blatta oblongata*, Linn.)

(*Thyrsocera.*)

1839. Burm., "Handb. Ent.," ii., p. 498. (Includes among other species the type of *Pseudomops*, which name is quoted as a synonym of the genus.)

ECTOBIUS.

1835. Steph., "Ill. Brit. Ent., Mand.," vi., p. 45. (Eight species described, including *Blatta germanica* and *lapponica*, Linn.)

(*Ectobia.*)

1839. Westw., "Mod. Class. Ins.," ii., Synopsis, p. 44. (Type, *B. lapponica.*)

|| (*Blatta.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 39. (Includes *B. lapponica*, &c.)

PHYLLODROMIA.

1839. Serv., "Ins. Orth.," p. 105. (Includes *Blatta germanica*, Linn., and allies.)

1865. Brunn. Watt., "Nouv. Syst. Blatt.," p. 88. (Restricted to *B. germanica* and allies.)

ISCHNOPTERA.

1839. Burm., "Handb. Ent.," ii., p. 500. (Types *I. gracilis, fumata*, and *morio*, Burm.)

BLATTA.

1758. Linn., "Syst. Nat.," ed. x., i., p. 424. (Nine species mentioned, including *B. orientalis*, Linn.)

1802. Latr., "Hist. Nat. Crust. Ins.," iii., p. 269. (Type, *B. orientalis.*)

(*Kakerlac.*)

1829. Latr., "Règne Anim.," v., p. 175, note. (Proposed for *Blatta orientalis* and allies.)

(*Steleopyya.*)

1833. Fisch., "Bull. Mosc.," vi., pp. 356 and 366. (Includes *Blatta orientalis*, &c.; the genus is stated by Fischer to be synonymous with *Kakerlac*, Latr.)

PERIPLANETA.

1839. Burm., "Handb. Ent.," ii., p. 502. (To include *Blatta americana*, Fabr., *P. brunnea* and *ustulata*, Burm., *B. australasiæ*, Fabr., and *orientalis*, Linn.) *P. americana* should be regarded as the type.

NYCTIBORA.

1839. Burm., "Handb. Ent.," ii., p. 501. (Includes *N. crassicornis*, *sericea*, *holosericea*, and *latipennis*, Burm.)

PARATROPES.

1839. Serv., "Ins. Orth.," p. 117. (Type *P. lycoides*, Serv.)

POLYZOSTERIA.

1839. Burm., "Handb. Ent.," ii., p. 482. (Types, *P. orientalis* and *occidentalis*, Burm., *Blatta decipiens*, Germ., and *P. limbata* and *ænea*, Burm.)

1865. Brunn. Watt., "Nouv. Syst. Blatt.," p. 203. (Restricted to *P. limbata* and allies.)

PERISPHÆRUS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 44. (Type, *P. armadilla*, Serv.)

(*Perisphæria.*)

1839. Burm., "Handb. Ent.," ii., p. 483.

(*Perisphæra.*)

1839. Serv., "Ins. Orth.," p. 132.

DEROPELTIS.

1839. Burm., "Handb. Ent.," ii., p. 486. (Types, *Blatta capensis* and *erythrocephala*, Fabr.)

BLEPHARODERA.

1839. Burm., "Handb. Ent.," ii., p. 486. (Type, *B. ciliata*, Burm.)

DEROCALYMMA.

1839. Burm., "Handb. Ent.," ii., p. 487. (Includes *Perisphæria versicolor*, Burm., *Blatta fusca*, Oliv.; and *P. gracilis*, *dispar*, *affinis*, and *flavicarnis*, Burm.)

ANAPLECTA.

1839. Burm., "Handb. Ent.," ii., p. 494. (To include *Blatta minutissima*, De Geer, and *A. dorsalis* and *unicolor*, Burm.)

MANTIS. Linn.

EREMIAPHILA.

1835. Lef., "Ann. Soc. Ent. France," iv., p. 468. (Six mature and five immature species described, all with French names; two species figured by Savigny, but not seen by Lefebvre, are also named.)

1839. Serv., "Ins. Orth.," p. 209. (Lefebvre's six species are here called *E. audouini*, *cerysii*, *genei*, *zetterstedtii*, *luxor*, and *bovei*.)

|| (*Eremophila.*)

1839. Burm., "Handb. Ent.," ii., p. 524. (Six species, the typical group including *E. audouini*, *genei*, *zetterstedtii*, and *bovei*.)

HETERONUTARSUS.

1835. Lef., "Ann. Soc. Ent. France," iv., p. 501. (Type, *H. aegyptiacus*, Lef.) Agassiz writes also *Heteronytarsus* and *Heteronychotarsus*.

METALLYTICUS.

1837. Westw., "Zool. Journ.," v., p. 441. (Type, *M. splendidus*, Westw.)

(*Metalleutica.*)

1839. Burm., "Handb. Ent.," ii., p. 526.

CHÆTEESSA.

1839. Burm., "Handb. Ent.," ii., p. 527. (New name proposed for *Hoplophora.*)

(*Chætessa.*)

1869. Sauss., "Mitth. Schweiz. Ent. Ges.," iii., p. 52.

|| (*Hoplophora.*)

1833. Perty, "Del. Anim. Art.," p. 126. (Type, *H. valida*, Perty.) (Placed by Perty near *Mantispa*, but referred to the *Mantidæ* by Burmeister and De Saussure.)

MANTOIDA.

1838. Newm., "Ent. Mag.," v., p. 178. (Type, *M. nitida*, Newm.)

CHÆRADODIS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 50. (Types, *Mantis strumaria*, Linn.; *M. hyalina*, Stoll.; and *C. laticollis*, Serv.)

1839. Serv., "Ins. Orth.," p. 206. (Includes *Mantis cancellata*, Fabr., and *C. peruviano* and *laticollis*, Serv.)

(*Craurusa.*)

1839. Burm., "Handb. Ent.," ii., p. 542. (Type, *Mantis cancellata*, Fabr.)

Orthodera.

1839. Burm., "Handb. Ent.," ii., p. 529. (Type, *O prasina*, Burm.)

Tarachodes.

1839. Burm., "Handb. Ent.," ii., p. 528. (Type, *T. perloides*, Burm.)

Acontista.

1869. Sauss., "Mitth. Schweiz. Ent. Ges.," iii., p. 55.

|| (*Acontistes.*)

1839. Burm., "Handb. Ent.," ii., p. 542. (Types, *Mantis indicata*, Oliv.; *precaria*, Stoll.; *cingulata*, Dru.; *concinna*, Perty; and *nana*, Stoll.)

Thespis.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 54. To include *Mantis purpurascens*, Oliv. (apparently the type, as it is redescribed), *fasciata*, *quinquemaculata*, and *parva*, Oliv.

1839. Burm., "Handb. Ent.;" ii., p. 533. (Burmeister excludes *M. fasciata.*)

(*Angela.*)

1839. Serv., "Ins. Orth.," p. 171. (Serville divides *Thespis* into two sections, giving the name *Angela* to the section including all his former types!)

Cardioptera.

1839. Burm., "Handb. Ent.," ii., p. 540. (Types, *Mantis oratoria*, Linn.; *M. abdominalis*, Oliv.; and *M. reticulata*, *brachyptera*, *gymnopyga*, and *ovalifolia*, Burm.)

1869. Sauss., "Mitth. Schweiz. Ent. Ges.," iii., p. 66. Type, *Mantis sublobata*, Serv. = *bradyptera*, Burm.)

Stagmatoptera.

1839. Burm., "Handb. Ent.," ii., p. 537. (Includes three sections, the first of which—(*a*) = *Epaphrodita*, Burm. The other two include the following species—(*b*) *Mantis carolina*, Stoll.; *latipennis* and *dimidiata*, Burm.; and (*c*) *præcaria*, Linn.; *rogatoria*, Ill., and *pavonina* and *unipunctata*, Burm.)

1869. Sauss., "Mitth. Schweiz. Ent. Ges.," iii., p. 67. (Includes *M. præcaria* and several other species mentioned by Burmeister.)

RHOMBODERA.

1839. Burm., "Handb. Ent.," ii., p. 536. (Types, *R. valida* and *laticollis*, Burm.)

HIERODULA.

1839. Burm., "Handb. Ent.," ii., p. 536. (To include *Mantis membranacea* and *hybrida*, Burm., and *simulacrum*, Fabr.)

1869. Sauss., "Mitth. Schweiz. Ent. Ges.," iii., p. 67. (Name used in an extended sense, but inclusive of *M. membranacea* and *simulacrum*.)

POLYSPILOTA.

1839. Burm., "Handb. Ent.," ii., p. 534. (Includes *Mantis conspersa* and *albimacula*, Burm.; *varia*, Ill.; *variegata*, Stoll.; and *catenata*, Burm.)

1869. Sauss., "Mitth. Schweiz. Ent. Ges.," iii., p. 68. (Types, *M. variegata* and *catenata*.)

(GRYLLUS) MANTIS.

1758. Linn., "Syst. Nat.," ed. x., i., p. 425. (Types, *G. M. gigas*, *pthisicus*, *siccifolius*, *gongylodes*, *religiosus*, *oratorius*, *precarius*, *bicornis*, *tricolor*, and *strumarius*, Linn.)

(*Mantes.*)

1762. Geoffr., "Hist. Ins.," i., p. 399. (Type, *M. religiosa*, Linn.)

TENODERA.

1839. Burm., "Handb, Ent.," ii., p. 534. (Types, *Mantis fasciata*, Oliv.; *chloreudeta* (= *aridifolia*, Stoll.) and *tessellata*, Burm.)

AMELES.

1839. Burm., "Handb. Ent.," ii., p. 531. (Types, *Mantis nana* and *minima*, Charp.; *aurantiaca*, Burm., and *flavicincta*, Stoll.)

1869. Sauss., "Mitth. Schweiz. Ent. Ges.," iii., p. 62. (Includes *M. nana* (= *spallanzania*, Rossi), and *decolor*, Charp. The former, therefore, becomes the type.)

MIOMANTIS.

1870. Sauss., "Mitth. Schweiz. Ent. Ges.," iii., p. 228. (Type, *Mantis forficata*, Stoll. = *fenestrata*, Fabr.)

|| (*Photina.*)

1839. Burm., "Handb. Ent.," ii., p. 531. (To include *M. fenestrata* and allies.)

Gen. ——— ?

|| (*Thespis.*)

1839. Serv., "Ins. Orth.," p. 171. (Types, *T. sulcatifrons* and *livida*, Serv.)

1871. Sauss., "Mém. Soc. Genève," xxi. (i.), p. 129. (Restricted to *T. sulcatifrons.*)

SCHIZOCEPHALA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 55. (Type, *Mantis striata*, Oliv.)

HYMENOPUS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 46. (Type, *Mantis coronata*, Stoll.)

(*Hymenopa.*)

1839. Serv., "Ins. Orth.," p. 162.

CREOBROTER.

1839. Serv., "Ins. Orth.," p. 160. (Types, *Mantis gemmata*, Stoll.; and *Harpax discifera* and *virescens*, Serv.)

(*Creobotra.*)

1871. Sauss., "Mém. Soc. Genève," xxi. (i.), p. 143. (Type, *M. gemmata*, Stoll., = *urbana*, Fabr.

Gen. ——— ?

|| (*Harpax.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 49. (Types, *Mantis lobata*, Fabr.; *cornuta*, Oliv.; *Empusa ocellata*, Beauv.; and *Mantis urbana*, Fabr.)

1871. Sauss., "Mém. Soc. Genève," xxi. (i.), p. 151. (Four species, including *Mantis tricolor*, Linn., of which *M. lobata* and *cornuta* are regarded as synonyms.)

TOXODERA.

1837. Serv., "Ann. Soc. Ent. France," vi., p. 27. (Type, *T. denticulata*, Serv.)

Acanthops.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 52. (Type, *Mantis fuscifolia*, Oliv.)

Deroplatys.

1839. Westw., "Mod. Class. Ins.," i., p. 430. (Type, *D. desiccata*, Westw.)

Epaphrodita.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 52. (Type, *Mantis musarum*, Beauv.)

Oxypilus.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 50. (Type, *O. annulatus*, Serv.)

Phyllocrania.

1839. Burm., "Handb. Ent.," ii., p. 548. (Type, *P. paradoxa*, Burm.)

Zoolea.

1839. Serv., "Ins. Orth.," p. 154. (Type, *Mantis lobipes*, Oliv. = *macroptera*, Stoll.)

Theoclytes.

1839. Serv., "Ins. Orth.," p. 150. (Type, *Mantis foliata*, Licht. = *subfoliata*, Stoll.)

Vates.

1839. Burm., "Handb. Ent.," ii., p. 543. (Types, *V. cnemidotus* and *orbus*, Burm.; and *Mantis macropterus*, Oliv.)
1869. De Sauss., "Mitth. Schweiz. Ent. Ges.," iii., p. 60. (Type, *V. subfoliata*, Stoll. = *cnemidotus*, Burm.)

Gen. ——— ?

|| (*Blepharis.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 47. (Type, *Mantis mendica*, Fabr.)

Gongylus.

1815. Thunb., "Mém. Pétersb.," v., p. 220. (Types, *G. pennatus* (= *Mantis flabellicornis* and *pectinecornis*, Fabr.) *gongylodes*, *marginatus*, *guttulus*, *lobatus*, *asutus*, *mendicus*, and *pauperatus*, L. and Th.)
1839. Burm., "Handb. Ent.," ii., p. 545. (Type, *M. gongylodes.*)

EMPUSA.

1798. Ill., "Käf. Preuss.," p. 499. (Types, *Mantis gongylodes*, *pauperata* and *filiformis*, Fabr.)

1871. Sauss., "Mém. Soc. Genève," xxv. (i.), p. 186. (Restricted to *M. pauperata* and allies.)

IDOLOMORPHA.

1839. Burm., "Handb. Ent.," ii., p. 547. (Types, *Empusa lateralis* and *gracilis*, Burm.)

PHASMA. Ill.

PHASMA.

1798. Ill., "Käf. Preuss.," p. 499. (Types, *Mantis gigas*, Linn.; and *M. calamu* and *rossia*, Fabr.)

1798. Fabr., "Ent. Syst. Suppl.," p. 186. (Includes same species and 14 others.)

1802. Latr., "Hist. Nat. Crust. Ins.," iii., p. 272. (Types, *Mantis*, *necydaloides*, Linn., and *rossia*, Fabr.)

1817. Latr., "Règne Animale," iii., p. 374. (Type *P. rossia*.)

(*Bacillus*.)

1825. St. Farg. and Serv., "Enc. Méth. Ent.," x., p. 446. (Type *P. rossia*).

|| (*Spectrum*.)

1815. Leach., "Edinb. Enc.," ix., p. 119. (Type, *P. rossia*.)

LINOCERUS.

1835. Gray, "Syn. Phasm.," p. 19. (Type, *L. gracilis*, Gray.)

1859. Westw., "Cat. Phasm.," p. 12. (*L. gracilis* is placed with *Bacillus* (= *Phasma*) under the subgeneric name of *Linocerus*.)

PACHYMORPHA.

1835. Gray, "Syn. Phasm.," p. 21. (Type, *Bacillus squalidus*, Gray.)

ANISOMORPHA.

1835. Gray, "Syn. Phasm.," p. 18. (Types, *Phasma ferruginea*, Beauv., and *buprestoides*, Stoll.)

DIAPHEROMERA.

1835. Gray, "Syn. Phasm.," p. 18. (Type, *Spectrum femoratum*, Say.)

Bacteria.

1825. St. Farg. and Serv., "Enc. Méth. Ent.," x., p. 446. (Types, *Phasma filiformis*, *ferula*, *calamus*, Fabr.)

1839. Serv., "Ins. Orth.," p. 223. (Includes *Phasma arumatia*, Stoll., = *ferula*, Fabr., and *rubispinosa*, Serv.)

Heteronemia.

1835. Gray, "Syn. Phasm.," p. 19. (Type, *H. mexicana*, Gray.) (Included by Westwood with *Bacteria*.)

Bacunculus.

1839. Burm., "Handb. Ent.," ii., p. 566. (Includes *B. spatulata*, Burm., *Spectrum femoratum*, Say, and *B. spinosa*, *tridens*, *striata*, *gracilis*, *hastata*, *linearis*, and *viridis*, Burm.)

1859. Westw., "Cat. Phasm.," p. 26. (*B. spatulata* is placed under *Bacteria*, with *Bacunculus* used as a subgeneric name.)

Lonchodes.

1835. Gray, "Syn. Phasm.," p. 19. (Types *L. brevipes*, *geniculatus*, and *pterodactylus*, Gray.)

Prisomera.

1835. Gray, "Syn. Phasm.," p. 15. (Includes *Phasma femorata*, Stoll., *P. spinicollis*, and *P.* (?) *phyllopus*, Gray.) (*P. spinicollis* is certainly the type.)

Acanthoderus.

1835. Gray, "Syn. Phasm.," p. 14. (Types, *Bacteria scabrosa*, Perch., and *A. dumerili* and *spinosus*, Gray.)

1859. Westw., "Cat. Phasm.," p. 48. (Restricted to *A. spinosus* and allies.) (Serville rejects Gray's name, on account of his own genus *Acanthoderes*, in the *Longicornia*, published in "Ann. Soc. Ent. Fr.," iv., p. 25 (1835, 1 trimestre); but as Gray's preface is dated Jan. 14, 1835, and Serville's Paper was only read on Nov. 19th, 1834, it is probable that Gray's work was actually published first.)

Pygirhynchus.

1839. Serv., "Ins. Orth.," p. 260. (Types, *P. subfoliatus* and *coronatus*, Serv.) Agassiz writes *Pygorhynchus*.

Ceroys.

1839. Serv., "Ins. Orth.," p. 262. (Types, *Cladomorphus perfoliatus*, Gray, and *Ceroys multispinosus*, Serv.) Agassiz writes *Cerous.*

Rhaphiderus.

1839. Serv., "Ins. Orth.," p. 245. (Type, *Bacteria scabrosa*, Perch.)

1859. Westw., "Cat. Phasm.," p. 62. (To include *B. scabrosa*, and allies.) (Originally proposed by Serville to replace *Acanthoderus* [vide antea]; but Westwood employed both names in different senses.)

Eurycantha.

1832. Boisd., "Voy. Astr. Ins.," ii., p. 647. (Type, *E. horrida*, Boisd.)

Cladomorphus.

1835. Gray, "Syn. Phasm.," p. 15. (Types, *C. phyllinus*, *ceratocephalus*, *dilatipes* and *perfoliatus*, Gray.)

1839. Serv., "Ins. Orth.," p. 224. (Type, *C. phyllinus.*)

(*Phibalosoma.*)

1835. Gray, "Syn. Phasm.," p. 42. (Type, *P. lepelletieri*, Gray.)

1859. Westw., "Cat. Phasm.," p. 71. (The types of these genera being sexes of the same species, Westwood prefers to retain the name given to the male, according to a common practice; but as this has frequently led to error, I prefer always to decide such questions (where priority of date is no guide) by order of position.)

Cladoxerus.

1825. St. Farg. and Serv., "Enc. Méth. Ent.," x., p. 445. (Type, *C. gracilis*, St. F. and S.) Included by Westwood with *Philalosoma* (= *Cladomorphus.*)

Monandroptera.

1839. Serv., "Ins. Orth.," p. 242. (Type, *M. inuncans*, Serv.) Agassiz writes *Monandropora.*

Heteropteryx.

1835. Gray, "Syn. Phasm.," p. 32. (Type, *Phasma dilatatum*, Shaw.)

Diapherodes.

1835. Gray, "Syn. Phasm.," p. 33. (To include *Mantis gigas*, Dru. (nec. Linn.), and 5 other species.)

1859. Westw., "Cat. Phasm.," p. 84. (To include *M. gigas*, Dru., and allies.)

HAPLOPUS.

1839. Burm., "Handb. Ent.," ii., p. 576.

(*Aplopus.*)

1835. Gray, "Syn. Phasm.," p. 34. (Type, *Cyphocrana microptera*, St. Farg. and Serv.)

PTERINOXYLUS.

1839. Serv., "Ins. Orth.," p. 226. (Type, *P. difformipes*, Serv.)

ASCHIPHASMA.

1834. Westw., "Zool. Journ.," v., p. 442. (Type, *A. annulipes*, Westw.)

(*Aschipasma.*)

1859. Westw., "Cat. Phasm.," p. 92.

(*Perlamorphus.*)

1835. Gray, "Mon. Phasm.," p. 21. (Types, *P. hieroglyphicus* (= *annulipes*, Westw.), and *pelens*, Gray.)

(*Perlamorpha.*)

1839. Serv., "Ins. Orth.," p. 275.

XERODERUS

1835. Gray, "Syn. Phasm.," p. 32. (Type, *X. kirbii*, Gray.)

XEROSOMA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 61. (Type, *X. canaliculatum*, Serv.)

CREOXYLUS.

1839. Serv., "Ins. Orth.," p. 265. (Type, *C. corniger*, Serv.)

CYPHOCRANA.

1825. St. Farg. and Serv., "Enc. Méth. Ent.," x., p. 445. (Types, *Mantis jamaicensis*, Stoll., *M. gigas*, Linn, &c.)
1835. Gray, "Syn. Phasm.," p. 35. (Type, *M. gigas.*)

(*Cyphocrania.*)

1839. Burm., "Handb. Ent.," ii., p. 578.

|| (*Spectrum.*)

1813. Stoll., "Spectres," p. 3. (Includes *M. gigas*, &c.)

EURYCNEMA.

1839. Serv., "Ins. Orth.," p. 235. (Types, *Cyphocrana semirubra*, and *versifasciata*, Serv.) Included by Westwood with *Cyphocrania*.

PLATYCRANA.

1835. Gray, "Syn. Phasm.," p. 36. (To include *Phasma viridana* and *maculata*, Oliv.; *hecticum*, Licht.; *Pl. punctata*, *affinis*, *rafflesii*, Gray; *Ph. rosea*, Stoll.; *Pl. annulipes*, Gray; *Ph. curvipes*, Stoll.; *jamaicensis*, Dru.; *reticulata*, Beauv.; *Pl. stollii*, and *rugicollis*, Gray.)

1839. Serv., "Ins. Orth.," p. 240. (To include *P. viridana* and *maculata*, and *venustula*, Serv.)

(*Platycrania.*)

1859. Westw., "Cat. Phasm.," p. 112. (To include *P. viridana* and allies.)

DIURA.

1833. Gray, "Ent. Austr.," p. 26. (To include *Phasma titan*, Macl.; and *D. chronus*, *japetus*, *typhœus*, *violascens* and *roseipenne*, Gray.)

(*Acrophylla.*)

1835. Gray, "Syn. Phasm.," p. 38.

1839. Serv., "Ins. Orth.," p. 231. (Types, *A. titan* and *chronus*).

CTENOMORPHA.

1833. Gray, "Ent. Austr.," p. 16. (Types, *C. spinicollis* and *marginipennis*, Gray. Included by Westwood with ACROPHYLLA (= *Diura*.)

PODACANTHUS.

1833. Gray, "Ent. Austr.," p. 26. (Type, *P. typhon*, Gray.)

Gen. ——— ?

||(*Phasma.*)

1825. St. Farg. and Serv., "Enc. Méth. Ent.," x., p. 100. (To include *Mantis necydaloides*, Linn., and allies).

NECROSCIA.

1839. Serv., "Ins. Orth.," p. 250. (Types, *N. fumata*, *roseipennis*, *chlorotisa*, *chloris*, *quadriguttata*, *vinosa*, and *vittata*, Serv.)

DINELYTRON.

1835. Gray, "Syn. Phasm.," p. 27. (Types, *D. hipponax* and *grylloides*, Gray.)

TROPIDODERUS.

1835. Gray, "Syn. Phasm.," p. 31. (Type, *T. childreni*, Gray.)

|| (*Trigonoderus.*)

1833. Gray, "Ent. Austr.," p. 26. (Type, *T. childreni*, Gray.)

PRISOPUS.

1825. St. Farg. and Serv., "Enc. Méth. Ent.," x., p. 444. (Types, *antis* *draco*, Stoll.; and *suorata*, Oliv.)

1839. Serv., "Ins. Orth.," p. 282. (Includes *Phasma flabelliformis*, Stoll. (= *sacreta*, Oliv.), and one other species.)

PLATYTELUS.

1835. Gray, "Syn. Phasm.," p. 28. (Type, *P. horridus*, Gray.) Included by Westwood with *Prisopus.*

EXTATOSOMA.

1833. Gray, "Ent. Austr.," p. 25. (Types, *E. hopei* and *tiaratum*, Gray.)

Agassiz writes *Ectatosoma.*

PHYLLIUM.

1798. Ill., "Käf. Preuss.," p. 499. (Type, *Mantis siccifolia*, Linn.)

|| (*Pteropus.*)

1815. Thunb., "Mém. Pétersb.," v., p. 219. (Type, *M. siccifolia.*)

ACHETA. Linn.

(GRYLLUS) ACHETA.

1758. Linn., "Syst. Nat.," ed. x., i., p. 428. (To include *G.* (*A.*) *gryllotalpa*, *domesticus*, *campestris*, and *umbraculatus*, Linn.)

1775. Fabr., "Syst. Ent." p. 279. (Includes Linné's first three species, and several others.)

1815. Leach, "Edinb. Enc.," ix., p. 119. (Type, *Gryllus campestris*, Linn.)

(*Liogryllus.*)

1877. Sauss., "Mém. Soc. Genève," xxv., p. 134. (Includes *G. campestris* and allies.)

CURTILLA.

1815. Oken., "Lehrb. Nat.," iii., p. 445. (Type, *Gryllus gryllotalpa*, Linn.)

(*Gryllotalpa.*)

1802. Latr., "Hist. Nat. Crust. Ins.," iii., p. 275. (Type, *Gryllus gryllotalpa*, Linn.) To be rejected, as founded on a specific name.

Gen. ——— ?

‖ (*Cylindrodes.*)

1832. Gray, "Griff. An. Kingd.," xv., p. 785. (Type, *C. campbelli*, Gray.)

HETEROPUS.

1805. Beauv., "Ins. Afr. Amer.," p. 231. (Type, *H. africanus* Beauv., = *paradoxus*, Latr.)

‖ (*Tridactylus.*)

1789. Oliv., "Enc. Méth. Ent.," iv., p. 26. (No type given.)
1802. Latr., "Hist. Nat. Crust. Ins.," iii., p. 276. (Type *T. paradoxus*, Latr.)

XYA.

1809. Latr., "Gen. Crust. Ins.," iv., p. 383.
1817. Latr., "Règne Anim.," iii., p. 378. (Type, *X. variegata*, Ill.)
(Walker includes this genus with *Tridactylus.*)

RIPIPTERYX.

1834. Newm., "Ent. Mag.," ii., p. 204. (Type, *R. marginatus*, Newm.)

(*Rhipipteryx.*)

1869. Walk., "Cat. Derm. Salt.," p. 8.
Agassiz writes *Rhipielopteryx.*

MYRMECOPHILA.

1829. Latr., "Règne Anim.," v., p. 183. (Type, *Blatta acervorum*, Panz.)

‖ (*Sphærium.*)

1825. Charp., "Hor. Ent.," p. 78. (Type, *Blatta acervorum*, Panz.)

SCHIZODACTYLUS.

1835. Brullé, "Hist. Nat. Ins.," ix., p. 162. (Type, *Gryllus monstrosus*, Dru.)

‖ (*Acheta.*)

1839. Burm., "Handb, Ent.," ii., p. 719. (Type, *G. monstrosus.*)

BRACHYTRUPES.

1839. Serv., "Ins. Orth.," p. 323. (Types, *Gryllus megacephalus*, Lef.; and *B. ustulatus*, Serv.)

(*Brachytrypes.*)

1846. Agassiz, "Nom. Zool. Ind. Univ.," p. 52.
1853. Fisch., "Orth. Eur.," p. 186. (Type, *G. megacephalus.*)

GRYLLUS.

1758. Linn., "Syst. Nat.," ed. x., i., p. 425. (Includes as subgenera *Mantis*, *Acrida*, *Bulla*, *Acheta*, *Tettigonia*, and *Locusta.*)
1761. Linn., "Faun. Suec.," ed. 2, p. 235. (15 species noticed, including *G. domesticus.* Several writers are quoted as having used the name *Gryllus* for this insect, which fixes it as the type, even if later authors had not usually taken *G. domesticus* (or its near ally, *G. campestris*, which, however, does not appear in Linné's earliest works) as the type of *Gry lus.*)

MOGOPLISTES.

1839. Serv., "Ins. Orth.," p. 357. (Type, *M. brunneus*, Serv.)

NEMOBIUS.

1839. Serv., "Ins. Orth.," p. 345. (Types, *Acheta sylvestris*, Fabr.; and *Gryllus lineolatus*, Brullé.)

ENEOPTERA.

1839. Burm., "Handb. Ent.," ii., p. 736. (Types, *Acheta brasiliensis*, Fabr.; and *livida*, Burm.)
1842. De Haan, Temminck's, "Verh. Nat. Gesch. Bezitt. Zool. Orth.," p. 231. (Restricted to *E. livida* and allies.)

PODOSCIRTUS.

1839. Serv., "Ins. Orth.," p. 361. (Type, *P. crocinus*, Serv.)

Gen. ——— ?

‖ (*Platydoctylus.*)

1835. Brullé, "Hist. Nat. Ins.," ix., p. 176. (Type, *Gryllus surinamensis*, De Geer.)

ŒCANTHUS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 134. (Types, *Acheta italica*, Fabr.; and *bipunctatus* and *niveus*, De Geer.)

Trigonidium.

1839. Ramb., "Faun. And.," ii., p. 39. (Type, *T. cicindeloides*, Ramb.)

1839. Serv., "Ins. Orth.," p. 349. (Types, *T. desjardinsii*, *longipenne*, and *paludicala*, Serv.; the last = *cicindeloides*.)

Phalangopsis.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 166. (Types, *P. longipes* and *annulipes*, Serv.)

Platyblemmus.

1839. Ramb., "Faun. And.," ii., p. 36. (Type, *P. lusitanicus* (Serv.), Ramb.)

1839. Serv., "Ins. Orth.," p. 352. (To include *P. velatus*, *lusitanicus*, and *ramburi*, Serv.; *Gryllus umbraculatus*, Linn.; and *P. delectus*, Serv.)

TETTIGONIA. Linn.

Listroscelis.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 160. (Type, *L. armata*, Serv.)

Cerberodon.

1832. Perty, "Del. Anim. Art.," p. 120. (Type, *C. viridis*, Perty.)

Anostostoma.

1837. Gray, Loudon's "Mag. Nat. Hist." (2), i., p. 141. (Type, *A. australasiæ*, Gray.)

Gryllacris.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 138. (Types, *Gryllus maculicollis*, Stoll., and *Gryllacris ruficeps* and *personata*, Serv.)

Stenopelmatus.

1839. Burm., "Handb. Ent.," ii., p. 720. (Types, *S. erinaceus*, *talpa*, *dregii*, *pattersonii* and *portentosus*, Burm.)

Rhaphidophora.

1839. Serv., "Ins. Orth.," p. 389. (Type, *R. piceæ*, Serv.)

HETRODES.

1833. Fisch., "Ann. Soc. Ent. France," ii., p. 318. (Type, *Gryllus pupa*, Linn.)

EUGASTER.

1839. Serv., "Ins. Orth.," p. 463. (Types, *Hetrodes* (*Eugaster*) *abortiva* and *guyoni*, Serv.)

BRADYPORUS.

1825. Charp., "Hor. Ent.," p. 96. (Type, *Locusta dasypus*, Ill.)

(*Dinarchus*.)

1874. Stål., "Rec. Orth.," ii., pp. 7, 24. (Type, *L. dasypus*, Ill.)

CALLIMENUS.

1830. Fisch., "Notice sur le *Tettigopsis*," p. 14. (Type, *C. obesus*, Stev.)

1833. Fisch., "Ann. Soc. Ent. France," ii., p. 317. (Type, *C. obesus*.)

|| (*Derarantha*.)

1833. Fisch., "Bull. Mosc.," vi., p. 375. (Includes *Locusta onos*, Pall.; and *D. cinctus*, *camelus*, *antilope*, and *aranea*, Fisch.)

(*Callimus*.)

1833. Fisch., "Bull. Mosc.," vi., p. 374. (Type, *C. obesus*, Stev., = *Bradyporus oniscus*, Charp.)

|| (*Bradyporus*.)

1839. Serv., "Ins. Orth.," p. 497. (Type, *L. dasypus*, Serv. (*nec* Ill.), = *oniscus*, Charp.)

1869. Walk., "Cat. Derm. Salt.," ii., p. 233. (Restricted to *L. onos* and allies.)

ONCONOTUS.

1839. Fisch., "Bull. Mosc.," 1839., p. 106. (Type, *Locusta laxmanni*, Pall.)

|| (*Bradyporus*.)

1839. Burm., "Handb. Ent.," ii., p. 677. (Restricted to *Locusta laxmanni* and *onos*, Pall., and *L. marginatus*, Fabr.)

Gen. ——— ?

|| (*Barbitistes.*)

1839. Ramb., "Faune And.," ii., p. 53. (Type, *B. baetica*, Ramb.)

Gen. ——— ?

(*Ephippigera.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 165. (Type, *E. vitium* Serv., = *Locusta ephippigera*, Fabr.)

(*Ephippiger.*)

1839. Serv., "Ins. Orth.," p. 473. To be rejected as based on a specific name, a principle never recognized in Entomology.

Acripeza.

1830. Guér., "Voy. Coq.," ii., p. 152. (Types, *A. reticulata* and *pectinata*, Guér.)

1839. Serv., "Ins. Orth.," p. 546. (Type, *A. reticulata.*)

(*Acridopeza.*)

1839. Burm., "Handb. Ent.," ii., p. 683.

Odontura.

1839. Ramb., "Faun. And.," ii., p. 44. (To include *O. spinulicauda* and *aspericauda*, Ramb.; *Locusta serricauda*, Hag.; and *Barbitistes denticauda*, *scutatus*, and *glabricauda*, Charp.).

|| (*Barbitistes.*)

1839. Burm., "Handb. Ent.," ii., p. 681. (To include *Locusta serricauda*, Fabr.; *B. glabricauda*, Charp.; *L. autumnalis*, Hagenb.; and *B. scutatus*, Charp.)

Pterolepis.

1839. Ramb., "Faun. And.," ii., p. 59. (Type, *P. spoliata*, Ramb.)

Thyreonotus.

1839. Serv., "Ins. Orth.," p. 495. (Types, *T. semiæneus* and *corsicus*, Serv.)

Barbitistes.

1825. Charp., "Hor. Ent.," p. 98. (Includes 8 species, of which *B. denticauda*, Charp., described in great detail, and figured, is certainly to be regarded as the type.)

PHOLIDOPTERA.

1838. Wesm., "Bull. Acad. Brux.," v., p. 592. (Type, *Locusta aptera*, Fabr.)

(*Olynthoscelis.*)

1839. Fisch., "Bull. Mosc.," 1839, p. 110. (Types, *Locusta aptera* and *serricauda*, Charp.; and *Barbitistes denticauda* and *autumnalis*, Charp.)

|| (*Micropteryx.*)

1835. Steph., "Ill. Brit. Ent., Mand.," vi., p. 12. (To include *Locusta aptera*, Fabr.; *rœselii*, Hag.; and *Gryllus brachypterus*, Linn.)

|| (*Pterolepis.*)

1839. Serv., "Ins. Orth.," p. 491. (Types, *Locusta chabrieri*, Charp.; *Pt. ramburi*, Serv.; *L. aptera*, Fabr.; and *Pt. armillata*, Serv.)

(*Thaumotrizon.*)

1853. Fisch., "Orth. Eur.," p. 261. (Types, *Locusta aptera*, Fabr.; *chabrieri*, Charp.; *transylvanicus* and *fallax*, Fisch., and *cinereus*, Zett.)

PSORODONOTUS.

1861. Brunn., Watt, "Verh. Zool.-bot. Ges., Wien.," xi., p. 291. (Type, *P. pancici*, B. W.; ? = *Peltastes venosa*, Fisch.)

|| (*Peltastes.*)

1839. Fisch., "Bull. Mosc.," 1839, p. 111. (Types, *P. venosus*, *specularis*, and *hastatus*, Fisch.)

METRIOPTERA.

1833. Wesm., "Bull. Acad. Brux.," v., p. 592. (Type, *Gryllus brachypterus*, Linn.)

|| (*Micropteryx.*)

1839. Westw., "Mod. Class. Ins.," ii., Syn., p. 45. (Type, *G. brachypterus.*)

(GRYLLUS) TETTIGONIA.

1758. Linn., "Syst. Nat.," ed. x., i., p. 429. (Includes *G. T. citrifolius*, *laurifolius*, *myrtilfolius*, *elongatus*, *lamellatus*, *ocellatus*, *acuminatus*, *triops*, *rugosus*, *coronatus*, *aquilinus*, *melanopterus*, *fastigiatens*, *coriaceus*, *viridissimus*, *verrucivorus*, *pupus*, Linn.)

1767. Linn., "Syst. Nat.," ed. xii., i. (2), p. 695. (Same types, with addition of *G.* (*T.*) *conocephalus* and *cinerarius*, Linn.)
1781. Schrank, "Enum. Ins. Aust.," p. 244. (Types, *T. viridissimus* and *verrucivorus*, L.; and *falcatus*, Poda.) (No later author having used the name, either *G. viridissimus* or *verrucivorus* must be regarded as the type; but the earliest admissible genus proposed for either species is *Phasgomera* of Stephens, which leaves *G. verrucivorus* as the type of *Tettigonia*.)

(*Decticus.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 155. (To include *Gryllus verrucivorus*, Linn.; *Locusta grisea*, Fabr.; *tessalata* and *maculata*, Charp.)
1839. Westw., "Mod. Class. Ins.," ii., Syn., p. 45. (Type, *G. verrucivorus.*)

(*Chelidoptera.*)

1838. Wesm., "Bull. Acad. Brux.," v., p. 591. (Types, *G. verrucivorus* and *L. grisea.*)

Anisoptera.

1829. Latr., "Règne Anim.," ed. 2, v., p. 184, note. (Types, *Locusta dorsalis*, Charp.; and *brachyptera*, L.)
1833. Fisch., "Bull. Mosc.," vi., p. 372. (Type, *L. dorsalis.*) Subsequently rejected by Serville as probably = *Decticus.*

Orchelimum.

1839. Serv., "Ins. Orth.," p. 522. (Types, *O. cuticulare*, *glaucum*, and *herbaceum*, Serv.)

Xiphidion.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 159. (Types, *Locusta fusca*, Fabr.; and *fasciata*, De Geer.)
1835. Steph., "Ill. Brit. Ent., Mand.," vi., p. 13. (Types, *Locusta fusca*, Fabr.; and *dorsalis*, Latr.)
1839. Serv., "Ins. Orth.," p. 505. (Types, *L. fusca*, Fabr.; and *X. iris*, Serv.)
1839. Westw., "Mod. Class. Ins.," ii., Syn., p. 45. (Type, *L. fusca.*)

(*Xiphidium.*)

1839. Burm., "Handb. Ent.," ii., p. 707.

(*Conocephalus.*)

1815. Thunb., "Mém. Pétersb.," v., p. 271. (Type, *C. hemipterus*, Thunb. (= *Gryllus conocephalus*, Linn.), but includes also 24 other species.) Later authors appear to have overlooked Thunberg's type; and the genus, being founded on a doubtful specific name, has no claim to stand.

MECONEMA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 157. (Type, *Locusta varia*, Fabr.)

PHASGONURA.

1835. Steph., "Ill. Brit. Ent., Mand.," vi., p. 15. (Type, *Gryllus viridissimus*, Linn.)

|| (*Locusta.*)

1762. Geoffr., "Hist. Ins.," i., p. 396. Includes *Gryllus viridissimus* and *verrucivorus.*)

1775. Fabr., "Syst. Ent.," p. 282. (25 species, including those of Geoffroy.)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 151. (Type, *G. viridissimus.*)

|| (*Conocephalus.*)

1817. Sam., "Comp.," p. 218. (Type, *Gryllus viridissimus.*)

|| (*Acrida.*)

1825. Curt., "Brit. Ent.," iii., pl. 82. (Type, *G. viridissimus.*)

HEXACENTRUS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 145. (Type, *H. unicolor*, Serv.) Subsequently rejected by Serville as synonymous with his *Locusta* (= *Phasgonura*).

SAGA.

1825. Charp., "Hor. Ent.," p. 95. (Type, *Locusta serrata*, Fabr.)

(*Tettigopsis.*)

1830. Fisch., "Notice sur le Tettigopsis," p. 15. (Types, *Gryllus pedo*, Pall.; *Locusta serrata*, Fabr.; and *T. nudipes* and *vittata*, Fisch.)

AGRÆCIA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 152. (Type, *Locusta punctata*, St. Farg. and Serv.)

EXOCEPHALA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 160. (Types, *Locusta bisulca*, St. Farg. and Serv.; and *falconaria*, De Geer.)

Gen. ——— ?

|| (*Conocephalus.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 148. (Types *C. flavescens*, Serv.; *Locusta xiphias*, St. Farg. and Serv.; *maxillosa*, Fabr.; *mandibularis*, Charp.; *acuminata*, Fabr.; and *cornuta*, De Geer.)

1839. Serv., "Ins. Orth.," p. 514. (For 9 species, including *L. xiphias* and *mandibularis.*)

BUCRATES.

1839. Burm., "Handb. Ent.," ii., p. 708. (Type, *Locusta capitatus*, De Geer.)

PSEUDORHYNCHUS.

1839. Serv., "Ins. Orth.," p. 509. (Types, *Locusta lanceolata*, Fabr.; *Conocephalus flavescens* and *P. lessonii*, Serv.)

COPIPHORA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 147. (Type, *C. longicauda*, Serv.) Agassiz writes *Copidophora.*

(*Copiophora.*)

1839. Burm., "Handb. Ent.," ii., p. 702.

Gen. ——— ?

|| (*Megalodon.*)

1835. Brullé, "Hist. Nat. Ins.," ix., p. 157. (Type, *M. ensifer*, Brullé.)

PHANEROPTERA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 158. (Types, *Locusta lilifolia*, Fabr.; and *curvicauda*, De Geer.)

1839. Serv., "Ins. Orth.," p. 413. (It is important to note that the types are here placed in the second division of the genus.)

EPHIPPITYTHA.

1839. Serv., "Ins. Orth.," p. 422. (Types, *Phaneroptera trigintiduo-guttata*, *irrorata*, *zebrata*, and *acanthocephala*, Serv.)

ANCYLECHA.

1839. Serv., "Ins. Orth.," p. 411. (Type, *A. lunuligera*, Serv.)

LEPTODERES.

1838. Serv., "Ins. Orth.," p. 409. (Type, *L. ornatipennis*, Serv.)

PHYLLOPTERA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 142. (Types, *Locusta myrtifolia* and *laurifolia*, Fabr., and *casinæfolia* and *bicordata*, St. Farg. and Serv.)

PYCNOPALPA.

1839. Serv., "Ins. Orth.," p. 408. (Type, *Locusta bicordata*, St. Farg. and Serv.)

STEIRODON.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 140. (Includes *Locusta citrifolia*, Fabr.; *prasinus*, Stoll.; and *S. thoracicus*, Serv.)
1839. Burm., "Handb. Ent.," ii., p. 694. (Restricted, as a sub-genus of *Phylloptera*, to *L. citrifolia*.)

SCAPHURA.

1825. Kirb., "Zool. Journ.," i., p. 432. (Type, *S. vigorsii*, Kirb.)

GYMNOCERA.

1835. Brullé, "Hist. Nat. Ins.," ix., p. 146. (Type, *G. lefeburii*, Brullé.)

CYRTOPHYLLUS.

1839. Burm., "Handb. Ent.," ii., p. 697. (Types, *Locusta perspicillaris*, Fabr., and *hypericifolius*, Stoll.)

|| (*Platyphyllum.*)

1869. Walk., "Cat. Derm. Salt.," ii., p. 397. (Types as above.)

PSEUDOPHYLLUS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 143. (Type, *Gryllus* (*Tettigonia*) *neriifolius*, Stoll.)

Gen. ——— ?

|| (*Aprion.*)

1839. Serv., "Ins. Orth.," p. 471. (Type, *A. virescens*, Serv.)

PLATYPHYLLUM.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 145. (Type, *Locusta viridifolia*, St. Farg. and Serv.)

1839. Serv., "Ins. Orth.," p. 443. (Used in an extended sense, and including the type of *Cyrtophyllus*, Burm.)

(*Platyphyllus.*)

1839. Burm., "Handb. Ent.," ii., p. 699.

‖ (*Thliboscelus.*)

1839. Serv., "Ins. Orth.," p. 441. (Type, *Locusta camellifolia*, Fabr. (nec De Geer), which = *viridifolia*, sec. Burm.)

PHYLLOPHORA.

1815. Thunb., "Mém. Pétersb.," v., p. 219. (Types, *Locusta citrifolia*, F., and *speciosa*, Thunb.)

1839. Burm., "Handb. Ent.," ii., p. 694. (Restricted to *P. speciosa.*)

(*Hyperhomala.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 161. (Type, *H. virescens*, Serv., = *speciosa*, Thunb.)

(*Hyperomala.*)

1839. Serv., "Ins. Orth.," p. 544.

ASPIDONOTUS.

1835. Brullé, "Hist. Nat. Ins.," ix., p. 143. (Type, *A. spinosus*, Brullé.)

POMATONOTA.

1839. Burm., "Handb. Ent.," ii., p. 683. (Type, *P. dregii*, Burm.)

STRONGYLODERUS.

1834. Westw., "Zool. Journ.," v., p. 443. (Type, *S. serraticollis*, Westw.)

POLYANCISTRUS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 153. (Type, *Locusta serrulata*, Beauv.)

MERONCIDIUS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 149. (Type, *M. obscurus*, Serv.)

Acanthodis.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 150. (Types, *Locusta fenestrata, femorata, specularis*, and *coronata*, Fabr.; and *aquilina* and *vulturina*, De Geer.)

1839. Burm., "Handb. Ent.," ii., p. 699. (The typical section restricted to *L. coronata, aquilina*, and allies.)

1870. Walk., "Cat. Derm. Salt.," iii., p. 455. (Type, *Gryllus coronatus*, Linn.)

Mecopoda.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 154. (Type, *M. maculata*, Serv.)

Pterochroza.

1831. Serv., "Ann. Sci. Nat.," xxi., p. 144. (Type, *Locusta ocellata*, Fabr.)

Cycloptera.

1839. Serv., "Ins. Orth.," p. 439. (Type, *Gryllus* (*Tettigonia*) *aurantifolia*, Stoll.)

Typophyllum.

1839. Serv., "Ins. Orth.," p. 439. (Type, *Gryllus* (*Tettigonia*) *erosa*, Stoll.)

Gen. ——— ?

‖ (*Prochilus.*)

1831. Brullé, "Hist. Nat. Ins.," ix., p. 135. (Type, *P. australis*, Brullé.)

ACRIDA, LOCUSTA, and BULLA. Linn.

Proscopia.

1820. Klug, "Hor. Phys. Berol.," p. 15. (For 15 new species, including *P. gigantea, spinosa, granulata*, &c.)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 265. (Type, *P. gigantea*, Klug.)

Cephalocœma.

1839. Serv., "Hist. Orth.," p. 577. (Type, *Proscopia pica*, Serv.)

(Gryllus) Acrida.

1758. Linn., "Syst. Nat.," ed. x., i., p. 427. (Types, *G. A. nasutus* and *turritus*, Linn.)

(*Truxalis.*)

1815. Leach, "Edin. Enc.," ix., p. 120. (Type, *G. nasutus*, Linn.)

TRUXALIS.

1775. Fabr., "Syst. Ent.," p. 279. (Types, *G. nasutus*, *tauricus*, and *brevicornis*, Linn.)

1873. Stål., "Recens. Orth.," i., p. 104. (Type, *G. brevicornis*, Linn.) Many authors write *Tryxalis.*

PYRGOMORPHA.

1839. Serv., "Ins. Orth.," p, 583. (Types, *Truxalis crenulatus*, Fabr.; and *rosea*, Charp.)

MESOPS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 267. (Type, *Truxalis abbreviatus*, Beauv.)

OPSHOMALA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 267. (Type, *O. viridis*, Serv.)

(*Opsomala.*)

1839. Burm., "Handb. Ent.," ii., p. 611. Agassiz writes *Opomala.*

COPIOCERA.

1839. Burm., "Handb. Ent.," ii., p. 610. (Types, *Gryllus euceros*, Marsch.; and *Xiphocera erythrogastra*, Perty.) Agassiz writes *Copidocera.*

Gen ——— ?

‖ (*Xiphicera.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 271. (Types, *X. emarginata* and *trilineata*, Serv.)

(*Xiphocera.*)

1839. Burm., "Handb. Ent.," ii., p. 612.

TROPINOTUS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 272. (Types, *Gryllus serratus*, Fabr., and *T. discoidena*, Serv.)

ACICERA.

1839. Burm., "Handb. Ent.," ii., p. 616. (Includes *A. grisea.*)

(*Akicera.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 268. (Type, *A. grisea*, Serv.)

1839. Serv., "Ins. Orth.," p. 603. (The type is placed in the second division of the genus.)

PAMPHAGUS.

1815. Thunb., "Mém. Pétersb.," v., p. 260. (To include *Gryllus serratus*, *serripes*, *elephas*, *gallinacens*, *reticulatus*, and *turcicus*, Fabr.; and *P. lateralis*, *canescens*, *fuscus*, and *vitreus*, Thunb.)

1839. Burm., "Handb. Ent.," ii., p. 615. (For 6 species, including *G. serripes*, Fabr. (= *canescens*, Thunb.) which thus becomes the type.)

(*Porthetis.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 270. (Type, *Acrydium dentatum*, De Geer, = *Gryllus serripes* and *elephas*, Fabr.) (Stoll., "Recens. Orth.," i., p. 25, incorrectly regards *G.* (*L.*) *elephas*, Linn. (nec Fabr.), as the type of *Pamphagus*, applying the name *Porthetis* to *P. carinatus*, Linn. (= *dentatum*, De Geer) and allies.)

ACINIPE.

1839. Ramb., "Faun. And.," ii., p. 68. (Types, *A. hesperica* and *monticola*, Ramb.)

|| (*Porthetis.*)

1853. Fisch., "Orth. Eur.," p. 381. (Includes Rambur's types of *Acinipe*, and some allied species.)

RHOMALEA.

1839. Burm., "Handb. Ent.," ii., p. 619. (Types, *R. giganteus*, Burm.; and *Gryllus centurio* (= *G. microptorum*, Beauv.) and *miles*, Dru.)

(*Romalea.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 280. (Type, *Acrydium micropterum*, Beauv.) Stål. (Recens. Orth., p. 51) improperly restricts this name to *Gryllus speciosus*, Thunb. (= *miles*, Dru.)

PHYMATEUS.

1815. Thunb., "Mém. Pétersb.," v., p. 257. (Types, *Gryllus morbillosus*, *miliaris*, *scabiosus*, *leprosus*, *cinctus*, and *punctatus*, Fabr.)

1839. Serv., "Ins. Orth.," p. 624. (Restricted to *G. morbillodrus*, *scabiosus*, *leprosus*, and *punctatus*.)

RUTIDODERES.

1837. Westw., Drury, "Ill. Ex. Ent.," i., p. 119. (Type, *Gryllus squarrosus*, Dru.) (Probably synonymous with *Phymateus*.)

PŒCILOCERA.

1839. Burm., "Handb. Ent.," ii., p. 621. (Includes Serville's types, and many other species.)

(*Pœkilocerus.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 275. (Types, *Acrydium sanguinolentum*, De Geer; and *P. sonneratii* and *roseipennis*, Serv.)

DICTYOPHORUS.

1815. Thunb., "Mém. Pétersb.," v., p. 258. (Types, *D. sponsus*, *papillosus*, and *reticulatus*, Thunb.)

‖ (*Petasia.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 278. (Types, *P. cruentata*, = *spumans*, Thunb., and *olivacea*, Serv.)

TRYBLIOPHORUS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 274. (Type, *T. octomaculatus*, Serv.)

TERATODES.

1835. Brullé, "Hist. Nat. Ins.," ix., p. 222. (Type, *Gryllus monticollis*, Gray.)

MONACHIDIUM.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 281. (Type, *M. flavipes*, Serv.,

DERICORYS.

1839. Serv., "Ins. Orth.," p. 638. (Type, *D. albidula*, Serv.)

Gen. ——— ?

‖ (*Acridium.*)

1831. Serv., "Ann. Sci. Nat.," xxii., p. 282. (Includes *Gryllus tataricus*, Linn, &c.)

OXYA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 286. (Type *O. hyla*, Serv.)

CALLIPTAMUS.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 284. (To include *Acrydium æneo-oculatum*, De Geer; *Gryllus italicus*, Linn.; and *morio*, Fabr.)

1839. Serv., "Ins. Orth.," p. 686.

(*Caloptenus.*)

1839. Burm., "Handb. Ent.," ii., p. 637. (5 species, including *G. italicus*, which thus becomes the type.) Agassiz writes *Caliptenus*.

OMMATOLAMPIS.

1839. Burm., "Handb. Ent.," ii., p. 636. (Types, *Acridium variegatum*, De Geer; *O. nodicellis* and *perspicillata*, Burm.; and *Gryllus minutissimus*, Linn.)

PODISMA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 289. (Types, *Gryllus pedestris*, Linn., and *giornæ*, Charp.)

1835. Steph., "Ill. Brit. Ent., Mand.," vi., p. 29. (Type, *G. pedestris*.)

(GRYLLUS) LOCUSTA.

1758. Linn., "Syst. Nat." ed. x., i., p. 431. (20 species mentioned, including *L. migratoria*, Linn.)

1781. Schrank, "Enum. Ins. Austr.," p. 246.

1819. Sam., "Comp.," p. 218. (Type, *L. migratoria*.)

|| (*Gryllus*).

1775. Fabr., "Syst. Ent.," p. 287. (Includes the Linnean types of *Locusta*.)

|| (*Acrydium*).

1802. Latr., "Hist. Nat. Crust. Ins.," iii., p. 282. (Includes the Linnean types of *Locusta*.)

ŒDIPODA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 287. (10 species mentioned, including *Gryllus migratorius* and *cærulescens*, Linn.)

1839. Serv., "Ins. Orth.," p. 718.

(*Eusternum.*)

1838. Wesm., "Bull. Acad. Brux.," v., p. 596. (Type *G. cærulescens*, Linn.)

ARCYPTERA.

1839. Serv., "Ins. Orth.," p. 743. (Types, *Gryllus variegatus*, Sulz.; and *parallelus*, Zett.) Agassiz writes *Arcyoptera.*

GOMPHOCERUS.

1815. Thunb., "Mém. Pétersb.," v., p. 221. (Types, *Gryllus rufus*, Linn.; and 3 others.)

1819. Sam., "Comp.," p. 219. (Type, *G. rufus.*)

PHLOCERUS.

1833. Fisch., "Notice sur le *Phlocerus*," p. 15. (Type, *P. menetriesii*, Fisch.)

Gen. ——— ?

|| (*Mastax.*)

1833. Perty, "Del. Anim. Art.," p. 122. (Type, *M. tenuis*, Perty.)

CHROTOGONUS.

1839. Serv., "Ins. Orth.," p. 702. (Type, *C. lugubris*, Serv.)

THRINCHUS.

1833. Fisch., "Bull. Mosc.," vi., p. 378. (Types, *T. campanulatus*, *turritus*, and *accessorius*, Fisch., and *muricatus*, Pall.)

|| (*Eremobia.*)

1839. Serv., "Ins. Orth.," p. 704. (Types, *Gryllus carinatus* and *cisti*, Fabr., and *E. continuata*, *pulchripennis* and *flexuosa*, Serv.) (Synonymous with *Thrinchus.*)

BATRACHOTETRIX.

1839. Burm., "Handb. Ent.," ii., p. 660. (Types, *B. bufo*, Burm., and *Acrydium granulatum*, Herbst.)

XIPHICERA.

1817. Lam., "Anim. sans Vert.," iv., p. 243. (Types, *Gryllus gallinaceus* and *serripes*, Fabr.; the latter being the type of *Pamphagus*, *G. gallinaceus* becomes the type of *Xiphicera.*)

PHYLLOCHOREIA.

1839. Westw., "Mag. Nat. Hist." (2), iii., p. 495. (Type, *P. unicolor*, Westw.) Probably congeneric with *Xiphicera.*

CHOROTYPUS.

1839. Serv., "Ins. Orth.," p. 751. (Type, *C. fenestratus*, Serv.) (Regarded by Walker as congeneric with *Phyllochoreia.*)

OMMEXECHA.

1831. Serv., "Ann. Sci. Nat.," xxii., p. 285. (Type, *O. virens*, Serv.)

(GRYLLUS) BULLA.

1758. Linn., "Syst. Nat.," ed. x., i., p. 427. (Includes *G.* (*B.*) *unicolor*, *variolosus*, *serratus*, *carinatus*, *bipunctatus* and *subulatus*, Linn.) (The only species to which the name is fully applicable is *G. B. variolosus*, which must therefore be considered as the type; besides Schrank's use of the name for *G.* (*B.*) *bipunctatus* is subsequent to the establishment and restriction of the genus *Acrydium*.)

PNEUMORA.

1775. Thunb., "Vet. Acad. Handl.," xxxvi., p. 254 (1775). (Types, *P. immaculata*, *maculata*, and *sexguttata*, Thunb.)
1802. Latr., "Hist. Nat. Crust. Ins.," iii., p. 281. (Types, *P. inanis*, *papillosa*, and *variolosa*, Oliv.)
1839. Serv., "Ins. Orth.," pp. 710–717. (Type, *Gryllus variolosus*, Linn., = *maculata*, Thunb.)

CYSTOCŒLIA.

1839. Serv., "Ins. Orth.," p. 713. (Types, *Pneumora scutellaris*, Latr., and *Gryllus inanis* and *papillosus*, Fabr.)

ACRYDIUM.

1762. Geoffr., "Hist. Ins.," i., p. 390. (6 species described.)
1775. Fabr., "Syst. Ent.," p. 278. (Types, *Gryllus bipunctatus* and *subulatus*, Linn.; Geoffroy's Nos. 5 and 6.)
1815. Leach, "Edinb. Enc.," ix., p. 120. (Type, *G. subulatus*.) Agassiz writes *Acridium*.

(*Tetrix*.)

1802. Latr., "Hist. Nat. Crust. Ins.," iii., p. 284. (Types, *Gryllus* (*Bulla*), *bipunctatus* and *subulatus*, Linn.; which are now considered conspecific.)

(*Tettix*.)

1846. Fisch., "Orth. Russ.," p. 347.

|| (*Bulla*.)

1781. Schrank, "Enum. Ins. Austr.," p. 242. (Types, *G.* (*B.*) *bipunctatus*, Linn., and *xyphothyreus*, Schrank.)

BATRACHIDEA.

1839. Serv., "Ins. Orth.," p. 764. (Types, *Tetrix mucronata*, St. Farg. and Serv., and *Gryllus bipunctatus*, Linn.) The latter being the type of *Acrydium*, *T. mucronatus*, if not congeneric, remains as the type of *Batrachidea*.

SCELIMENA.

1839. Serv., "Ins. Orth.," p. 762. (Types, *Tetrix producta*, *harpago* and *uncinnata*, Serv.)
Agassiz writes *Scelymena*.

AMORPHOPUS.

1839. Serv., "Ins. Orth.," p. 756. (Type, *A. notabilis*, Serv.)

TRIPETALOCERA.

1834. Westw., "Zool. Journ.," v., p. 444. (Type, *T. ferruginea*, Westw.)

CHORIPHYLLUM.

1839. Serv., "Ins. Orth.," p. 754. (Type, *C. sagrai*, Serv.)
Agassiz writes *Chorophyllum*.

HYMENOTES.

1837. Westw., "P. Z. S.," 1837, p. 130. (Types, *Cicada rhombea*, Linn., and *H. triangularis*, Westw.)
1871. Walk., "Cat. Derm. Salt.," v., p. 846. (Restricted to *H. triangularis*, and 2 other species.)

[BIBLIOGRAPHY.

BIBLIOGRAPHY.

LIST OF AUTHORS QUOTED, ARRANGED IN CHRONOLOGICAL ORDER.

(*A few which have not been verified at first-hand are marked with an asterisk.*)

1758. Linné, ... "Systema Naturæ," ed. x., i.

1761. Linné, ... "Fauna Suecica," ed. ii.

1762. Geoffroy, ... "Histoire abregée des Insectes qui se trouvent aux environs de Paris," i.

1767. Linné, ... "Systema Naturæ," ed. xii., i. (2).

1775. Fabricius, ... "Systema Entomologiæ."

1775. Thunberg, ... "Kongl Vetenskaps Academicus Handlingar," xxxvi.

1781. Schrank, ... "Enumeratio Insectorum Austriæ indigenorum."

1783. Retzius, ... "Caroli De Geer, Genera et Species Insectorum."

1789. Olivier, ... "Encyclopédie Méthodique, Histoire Naturelle," iv.

1798. Fabricius, ... "Supplementum Entomologiæ Systematicæ."

1798. Illiger, ... "Kugelann's Verzeichniss der Käfer Preussens."

1802. Latreille, ... "Histoire naturelle, générale et particulière, des Crustacés et des Insectes," iii.

1805 (?) Palisot de Beauvois,... "Insectes recueillis en Afrique et en Amérique."

1809. Latreille, ... "Genera Crustaceorum et Insectorum," iii.

1813. Stoll., ... "Representation des Spectres ou Phasmes," &c.

1815. Leach, ... "Edinburgh Encyclopedia," ix.

1815. Thunberg, ... "Mémoires de l'Academie des Sciences de St. Pétersbourg," v.

1815.	Oken.,	"Lehrbuch der Naturgeschichte," iii.
1817.	Samouelle,	"Entomologist's Useful Compendium."
1817.	Latreille,	"Cuvier's Règne Animal."
1817.	Lamarck,	"Histoire Naturelle des Animaux sans Vertèbres."
*1820.	Klug,	"Horæ physicæ Berolinensis."
1825.	St. Fargeau & Serville,	"Encyclopédie Méthodique, Histoire Naturelle," x.
1825.	Charpentier,	"Horæ Entomologicæ."
1825.	Curtis,	"British Entomology," iii.
1825.	Kirby,	"Vigors' Zoological Journal," i.
1829.	Latreille,	"Cuvier's Règne Animal," ed. ii.
1830.	Guérin-Méneville,	"Voyage de la Coquille" (Duperrey), ii.
1830.	Fischer de Waldheim,	"Notice sur le Tettigopsis."
1831.	Serville,	"Annales des Sciences Naturelles," xxii.
1832.	Boisduval,	"Voyage de l' Astrolabe" (Dumont d' Urville).
1832.	Gray,	"Griffith's Animal Kingdom," xv.
1832.	Fischer de Waldheim,	"Bulletin de la Soc. Imp. des Naturalistes de Moscou," v.
1833.	Perty,	"Delectus Animalium Articulatorum."
1833.	Fischer de Waldheim,	"Bull. Soc. Nat. Moscou."
1833.	Fischer de Waldheim,	"Annales de la Société Entomologique de France," ii.
*1833.	Fischer de Waldheim,	"Notice sur le *Phlocerus*."
1833.	Gray,	"Entomology of Australia."
1834.	Newman,	"Entomological Magazine," ii.
1834.	Westwood,	"Vigors' Zoological Journal," v.
*1835.	Brullé,	"Histoire Naturelle des Insectes," ix.
1835.	Gray,	"Synopsis of the Species of *Phasmidæ*."
1835.	Lefebvre,	"Annales de la Soc. Ent. de France," iv.
1835.	Stephens,	"Illustrations of British Entomology: *Mandibulata*," vi.
1837.	Gray,	"Loudon's Magazine of Natural History" (2), i.

1837. Westwood, ... "Drury's Illustrations of Exotic Entomology," i.
1837. Westwood, ... "Proceedings of the Zoological Society of London."
1838. Wesmael, ... "Bulletin de l'Academie des Sciences de Bruxelles."
1838. Newman, ... "Entomological Magazine," v.
1839. Burmeister, ... "Handbuch der Entomologie," ii.
1839. Fischer de Waldheim, "Bull. Soc. Nat. Moscou."
1839. Rambur, ... "Faune Entomologique de l' Andalusie," ii.
1839. Westwood, ... "Introduction to the Modern Classification of Insects."
1839. Westwood, ... "Loudon's Magazine of Nat. Hist." (2), iii.
1839. Serville, ... "Histoire Naturelle des Insectes Orthoptères."

WORKS SUBSEQUENT TO 1839 REFERRED TO.

1842. De Haan, ... Temminck's "Verhandelingen over de Natuurlijke Geschiedenis der Nederlandsche overzeesche Bezittingen."
1846. Fischer de Waldheim, "Orthoptères de la Russie."
1846. Agassiz, ... "Nomenclator Zoologicus," et "Index Universalis."
1853. Fischer (L. H.), ... "Orthoptera Europæa."
1859. Westwood, ... "Catalogue of Orthopterous Insects in the Collection of the British Museum," pt. i. *Phasmidæ.*
1861. Brunner de Wattenwyl, "Verhandlungen der k. k. zoologisch-botanischen Gesellschaft in Wien," xi.
1865. Brunner de Wattenwyl, "Nouveau Système des Blattaires."
1869–1871. Walker, ... "Catalogue of the Specimens of Dermaptera Saltatoria in the Collection of the British Museum," i.–v.

1869.	Saussure,	... ...	"Mittheilungen der schweizerischen entomologischen Gesellschaft," iii.
1871.	Saussure,	... ...	"Mémoires de la Société de Physique et d'Histoire Naturelle de Genève," xxii.
1873–1875.	Stål.,	... ...	"Recensio Orthopterorum," i.–iii.
1877.	Saussure,	... ...	"Mémoires de la Société de Physique et d'Histoire Naturelle de Genève," xxv.
1877.	Scudder,	... ..	"Proceedings of the Boston Society of Natural History," xviii.

LVI.

ON A HELIOSTAT FOR THE SMITHSONIAN INSTITUTION, WASHINGTON. By SIR HOWARD GRUBB, F.R.S., an Hon. Secretary of the Royal Dublin Society. (Plate XIII.)

[Read January 15, 1890.]

In a large heliostat which I have recently made for the Smithsonian Institution of Washington, I have introduced some modifications which may possibly be interesting to Members of the Royal Dublin Society. Some of them were designed to meet certain peculiar conditions imposed upon me in the contract, and some were introduced in the hope of improving the efficiency of an instrument which from its necessarily unmechanical construction is unlikely ever to take rank as an instrument of precision.

The heliostat, or siderostat as it is sometimes called, is, as its name implies, an instrument carrying a mirror or mirrors which reflect the rays from any celestial object in a constant direction, irrespective of the apparent motion of that object due to the diurnal rotation of our earth.

There are many forms given to these instruments according to the various uses to which they are intended to be applied; but all these modifications may be classified into two essentially different forms, viz. the double mirror and the single mirror heliostat.

The double mirror heliostat is a comparatively simple instrument. It consists essentially of an axis carrying a mirror at one end, the axis being mounted precisely parallel to the axis of our earth, similarly to the polar axis of any equatorial instrument.

This mirror is so set as to reflect the light from the object under examination in the direction of the axis itself, *i.e.* towards the north or south pole. If now in the direction of this axis another mirror be placed capable of being set to any position, the light from the celestial object can be directed into the desired position, in which position it will remain constant so long as the polar axis is kept rotating at the same rate as our earth, and in an opposite direction.

The simplicity of this arrangement is so great that it would no doubt be invariably adopted were it not that the second reflection causes some additional loss of light, which, for some purposes of research, is undesirable.

The single mirror heliostat is a much more complicated instrument. The best known arrangement is that called the Foucault heliostat. There are many modifications to suit particular conditions, notably that of Dr. Stoney's, which has already, I think, been described at this Society, but the same general principle is embodied in all.

The single mirror heliostat consists essentially of two parts. One is a mirror mounted with a vertical and horizontal motion, and capable, therefore, of being placed in any angular position. It is carefully balanced, and attached to its box is a strong cylindrical bar. In Foucault's design this bar projects at right angles to the plane of the mirror; in Dr. Stoney's the bar is in the same plane, or parallel to the plane of the mirror.

The second portion of the instrument is similar to any ordinary equatorial mounting of a telescope. It has its polar axis set parallel to the pole of our earth, and carried by clockwork: on one end of this is mounted a declination axis, which generally carries a small telescope for finding purposes. Across this declination axis is mounted another, which is prolonged into a fork-shaped casting at one end, in which is carried on a pair of trunnions a casting which slides on to the bar above described as attached to the mirror box, and which forms the connection between the two parts of the apparatus.

If the equatorial portion of the instrument be accurately adjusted and placed in position, and the distance between the centre of declination axis and the centre of motion of mirror be made exactly equal to the distance between the centre of declination axis and the centres on which the slipping pieces work in the fork, any object seen in the little finder telescope is reflected from the mirror in a direction which is a prolongation of a line drawn from centre of declination axis to centre of motion of mirror. If, then, the polar axis be kept rotating at the proper speed and in the proper direction, the light from that object will be reflected in a constant direction.

To anyone who has used a single mirror heliostat, or is familiar with its construction, it is unnecessary to point out that while in some positions near the meridian, and with moderate altitudes, a fair amount of accuracy of motion can be obtained, in other positions the direction of the driving force acts at such acute angles that the greater portion tends to twist or bend some part of the apparatus, instead of driving it in the required direction, which in some extreme positions the mechanism often refuses altogether to work.

As the geometric principles involved actually necessitate the existence of these very unmechanical conditions, there appears to be no opportunity of improving the construction except by making the instrument in such a manner that the work to be done shall be as light as possible, while the driving portion of the instrument, which is to do the work, is as strong, rigid, and powerful as possible.

In the present instrument, therefore (see Plate XIII.), the mirror is mounted on a pair of trunnions, which bear lightly in Y bearings; but 90 per cent. of the weight is carried on a pair of sectors which are equivalent to friction rollers of 4 ft. diameter. The frame in which these trunnions are carried, which is very massive and heavy, revolves on a strong steel taper spindle, and has a flotation tank attached, which nearly fits into a cast-iron cistern forming the base of that portion of the instrument. Mercury is poured into this; and thus 90 per cent. of the weight of the whole mirror-carrying apparatus is actually floating on mercury, the result being that this frame, mirror, &c., which weighs some 200 lbs., can be revolved, &c., by a force of less than 2 oz.

On the other hand, the equatorial portion, which acts as the driver, is made of a strength and solidity capable of carrying efficiently a 6-in. or 8-in. telescope, and the clockwork is of the same size and strength used with the instruments for the Photographic Survey, which each carry a 13-in. and 10-in. telescope. In this way I hope to attain an accuracy of movement greater than is obtained with instruments of the usual proportions. The clockwork is supplied with the newest form of electrical control, which, from recent experiments with the photographic telescopes, we find we can thoroughly depend on to the one-fortieth part of a second.

This particular instrument is intended for use with a large spectroscope placed at 50 ft. distance, the slit of which is always in the same position, and of course vertical.

The slow motions in right ascension and declination are available to the observer at this 50 ft. distance by cords, &c.; but, besides, there are other motions necessary.

As the slit is necessarily always vertical, it is sometimes desirable to be able to give a purely vertical or horizontal motion to the image. When the object is exactly on the meridian, the slow motions in right ascension and declination do then give horizontal and vertical motions, but not when in any position off the meridian. It is necessary, therefore, to have another pair of slow motions which will cause the image to move in a purely vertical and horizontal direction, whether the object be at the meridian or off of it.

The vertical slow motion is effected by the simultaneous raising or lowering of the two vertical bars which carry the bearings of the mirror trunnions. On the upper end, each of these bars has a screw cut upon it; the nuts which fit these screws are cut into teeth, forming mitre wheels, and these two mitre wheels or nuts are coupled together by a horizontal shaft to which the 50-ft. slow motion rod is geared.

The horizontal motion is effected by a tangent screw and nut which moves the whole mirror frame horizontally about a centre, which is vertically under the centre of the declination axis. In addition to the small horizontal motion required for this, the whole mirror frame can be rotated about this same centre through 45° on each side of the meridian, so that for certain special purposes the reflected beam of light can be directed to the S.E. or S.W. instead of due S. The vertical and horizontal slow motions mentioned above are connected to shafts 50 ft. long to bring them under the control of the observer.

The adjustments of these instruments are very numerous and delicate. It may be interesting to note how some of these were effected.

A portion of the "bushings" carrying the trunnions of the piece which slides on the bar attached to the mirror was cut away to allow a striding or hanging level to be applied to these trunnions.

By a series of testings and reversals, these trunnions were brought exactly at right angles to the shaft which carries the fork on which these trunnions revolve. By a second series the shaft itself was brought at right angles with the declination axis; and by a third series the declination axis was brought at right angles with the polar axis.

The polar axis was then set to the correct inclination by an "inclinometer." Thus the whole equatorial part was adjusted without aid of any celestial observations, in every respect except azimuth, which can only be found by observation. Then a specially prepared plumb bob, hung from centre of declination axis, gave the exact position of the centre of rotation of the mirror frame; and finally (the slipping piece having been removed from its fork) the fork was raised until its centres coincided with the horizontal axis of the mirror. Bushings with small electrical holes were fitted into the bearings of mirror and of fork, and a fine silver wire stretched through all four holes; this insured that the distance from declination axis to mirror axis was precisely similar to that from declination axis to centre of motion of slipping piece, and this completed the adjustment so far as it is possible to do it mechanically.

I am indebted to the Editors of "Engineering" for the illustrations to this Paper.

LVII.

REPORTS ON THE ZOOLOGICAL COLLECTIONS MADE IN TORRES STRAITS BY PROFESSOR A. C. HADDON, 1888–1889.

HYDROIDA AND POLYZOA. By R. KIRKPATRICK (British Museum). (Plates XIV.–XVII.)

[communicated by professor haddon.]

[Read November 19, 1890.]

Most of the specimens were collected in the passages between the coral reefs, in depths of fifteen to twenty fathoms, off Murray Island (Station 14), and from Albany Passage in ten fathoms (Station 8). Only a few specimens were collected at the other stations mentioned in Professor Haddon's list.

The published accounts of collections of Hydroida and Polyzoa from Torres Straits are those of Busk, in the Appendix to Vol. I. of the "Voyage of the 'Rattlesnake,'" 1852; and of Busk and Allman, in the "Challenger" Reports on the Polyzoa and Hydroida respectively. Several species of Hydroida from this region are described in Kirchenpauer's writings.

Bale describes in his Catalogue of Australian Hydroid Zoophytes all the Hydroida that had been found in this region up to 1884. Descriptions of zoophytes from Australian seas are found in the works of Lamarck and Lamouroux, and doubtless many of the species described are from Torres Straits.

A large amount of material was dredged in Torres Straits by the "Chevert" expedition in 1875, and by the "Alert" expedition in 1881–2; but the Hydroida and Polyzoa have not yet been worked out.

Specimens of Hydroida and Polyzoa were collected at the following stations:—

Station 2.—Twenty miles N.N.W. of Warrior Island (Tud.), 5½ fms.; broken shells.

Station 3.—Channel between Saibai and New Guinea, 10 to 17 fms. mud, rolled stone, and dead shells.

Station 4.—Between Orman's Reef and Brothers Island (Gaba), 6 to 7 fms.

Station 8.—Albany Pass, Somerset, N. Queensland, 10 fms.

Station 14.—Channels between reefs, Murray Island (Mer.), 15 to 20 fms.

The specimens here described have been presented to the British Museum (Natural History) by Professor A. C. Haddon.

HYDROIDA.

[The numbers correspond to the numbers of the Stations.]

Gymnoblastea.

Cladocoryne haddoni, n. sp. 14.
Coryne vel *Syncoryne cylindrica*, n. sp. 8.
Eudendrium infundibuliforme, n. sp. 2.
,, *generalis*, Lendenfeld. 2, 14.

Calyptoblastea.

Campanularia toresii, Busk. 14.
Lafoëa costata, Bale. 14.
Lictorella halecioides, Allman. 14.
Diplocyathus dichotomus, Allman. 14.
Sertularia trigonostoma, Busk. 14.
Pasythea hexodon, Busk. 14.
Diphasia scalariformis, n. sp. 2.
,, *sub-carinata*, Busk. 2, 4.
,, *digitalis*, Busk. 2.
Synthecium orthogonium, Busk. 14.
Thuiaria fenestrata, Bale. 14.
,, *lata*, Bale. 14.
Idia pristis, Lamouroux. 2, 14.
Plumularia ramsayi, Bale. 14.
Monostaechas dichotoma, Allman. 4.
Acanthella effusa, Busk. 14.
Sciurella indivisa, Allman. 14.
Acanthocladium huxleyi, Busk. 2.
Lytocarpus phœniceus, Busk. 14.
,, *philippinus*, Kirchenpauer. 14.
Aglaophenia longicornis, Busk. 14.
,, *macgillivrayi*, Busk. 14.
,, *brevirostris*, Busk. 14.
Halicornaria hians, Busk. 14.

In addition to the above, the following are recorded from Torres Straits, but are not *in Professor Haddon's Collection.*

Thyroscyphus simplex, Allman.
Desmoscyphus obliquus, Allman.
Thuiaria vincta, Allman.
Aglaophenia delicatula, Busk.

Total species of Hydroida, recorded from Torres Straits, 32 :—

TUBULARINÆ, 4 species.
CAMPANULARINÆ, 5 species.
SERTULARINÆ, 11 species.
PLUMULARINÆ, 12 species.

The above list includes four new species, viz. :—

Coryne vel *Syncoryne cylindrica*, n. sp.
Cladocoryne haddoni, n. sp.
Eudendrium infundibuliforme, n. sp.
Diphasia scalariformis, n. sp.

Coryne vel *Syncoryne cylindrica*, n. sp.

(Pl. xiv., fig. 1.)

Hydrocaulus consisting of a creeping network of slender tubes, invested by a horny perisarc.

Hydranths sessile, stout, cylindrical, about ·4 mm. in height, without horny perisarc; tentacles about 15 in number, clustered on the upper half of the hydranth, capitate, sub-sessile. Gonosome not present.

Habitat.—Growing with *Cellepora granulosa.* Albany Passage, 8 fms.

As it is uncertain whether reproduction is effected by means of fixed sporosacs or by free medusiform gonozooids, it is impossible to determine to which genus this species belongs.

The habitat of the specimen is very curious. A slender network was seen on the dorsal surface of a small fragment of *Cellepora granulosa.* On examining more carefully the upper surface of the Polyzoon, the heads of the Hydroid were seen in the angles between the zooecia. To satisfactorily examine the Hydroid, it was necessary to decalcify the Cellepora.

The absence of horny perisarc from even the base of the hydranths may be due to the peculiar habitat of the species.

Cladocoryne haddoni, n. sp.

(Pl. xiv., fig. 2.)

Hydrocaulus consisting of straight, simple stems, attaining a height of from 1 to 2 mm. and rising from a simple, creeping stolon; the stems with two annulations at the base, and increasing slightly in diameter, from below, upwards.

Hydranths bottle-shaped, with a double verticil of six to ten large compound capitate tentacles at the base, and three or four simple, sub-sessile ones near the orifice.

Large thread-cells present in the body of the hydranth, and numerous smaller ones in the tentacles.

Gonosome (?)

Habitat.—Growing on *Idia pristis*, Murray Island, 15 to 20 fms. (Station 14), Torres Straits.

This species closely resembles *Cladocoryne pelagica*, Allman,[1] found growing on the Gulf weed, and might be regarded as merely a variety of the latter. *Cladocoryne haddoni* is smaller, the greatest height of the stems being 2 mm., whereas *C. pelagica* attains a height of 5 mm.; the annulations of the perisarc are more numerous in *C. pelagica* than in *C. haddoni*; lastly, the thread cells (fig. 2 B), with regard to their size and shape, are probably characteristic. These organs, before extrusion, appear as large oval cells, measuring ·06 × ·02 mm.; when extended, they present a long, slender, filiform portion, followed by a fusiform, barbed termination, which is generally lost. Occasionally the barbed part is in the middle of the thread. The bristles on the barbed end point away from the sac.

In Pl. xiv., fig. 2 B (× 375, drawn by camera lucida), the sac is dotted, as it is invisible in the specimen, being buried in the tissue of the polyp.

The heads of the tentacles bristle with numerous very minute club-shaped threads, with the broad ends terminal.

A third species of Cladocoryne is *C. floccosa*, Rotch,[2] from Guernsey; it is about 12 mm. in height, and the compound tentacles are arranged somewhat irregularly on the body of the polypite.

Eudendrium infundibuliforme, n. sp.

(Pl. xiv., fig. 3).

Zoophyte pinnate; main stem dark brown, polysiphonic; branches simple; ultimate ramules alternate, contracted and

---

[1] Allman, Jour. Linn. Soc. vol. xii. p. 255, Pl. X. figs. 6, 7.

[2] Rotch, Ann. Mag. Nat. Hist. (Ser. 4), vii. 1871, p. 227.

wrinkled transversely at their origin, widening out towards their termination.

Polypites large, with a long peduncular portion between the end of the perisarc and the base of the tentacles, and with a large proboscis surrounded by about twenty tentacles.

Gonophores (?).

The solitary specimen is about one and a-half inches in height, and two inches in breadth. The characters of the perisarc are here sufficient to characterise the species. The diameter of the ultimate ramules at their origin is about ·14 mm., and at their termination about ·3 mm. Occasionally the peduncular part of a polypite bifurcates.

Habitat.—Twenty miles N.N.W. of Warrior Island; 5½ fms. (Station 2).

Eudendrium generalis, Lendenfeld.

(Pl. xv., figs. 1, 2.)

Specimens of this species come from two localities, viz. twenty miles N.N.W. of Warrior Island, 5½ fms. (Station 2), and from Murray Island, 15–20 fms. (Station 14). Dr. Lendenfeld[1] describes the male form of *E. generalis* as possessing four large globular spermatophores, and the female as possessing moniliform clusters of gonophores on irregular verticils of sexual tentacles.

Seeing that the external form of the male and female gonophores respectively is here stated to be the reverse of what usually obtains in this genus, it would have been desirable to give the evidence of detailed observation as to the sexes of *E. generalis*. In the absence of this, it may be permissible to doubt whether the supposed male gonophores were not female, and *vice versa*. Judging from Dr. Lendenfeld's specimen in the British Museum the moniliform clusters appear to have grown from the base of a hydranth, the body and tentacles of which have disappeared. The sacs are filled with small, nucleated, and apparently spermatogenic cells, and not with yelk granules. The masses of cells are situated between the ectoderm and endoderm, leaving a clear linear space bounded by endoderm along the centre of each linear

[1] Proc. Linn. Soc. N.S.W. vol. ix. Part 2, p. 351, Plate VI.

cluster of sacs. Although thread cells occur in and beneath the ectoderm, they do not form a cushion or battery on the summit of the spermatophore, as in *Eudendrium arbusculum*, Strethill Wright.

The specimens from Station 14, growing on *Sciurella indivisa* are the female forms of *E. generalis*. The female gonophores, from three to five, but usually four in number, grow from the base of the hydranth in the form of sub-sessile, oval bodies, 4 mm. in diameter.

The specimens from Station 2 are the male form. The spermatophores form verticils of moniliform sacs growing from the base of a hydranth. Some of the sexual hydranths remain, but atrophy, more or less complete, has overtaken others.

The specimens from Torres Straits, attaining a height of from 1 to 2½ inches, are larger than those found at Port Jackson and Port Phillip. The diameter of the branches varies from ·1 mm to ·2 mm. The annulations of the perisarc are very feebly marked, usually amounting to a slight wrinkling at the base of the branches.

Eudendrium capillare, Alder, is a more slender growth, the diameter of the branches varying from ·06 to ·08 mm., and the ramification is more profuse.

Eudendrium arbusculum, Strethill Wright, forms a bushy tree of adnate stems.

Habitat.—Port Jackson (Brit. Mus. Coll. Lendenfeld); Port Phillip, Lendenfeld; Torres Straits, Haddon.

Lafoëa costata, Bale.

Many of the hydrothecæ are smooth, and without the ridges. The plane of the orifice is oblique to the long axis of the hydrotheca.

Habitat.—Growing on *Sciurella indivisa*, Murray Island; 15–20 fms.

Lictorella halecioides, Allman.

Lafoëa halecioides, Allman.—Trans. Zool. Soc. viii. 1874, p. 472.

Campanularia rufa, Bale.—Trans. Roy. Soc. Vict. xxiii. p. 91.

Lictorella halecioides, Allman.—Chall. Rep. Hydroida, II. p. 35.

The distribution of this species is interesting. Between Shetland and Faroe (cold area), 345 and 630 fms. (Allman, "Porcupine"); Holborn Island, 20 fms. (Bale); off Somerset, Cape York, 2–8 fms. (Allman, "Challenger"); Murray Island, 15–20 fms. (Haddon).

Diphasia scalariformis, n. sp.

(Pl. xv., fig. 3).

Hydrocaulus irregularly branched, forming tufts about 1·25 inches in height.

Hydrothecæ, in pairs, adnate to one side of the rachis, and to each other; upper outer half of hydrotheca expanding, alate, sinuous; surface of stem and hydrothecæ marked with longitudinal serrations and delicate horizontal lines.

Gonothecæ, in a single line along front rachis, adpressed to hydrothecæ, oval, sub-sessile, marked with strong curved spines on upper surface ; under surface smooth.

Length of hydrothecæ, ·4 mm.; width of a pair at widest part, ·4 mm.

Habitat.—Twenty miles N.N.W. Warrior Island, 5½ fms.; growing on *Aglaophenia huxleyi*.

Sciurella indivisa, Allman.

Sciurella indivisa, Allman, "Challenger" Hydroida, I. p. 26, Pl. V.

Antennularia cylindrica, Bale. Cat. Zooph., p. 146, Pl. X. fig. 7.

At first the arrangement of the ramules is bipinnate, each half of the pinna being composed of ramules arranged "two-deep." Higher up the bipinnate arrangement is obscured, the ramules growing along three or four sides of the stem, as in Antennularia.

In the British Museum Collection is a specimen acquired from Dr. v. Lendenfeld, labelled "*Antennularia cylindrica*, Bale, Port Curtis Type," and there was therefore no difficulty in settling the synonomy.

Kirchenpauer[1] refers to a specimen of *Plumularia cylindrica*,

[1] Kirchenpauer, Plumularidæ. Abhand der Nat. Ver. Hamburg, p. 45, Taf. i. and iv. fig. 1, 1876.

Kirch., from Java, in which the lateral hydrocladia stand one in front of another. In this species the hydrothecæ are cylindrical and adnate; but the supra-calycine sarcothecæ arise below the edge of the calycli; whereas in *Sciurella indivisa* they arise at the edge, and lie across the orifice.

Habitat.—Murray Island, 15 to 20 fms.; off Warrior Island 5½ fms.

Note on *Antennularia cymodocea*, Busk.

While engaged in determining the species of Plumularidæ, it became desirable to settle the position of *Antennularia cymodocea*, Busk. By the kind permission of the late Mrs. Busk, I was enabled to examine two specimens (one of which is probably the type) from Algoa Bay. Mr. Busk describes[1]: *Antennularia cymodocea*, "caulibus simplicibus; ramulis, biseriatis, utraque serie, alternantibus," South Africa, Australia. As Mr. Bale observes, such an arrangement is found only in *Nemertsia decussata*, Kirchenpauer. An examination of *A. cymodocea* shows that *Nemertsia decussata*, Kirchenpauer,[2] from the Cape of Good Hope, is synonymous with it. Unfortunately the Australian specimen could not be found.

In *A. cymodocea* the ramules of a pair are opposite, and the plane of each pair is at right angles to the planes of the pairs immediately above and below them.

The ramules are short, and composed of five or six joints, each bearing a cupped sarcotheca, and on the last joint a hydrotheca, adnate and dovetailed into the joint; a second hydrotheca is only exceptionally present.

Only one supra-calicular sarcotheca is present; the mesial one may or may not be present on the calicular internode.

Diameter of ramule, ·08 mm.; length of calicle, ·1 mm.; diameter of orifice, ·1 mm.

Acanthella effusa, Busk.

(Pl. xiv., fig. 4.)

There are three dried specimens of this species, varying from 7 to 13 inches in height. The gonangia, which have not hitherto

---

[1] Report, British Association, 1850, p. 119.

[2] Abhand. der Nat. Vereins, Hamburg, vi. Taf. ii. iii. vii. fig. 24 *a*, *b*, *c*.

been found, are present. They form small sub-sessile, flattened, obliquely truncate bodies, with one of the two lateral borders longer and more convex than the other. They form a line along the stem, one at the base of each ramule.

Some of the lower branches in *A. effusa* are opposite.

Generally, there is only one supra-calycine sarcotheca, but two sometimes occur.

Habitat.—Murray Island, 15 to 20 fms.

Aglaophenia brevirostris, Busk.

There are several specimens of this elegant species. The stems grow to a height of 1 to 1½ inches. The curved tubular hydrothecæ resemble those of *Aglaophenia vitiana*, Kirchenpauer. In the former the mesial sarcotheca is tubular, and opens at the summit by a circular pore ; in the latter it is canalicular.

The ramules are alternate, with two flattened sarcothecæ at the base.

There are three teeth on each side of the hydrothecal orifice and a median anterior one.

The corbulæ are about 2 mm. in length, with a hydrotheca at the base of each rib.

Habitat.—Murray Island, 15 to 20 fms.

POLYZOA.

[The numbers correspond to the numbers of the Stations.]

Catenicella elegans, Busk. 8, 14.
,, *gibbosa*, Busk. 8, 14.
,, *taurina*, Busk. 14.
Scrupocellaria cervicornis, Busk. 14.
,, *diadema*, Busk. 14.
Caberea lata, Busk. 14.
Farcimia simplex, Busk. 8.
,, *oculata*, Busk. 2, 8, 14.
Cellaria gracilis, Busk. 14.
Tubucellaria cereoides, Ellis & Solander. 14.
Bicellaria (*Stirparia*) *haddoni*, n. sp. 8.
Bugula johnstonæ, Gray. 2, 14.
,, *dentata*, Lamouroux. 4.
Beania hirtissima, Heller ; form *cylindrica*, Hincks. 14.
Euthyris obtecta, Hincks. 14.
Flustra cribriformis, Busk. 2, 4, 8, 14.
,, *reticulum*, Hinks. 14.
Membranipora coronata, Hincks. 14.

Membranipora radicifera, Hincks; var. *intermedia*, nov. var. 14.
,, (*amphiblestrum*) *cervicornis*, Busk. 14.
Cribrilina radiata, Moll. 14.
Steganoporella magnilabris, Busk. 8, 14.
Thalamoporella rozieri, Audouin;
,, form *gothica*, Hincks. 8, 14.
,, form *indica*, Hincks. 14.
Chorizopora vittata, Mac Gillivray. 14.
,, *brongniartii*, Audouin; var. *spinosa*, nov. var. 14.
Microporella malusii, Audouin. 14.
,, *inversa*, Waters. 14.
Adeonella intricaria, Busk. 2, 8.
,, *platalea*, Busk. 8, 14.
Schizoporella auriculata, Hassall. 14.
,, *immersa*, Haswell. 14.
,, *fenestrata*, Smitt. 14.
,, *venusta*, Norman. 14.
Haswellia australiensis, Haswell. 8, 14.
Lepralia mucronata, Smitt. 8.
,, *dorsipora*, Busk. 8, 14.
,, *lonchæa*, Busk. 14.
,, *depressa*, Busk. 14.
,, *acanthina*, Quoy & Gaimard. 14.
,, *filamentosa*, n. sp. 14.
Lepralia occlusa, Busk. 8.
,, var. *areolata*, n. var. 14.
Rhynchopora longirostris, Hincks. 14.
Retepora carinata, Mac Gillivray. 14.
,, *monilifera*; form *munita*, Mac Gillivray. 8, 14.
,, *monilifera*; form *umbonata*, Mac Gillivray. 14.
,, *phœnicea*, Busk. 14.
,, *producta*, Busk. 14.
Mucronella bisinuata, Smitt. 8.
,, *magnifica*, Busk. 14.
Smittia spathulata, Smitt. 14.
,, *levis*, n. sp. 14.
Cellepora granulosa, Haswell. 8.
,, *fusca*, Busk. 14.
,, *tridenticulata*, Busk. 8.
,, *discoidea*, Busk. 14.
,, ,, ,, var. *frutetosa*, nov. var. 3, 8.
Stichoporina simplex, Koschinsky. 14.
Bipora crassa, Tenison-Woods. 14.
Crisia denticulata, M. Edwards. 14.
Idmonea radians, Lamarck. 14.
Lichenopora radiata, Audouin. 14.
Amathia tortuosa, Tenison-Woods. 14.
Buskia setigera, Hincks. 2.
Barentsia laxa, n. sp. 4.

In addition to the species above mentioned, the following have been previously recorded from Torres Straits (Long. 139° – 145° E.), but are not in Professor Haddon's collection:—

Aetea dilatata, Busk.
Chlidonia cordieri, Audouin.
Retepora hirsuta, Busk.
,, *tubulata*, Busk.
Adeonella pectinata, Busk.
Cupularia guineensis, Busk.
Idmonea eboracensis, Busk.
Amathia connexa, Busk.
,, *semispiralis*, Kirchenpauer.
Vesicularia papuensis, Busk.
Cylindroecium papuense, Busk.

Total species and varieties of Polyzoa from Torres Straits, 77 :—

Chilostomata, 66 species.	Ctenostomata, 6 species.
Cyclostomata, 4 species.	Pedicellinea, 1 species.

Professor Haddon's collection contains four new species, and four new varieties, viz. :—

Bicellaria (*Stirparia*) *haddoni*, n. sp. 14.
Lepralia filamentosa, n. sp. 14.
Smittia levis, n. sp. 14.
Barentsia laxa, n. sp. 4.
Membranipora radicifera, Hincks; var. *intermedia*, nov. var. 14.
Chorizopora brongniartii, Audouin; var. *spinosa*, nov. var. 14.
Lepralia occlusa, Busk; var. *areolata*, nov. var. 14.
Cellepora discoidea, Busk; var. *frutetosa*, nov. var. 3, 8.

With regard to the distribution of Polyzoa, the Torres Straits does not form a limited and defined region, but only the northern part of an intratropical area, extending along the coast of Queensland, within the Great Barrier Reef.

Eighteen of the species in the above list are also recorded by Mr. Haswell[1] from Holborn Island, ten degrees of latitude south of Torres Straits.

Stirparia haddoni, n. sp.

(Pl. xv., fig. 4.)

Zoarium forming celliferous caliculate tufts at the ends of jointed corneous stems; the tufts composed of dichotomous branches, with the zooecia opening on the outer surface. Zooecia biserial, alternate, sub-turbinate, facing towards the centre of the branches, and with the outer margins curved round so as almost to meet along the central line; aperture quadrate with concave lower border; area occupying about half the front of the cell; upper borders of zooecia sinuous, and ending in a spinous process at the upper outer angle.

No spines; no avicularia.

Ooecia (?)

[1] "Proc. Linn. Soc. N S. Wales," vol. v., p. 33, 1860.

Stem with internodes uniformly lessening in length and calibre.

Breadth of branches in front,	·24 mm.
,, ,, ,, laterally,	·3 mm.
Length of zooecium,	·6 mm.
Breadth of zooecium (unrolled),	·2 mm.

Habitat.—Albany Passage; 10 fms.; Station 8.

Professor Haddon's specimen consists of only one jointed stem, crowned by its tuft. Some of the lower joints of the stem project laterally; and from these other jointed stems probably branch off.

The joints and internodes of the stem, in their construction, combine lightness and flexibility with firmness and strength. Each internode consists of a horny scaffolding, leaving two long, oval (membranous) fenestræ; at the nodes the horny bands break up into numerous shorter fascicles. The fenestræ form a line on each side of the stem. Several muscular fasciculi can be seen in the topmost internode.

The transition from the internodes to the zooecia is well shown; and the origin of the scaffoldings on the stem becomes manifest. The highest single internode bifurcates, and each bifurcation again divides. The internodes more and more resemble zooecia, and the internodal fenestræ become the apertures of the zooecia.

The genus Stirparia has been objected to on the ground that it is not founded on zooecial characters; but the metamorphosis of zooecia to form stems may, perhaps, be considered as a zooecial and, therefore, generic characteristic. If not, Stirparia would form a sub-genus under Bicellaria.

The other species of Stirparia are—

Stirparia annulata, Maplestone,	Victoria.
,, *glabra*, Hincks, . .	Bahia, Western Australia, [Victoria.
,, *exilis*, Mac Gillivray,	Port Phillip.

In *Stirparia glabra* fenestræ are present in the internodes, which are alternately longer and shorter.

Bugula dentata, Lamouroux.

The zoarium is of a leaden-blue colour, and forms spirally arranged fronds. There is one well-developed spine at each upper angle, and two quite rudimentary ones on the upper outer margin.

The beaks of the avicularia curve round at right angles, and the ends are broad and grooved, and not pointed.

Habitat.—Station 4; 6–7 fms.

Membranipora coronata, Hincks.—" Ann. Mag. Nat. Hist." (5), vii. 1881, p. 147, Pl. x., fig. 1.

Membranipora hastilis, Kirkpatrick.—*Ibid.* (5), ix., 1882, p. 188.

I regret that Mr. Hincks' note, giving further particulars of the structure of *Membranipora coronata*, escaped my notice. There is no doubt that *Membranipora hastilis* is synonymous with *M. coronata.*

Habitat.—Ceylon; Singapore or Philippines; Macclesfield Bank, China Sea; Murray Island, Torres Straits.

Chorizopora brongniartii, Audouin, var. *spinosa.*

(Pl. xvi., fig. 4.)

The variation consists in the presence of two pairs of short glossy spines on each side of the orifice. The upper pair is bifurcated. The interzooecial network is largely developed. A slight peristomial ring is developed round some of the orifices of the cells. In every other respect this variety resembles the typical form of the species. *Chorizopora vittata*, Mac Gillivray, also occurs, growing on the same fragment of rock. The marking on the front wall of the zooecium is trifoliate.

Habitat. — Encrusting rock: Murray Island, 15–20 fms. (Station 14).

Membranipora radicifera, Hincks, var. *intermedia*, nov. var.

(Pl. xvi., figs. 1, 2.)

Three small fragments of this variety occur, one of which is firmly attached to a piece of coral. The variation from the type consists chiefly in the development of the spines.

On one side of the orifice is a bifurcated spine, growing partly vertically, and partly arching over the area; on the opposite side is a spine with a vertical branch bearing an avicularium with a long curved pointed mandible, and with a horizontal bifurcating branch arching over the area. At the oral end of the cell are two vertical bifurcated spines.

The radical tubes are present in this variety, but not in such abundance as in the typical form of the species. Some of the cells are quite destitute of processes giving origin to radical tubes.

The zooecia are packed close together, so that the probable original separation of the cells would never be suspected.

In a valuable collection of the Polyzoa of Port Phillip, presented to the Natural History Museum by Mr. Bracebridge Wilson, is a specimen of *Membranipora radicifera*.[1] The radical tubes form a thick felt-work. In the same collection is a specimen of *Hiantopora ferox*, Mac Gillivray.[2] The variety of *M. radicifera*, from Torres Straits, is evidently a form intermediate between *Membranipora radicifera* and *Hiantopora ferox*. In the latter the spines have undergone further development; the horizontal portion on the avicularian side of the cell has grown over the whole area, and fused with the opposite cell margin.

The resemblance between *Cribrilina ferox* and *M. radicifera*, with regard to the presence of radical tubes and the disjunct arrangement of the zooecia, was observed by Mr. Hincks.[1] The discovery of the intermediate form from Torres Straits was necessary in order to show the intimate relations between two such diverse forms as *M. radicifera* and *C. ferox*. Viewed by itself it may have been justifiable to place the latter form in the genus Cribrilina, or to make a new genus, Hiantopora; but in view of its relationship to *M. radicifera*, this can no longer be done, unless the slightly increased development of spines (in this particular instance) is to be considered a generic character.

The following arrangement is proposed :—

Membranipora radicifera, Hincks.

Membranipora radicifera, Hincks, var. *intermedia*, nov. var.

Membranipora radicifera, Hincks, var. *ferox*.

---

[1] Hinck's "Ann. Mag. Nat. Hist." (5) viii., 1881, p. 5 and 7., Pl. II., figs. 6, 6*a*, 6*b*.

[2] Mac Gillivray, "Cat. Mar. Pol. Vict.," p. 22; "Prod. Zool. Vict.," Decade X., p. 34, Pl. XXXVIII., fig. 8.; "Prod. Zool. Vict.," Decade XII., p. 69, Pl. CXVII., figs. 6–8.

The saving clause "in this particular instance" is used advisedly, since it is not possible to say, in other instances, whether any particular species of Cribrilina is related to any particular form of recent Membranipora.

It might be urged that if *Cribrilina* (*Hiantopora*) *ferox* is "brought back" to Membranipora, *Membranipora radicifera* should logically be relegated to Beania, since, in the disjunct arrangement of the zooecia, in the presence of radical tubes, and the elevation of the oral end of the zooecia, *M. radicifera* shows evident traces of its origin from a form possessing the characters of Beania.

In spite of these traces of its ancestry, *M. radicifera* now possesses Membraniporidan characters that cannot be claimed for Beania; and if *Cribrilina ferox*, Mac Gillivray, possessing Cribrilinidan characters, has thus appeared to belong to a higher group, the appearance of the closely related form *M. radicifera*, var. *intermedia*, necessitates the removal of the former to a lower group.

Distribution. — *M. radicifera*, Bass's Straits, Port Phillip Heads.

M. radicifera, var. *intermedia*, Murray Island, Torres Straits, 15–20 fms.

M. radicifera, var. *ferox*, Port Phillip Heads.

Fossil.—Aldinga, Mount Gambier, Bairnsdale (Waters).

Schizoporella auriculata, Hassall.

? *Schizoporella lata*, Mac Gillivray.

A minute circular avicularium is situated below the sinus of the orifice.

Oral spines, usually present in this species, do not occur on the specimen. The marks for muscular attachment on the opercula are more prominent in British specimens.

Habitat.—Murray Island, 15–20 fms.

Lepralia acanthina, Quoy & Gaimard.

(Pl. xvi., fig. 6.)

Flustre épineuse, *Flustra acanthina*, Quoy & Gaimard. Voyage de l'Uranie, 1824. "Zoologie," p. 605, Pl. LXXXIX., figs. 1, 2.

Flustra acanthina, Qu. & Gaim. Lamarck. "Anim. sans vertebres," ed. 2, tom. ii., p. 226.

Membranipora spinosa, Busk. "Phil. Trans. Roy. Soc.," vol. clxviii. (extra), p. 195, Pl. X., fig. 3.

Amphiblestrum spinosum, Qu. & Gaim. (?) P. H. Mac Gillivray. "Cat. Mar. Pol. Vict.," p. 20.

Amphiblestrum ciliatum, Mac Gillivray. "Cat. Mar. Pol. Vict.," p. 20.

Lepralia judex, Kirkpatrick. "Ann. Mag. Nat. Hist." (6), I., 1888, p. 78.

Chaperia australis, Jullien. "Bull. Soc. Zool. France," VI., 1881, p. 163.

By an oversight the specific name, "acanthina," given to the species by Quoy & Gaimard, has been overlooked, "épineuse" having been translated "spinosa" by later authors.

Lamarck wrote "Cette espece nous parait appartenir au genre Membranipora."

Waters ("'Challenger' Supplementary Report, Polyzoa," pp. 10, 11) objects to Jullien's genus, Chaperia, founded on the presence of calcareous muscle plates inside the orifice, on the score that these plates are found in other forms, which differ too widely in other respects to be included under one genus. The thick, well-developed operculum, present in this form, seems quite other than a Membraniporidan characteristic. The species is included provisionally under the genus Lepralia.

Habitat.—Victoria, New South Wales, South Patagonia, Kerguelen Land, New Zealand, Falkland Island, Murray Island.

Fossil.—Napier, New Zealand (Waters).

Lepralia occlusa, Busk, var. *areolata*, nov. var.

(Pl. xvi., fig. 7.)

The zoarium forms thick nodulated encrusting masses.

The zooecia are rhomboidal, and separated by raised lines; at first the front surface is uniformly punctured with round pores, and later becomes covered with a thick areolated crust, the oval areolæ generally radiating from a central umbonate area.

The lines bounding the zooecia form a prominent feature.

The ooecium, in early stages, has a semi-elliptical membranous area on its upper face; later the area becomes partly covered by a calcareous reticulum, and finally wholly calcified on the surface.

This variety is a distinct and very interesting one. In the typical form the zoarium is escharan, and the zooecia are long and oval, and the surface uniformly areolated. The opercula are similar in both.

Habitat.—Loosely adnate to rock: Murray Island, Torres Straits, 15–20 fms.

Lepralia filamentosa, n. sp.

(Pl. xvi., fig. 5.)

Zoarium free, dome-shaped, concavo-convex; zooecia in radiating lines, alternate.

Zooecia large, ·7 × ·5 mm.; rectangular; upper surface uniformly punctured by large round pores.

Orifice quadrangular; rising from the proximal border a small, scroll-like mucro, from the outer convex surface of which rises a thick calcareous process branching out into membranous filaments; three similar spines rising directly from the postero-lateral margin of the orifice.

Dorsal surface of zooecia smooth, transparent, bound by raised lines.

Ooecia?

Operculum, ·24 mm. in length × ·26 in width, with a slightly concave proximal border, and a thick rim round the rest of the margin.

Habitat.—Growing free: Murray Island, Torres Straits, 15–20 fms.

Smittia spathulata, Smitt.

(Pl. xvii., fig. 1.)

Escharella spathulata, Smitt.—"Flor. Bry." II. p. 60.

Smittia reticulata, var. *spathulata*, P. Mac Gillivray. "Trans. Roy. Soc. Vict." XIX., p. 135, Pl. III., fig. 14.

Smittia spathulata, Mac Gillivray. "Cat. Mar. Pol. Vict." p. 27.

In his "Floridan Bryozoa" Smitt described an hemescharon form of Smittia, and proposed to name it *Escharella spathulata;* a similar form from Torres Straits, and in the British Museum Collection, is referred to.

In Professor Haddon's Collection several handsome masses of this species occur in the form of masses about 3½ inches in area, by 2 to 3 inches in height, and composed of stout, hollow, tubular anastomosing branches.

Avicularia of several kinds abound; on one side of the orifice is one with a spathulate mandible. There are three oral denticles. The operculum is membranous, and generally shrivelled up. It scarcely takes the stain of picrocarmine. The trace of a pectinate ridge exists at the back of the orifice of some zooecia. Traces, also, of spines exist in the form of one to three minute pits at the back of the peristome.

The ovicell is frosted, with a semicircular punctured area in front, bounded by a ridge. In the earliest stage the ovicell is probably uniformly punctured.

Mucronella (*Discopora*) *nitida*, Verrill, has been given as a synonym of *Smittia spathulata;* but, judging from a specimen sent to the British Museum by the U. S. National Museum, the former species is quite distinct, and would be classed under Schizoporella. Professor Verrill's[1] figure is, however, certainly that of a species of Smittia.

Habitat.—Murray Island, 15–20 fms.

Smittia levis, n. sp.

(Pl. xvi., fig. 8.)

Zoarium encrusting, orange-coloured zooecia ·2 mm. in breadth by ·5 mm. in length. Front surface smooth, with large marginal areolæ; primary orifice oval; proximal margin with one large denticle, and two rudimentary lateral ones; distal margin with a well-developed horizontal pectinate ridge. On the centre of the front of each cell an avicularium with triangular mandible pointing downwards; ooecium smooth, hyaline, depressed.

---

[1] Verrill. "American Journal of Science" (3), IX., 1875, p. 415, Pl. VII., fig. 3. Verrill. "Proc. U. S. Nat. Mus." II., 1879, p. 195.

Operculum ·14 mm. in width by ·1 mm. in length, with an articular process at each proximal angle.

Habitat.—Encrusting rock: Murray Island, 15–20 fms.

The chief specific characters of this form are the smooth surfaces of the zooecia (surrounded by areolæ) and of the ooecia, the presence of a well-marked pectinate ridge, and the position of the avicularium in the centre of the front wall of each zooecium.

Cellepora discoidea, Busk, var. *frutetosa*, nov. var.

(Pl. xvii., fig. 3.)

Zoarium forming a bushy growth, composed of short, stout, solid, cylindrical, anastomosing branches.

Zooecia hyaline; orifice sub-orbicular, with three or four slender denticles on the proximal border; the rostrum short, with a small avicularium with a small semicircular or oval mandible, which latter grows longer on older cells.

Ooecia smooth, hyaline, cucullate; operculum semicircular, with straight lower border; ·16 × ·1 mm.

Habitat.—Albany Passage, 10 fms.; Saibai Channel, 10–17 fms.; Thursday Island (Haswell).

The larger of the two specimens sent is from Albany Passage, and measures about 2 inches in height by 3 inches in breadth.

The surface of the branches is covered with numerous small round holes about 1·05 mm. in diameter; these are the orifices of a parasitic or commensal "Actinid," first observed by Mr. Haswell,[1] who saw the mesenteries. The tubes do not penetrate far, and have cæcal endings; often two or three communicate, and have a common cæcal termination.

Cellepora discoidea, var. *frutetosa*, may possibly be simply the adult form of *Cellepora discoidea*, Busk. There is a resemblance in the general form and appearance of the cells, in the shape of the orifice, presence of denticles, and in the size and shape of the operculum. The variation from the type consists in the smaller size of the rostra and rostral avicularia, and in the mode of growth.

---

[1] "Proc. Linn. Soc. N. S. Wales," vol. vii., p. 608, 1882.

Three small disc-shaped specimens of Cellepora occur, from Murray Island; these I have referred to *Cellepora discoidea*, Busk; though the rostra are not so strongly developed in the former as in the type specimen of the latter. The walls are thicker, and the upper half of the cell is more ventricose; indeed, though the mode of growth of the zoarium of these specimens is similar to that of the type, the cells vary almost more than those of *Cellepora discoidea*, var. *frutetosa*.

Cellepora granulosa, Haswell.

(Pl. xvii., fig. 2.)

The specimen from Albany Passage forms an extensive encrusting basal portion, whence arise broad, flattened, hollow branches from various parts, and these again divide.

In the British Museum Collection are some fragments of this species from Holborn Island, which have been named by Mr. Haswell. They appear to have been broken off from a specimen with narrower branches than those of the present specimen.

The zooecia are large; the aperture sub-quadrate. The ooecium is cucullate, smooth, but granular in later stages. The mandibles of the rostral avicularia have their margins bent at an angle to the general surface. Operculum, ·3 mm. in width by ·26 in length.

Habitat.—Albany Passage, 8 fms.

Bipora crassa, Tenison-Woods.

(Pl. xvii., fig. 5.)

Sixteen specimens, varying from 5 to 10 mm. in diameter, occur, from Murray Island, 15 to 20 fms.

Figures and measurements of the chitinous appendages are given to further assist in identification.

Opercula, broadly pyriform, ·21 mm. × ·16 mm.; mandibles of avicularia semicircular, ·1 mm. × ·06 mm.

Habitat.—Cape Three Points, 70 to 80 fms.; Port Stephens N. S. W. (Tenison-Woods); Murray Island, 15 to 20 fms., Torres Straits (Haddon).

Stichoporina simplex, Koschinsky.

(Pl. xvii., fig. 4.)

Stichoporina simplex, Koschinsky, Bryozoen ält Tertiär Süd-Bayerns. Paleontographica (Zittel), xxxii. p. 64, Taf. VI. figs. 4–7.

Zoarium free, dome-shaped, concavo-convex, about 20 mm. in diameter, by 4 mm. in height.

Zooecia arranged in radiating lines; the cells vertical in position—the upper and lower surfaces of each varying from rhomboidal to hexagonal.

Orifice quadrangular, with a small articulating denticle on each side.

Above the orifice of each cell, an avicularium with a vibraculoid mandible.

Dorsal surface resembling a mosaic, the lower convex surface of each cell being visible.

Ooecia large, depressed, dome-shaped, finely punctured.

Opercula ·26 mm. in length, by ·20 in breadth. Opercula of ooecial cells ·22 in length by ·24 in breadth.

Habitat.—Murray Island, 15 to 20 fms.

Distribution.—Recent. Cape of Good Hope and Malacca (Belcher Collection, Brit. Mus. Coll.). Murray Island (Haddon).

Fossil.—Götzreuth, South Bavaria, Tertiary (Koschinsky); Brendola, Colle Berici, N. Italy, and Ronzo, Tyrol; Bartonian (A. W. Waters, M.S.).

I am indebted to Mr. A. W. Waters for pointing out that the specimens from Murray Island belong to Koschinsky's species.

The four specimens are broad and low; those in the Belcher Collection are much narrower in diameter, and more convex. In external form, a fossil specimen of Mr. Waters', from Brendola, more nearly resembles the latter.

Stoliczka[1] observes that Stichoporina differs from Cupularia and Lunulites in the irregular arrangement of the cells, which may be

[1] Stoliczka. Sitzungb. Math. Nat. Akad. Wiss. Wien. 1862. Bd. xlv. p. 92.

seen on the lower surface, and in the absence of intermediate cells. The inclusion of *S. simplex* within the genus Stichopora requires a modification of the definition of the genus, since the cells in this species are arranged in radiating series, with the interpolation of other series towards the periphery.

The fertile zooecia, with their ooecia, occupy an area about twice the size of the others; the operculum is broadened out, at the expense of the length, the pressing out of the lateral margins leaving the muscle marks more plainly visible (see figure).

Barentsia laxa, n. sp.

(Pl. xvii., fig. 6.)

Polypides arising from a jointed, creeping stolon.

Expanded basal portion of pedicels plain and unmarked; pedicels cylindrical and chitinous below, membranous above and attached to the polypide directly, and without the intervention of a fleshy peduncle.

Polypides large and gibbous.

Measurements.—Total length, 3 mm. Length of 'barrel' portion (including the superior conical part), ·25 mm. Breadth of barrel, ·16 mm. Polypide, ·35 to ·4 mm. in breadth; ·4 to ·5 mm. in height.

Habitat.—Station 4; growing over *Flustra cribriformis.*

The new species resembles, in several particulars, *Barentsia major*, Hincks,[1] from the St. Lawrence, but differs from the latter in manner of attachment of the polypide to the pedicle. *B. laxa* is without the fleshy stalk, which Mr. Hincks refers to as a distinct feature in his species.

Barentsia discreta, Busk, is considerably larger; the barrel is marked with broad annulations, and the pedicle is chitinous throughout, and marked with funnel-shaped pits.

---

[1] Hincks, Ann. Mag. Nat. Hist. (6) I. 1888, pp. 226, Pl. XV. fig. 2.

EXPLANATION OF PLATES.

PLATE XIV.

FIG. 1. Coryne *vel* Syncoryne cylindrica, *n. sp.*, × 30.

FIG. 2. Cladocoryne haddoni, *n. sp.*, nat. size; 2A, × 50; 2B, thread cell × 375, the sac (dotted in the figure) was not, in this case, visible.

FIG. 3. Eudendrium infundibuliforme, *n. sp.*, nat. size; 3A, × 10; 3B, × 20.

FIG. 4. Acanthella effusa, *Busk;* gonotheca × 30.

PLATE XV.

FIG. 1. Eudendrium generalis, *Lendenfeld;* male specimen, nat. size; 1A, × 30.

FIG. 2. Eudendrium generalis, *Lendenfeld;* female, × 30.

FIG. 3. Diphasia scalariformis, *n. sp.*, nat. size; 3A, × 40; 3B, × 50.

FIG. 4. Bicellaria (Stirparia) haddoni, *n. sp.*, × $1\frac{1}{2}$; 4A, front view of branch, × 40; 4B, lateral view, × 40; 4C, joint of stem, × 15.

PLATE XVI.

FIG. 1. Membranipora radicifera, *Hincks*, × 30.

FIG. 2. Membranipora radicifera, *var.* intermedia, *nov. var.*, × 30.

FIG. 3. Membranipora radicifera, *var.* ferox, × 30.

FIG. 4. Chorizopora brongniartii, *Audouin*, *var.* spinosa, *nov. var.*, × 30.

FIG. 5. Lepralia filamentosa, *n. sp.*, × 30; 5A, operculum, × 50.

FIG. 6. Lepralia acanthina, *Quoy & Gaimard;* operculum, × 50.

FIG. 7. Lepralia occlusa, *Busk*, *var.* areolata, *nov. var.*, nat. size; 7A, × 30.

FIG. 8. Smittia levis, *n. sp.*, × 50; 8A, orifice, × 60; 8B., operculum, × 60; 8C, mandible, × 100.

*

PLATE XVII.

Fig. 1. Smittia spathulata, *Smitt*, nat. size.

Fig. 2, 2a, 2b, Cellepora granulosa, *Haswell*, chitinous appendages, × 50.

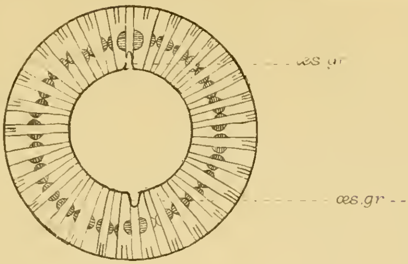
Fig. 3. Cellapora discoidea, *Busk*, *var.* frutetosa, *nov. var.*, nat, size; 3a, × 30; 3b, orifice, × 100; 3c, operculum, × 100; 3d, mandible, × 100.

Fig. 4. Stichoporina simplex, *Koschinsky*, nat. size; 4a, × 25; 4b, 4c, opercula, × 60; 4d, mandible, × 100.

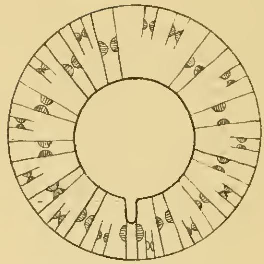
Fig. 5, 5a, Bipora crassa, *T.–Woods*, chitinous appendages, × 100.

Fig. 6. Barentsia laxa, *n. sp.*, × 30,

END OF VOLUME. VI.

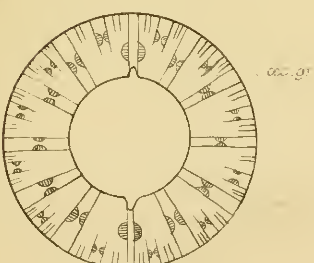


1



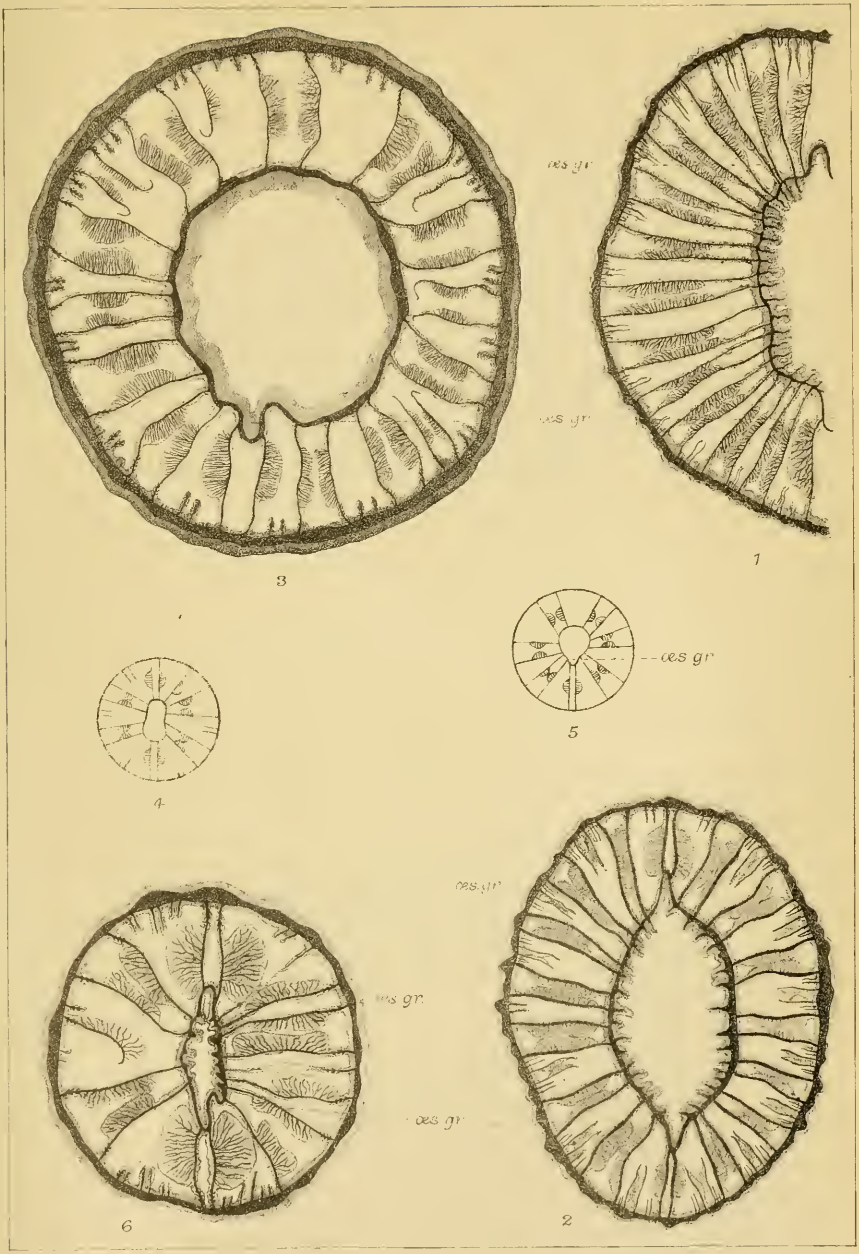
2

5



4

3



West Newman & Co lith

Fig 1

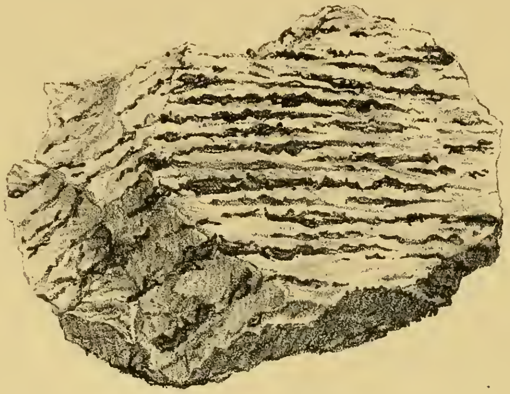
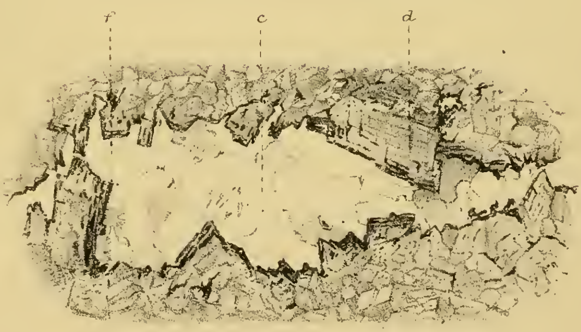
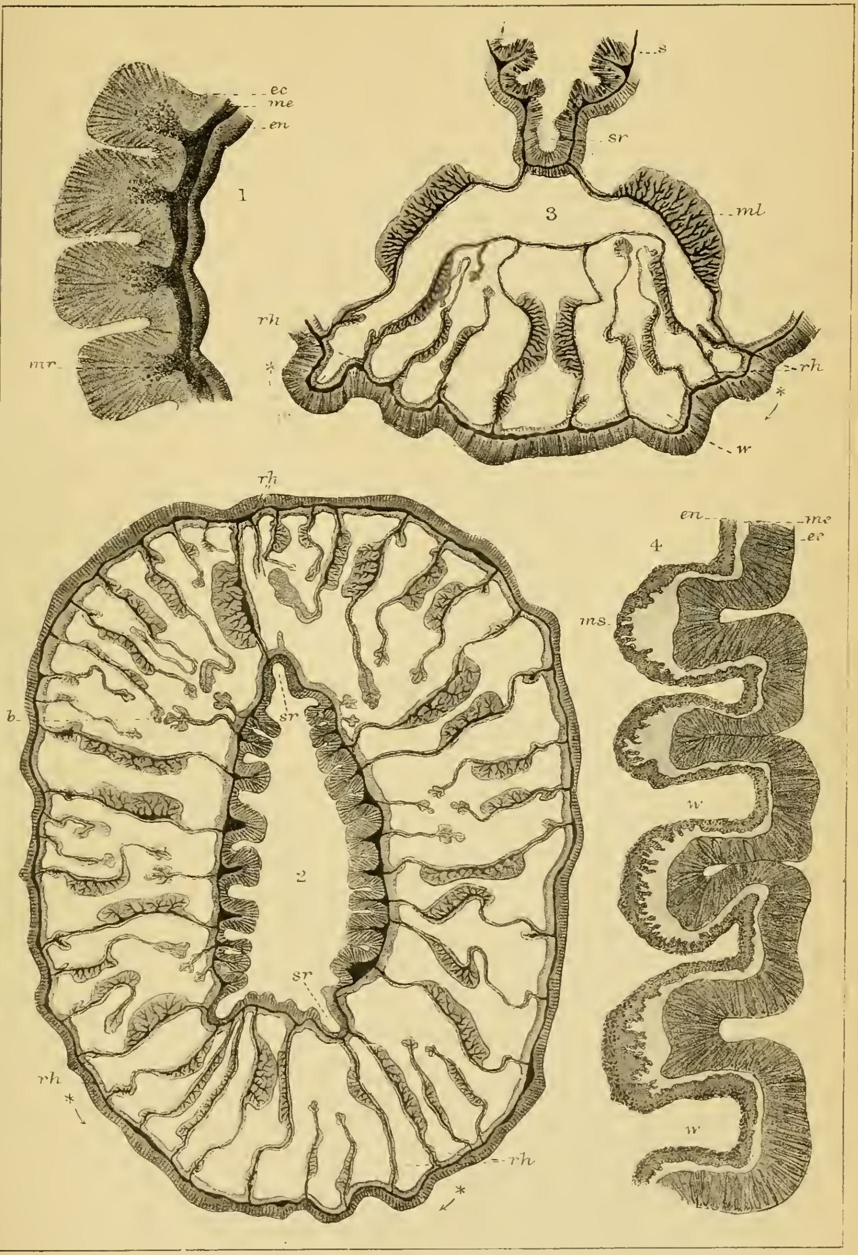


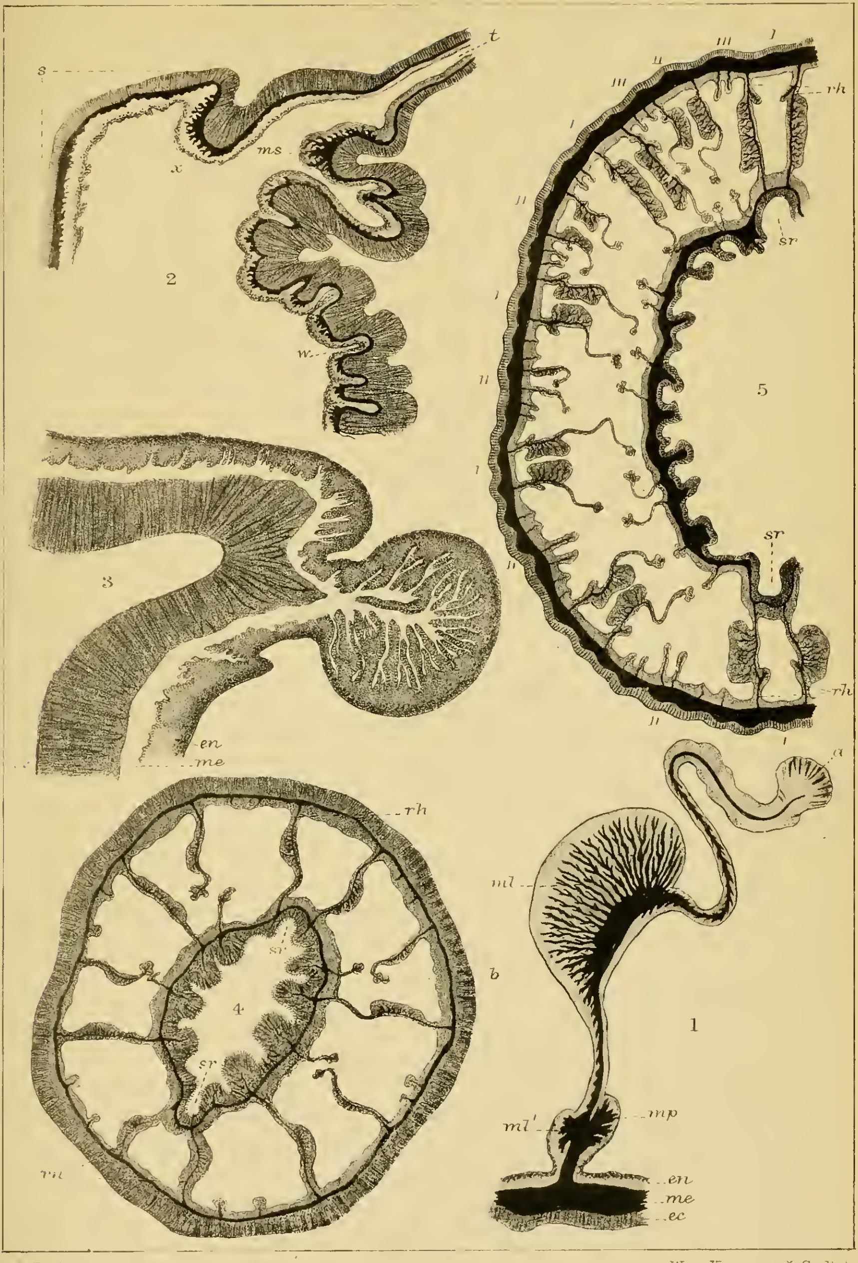
Fig 2.



West, Newman & Co. lith.



A F D. del. West Newman & Co lith



A.F.D. del.

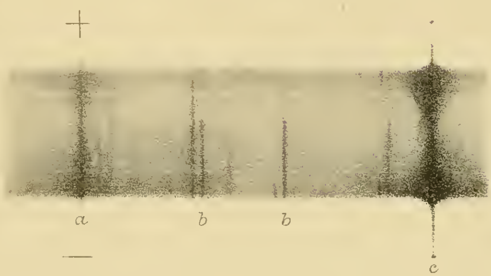
West, Newman & Co lith.

× 40 diam

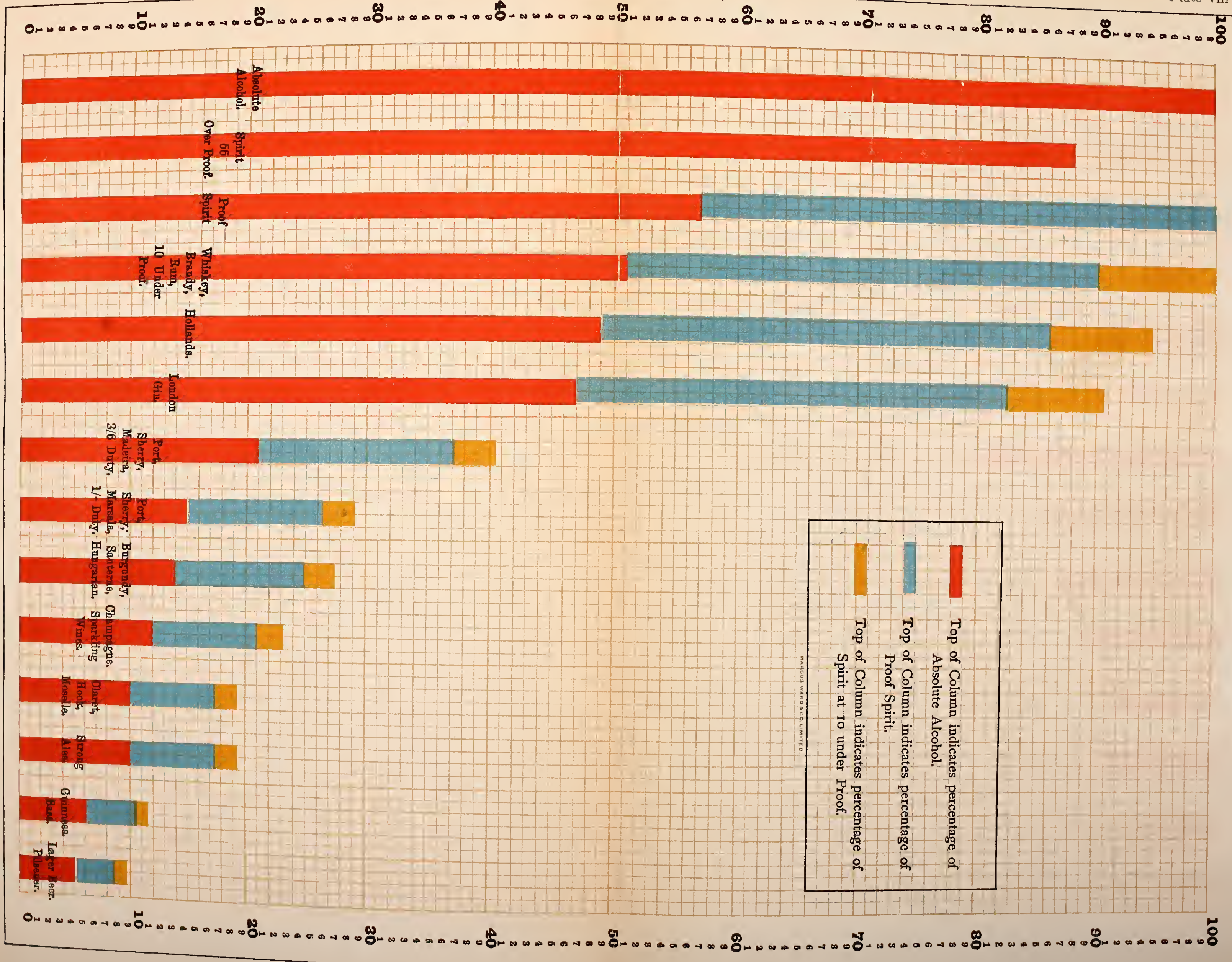
× 40 diam

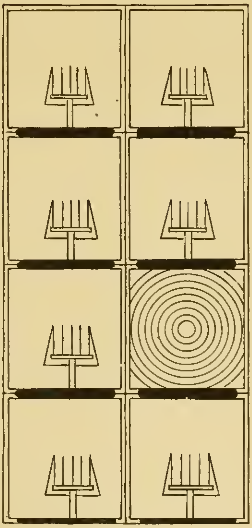
W.N.H. del

West, Newman chr lith

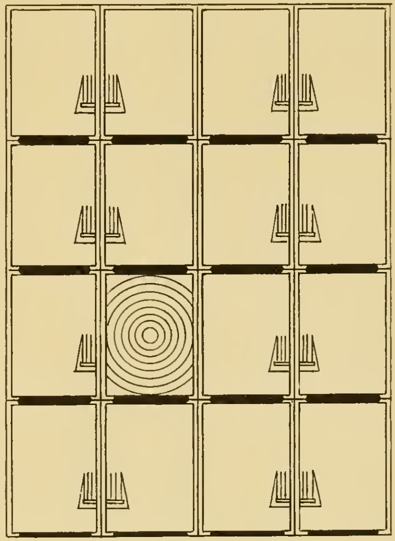


West, Newman lith.

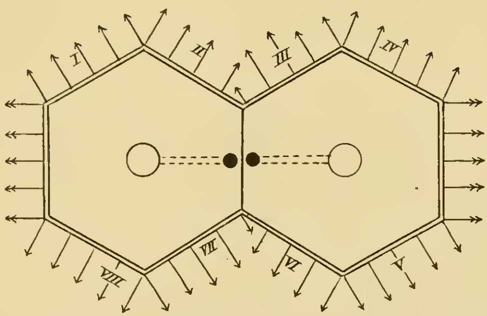

0
10
20
30
40
50
60
70
80
90
100
Absolute Alcohol.
Spirit 65 Over Proof.
Proof Spirit
Whiskey, Brandy, Rum, 10 Under Proof.
Hollands.
London Gin.
Port, Sherry, Madeira, 2/6 Duty.
Port, Sherry, Marsala, 1/- Duty.
Burgundy, Sauterne, Hungarian.
Champagne, Sparkling Wines.
Claret, Hock, Moselle.
Strong Ales.
Guinness. Bass.
Lager Beer. Pilsener.
Top of Column indicates percentage of Absolute Alcohol.
Top of Column indicates percentage of Proof Spirit.
Top of Column indicates percentage of Spirit at 10 under Proof.
MARCUS WARD & CO. LIMITED



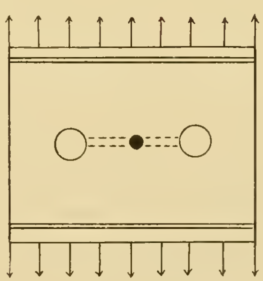
ELEVATION A.



ELEVATION B.

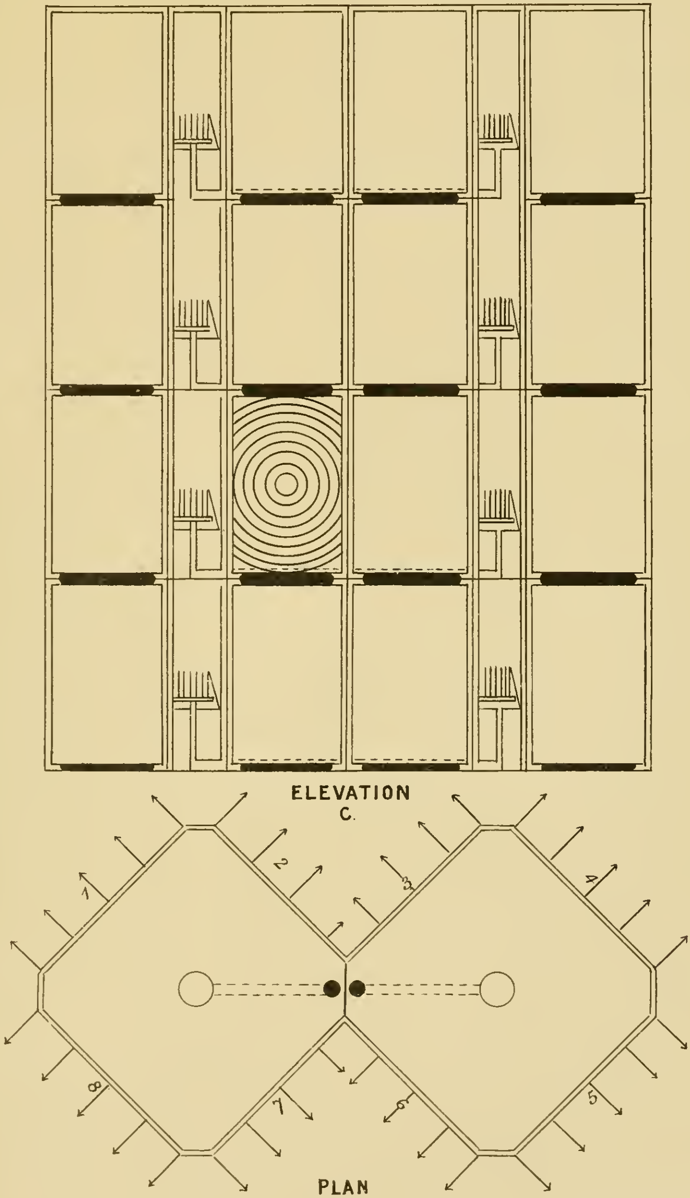


PLAN B.



PLAN A.

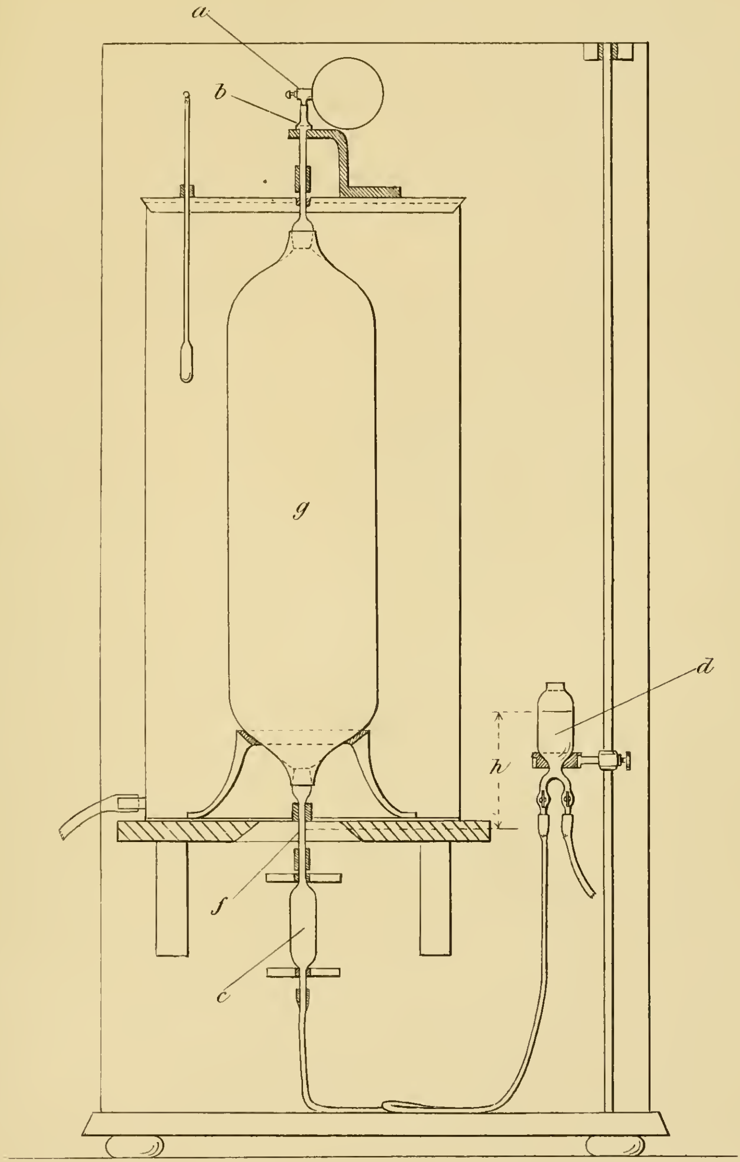
Geo West & Sons lith et imp



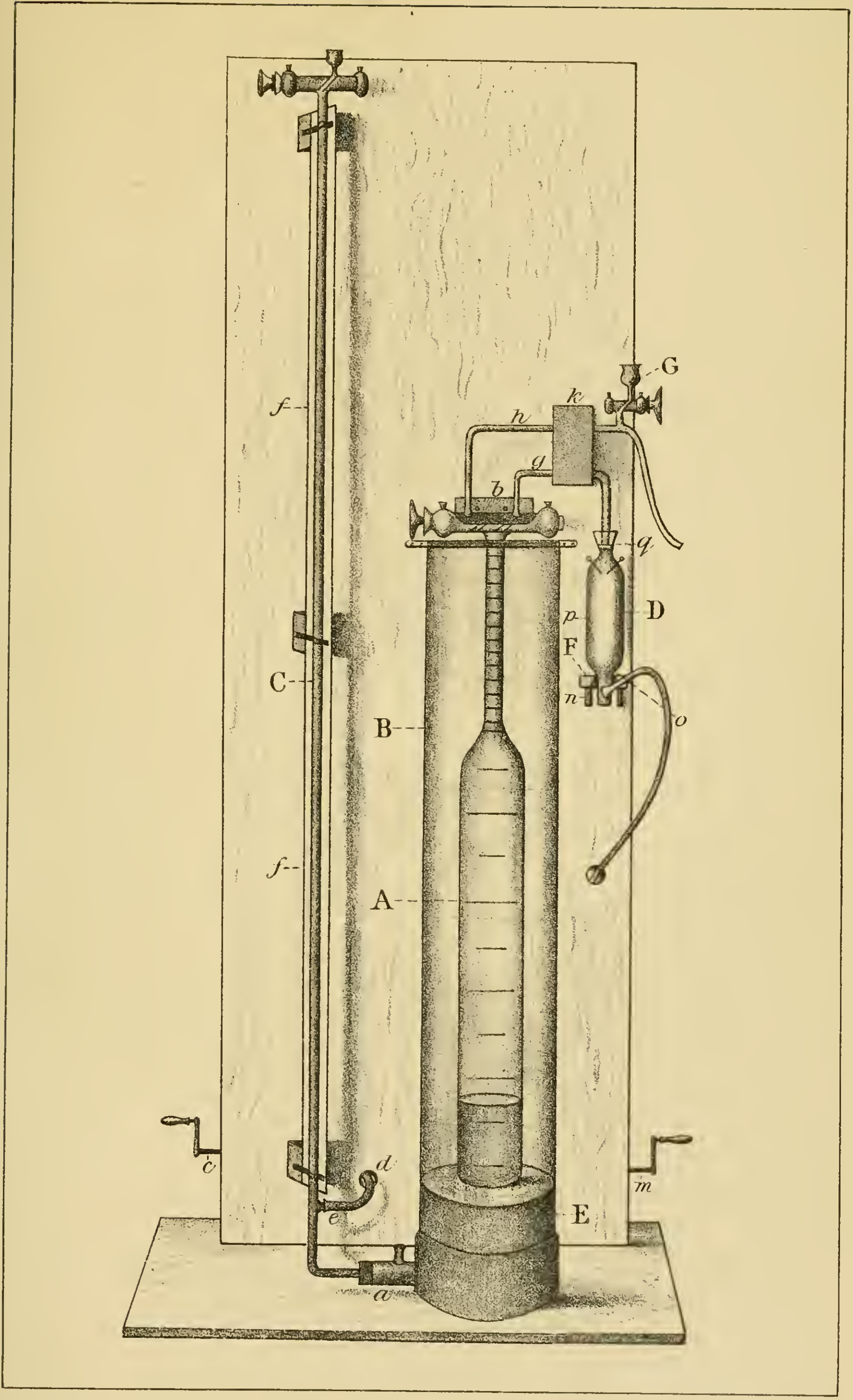
ELEVATION
C.

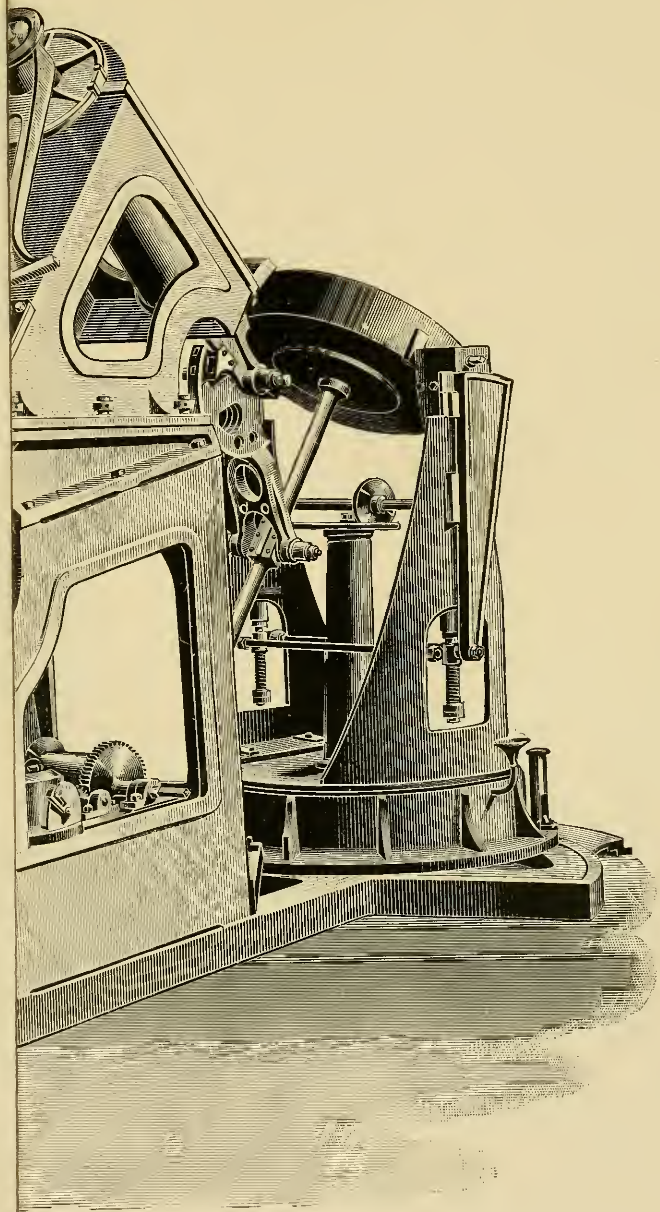
PLAN
C.

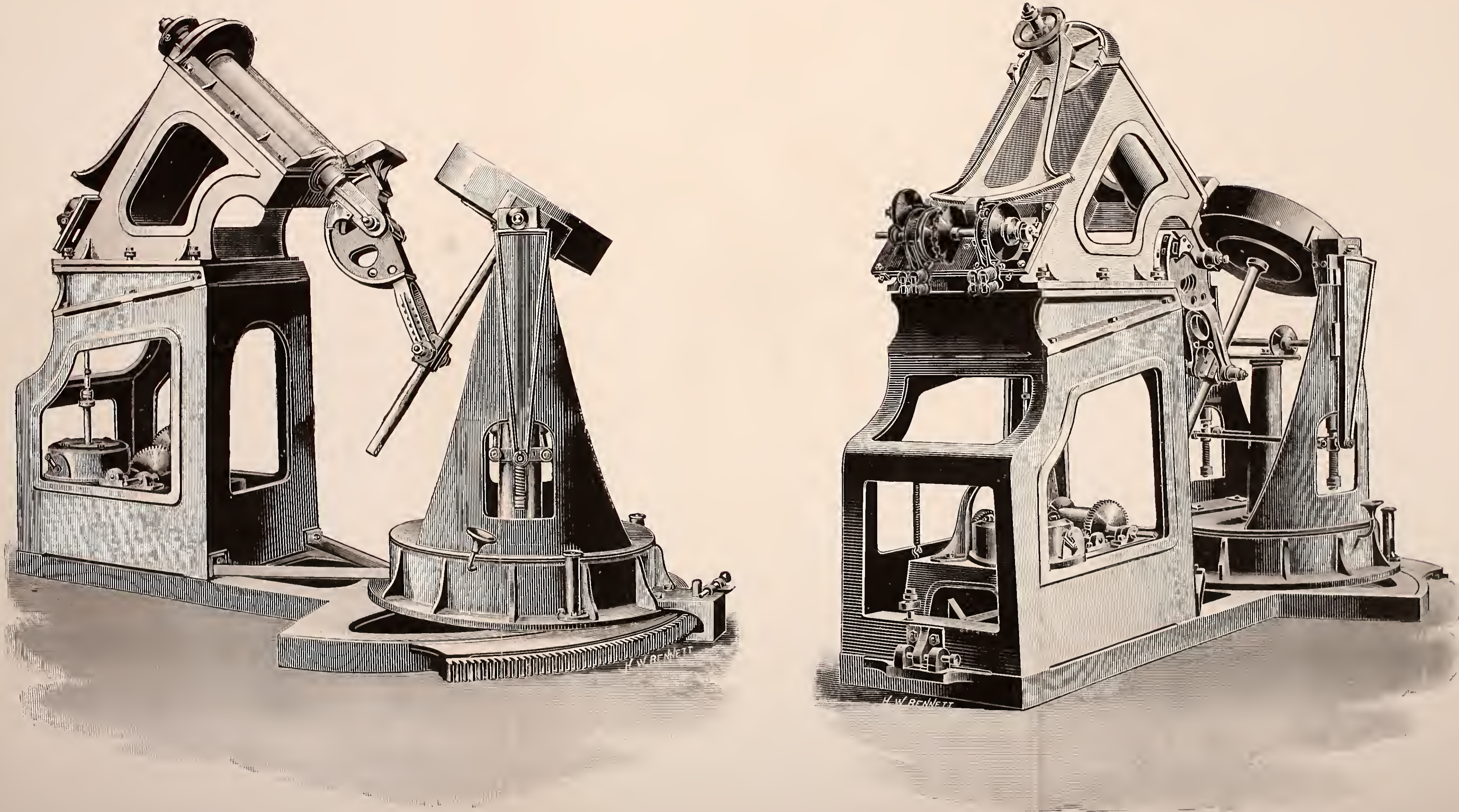
Geo West & Sons lith et imp



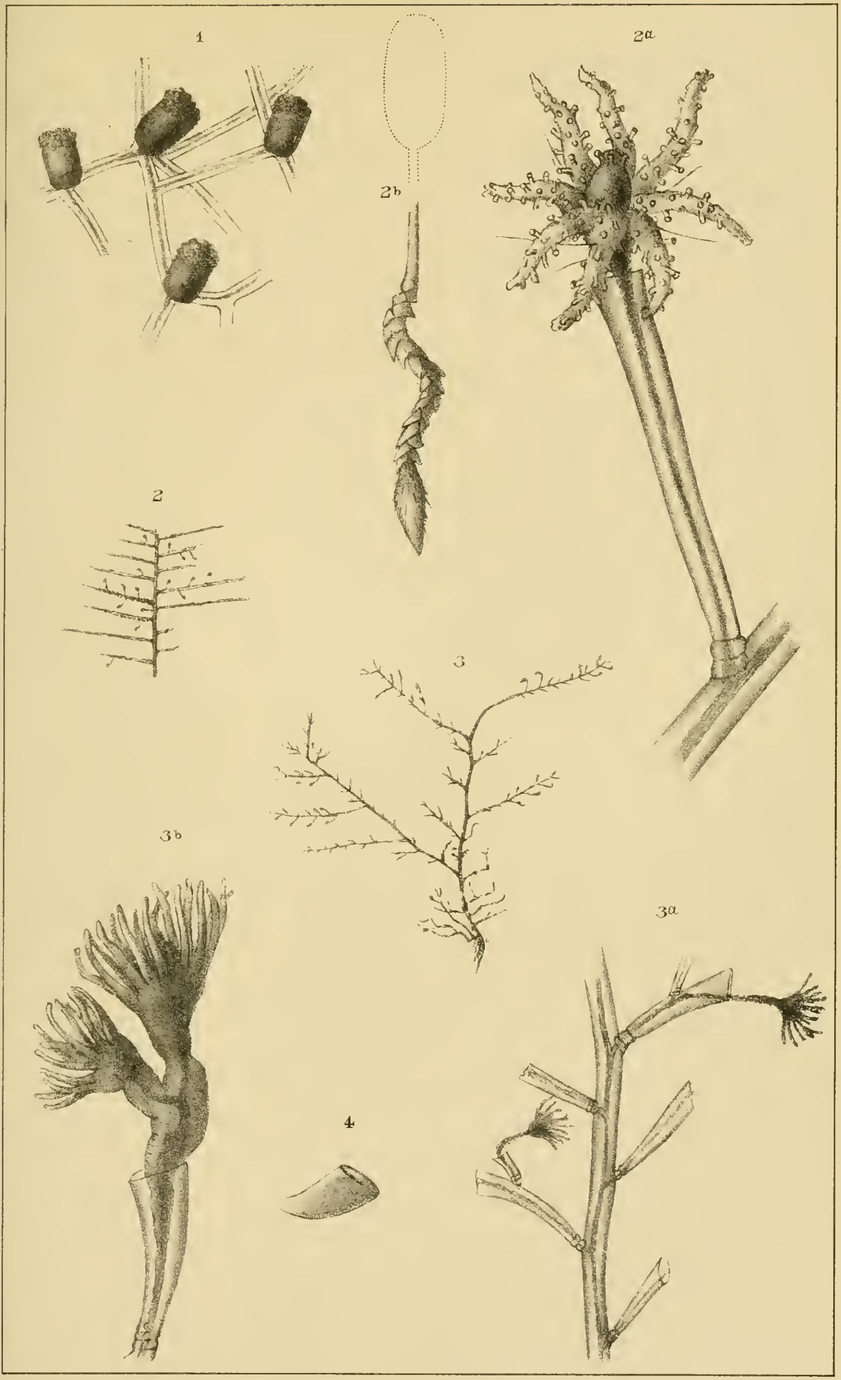
Geo West & Sons lith et imp


G
k
h
g
b
q
D
p
F
n
o
f
C
B
A
f
c
m
d
e
E
a

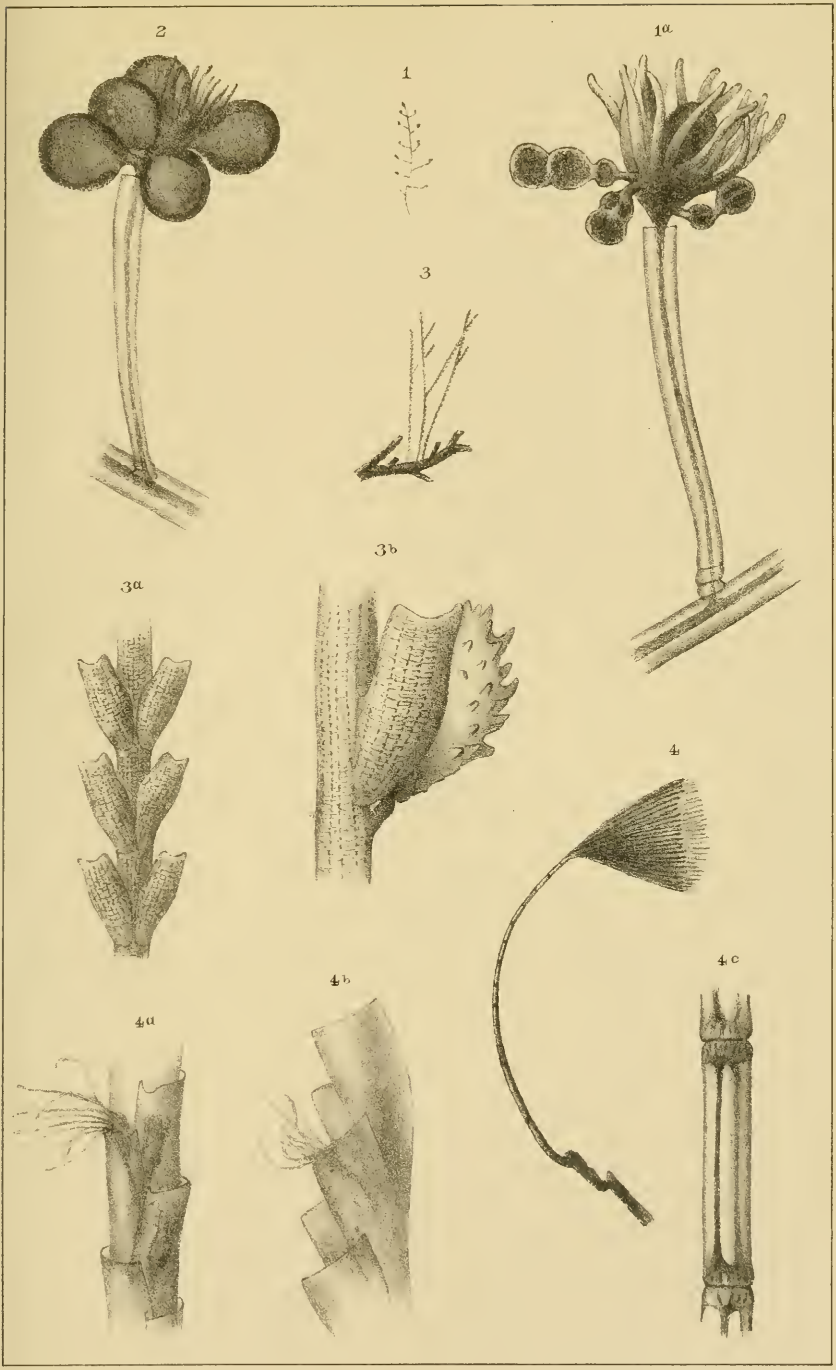




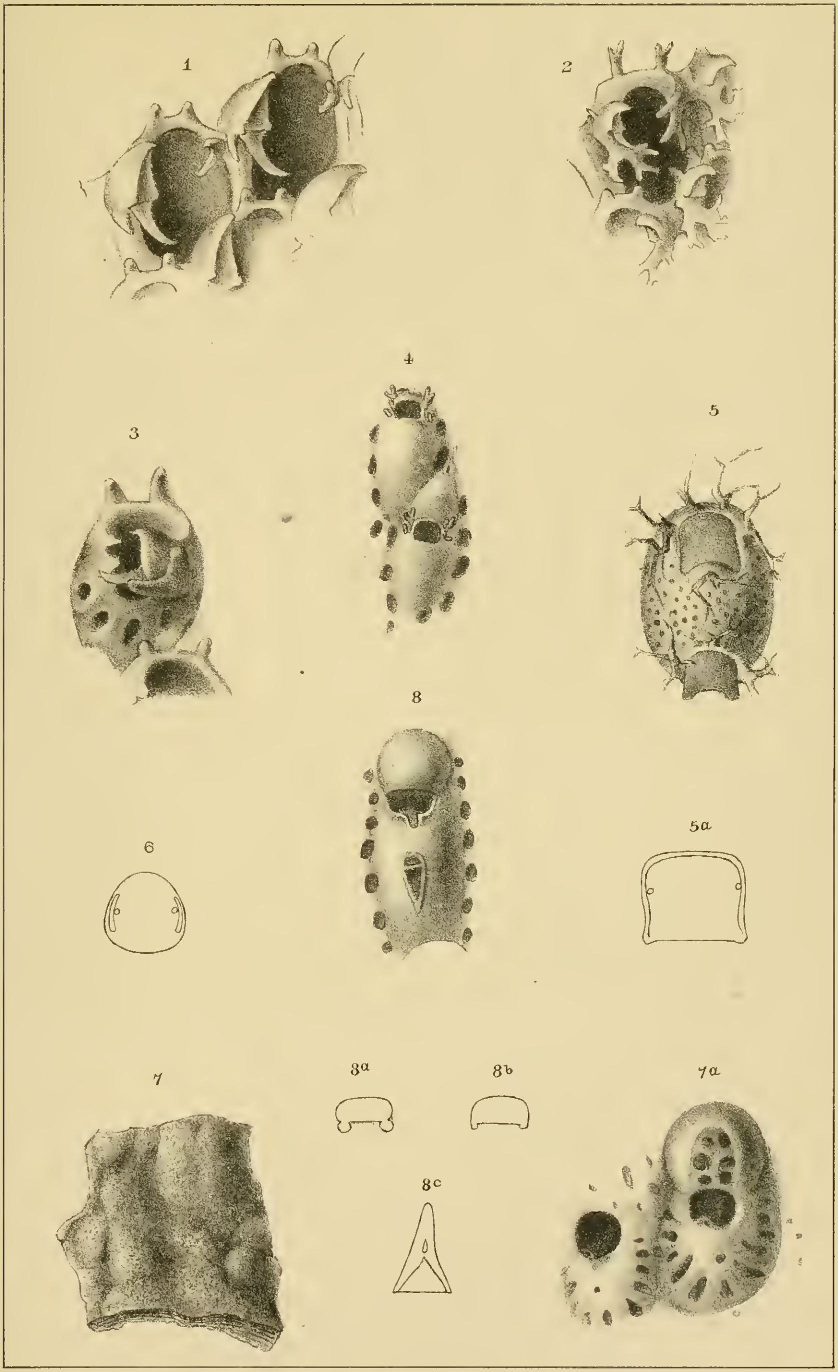
Heliostat for the Smithsonian Institution, Washington.



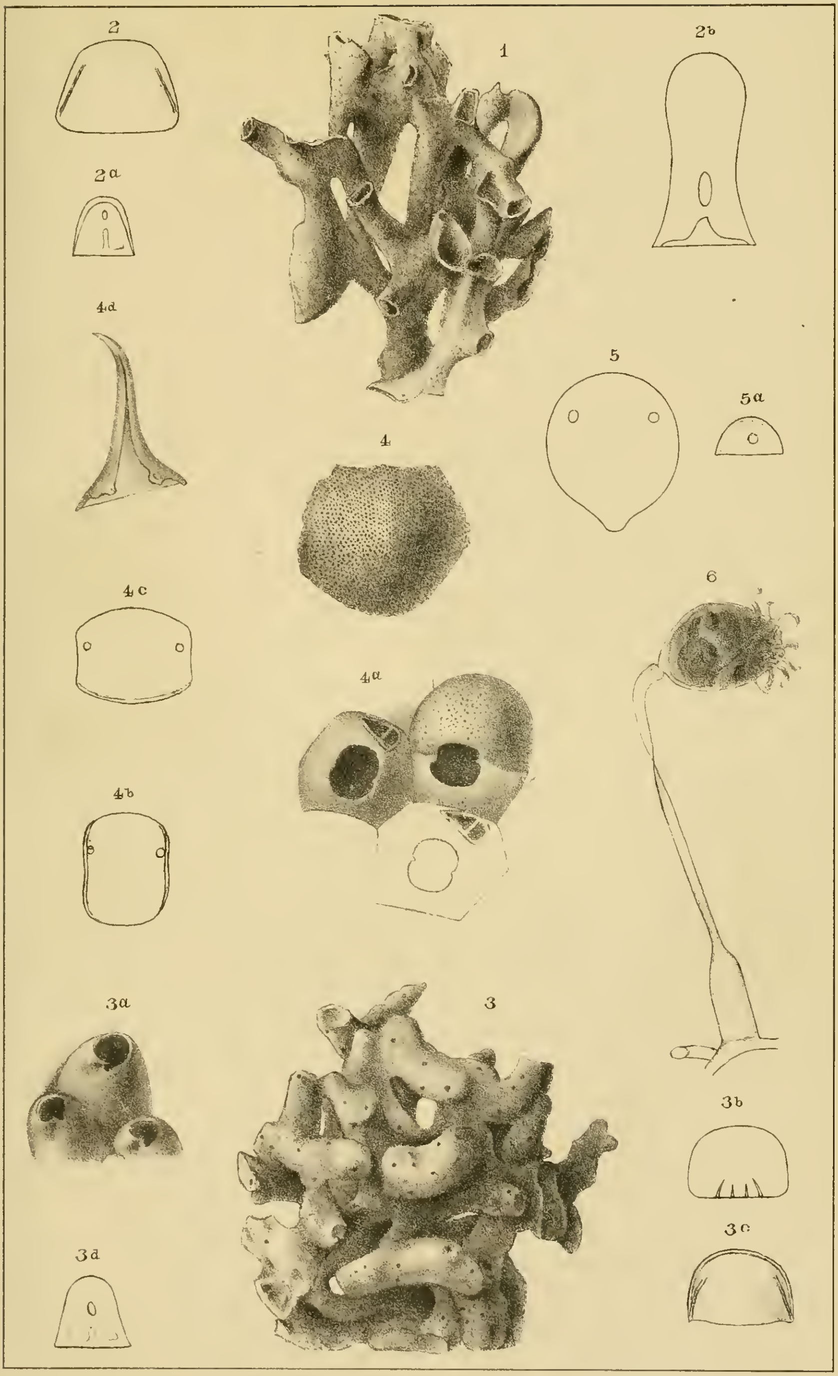
Geo. West & Sons del lith et imp.



Geo. West & Sons del lith et imp.



Geo. West & Sons del lith et imp.



Geo. West & Sons del lith et imp.

LIST

OF

SOCIETIES, INSTITUTIONS, ETC.,

WITH WHICH THE ROYAL DUBLIN SOCIETY EXCHANGES PUBLICATIONS.

ABERDEEN, ...	Natural History Society.
ADELAIDE, ...	Royal Society of South Australia.
ALBANY, ...	New York State Library.
AMSTERDAM, ...	Kön. Akademie van Wetenschappen.
,, ...	Kön. Zoologisch Genootschap.
APT, ...	Société Litteraire Scientifique et Artistique.
ARMAGH, ...	The Observatory.
BALTIMORE (MARYLAND) ..	Johns Hopkins University.
BASEL, ...	Naturforschende Gesellschaft.
BATAVIA, ...	Bataviaasch Genootschap.
BATH, ...	Postal Microscopical Society.
BERGEN, ...	Museum de Bergen.
BELGRADE, ...	Académie Royale de Serbie.
BERLIN, ...	Gesellschaft für Erdkunde.
,, ...	Die Sternwarte.
,, ...	Deutsche Geologische Gesellschaft.
,, ...	Kön. Akademie der Wissenschaften.
,, ...	Physikalische Gesellschaft.
BELFAST, ...	Natural History Society.
BERWICK, ...	Berwickshire Naturalists' Field Club.

Batavia, ...	Magnetical and Meteorological Observatory.
Bern, ...	Allgemeine Schlesische Gesellschaft.
,, ...	Naturforschende Gesellschaft.
Birmingham, ...	Free Central Library.
,, ...	Institution of Mechanical Engineers.
,, ...	Sir Josiah Mason's Science College.
Birkenhead, ...	Literary and Scientific Society.
Bombay, ...	Geographical Society.
,, ...	Royal Asiatic Society.
,, ...	Natural History Society.
Bootle-cum-Linacre, ...	Free Public Library.
Bordeaux, ...	Académie des Sciences.
,, ...	Faculté des Sciences.
,, ...	Société des Sciences physiques et naturelles.
,, ...	Société de Médecine et de Chirurgie.
,, ...	L'Observatoire.
Bologna, ...	Academia della Scienze.
Boston, ...	Natural History Society.
,, ...	American Academy of Sciences.
,, ...	Gynaecological Society.
Bradford, ...	Public Art Museum.
Bremen, ...	Naturwissenschaftlicher Verein.
Breslau, ...	Schlesische Gesellschaft für Väterlandisch-Cultur.
Brisbane, ...	Government of Queensland.
Brünn, ...	Naturforschende Verein.
Brussels, ...	Académie Royale de Médecine.
,, ...	Académie Royale des Sciences.
,, ...	Observatoire Royale.
,, ...	Société Malacologique.
Buda-Pesth, ...	Académie Hongroise des Sciences.
Bucharest, ...	Academia Romania.
,, ...	Institut Météorologique.
Buffalo, ...	Medical and Surgical Journal.
,, ...	Society of Natural Sciences.
Buenos Ayres, ...	Observatorio.
,, ...	Academia de Ciencias.
Cadiz, ...	Observatorio di San Fernando.
Calcutta, ...	Meteorological Office.

Calcutta, ...	Asiatic Society.
,, ...	Geological Survey of India.
,, ...	Geological Museum.
Cambridge, ...	Philosophical Society.
Cambridge (Mass.), ...	Harvard University.
Cape Town, ...	South African Library.
Cape of Good Hope, ...	The Observatory.
Cardiff, ...	Naturalists' Society.
Catanea, ...	Accademia Giœnia di Scienze Naturali.
Chapel Hill (N. Car.),	Elisha Mitchell Scientific Society.
Charleston, ...	Elliot Society of Natural History.
Cherbourg,	Société des Sciences Naturelles.
Chemnitz, ...	Kön. Sächsische Meteorologisches Institutes.
Chicago, ...	Academy of Sciences.
Christiania, ...	K. Norske Frederiks Universitet.
Cincinnati, ...	Observatory.
Coimbra, ...	Universidade.
Copenhagen, ...	K. Danske Videnskabers Selskabs.
Danzig, ...	Naturforschende Gesellschaft.
Darlington, ...	Public Library.
Denison (Ohio), ...	University Laboratories.
Dijon, ...	Académie des Sciences.
Delft, ...	Ecole Polytechnique.
Dresden, ...	Verein für Erdkünde.
Dublin, ...	Geological Survey of Ireland.
,, ...	King and Queen's College of Physicians.
,, ...	National Library of Ireland.
,, ...	Royal College of Surgeons.
,, ...	Royal Geological Society.
,, ...	Royal Historical and Archæological Association.
,, ...	Royal Irish Academy.
,, ...	Trinity College Library.
,, ...	University Zoological and Botanical Association.
Dudley, ...	Dudley Geological and Scientific Society.
Dunsink, ...	The Observatory.
Dunecht, ...	Observatory.

EDINBURGH, ... Botanical Society.
" ... ... Geological Society.
" ... ... Highland and Agricultural Society.
" ... ... Medical Society.
" ... ... Observatory.
" ... ... Royal Physical Society.
" ... ... Royal Scottish Society of Arts.
" ... ... Royal Society of Edinburgh.
" ... ... Scottish Agricultural Gazette.
EMDEN, ... Naturforschende Gesellschaft.
ERLANGEN, ... Physikal.-Medicinische Gesellschaft.

FALMOUTH, ... Royal Cornwall Polytechnic Society.
FLORENCE, ... Gabinetta di Fisica.
" ... ... R. Bibliotheca Nazionale Centrale.
" ... ... Reale Museo di Fisica.
" ... ... R. Comitato Geologico d'Italia.
FRANKFURT-A-M., ... Senckenbergische Gesellschaft.
" ... Zoologische Gesellschaft.
FREIBURG-IM-B., ... Naturforschende Gesellschaft.

GLASGOW, ... Institute of Engineers.
" ... ... Mitchell Library.
" ... ... Natural History Society.
" ... ... Philosophical Society.
GENEVA, ... Institut National Génévois.
" ... ... Société de Physique et d'Histoire Naturelle.
GIESSEN, ... Grossherzoglishe Universitet.
GOTTENBURG, ... K. Gesellschaft der Wissenschaften.
GOTTINGEN, ... K. Vet. och Vitterhets Samhalle.
GORLITZ, ... Naturforschende Gesellschaft.
GRATZ, ... Naturwissens. Verein für Steiermark.
GREENWICH, ... Observatory.

HALIFAX, ... Geological and Polytechnical Society.
HALLE, ... Kais. Leopold-Carolin. Akademie der Naturforscher.
" ... ... Naturwissens. Verein für Sächsen und Thüringen.
HAMBURG, ... Naturforschende Verein.

HAARLEM, ...	Musée Teyler.
,, ...	Société Hollandaise des Sciences.
HELSINGFORS, ...	Société des Sciences.
HEIDELBERG, ...	Naturhistorisch-Medicinischer Verein.
,, ...	Naturhistorisch-Medizinische Gesellschaft.
,, ...	Universität.
HOBART TOWN, ...	Royal Society of Tasmania.
INNSBRÜCK, ...	Das Ferdinandeums.
,, ...	Naturwissens. Medicin. Verein.
INVERNESS, ...	Gaelic Society.
JENA, ...	Medicinische-Naturwissens. Gesellschaft.
KARLSRUHE, ...	Grossherzoglische Sternwarte.
KAZAN, ...	Imp. Kazansky Universitet.
KEW, ...	Observatory.
KIEL, ...	Universität.
,, ...	Die Sternwarte.
KONIGSBERG, ...	K. Physik. Gesellschaft.
KOLOSVAR, ...	Société du Musée de Transylvanie.
LANDSHÜT	Botanischer Verein.
LEEDS, ...	Philosophical and Literary Society.
,, ...	The Naturalist.
,, ...	Yorkshire College of Science.
,, ...	Yorkshire Naturalists' Union.
LEICESTER, ...	Literary and Philosophical Society.
,, ...	Provincial Medical Journal.
LEIPSIG, ...	Astronomische Gesellschaft.
,, ...	Kön. Meteorologisches Institutes.
,, ...	Kön. Sächsische Gesellschaft der Wissenschaften.
,, ...	Kön. Sternwarte.
,, ...	M. E. Wiedemann.
LIÈGE, ...	Société des Sciences.
LIVERPOOL, ...	Biological Society.
,, ...	Free Public Library.
,, ...	Historical Society of Lancashire and Cheshire.

LIVERPOOL, ...	Astronomical Society.
,, ...	Geological Society.
LONDON, ...	Anthropological Institute.
,, ...	British Archæological Association.
,, ...	British Association.
,, ...	British Museum (Natural History).
,, ...	British Museum.
,, ...	Chemical Society.
,, ...	East India Association.
,, ...	Educational Library (South Kensington).
,, ...	Entomological Society.
,, ...	Geological Survey of Great Britain.
,, ...	Guildhall Library.
,, ...	Institution of Civil Engineers.
,, ...	Institution of Mechanical Engineers.
,, ...	Institution of Naval Architects.
,, ...	Iron and Steel Institute.
,, ...	Linnean Society.
,, ...	London Institute.
,, ...	London Library.
,, ...	Mathematical Society.
,, ...	Meteorological Office.
,, ...	National Association for the Promotion of Social Science.
,, ...	Odontological Society.
,, ...	Patent Office.
,, ...	Pathological Society.
,, ...	Pharmaceutical Society.
,, ...	Physical Society.
,, ...	Quekett Microscopical Club.
,, ...	Royal Agricultural Society of England.
,, ...	Royal Asiatic Society.
,, ...	Royal Astronomical Society.
,, ...	Royal College of Physicians.
,, ...	Royal College of Surgeons.
,, ...	Royal Geographical Society.
,, ...	Royal Institution of British Architects.
,, ...	Royal Institution of Great Britain.
,, ...	Royal Medical and Chirurgical Society.
,, ...	Royal Meteorological Society.
,, ...	Royal Microscopical Society.

London, ...	... ...	Royal Society.
,, ...	... ...	Royal Society of Literature.
,, ...	... ...	Russell Institution.
,, ...	... ...	Scientific News Office.
,, ...	... ...	Society of Biblical Archæology.
,, ...	... ...	Society of Telegraph Engineers and Electricians.
,, ...	... ...	Victoria Institute.
,, ...	... ...	Zoological Society.
Lausanne,	... ...	Société Vaudoise des Sciences Naturelles.
Lisbon, ...	... ...	Academia Reale das Sciencias.
Londonderry,	... ...	Magee College.
Louvain, ...	... ...	L'Université.
Lund, ...	... ...	Universitet.
Luxembourg,	... ...	Société des Sciences Naturelles.
Luzern, ...	... ...	Naturforschende Gesellschaft.
Lyons, ...	... ...	Société Nationale d'Agriculture.
,, ...	... ...	Société Linnéenne.
Madison (Wis.), ...	...	Wisconsin Academy of Sciences,
Madras, ...	... ...	The Observatory.
Madrid, ...	... ...	Real Academia de Ciencias.
Malta, ...	...	Public Library.
Manchester,	... ...	Free Library.
,,	... ...	Geological Society.
,,	... ...	Literary and Philosophical Society.
Marlborough,	... ...	Natural History Society.
Marseilles,	... ...	Société Scientifique Industrielle.
Melbourne,	... ...	Observatory.
,,	... ...	Royal Society of Victoria.
,,	... ...	University Library.
,,	... ...	Patent Office.
,,	... ...	Geological Society of Australasia.
Meudon, ...	... ...	L'Observatoire.
,, ...	... ...	Mons. Jannsen.
Meriden (Conn.),	...	Scientific Association.
Milan, ...	... ...	Reale Osservatorio di Brera.
,, ...	... ...	R. Instituto Lombardo di Scienze.
,, ...	... ...	Societa Italiana di Scienze Naturali.
Minneapolis (Minn.),	...	Geological and Natural History Survey.

MODENA, ... R. Accademia di Scienze, Lettere, ed Arti.
MONTPELIER, ... Faculté de Médecine.
,, ... Académie des Sciences.
MONTREAL, ... M'Gill College.
,, ... Natural History Society.
,, ... Canadian Record of Science.
,, ... Canadian Society of Engineers.
MOSCOW, ... Le Musée Publique.
,, ... Société Impériale des Naturalistes.
MÜNICH, ... Zeitschrift für Biologie.
,, ... Kön. Böhmische Akademie der Wissenschaften.

NAPLES, ... Società Reale Accademia delle Scienze.
,, ... Zoologische Station.
NEUCHATEL, ... Société des Sciences Naturelles.
NEWCASTLE-ON-TYNE, ... Chemical Society.
,, ... North of England Institute of Mining and Mechanical Engineers.
,, ... Natural History Society of Northumberland and Durham.
,, ... North-east Coast Institution of Engineers and Shipbuilders.
NEW HAVEN (CONN.), ... American Journal of Science.
NEW YORK, ... American Geographical and Statistical Society.
,, ... American Journal of Obstetrics.
,, ... Gaillard's Medical Journal.
,, ... Linnean Society.
,, ... Lyceum of Natural History.
,, ... New York Medical Journal.
,, ... School of Mines.
NOTTINGHAM, ... Free Public Library.
NOVA SCOTIA, ... King's College Library.

ODESSA, ... Natural History Society.
OHIO, ... Mechanics' Institute.
OSNABRÜCK, ... Naturwissenschaftlicher Verein.

Ottawa, ... Canadian Patent Office.
,, ... Geological Survey of Canada.
Oxford, ... Ashmolean Society.
,, ... Archæological and Historical Society.
,, ... Radcliffe Library.
,, ... Radcliffe Observatory.

Palermo, ... Reale Instituto Technico.
,, ... Société des Sciences Naturelles.
Paris, ... Académie des Sciences.
,, ... Depôt de la Marine.
,, ... Ecole des Mines.
,, ... Ecole Normale Supérieure.
,, ... Ecole Polytechnique.
,, ... Faculté de Médecine.
,, ... Feuille des Jeunes Naturalistes.
,, ... Jardin des Plantes.
,, ... L'Observatoire.
,, ... Revue Scientifique.
,, ... Société Académique Indo-Chinoise des Sciences.
,, ... Société Entomologique de France.
,, ... Société de Biologie.
,, ... Société d'Encouragement pour l'Industrie Nationale.
,, ... Société de Géographie.
,, ... Société Géologique.
,, ... Société Météorologique.
,, ... Société de Physique.
,, ... Société Zoologique de France.
Penzance, ... Geological Society of Cornwall.
Philadelphia, ... Academy of Natural Sciences.
,, ... American Philosophical Society.
,, ... Franklin Institute.
Plymouth, ... Devon and Cornwall Natural History Society.
Prague, ... Kön. Böhmische Gesellschaft.
,, ... Bohemian Chemical Society.
Pulkowa, ... Nikolai Hauptsternwarte.

Quebec, ... Literary and Historical Society.

Rio de Janeiro, ...	... Observatorio.
Rome, ...	... Academia Pontificia de Nuovi Lincei.
,, ...	... Observatorio del Collegio Romano.
,, ...	... Societa Geologica Italiana.
,, ...	... Ufficino Centrale Meteorologia Italiana.
Rotterdam, ...	... Bataviaasch Genootschap.
Rostock, ...	... Universitat.
Rouen, ...	... Académie des Sciences et Belles Lettres.
Salem (Mass.), ...	... Peabody Academy of Science.
,, ...	... Essex Institute.
Salford, ...	... Royal Museum and Library.
San Francisco, ...	... Academy of Sciences.
St. Louis, ...	... Academy of Science.
Stockholm, ...	... Kön. Svenska Vetenskaps Akademiens.
St. Petersburg,	... Bureau de la Recherche Géologique.
,, ...	... Compass Observatory.
,, ...	... Imperial Academy of Sciences.
,, ...	... Société Impériale de Géographie.
Shanghai, ...	... Royal Asiatic Society (China Branch).
Siena, ...	... Reale Academia dei Fisiocritici.
Stuttgart, ...	... Verein für Väterlandische Cultur.
Sydney, ...	... Department of Mines.
,, ...	... Linnean Society of New South Wales.
,, ...	... Royal Society of New South Wales.
,, ...	... University Library.
Schemnitz, ...	... Kön. Ungarische Akademie.
Swansea,... ...	... Royal Institution.
Tacubaya (Mex.),	... Osservatorio Nacional.
Taunton, ...	... Somersetshire Archæological and Nat. Hist. Society.
Tiflis, ...	... Physikalische Observatorium.
Tokyo, ...	... Imperial University of Japan.
Topeka (Kan.), ...	... Kansas Academy of Science.
Toronto, ...	... Canadian Institute.
Toulouse, ...	... Académie des Sciences.
Trieste, ...	... Naturwissenschaftliche-Adriatische.
Trondjheim, ...	... Kön. Norske Videns. Selskabs.
Truro, ...	... Mining Institute of Cornwall.
,, ...	... Royal Institution of Cornwall.

TURIN, ... Reale Accademia di Scienze.

UPSALA, ... Universität.
UTRECHT, ... Provinciaal Genootschap van Künsten.

VENICE, ... L'Ateneo Veneto.
" ... ... Reale Istituto Veneto.
VERMONT, ... Orleans County Society of Natural History.
VIRGINIA, ... Medical Society.

WASHINGTON, ... Bureau of Education.
" ... ... Department of Agriculture.
" ... ... Geological Society.
" ... ... Smithsonian Institution.
" ... ... Surgeon-General's Office, U. S. Army.
" ... ... United States Coast and Geodetic Survey.
" ... " " Fish Commission.
" ... ... " " Naval Observatory.
WELLINGTON, ... Colonial Museum and New Zealand Institute.
" ... ... Registrar General's Office.
WIEN, ... Anthropologische Gesellschaft.
" ... . Central Anstalt für Meteorologie.
" ... ... Geographische Gesellschaft.
" ... ... Geologische Reichsanstalt.
" ... ... Kön. Akademie des Wissenschaften.
" ... ... Oesterreichische Gesellschaft.
" ... . Zoologisch-Botanische Gesellschaft.
WÜRZBURG, ... Physikalisch-Medizinische Gesellschaft.

YOKOHAMA, ... Asiatic Society of Japan.

ZURICH, ... Naturforschende Gesellschaft.
" ... ... Schweizerische Polytechnikum.

SCIENTIFIC PUBLICATIONS

OF THE

ROYAL DUBLIN SOCIETY.

TRANSACTIONS:

Quarto, Published in Parts, stitched.

CONTENTS OF VOLUME I. (New Series).

PART.

1.—On Great Telescopes of the Future. By Howard Grubb, F.R.A.S. (November, 1877.)

2.—On the Penetration of Heat across Layers of Gas. By G. J. Stoney, M.A., F.R.S. (November, 1877.)

3.—On the Satellites of Mars. By Wentworth Erck, LL.D. (May, 1878.)

4.—On the Mechanical Theory of Crookes's, or Polarization Stress in Gases. By G. J. Stoney, M.A., F.R.S. (October, 1878.)

5.—On the Mechanical Theory of Crookes's Force. By George Francis Fitz Gerald, M.A., F.T.C.D. (October, 1878.)

6.—Notes on the Physical Appearance of the Planet Mars, as seen with the Three-foot Reflector at Parsonstown, during the Opposition of 1877. By John L. E. Dreyer, M.A. Plates I. and II. (Nov. 1878.)

7.—On the Nature and Origin of the Beds of Chert in the Upper Carboniferous Limestone of Ireland. By Professor Edward Hull, M.A., F.R.S., Director of the Geological Survey of Ireland. And On the Chemical Composition of Chert and the Chemistry of the Process by which it is formed. By Edward T. Hardman, F.C.S. Plate III. (November, 1878.)

8.—On the Superficial Tension of Fluids and its Possible Relation to Muscular Contractions. By G. F. Fitz Gerald, M.A., F.T.C.D. (December, 1878.)

9.—Places of One Thousand Stars observed at the Armagh Observatory. By Rev. Thomas Romney Robinson, D.D., LL.D., D.C.L., F.R.S., &c. (February, 1879.)

10.—On the Possibility of Originating Wave Disturbances in the Ether by Means of Electric Forces. Part I. By George Francis Fitz Gerald, M.A., F.T.C.D. (February, 1880.)

11.—On the Relations of the Carboniferous, Devonian, and Upper Silurian Rocks of the South of Ireland to those of North Devon. By Edward Hull, M.A., LL.D., F.R.S., Director of the Geological Survey of Ireland, and Professor of Geology, Royal College of Science, Dublin. Plates IV. and V., and Woodcuts. (May, 1880.)

12.—Physical Observations of Mars, 1879–80. By C. E. Burton, B.A., M.R.I.A., F.R.A.S. Plates VI., VII., and VIII. (May, 1880.)

13.—On the Possibility of Originating Wave Disturbances in the Ether by means of Electric Forces. Part II. By George Francis Fitz Gerald, M.A., F.T.C.D. (November, 1880.)

14.—Explorations in the Bone Cave of Ballynamintra, near Cappagh, Co. Waterford. By A. Leith Adams, M.B., F.R.S., G. H. Kinahan, M.R.I.A., and R. J. Ussher. Plates IX. to XIV. (April, 1881.)

15.—Notes on the Physical Appearance of the Planet Jupiter during the Season 1880–1. By Otto Boeddicker, PH.D. Plate XV. (January, 1882.)

16.—Photographs of the Spark Spectra of Twenty-one Elementary Substances. By W. A. Hartley, F.R.S.E., Professor of Chemistry, Royal College of Science, Dublin. Plates XVI., XVII., and XVIII. (Feb. 1882.)

17.—Notes on the Physical Appearance of the Comets *b* and *c*, 1881, as observed at Birr Castle, Parsonstown, Ireland. By Otto Boeddicker, PH.D. Plate XIX. (August, 1882.)

18.—On the Laurentian Rocks of Donegal, and of other parts of Ireland. By Edward Hull, LL.D., F.R.S., &c., Director of the Geological Survey of Ireland. Plates XX. and XXI. (February, 1882.)

19.—Palæo-Geological and Geographical Maps of the British Islands and the adjoining parts of the Continent of Europe. By Edward Hull, LL.D., F.R.S., &c., Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science, Dublin. Plates XXII. to XXXV. (November, 1882.)

20.—Notes on the Physical Appearance of the Planet Mars during the Opposition in 1881. Accompanied by Sketches made at the Observatory, Birr Castle. By Otto Boeddicker, PH.D. Plates XXXVI. and XXXVII. (December, 1882.)

21.—Notes on the Aspect of Mars in 1882. By C. E. Burton, B.A., F.R.A.S., as seen with a Reflecting Telescope of 9-inch Aperture, and Powers of 270 and 600. Plate XXXVIII. (January, 1883.)

22.—On the Energy expended in Propelling a Bicycle. By G. Johnstone Stoney, D.SC., F.R.S., a Vice-President of the Society; and G. Gerald Stoney. Plates XXXIX. to XLI. (January, 1883).

23.—On Electromagnetic Effects due to the Motion of the Earth. By George Francis Fitz Gerald, M.A., F.T.C.D., Erasmus Smith's Professor of Experimental Science in the University of Dublin. (Jan., 1883.)

24.—On the Possibility of Originating Wave Disturbances in the Ether by Means of Electric Forces—Corrections and Additions. By George Francis Fitz Gerald, M.A., F.T.C.D. (January, 1883.)

25.—On the Fossil Fishes of the Carboniferous Limestone Series of Great Britain. By J. W. Davis. Plates XLII. to LXV. (September, 1883.) [*With Title-page to Volume.*]

CONTENTS OF VOLUME II. (New Series).

PART.
1.—Observations of Nebulæ and Clusters of Stars, made with the Six-foot and Three-foot Reflectors at Birr Castle, from the year 1848 up to the year 1878. Nos. 1 and 2. By the Right Hon. the Earl of Rosse, L.L.D., D.C.L., F.R.S. Plates I. to IV. (August, 1879.) No. 3. Plates V. and VI. (June, 1880.)

2.—On Aquatic Carnivorous Coleoptera or Dytiscidæ. By Dr. Sharp. Plates VII. to XVIII. (April, 1882.) [*With Title-page to Volume.*]

CONTENTS OF VOLUME III. (New Series).

PART.
1.—On the Influence of Magnetism on the rate of a Chronometer. By Otto Boeddicker, PH.D. Plate I. (October, 1883.)

2.—On the Quantity of Energy transferred to the Ether by a Variable Current. By George F. Fitz Gerald, M.A., F.R.S. (March, 1884.)

3.—On a New Form of Equatorial Telescope. By Howard Grubb, M.E., F.R.S. Plate II. (March, 1884.)

4.—Catalogue of Vertebrate Fossils, from the Siwaliks of India, in the Science and art Museum, Dublin. By R. Lydekker, F.G.S., F.Z.S. Plate III., and Woodcuts. (July, 1884.)

5.—On the origin of Freshwater Faunas: A study in Evolution. By W. J. Sollas, M.A., Dublin; D.Sc., Cambridge. (November, 1884.)

6.—Memoirs on the Coleoptera of the Hawaiian Islands. By the Rev. T. Blackburn, B.A., and Dr. D. Sharp. Plates IV., V. (February, 1885.)

7.—Notes on the Aspect of the Planet Mars in 1884. Accompanied by Sketches made at the Observatory, Birr Castle. By Otto Boeddicker, PH.D. Plate VI. [Communicated by the Earl of Rosse.] (March, 1885.)

8.—On the Geological Age of the North Atlantic Ocean. By Edward Hull, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Ireland. Plates VII. and VIII. (April, 1885.)

9.—On the Changes of the Radiation of Heat from the Moon during the Total Eclipse of 1884, October 4th, as measured at the Observatory, Birr Castle. By Otto Boeddicker, PH.D. Plates IX. and X. [Communicated, with a Note, by the Earl of Rosse.] (October, 1885.)

10.—On the Collection of the Fossil Mammalia of Ireland in the Science and Art Museum, Dublin. By V. Ball, M.A., F.R.S., F.G.S., Director of the Museum. Plate XI. (November, 1885.)

11.—On New Zealand Coleoptera. With Decriptions of New Genera and Species. By David Sharp, M.B. Plates XII., XIII. (November, 1886.)

12.—The Fossil Fishes of the Chalk of Mount Lebanon, in Syria. By James W. Davis, F.G.S., F.L.S. Plates XIV. to XXXVIII. (April, 1887.)

13.—On the Cause of Iridescence in Clouds. By G. Johnstone Stoney, M.A., D.SC., F.R.S., a Vice-President, R.D.S. (May, 1887.)

14.—The Echinoderm Fauna of the Island of Ceylon. By F. Jeffrey Bell, M.A., Sec. R.M.S., Professor of Comparative Anatomy and Zoology in King's College, London; Cor. Mem. Linn. Soc., N.S. Wales. Plates XXXIX. and XL. (December, 1887.) [*With Title-page and Contents to Volume III., also cancel page to Part* 13.]

CONTENTS OF VOLUME IV. (New Series.)

PART.

1.—On Fossil-Fish Remains from the Tertiary and Cretaceo-tertiary Formations of New Zealand. By James W. Davis, F.G.S., F.L.S., etc. Plates I. to VII. (April, 1888.)

2.—A Monograph of the Marine and Freshwater Ostracoda of the North Atlantic and of North Western Europe. Section I. Podocopa. By George Stewardson Brady, M.D., F.R.S., F.L.S.; and the Rev. Alfred M. Norman, M.A., D.C.L., F.L.S. Plates VIII. to XXII. (March, 1889.)

3.—Observations of the Planet Jupiter, made with the Reflector of Three Feet Aperture, at Birr Castle Observatory, Parsonstown. By Otto Boeddicker, PH.D. Plates XXIV. to XXX. (March, 1889.)

4.—A New Determination of the Latitude of Dunsink Observatory. By Arthur A. Rambaut. (March, 1889.)

5.—A Revision of the British Actiniæ. Part I. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin. Plates XXXI. to XXXVII. (June, 1889.)

6.—On the Fossil Fish of the Cretaceous Formations of Scandinavia. By James W. Davis, F.G.S., F.L.S., F.S.A., etc. Plates XXXVIII. to XLVI. (November, 1890.)

7.—Survey of Fishing-Grounds, West Coast of Ireland, 1890. I.—On the Eggs and Larvæ of Teleosteans. By Ernest W. L. Holt, St. Andrew's Marine Laboratory. Plates XLVII. to LII. [*Iu the Press.*]

PROCEEDINGS:

Octavo, Published in Parts, stitched.

Volumes I. to V. (New Series) Complete (1877 to 1887.)

Volume VI. :—

Part 1.—Pages 1 to 38. (February, 1888.)
Part 2.—Pages 39 to 110. (May, 1888.)
Part 3.—Pages 111 to 168. (August, 1888.)
Part 4.—Pages 169 to 262. (November, 1888.)
Part 5.—Pages 263 to 289. (February, 1889.)
Part 6.—Pages 289 to 359. (May, 1889.)
Part 7.—Pages 359 to 374. (August, 1889.)
Part 8.—Pages 375 to 474. (May, 1890.)
Part 9.—Pages 475 to 602. (August, 1890.)
Part 10.—Pages 603 to 626. (December, 1890.) [*With Title-page and Contents to Volume VI.*]