RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA

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THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1894. [February.

Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1893.

1. During the year, connected surveying was carried out in Baluchistan by Mr. Griesbach, assisted for a short time near the end of the field season by Mr. W. B. Edwards. Mr. LaTouche was occupied for the full season at the Bhaganwalla coal-field in the Salt Range, Punjab. In Hazara, Mr. Middlemiss, accompanied by Sub-Assistant Hira Lal, completed the survey in that part of the Punjab. Mr. Bose and Mr. Datta were engaged in Tenassarim on coal exploration; while Dr. Noetling, more directly in communication with the Local Government, was engaged on several enquiries in Upper Burma. Dr. Noetling was also engaged, just towards the end of the year, in reporting on the condition of the Dandot and Warora Collieries (in the Punjab and the Central Provinces) in view of a rather large percentage of accidents; a deputation which was of immediate necessity, the awaited Inspector of Mines not having at the time arrived in India. Mr. F. H. Smith and Sub-Assistant Kishen Singh were at work in the Rewa State, where surveying was done in connection with the mineral exploitation left by Mr. Hughes in the hands of the State Mining Assistant, Mr. Sewell. In the Madras Presidency, field petrology and mineral survey were carried out by Mr. Holland at such times as he could be spared from the Laboratory and Museum at Calcutta, and his Professorial work at the Presidency College. Mr. Oldham remained at head-quarters for the greater part of the year, engaged on the preparation of the new edition of the Manual of the Geology of India, which was published in August. He was, however, able to pay a short visit to Burma in March when he enquired into and reported on the prospects of an artesian water-supply for Rangoon; and also inspected the oil region of Yenangyoung and that neighbourhood regarding an apparent tendency to a decrease in the well supplies, which was happily not confirmed. I myself was on tour in March and April at Sukkur and Karachi in connection with the proposed experimental oil-boring at the former place, and at the Salt Range coal-fields: in April and May, I had an opportunity of conferring with the Financial Commissioner at Rangoon on the gold enquiry in the Kathá district and inspected the coal exploitation on the Tenassarim river; and after return to Calcutta proceeded to Warora Colliery in the Central Provinces to advise the Manager on some deep borings which were being carried out in a new part of the field. In September and October, I visited parts of Madras, examining

certain areas of hypersthenic igneous rocks, lately brought to notice by Mr. Holland; and arranged with the Government for a more connected mineral survey of the Salem district: and at the end of the year a further visit was made to Burma to examine the conditions of the Kathá gold occurrences, and the capabilities of the Tingadaw coal-field.

2. The operations of the Survey have thus been mainly confined to extra-Peninsular India; that is, in the Punjab, the North-West Frontier, and Burma; while a small, though at the same time very important, advance has been made in Peninsular geology.

EXTRA-PENINSULAR GEOLOGY.

3. BALUCHISTAN.—*Tertiary* and *Cretaceous.*—A large tract of country in the Harnai valley has been added on to that already surveyed and reported on by Mr. R. D. Oldham in 1892, in his *Geology of Thal Chotiali and part of the Mari country*; and Mr. Griesbach has given a portion of the results of this later work in his paper on the *Geology of the country between the Chuppar Rift and Harnai.* We have thus a completely mapped and reported record of the area extending from the neighbourhood of Sibi to Mangi, along the line of the Sind-Pishin Railway. His survey, however, covered a far larger area than this, as it extended on to and around Quetta, dealing especially with the completer examination of the coal out-crops in the latter region; and over the Kojak-Zhob line of country, where he came across a very interesting zone of volcanic instrusions among the lower eocene rocks.

4. Mr. Griesbach was the first member of the Survey who entered on the Bolan-Quetta ground so far back as 1880, though then only by traverse work alongside of the military occupation of the country, so that his interpretations, which sometimes extended on either side well beyond his line of march, were necessarily sketchy and so far open to a certain amount of criticism by his then senior officer, Mr. W. T. Blanford, who, armed already with his wide experience of the Sind cretaceo-tertiaries, followed pretty much on the same track to Quetta and out again by the Harnai route in 1881-82. Blanford's march was also a traverse, and he was harassed by illness over the latter part of his journey. The subsequently settled and railway-opened-up condition of the country eventually permitted of a more detailed survey being made, though this was interrupted at times by excursions after coal and oil; and Mr. Oldham was deputed for the work the results of which he gave in the report referred to above, the principal one being that there is an absence of definite break between the eocene and cretaceous formations; that there is, in fact, considerable indication of a series of passage beds. With the evidence of his two colleagues before him, the later observer is therefore fortunate in having the opportunity of settling the geology of this interesting region—interesting not only in its structural relations, but as being a connecting area between the Europe-Persia tract and the Indian extension of the ancient Mediterranean area of cretaceo-tertiary life and deposition. The question of the relations between our Indian tertiaries and the cretaceous formation is indeed of the greatest interest to geological science, because, whereas in England and Western Europe the distinction between the two is absolute stratigraphically and palæontologically, the evidences in Eastern Europe and thence eastward are

much less pronounced in that connection. In Peninsular India, it has long been known that the *quasi*-cretaceous facies of certain fossiliferous beds associated with the Deccan Trap Series, as well as other characteristics, point very decidedly to a period of passage life and volcanic activity; and our later progress in the Punjab and in Baluchistan appears to be more and more confirmatory of this.

5. So far, however, Mr. Griesbach is not able, on the stratigraphical and fossil evidence obtained by him, to follow Mr. Oldham, in his exposition of a passage series characterised by an anomalous fauna, in the Harnai valley, preferring to consider that Mr. Oldham's "Dungan Beds" are really of lower eocene age; an examination of the fossils (*Crioceras, Baculites* and *Ammonites*, with an abundance of *Nummulites*) by Dr. Nœtling showing rocks yielding them to be of true cretaceous—rather lower than upper-age, with *Orbitolites;* no nummulite being recognizable in the collection sent down to Calcutta. The question, therefore, still remains an open one for Mr. Griesbach to work out during his further progress on the Baluchistan survey: although the balance of evidence, outside of this fossil case, as displayed generally over the Harnai-Thal Chotiali tract and in the Western Punjab hills, is still considerably in favor of a passage series. Indeed, only lately, in December, a note has come in from Dr. Nœtling, who has been engaged on a mining inspection of the Dandot colliery in the Salt Range, wherein he mentions that on examining the coal shale basin underlying the nummulitic limestone, he had found the fossils having a decided tertiary facies, but that there were among them others with an upper Senonian (White Chalk) aspect; so that here again is a further item in the evidence for a passage series. A presumed corrolation of the dark shales of the Kojak range with the Simla slates (attributed to carboniferous age by Mr. Oldham) has been corrected so far by Griesbach's finding within them a true nummulitic bed, thus adding confirmatory evidence to his original view of the tertiary age of the Kojak series.

6. PUNJAB: SALT RANGE.—The nature of Mr. LaTouche's duties in connection with the boring exploitation in the Bhaganwalla coal-field prevented his devoting much time and attention to geology except in the immediate vicinity of his work; he was therefore unable to add much to the discussions of the numerous interesting problems which have arisen since the time of Mr. Wynne's splendid work in that area.

7. *Palæozoic.*—The strange occurrence of the comparatively soft series of the Salt-marl group, generally underneath a very thick and massive series of older palæozoic age; and again in apparent natural position under yet newer formations has, within the last few years, aroused under Mr. Middlemiss' and my own study, much discussion not only as to its position but as to its origin. This series is, however, only very slightly exposed in the gorge at Bhaganwalla, and its relations with the overlying purple sandstone are only clearly seen at one point, on the right bank of the stream immediately above the village. Mr. LaTouche observed that the appearance of injection into the overlying sandstones is certainly noticeable, but it does not seem impossible that this appearance may have been caused by a squeezing out of the soft marl along the line of a fold.

8. *Cambrian.*—The "Silurian shales" of Wynne, which, however, ultimately yielded remains of trilobites at Khusak, thus determining their Cambrian age, are exposed on the right bank of the more westerly of the two streams which issue

from the range at Bhaganwalla, and Mr. LaTouche was fortunate enough to discover specimens of trilobites in an identically similar position to that in which they occur at Khusak, *viz.*, in a band of dark shale, a few feet below the base of the Magnesian Sandstone. The specimens were in the same state of preservation as at Khusak, only heads being found; and no additional species were discovered. They occurred here in only this single zone, the lower "galleries" of Khusak being apparently unrepresented.

9. *Permo-carboniferous.*—The "Boulder Bed," so conspicuous in the middle portion of the southern escarpment of the Salt Range, is not well-developed near Bhaganwalla; occurring only in lenticular patches, never more than a few feet in thickness, between the white sandstones at the base of the coal-bearing group (tertiary) and the "Salt Pseudomorph" zone of Triassic age. No unconformity could be detected between it and the beds above and below; indeed it appears to pass up into the white sandstones, the base of which sometimes contains strings and thin beds of pebbles and small boulders, similar to those in the boulder bed proper.

10. *Cretaceous-eocene.*—In describing the existence of fossil resin in the coal which is considered so far to be of tertiary age, Mr. LaTouche recalls the fact that in Assam, where coal seams occur in beds of both cretaceous and nummulitic age, an exactly similar fossil resin is found, but only in the coal of cretaceous age which it serves to distinguish from the newer nummulitic coal. If, as seems likely this resinous substance points to some peculiarity in the vegetation from which the coal was formed, its occurrence in beds of different ages in the two areas would seem to indicate either that the coal-producing vegetation of cretaceous age in Assam persisted to nummulitic times in the Punjab, while it was replaced by a different vegetation in the former province, or that the nummulitic coal of the Punjab is really homotaxial with the cretaceous coal of Assam—a supposition which its position, at the base of the nummulitic limestone (instead of overlying it as the nummulitic coal of Assam does), and the absence of any break in deposition between the beds of the two ages in both areas, renders not unlikely.

11. *Upper Tertiary.*—Regarding the questions of the relations of the Nummulitics to the Nahans, no signs were observed of unconformity. The transition is always abrupt, and pebble beds are of frequent occurrence at and near the base of the sandstones, but the rolled pebbles are always of crystalline rocks, and do not include any from the underlying limestone. Nodules of the latter are of occasional occurrence in the lowermost beds of the Nahans, but, so far as was seen, they are not rolled, and do not form anything like a pebble bed. Their occurrence however, imbedded in the sandstones, shows that before the deposition of the latter, the limestone had assumed its present highly nodular structure and therefore would appear to indicate the lapse of a considerable period of time between the laying down of the two formations.

12. HAZARA.—The cold weather of 1893 brought to a close Mr. Middlemiss' three seasons' work in Hazara. During that time the chief objects of the re-survey were to fill in the gaps in the maps left unfinished by Mr. Wynne, dated 1877-; and to link together the scattered information on the subject to be found in the Records and Memoirs of the Geological Survey, by supplying an organised account of the whole district. These objects have in the main been attained, and as in nearly all important points the work harmonizes with that of Dr. Waagen a

Mr. Wynne, their classification of the historical rocks has been adopted. The following is a list of the Geological formations represented in Hazara, in descending order :—

(1) Alluvium and Recent gravels.
(2) Murree beds, *Miocene*.
(3) Kuldana beds (=passage beds).
(4) Nummulitic, *Eocene*.
(5) *Middle Cretaceous*.
(6) *Jurassic*.
(7) *Triassic*.
(8) *Infra-Trias*.
(9) Slate Series.

13. In the northern parts of Hazara certain rocks are invaded by lenticular beds of gneissose-granite, the result being a complex of crystalline and metamorphic rocks, which occupy large areas among the secluded mountains and glens of Agror, Khagan and the Black Mountain. One of the points to which Mr. Middlemiss' attention was chiefly directed was to settle if possible how many of the formations enumerated above had been affected by metamorphism during this irruptive period. The results show that the Infra-Trias and the Slate Series have been so affected to the exclusion of the rest. The various stages of metamorphism and the complicated mode of intrusion of the gneissose-granite offer many points of great interest which will be fully described in the forthcoming memoir on Hazara. The identity of character of these rocks with those of a great part of the Himalayan range is important as implying a unity of age and structure.

14. As regards the distribution of the formations over the surface of the country, there is a natural scheme into which they fall, *viz.*, a set of zones or elongated strike areas, each of which is characterised by the prevalence at the surface of a particular formation. There are many other peculiarities defining these zones which will be given in detail in the memoir, but one particularly striking feature is that each of these zones is divided from its neighbour-zone by a long fold-fault extending generally the whole breadth of Hazara. The following is a list of the zones from N.W. to S.E :—

I.—Younger Tertiary Zone.
II.—Nummulitic Zone.
III.—Slate Zone.
IV.—Crystalline and Metamorphic.

As to what these formation-zones, which are also disturbance-zones, means; it is believed that they have important bearings on the history and development of the great mountain ranges, portions of which lie within the boundaries of Hazara.

15. The district has not yielded any fine collections of fossils comparable to those of the Salt Range or the Central Himalaya, but from the cretaceous band a good number of forms have been gathered which without much difficulty can be matched by those from the cretaceous of Southern India at about the horizon of the Utatur group. The geological mapping of the area has been done on the sheets of the Revenue Survey (1 inch=1 mile), and a map is being prepared for publication on half the above scale. Horizontal sections will accompany the map, and panoramic views of the country, drawn with the camera lucida, and colored geologically, will be added, so as to present the rock structure and physical features of the country together at a glance.

16. LOWER BURMA.—*Palæozoic* and *Tertiary*.—While engaged at the exploitation for coal on the Great Tenassarim river, Messrs. Bose and Datta had necessarily to devote a considerable part of their time to working out the geology of that part of Tenassarim; and mainly because the mineral itself appeared to be of different quality in separate places, while it is at the same time associated with two different series of rocks. As a matter of fact, the coal is of two ages, the older but poorer coal being of carboniferous age, while the latter of the two is of tertiary age. In this enquiry, we have now obtained a fairly connected knowledge of the geology of Tenassarim from Victoria Point, the southern limit of the country, up to the parallel of Mergui.

17. Dr. Oldham's original conclusion as to the carboniferous age has been further established through Mr. Bose's find of a series of true carboniferous fossils in one of the strangely picturesque and cavernous isolated ridges of limestone so frequently met with in Moulmein, Tavoy, and Mergui; though until now, never in such close association with the strata carrying the poorer coal referred to above, He was also able to determine the much later (tertiary) age of the series (Tendaw) containing the proper workable coal; this particular development of which forms a shallow synclinal basin lying along the bottom of the main river valley, which has been excavated in one of the great anticlinal folds into which the palæozoic series of Tenassarim has been thrown, and which extends—marked by bands of cavernous limestome—with a fairly north and south strike through the districts of Tavoy and Amherst and thence northwards into Upper Burma.

18. UPPER BURMA.—*Palæozoic and Tertiary*.—The same carboniferous series was met with by Dr. Noetling far to the north in Mogaung and Bhamaw, whence he has been able to connect it past Mandalay, Yamethin, Toungoo, and Shwegyin, with the cavernous limestones of Moulmein, which country he was able to visit early in the season. He also examined the Moulmein caves for remains of bone-bearing gravels, traces of which he had already found in the Irrawaddi valley, but so far without success. His work during the season was however principally in connection with the oil and mineral developments of the country, particularly around Wuntho in the Kathá district, which he examined for gold, lead and coal. This is a large area of about 2,000 square miles in extent and mainly covered with jungle, so nothing but traverse observations could be made and the general position and lie of the rocks ascertained. The formations met with were palæozoic limestones (already mentioned as extending northwards in this district) on the extreme east of the present area; lower and upper mesozoics, and the alluvium in a wide bay on which lies the town of Wuntho, and in the Mu river valley. The latter valley is bordered on its eastern side by north-north-east—south-south-west striking belts of two miocene groups, in the lower of which good coal seams are found in blue shales. They resemble so closely the coal measures in the Chindwin district that there can be little doubt as to their being of the same geological period. Several small outliers of the same series, though without indications of coal, are scattered over the Wuntho alluvial plain, and a wider and fuller development constitutes the low hill tract to the eastward. The middle region—that is, the lofty hilly tract of Mankaw (3,911 ft.)—is made up of a wide expanse of schists and trappoid rocks in which are frequent traces of poorly auriferous occurrences in the diorites themselves, and in some of the quartz veins distributed through this series, the age of which has not yet been ascertained with any degree of certainty.

PENINSULAR GEOLOGY.

19. MADRAS.—*Crystalline series.*—As was the case last year, investigation of the crystalline series has only been carried out as opportunity offered when Mr. Holland could be freed from his proper duties. In this way, he was able to pay visits during the months of May and June, and again in part of September and October, during the first of which he was at last able to carry his experiences of Salem into the Coimbatore and Nilgiri districts. The Nilgiris had been surveyed so far back as 1857, at which time the study of the metamorphic crystalline rocks was still, owing to their presenting a certain laminated and even, in cases, a decidedly bedded structure, biassed with a tendency to consider them as a highly altered form of sedimentary deposits; while investigation as to their composition and the aggregation or mode of occurrence of their mineral constituents was as yet only open to but an initial stage of the splendid microscopical research which has since developed into the specialized science of petrology. Thus, though somewhat against the views of the then Director (Dr. Oldham) of the Survey, these mountains, and later on, the Shevaroys and other hill masses in the Salem district, were finally considered to be made up of very highly altered massive gneisses of original sedimentary accumulation.

20. Step by step, however, new points of evidence have been brought together confirming Mr. Holland's original conclusion, referred to in my last annual report, that whatever may have been the origin of the materials now forming the principal part of the greater mountain masses of Southern India, their mineral composition and microscopic structures which are so strikingly the same in widely separated and apparently isolated localities can only be the result of having been formed under conditions identical with those ordinarily regarded as belonging to igneous rocks. Rocks, indistinguishable in hand-specimens, occur at St. Thomas' Mount, in the hills near Pallavaram railway station, at Mailam, on the Shevaroy hills, the Nilgiris, the Pulnis, the Anaimalais and the Western Ghats which, in each district, contribute a complete pyroxenic series ranging from acid granites to very basic pyroxenites.

21. The occurrence of these rocks in India will doubtless yield suggestive evidence towards the solution of some of the larger questions which have of recent years occupied the attention of workers in the so-called archæan gneisses and schists with which in other parts of the world similar rocks have been found always associated; as in the cases of the trap-granulites of Waldviertel in Saxony, in the Hebridean gneissic system of Sutherlandshire and Aberdeen in Scotland; the norites of the "Cortlandt Series" and the gabbros of Baltimore in America. With regard to the Cortlandt Series of the latter country, the microscopic characters of which were described by Professor G. H. Williams, in a series of well-known papers published in 1886-87; almost every type described by that author has been matched in our recent survey by specimens from the Madras Presidency; in addition to which I may also announce the discovery of a distinctly acid pyroxene-bearing rock, which seems to be a type of igneous rock hitherto undescribed, the pyroxene being generally of the rhombic type, and approaching proto-hypersthene in composition. From this fact and because the rock, both in hand specimens and in field characters, presents an unmistakable individuality; Mr. Holland feels justified in describing it under the new name *Charnockite*, one of the first specimens of the rock (which is largely used for stuctural and ornamental purposes)

brought to Calcutta and the first examined under the microscope, being a splinter from the tombstone of Job Charnock (1693).

22. To complete the parallel with the American rocks: spinelloid *hercynite*, a constant associate of corundum, has been found among the other rather rare minerals in the Madras pyroxene series; and it is thus possible that the obscurity in which the origin of corundum still lies may be dissipated by the researches now being pursued in the field and laboratory.

23. That the petrological variety for which the Norwegian and Ural rocks have long been famed may be paralleled in India, as pointed out by Mr. Holland last year when announcing his discovery in India of the rare mineral *riebeckite*, appears to be well sustained by the evidence afforded by these rocks; yet we have even a later determination of what was supposed (by the sender) to be a piece of iron ore found in Bengal, as the rare mineral *columbite*, one of the characteristic niobates and tantalates of Scandinavia and the Urals. In this connection, too, is the very interesting discovery by an independent observer (Dr. J. W. Evans, State Geologist of Jonagadh in Kattiwar) of the remarkable rock, elœolite-syenite, known more especially from its occurrence in South Norway; where, as in India, it is associated also with angite-syenite.

ECONOMIC SURVEY.

24. Coal investigation has gone on in Baluchistan, the Salt Range in the Punjab, and in Tenassarim: while coal, oil, gold, and lead ores have been explored in Upper Burma. Lead enquiry has been carried out to some extent in Rewa; and the extended occurrence of corundum and the iron ores has received a certain amount of attention in the Madras Presidency.

Quetta Coal.

25. The coal enquiry in Baluchistan had reference to the coal outcrops near Quetta, or more strictly speaking in the high valleys of Les and As Tangi to the eastward of that town, which have been under desultory working by native contractors, but which it was hoped might on closer survey be found worth working in a more systematic way. The detailed survey was undertaken by Mr. Assistant Superintendent Edwards under the orders of Mr. Griesbach, but the survey was not completed owing to the illness of the former officer which culminated in a severe attack of typhoid fever. The survey was again resumed by Mr. F. H. Smith in October last. In the meantime, Mr. Griesbach completed the survey on the Khóst side of the country when he was able to offer a much more sanguine opinion as to the future of the coal in that direction, and he has given details of the various sections exposed in the Harnai valley in his report of the country between the Chuppar Rift and Harnai which was published in the last part of the Records of the Survey, and from which I take his concluding remarks:—

Harnai Coal.

"It only remains to add a few words on the economic value of the area. This, of course, consists in the large amount of coal which is available in the more or less constant horizon of the middle nummulitic subdivision. Most of the outcrops have either been worked or are sufficiently tested to prove the usefulness of the coal as regards quality and the limited thickness of the seams, and it is certain that even after the complete exhaustion of the Khóst collieries there will be a very large amount of coal left in other sections of the field. I will not enter here into the composition of the coal; this has been done already by other observers. Mr. Jones has also attempted to compute the quantity of coal available, but he has certainly much under-estimated the latter. The fact is, no estimate, even approximately correct, can possibly be arrived at, which would be of the least practical use. The whole basin of the 'trough,' including the entire hill-range which bounds it along the southern rim, with probably a large area south of it, is part of the field and contains seams of coal. If only the Khóst seams are taken as examples and the amount of coal calculated on the thickness of these seams and the area of the basin, no doubt a fairly accurate idea of the amount of coal *present* in these strata would result; but that is not the amount actually available. The greater portion of the basin is broken up by faults, folds, and some of it has been carried away by denudation, so that only a small proportion of the total coal is available for mining purposes, and of these portions the exact limits are not known. In the above paper I have given a description of the distribution of the seams, and also indicated in outlines which I consider the most promising localities for opening works, after Khóst is exhausted or nearing that stage.

"Amongst the best of these localities is the cliff, 3½ miles south-east of Sháhrág Station, with the area immediately adjoining it. This will undoubtedly offer as good chances as did the Khóst workings, and the locality is near enough to the line of railway to be worked cheaply. Next to Sháhrág in importance, I consider the cliff between Púnga Ghát and Harnai; there the seams are good, but the outcrops are too low down the hill-side to allow the same process of mining to be adopted as at Khóst and Sháhrág. The workings would be soon below the level of the ground-water, and therefore pumping would have to be resorted to, which would increase the cost of the output considerably.

"Still more difficult to work, on account of the underground water, would be mines established on the Púnga Ghát, or north of the river near Ali Khan, were it decided to bore in these localities for coal, which most probably would be met with not far below the present surface."

Salt Range Coal.

26. The coal enquiry at Bhaganwalla in the Salt Range was instituted on account of a proposal by the North-Western Railway administration to work the Bhaganwalla area, the supply from the Dandot colliery to the westward being inadequate to meet the demand. Mr. Luckstedt, the Executive Engineer in charge of the coal operations, having made a report on what he considered to be the probable available amount of coal under the Ara plateau and in the eastward end of the Salt Range, which certainly appeared to me to be over-exaggerated; it was decided to test this by borings and detailed survey, for which duty Mr. LaTouche was deputed from the Survey. A detailed plane-table survey on a scale of 6 inches to the mile was made by Mr. Edwards; and, although the large area of the Ara plateau must be left out of consideration, as all the evidence goes to show that no continuous seam of coal can be expected to lie under it, it was found that at the eastern end of the range, where the coal suddenly becomes high-dipping, there is probably an available output of over a million tons, provided working can be carried on to a sufficient depth along the dip. Mr. LaTouche's report is given in full in the current part of the Records.

Tenasserim Coal.

27. In Tenassarim, it was decided to test the Tendaw-Kamapying coal-fields, on the Great Tenassarim river, by a series of borings and pits, which were carried out by Mr. Bose assisted by Mr. Datta. The old interest in this field was revived by Mr. Hughes during his exploitation of the Tenassarim tin areas, a preliminary report having been published by him in the Records for 1892. Mr. Bose's report confirms the estimate of Mr. Hughes as regards the presumable quantity of available coal under not difficult working, *viz.*, about a million tons; and this is what may be called a safe estimate. Extended and somewhat more troublesome mining would probably disclose a larger

amount of coal. Mr. Hughes relied on this further exploration as likely to show some extension of the coal-field considerably further southwards down this long reach of the Tenassarim river, but this has not been proved ; indeed, the evidence obtained is decidedly against it. From my own inspection of this river's wonderfully zig-zag course through the frequently high-ridged tract of country between Mergui and the coal valley, I should say that there is little chance of finding an easily workable road or tram-track between the coal and the seaboard, while a route partly by land and partly by river would only involve a ruinous break of bulk in carriage of the fuel. Getting the coal to the coast solely by the river route seems inevitable ; and this can only be done by barges and stern-wheel steamers of the shallowest draught.

Kathá gold tract.

28. In Upper Burma, Dr. Noetling reported on the occurrence of coal in the Pinlebu subdivision, Kathá district; on the lead-mines in the same subdivison; and on the auriferous tracts in Wuntho. With regard to the latter, he found on arriving at the place that very little was known as to the actual situation of the localities where gold was said to have been extracted from the ground by the natives. The chief importance of the meagre information that could be obtained consisted in the fact that everything tended to prove that the gold was not extracted from the alluvial formation, but that there actually existed veritable "reefs." But nothing could be ascertained as to their whereabouts, the natives apparently being very reluctant to give any information. The only information supplied was that Mr. Bidoulac had applied for, and been granted, a concession of $\frac{1}{4}$ square mile of land supposed to be gold-producing, near a village called Kokkotta, north of Wuntho. At least seven different localities were ultimately discovered where the natives used to dig for gold. However, the examination of the places was sufficient to form an opinion as to the occurrence of gold, so far as this could be done without extensive digging. Just at the end of the year, however, I have myself had an opportunity of inspecting this region, which is one of a schistose series, which may answer to our Dharwar series of Peninsular India. It is very extensively traversed by a complex of basic igneous rocks, and in certain belts, particularly where the schists are very talcose, there is a decided development of quartz infiltrations in the form of generally small reefs, ledges, and strings which are more or less auriferous. The whole area, covered as it is by fairly thick and lofty forest and subject to a moderately moist climate, is wonderfully decomposed as to its rocks, which are now, for considerable depths, little else but red and brown ferruginous, sometimes lateritic, clays, which however still show their original bedded or laminated structure in the deeper gullies and in some of the artificial excavations; and in this decomposed rock, or scattered over its slopes, may be seen the outcrops of strings and ledges, or the debris of these. As a consequeuce, there are several localities which have been extensively and cleverly washed for gold by the natives—more steadily in old times because tribute was then forcibly demanded in gold in this part of the country ; but much less often now. I did not see, or hear the least evidence of, any quartz having been pounded up for gold-washing; the old washers simply sluiced the weathered rock in a primitive but effective fashion and then washed out the coarse gold. The present people think nothing of the fine gold which is obtainable more or less from almost every hand lump of the pyritous quartz debris when pounded in a mortar. The present development, of nearly eight months' standing, is as yet scarcely beyond the initial stage; no very decided well-

defined or continuous reef having been met with, though there are outcrops of biggish ledges the quartz of which is, however, not so rich as in the smaller strings. The poor show of quartz occurrences now reported may indeed be more frequent in thickness as they are followed in depth, or they may not: there is no evidence in either one or the other direction.

Pinlebu Coal.

29. For the Pinlebu coal, which occurs exclusively in the low hills skirting the western side of the Maingthong hill tract; the summary of Dr. Noetling's report is, that there is only a small number of seams, which are generally of very inferior quality, consisting chiefly of shaly coal: only in two cases is it probable that the thickness of workable coal comes up to five feet. Although the coal is of good quality, it may safely be said that the quantity is insufficient. Even if there were a considerable quantity of coal available, it is doubtful whether the distance of at least 32 miles from the nearest railway station would not prevent a successful exploitation, the cost of transport being too high. Under these circumstances, the coal seams in the Pinlebu subdivision may be considered as relatively of little value, except for local use.

Pinlebu Lead.

30. The lead-mines in the Pinlebu subdivision occur at two localities where the Shan settlers in the Maingthong hill tract have been extracting lead-ore for a considerable time past,—*viz.*, (*a*) Kaydwin, and (*b*) Mawkwin. At the former place several large and deep holes may be seen which have been driven from the river bank into the hill-side; work has, however, been stopped for some time. So far as can be noticed, the ore occurs in the cracks of a dyke of an igneous rock belonging to the aphanite group, of considerable thickness; at one place its thickness is not less than 20 feet. The ore being *cerusite*, is found in strings up to ¼ inch of thickness filling the cracks of the rocks all throughout. On assay it yielded 69·1 per cent. of lead and 33 oz. 16 dwts. 4 grs. of silver to the ton of lead. At Mawkwin, the dyke is considerably thinner, and the old workings are less extensive; the occurrence of the ore being, however, exactly the same as at Kaydwin.

31. So far as can be judged from the examination of these two localities without extensive diggings being undertaken, the diggings at Kaydwin and Mawkwin are situated on one and the same dyke, running approximately south-west—north-east. If the dyke should contain an equal quantity of ore strings at intermediate places, such an occurrence of this lead-ore would certainly have a considerable value. This, however, can only be settled by extensive diggings.

MUSEUM AND LABORATORY.

32. Mr. Holland, the Officer in charge of the Museum, has made considerable progress in the classification and microscopic description of the large series of rocks collected during former years by officers of the department and private individuals, and results obtained add greatly to our knowledge of the eruptive and crystalline rocks, which have recently proved to be of great petrological interest. Amongst features of noteworthy interest which have resulted from this work, may be mentioned the curious inclusions of heulandite, celadonite and glauconite in handsome green crystals of calcite, and a new variety of magnetite. The so-called "mica-traps," intrusive in the coal-bearing rocks of Raniganj, Karharbari, and Darjeeling, are found to be interesting types of an ultra-basic rock, mica-peridotite.

33. A large number of assays of ores and coals, and the determinations of minerals, have been published from time to time in the Records; and in this work of the Laboratory as well as in the Museum, Mr. Holland reports most favourably of the carefulness and accuracy of the work done by the Museum Assistant, Mr. T. R. Blyth.

34. Mr. Holland has especially for the sake of students, written an Introduction to the Study of Indian Minerals, with a descriptive list of the species represented and an Index to the Museum collection.

35. *Survey publications.*—A new edition of the Manual of the Geology of India has been revised and largely rewritten by Mr. R. D. Oldham and published during the year, which has been very favourably received. The progress of survey since the first edition was issued, has been so marked that an entire change has been made in the arrangement of the book, the rocks being described, in chronological order instead of being treated under a series of descriptions of separate districts. Still, many districts have had to remain untouched, so that as regards these, and where no serious modifications were necessary, the original text has been allowed to stand. The number of plates, maps, and page illustrations has been considerably increased, and the volume itself is in handier form. The year's volume of the Records contains 15 papers and appendices, of which six deal with industrial and allied subjects. In the Palæontologia Indica, Dr. G. W. Gregory's volume on the Jurassic Echinoidea of Cutch has been issued.

36. *Library.*—The additions to the Library amounted to 1,938 volumes or parts of volumes, of which 1,209 were acquired by presentation and 729 by purchase.

37. *Personnel.*—Mr. T. W. H. Hughes, through a most regrettable accident, was compelled to take leave from the 26th January 1893. Mr. R. D. Oldham has taken furlough from the 18th July 1893. Mr. W. B. D. Edwards has also, through illness, been granted leave from the 4th November 1893.

WILL. KING,
Director, Geological Survey of India.

CALCUTTA:
31st January 1894.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1893.

ADELAIDE.—Royal Society of South Australia.
ALGIERS.—Geological Survey of Algiers.
BALLARAT.—School of Mines.
BALTIMORE.—Johns Hopkins University.
BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Science.
,, Royal Prussian Geological Institute.
BOMBAY.—Bombay Branch of the Royal Asiatic Society.
,, Marine Survey of India.
,, Meteorological Department, Government of Bombay.
,, Natural History Society.
BOSTON.—American Academy of Arts and Sciences.
,, Society of Natural History.
BRESLAU.—Silesian Society.
BRISBANE.—Royal Geographical Society of Australia.
,, Royal Society of Queensland.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Royal Malacological Society of Belgium.
BUDAPEST.—Hungarian Geological Institute.
,, Hungarian National Museum.
BUENOS AYRES.—National Academy of Sciences, Cordoba.
CAEN.—Linnæan Society of Normandy.
CALCUTTA.—Agricultural and Horticultural Society of India.
,, Asiatic Society of Bengal.
,, Editor, *The Indian Engineer*.
,, ,, *Indian Engineering*.
,, Meteorological Department, Government of India.
,, Reporter on Economic Products, Government of India.
,, Survey of India.
CAMBRIDGE.—Philosophical Society.
,, University of Cambridge.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CASSEL.—Vereins für Naturkunde.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey.
DIJON.—Academy of Sciences.
DRESDEN.—Isis Society.
,, Royal Mineralogical, Geological, and Pre-Historic Museum.
DUBLIN.—Royal Irish Academy.
,, Science and Art Museum.
EDINBURGH.—Geological Society.

EDINBURGH.—Royal Scottish Society of Arts.
„ Royal Society.
„ Scottish Geographical Society.
FREIBURG.—Natural History Society.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Glasgow University.
„ Philosophical Society.
GOTHA.—Editor, *Petermann's Geographische Mittheilungen.*
GÖTTINGEN.—Royal Society.
HALLE.—Natural History Society.
HAMILTON.—Hamilton Association.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Vaudois Society of Natural Sciences.
LEIPZIG.—Verein für Erdkunde (Geological Society).
LIÈGE.—Geological Society of Belgium.
LILLE.—Société Géologique du Nord.
LISBON.—Geological Commission, Portugal.
„ Geological Survey, Portugal.
LIVERPOOL.—Geological Society.
LONDON.—Geological Society.
„ Iron and Steel Institute.
„ Linnæan Society of London.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoological Society.
LYONS.—Museum of Natural History.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
„ Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
„ Royal Society of Victoria.
MILANO.—Italian Society of Natural Sciences.
MONTREAL.—Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
NAPLES.—Royal Academy of Science.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
NEW YORK.—Academy of Sciences.
OXFORD.—University Museum.
OTTAWA.—Geological and Natural History Survey of Canada.
PARIS.—Editor, *Annuaire Géologique Universel.*
„ Geographical Society.
„ Geological Society of France.
„ Geological Survey of France.
„ Mining Department.

PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.
,, Wagner Free Institute of Science.
PISA.—Society of Natural Sciences, Tuscany.
QUEBEC.—Literary and Historical Society.
RICHMOND.—Virginia University.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Geological Survey of Italy.
,, Royal Academy.
SAINT PETERSBURG.—Geological Commission of the Russian Empire.
,, Imperial Academy of Sciences.
,, König. Russische Mineralogische Gesellschaft.
SALEM.—American Association for the Advancement of Science.
,, Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch of the Royal Asiatic Society.
SYDNEY.—Australian Museum.
,, Department of Mines and Agriculture, New South Wales.
,, Geological Survey of New South Wales.
,, Linnæan Society of New South Wales.
,, Royal Society of New South Wales.
TOKIO.—Asiatic Society of Japan.
,, Deutsche Gesellschaft für Natur und Völkerkunde.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
,, Royal University.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Geological Institute.
,, Imperial Natural History Museum.
,, Royal Academy of Science.
WASHINGTON.—National Academy of Sciences.
,, Smithsonian Institution.
,, United States Department of Agriculture.
,, United States Geological Survey.
,, United States Mint.
,, United States National Museum.
WELLINGTON.—Colonial Museum and Geological Survey of New Zealand.
,, New Zealand Institute.
,, The Minister of Mines, New Zealand.
YOKOHAMA.—Asiatic Society of Japan.
,, Seismological Society of Japan.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Natural History Society.

The Governments of Bengal, Bombay, India, Madras, Perak, and Punjab.
The Chief Commissioners of Assam, Burma, and Central Provinces.
The Resident at Hyderabad.

Report *on the* Bhaganwala Coal Field, Salt Range, Punjab, *by* Tom. D. LaTouche, B.A., *Deputy Superintendent, Geological Survey of India.* (*With map and 2 plates.*)

Situation of the field.

This coal-field is situated near the eastern end of the Salt-Range, on the plateau overlooking the village of Bhaganwala, which lies at the foot of the range at about 10 miles to the north-east of Haranpur station, on the Sind-Sagar Railway, on the right bank of the Jhelum. It occupies a roughly triangular area, as shown in the accompanying plan, of about 7 square miles in extent, of which only the western portion, for the most part covered with alluvium, and highly cultivated, can be described as a plateau, while the eastern portion is hilly and cut up by deep ravines. Several small villages are situated on the plateau, the largest being Ara, which might have given its name to the coal-field, lying as it does in the centre of it, with more propriety than Bhaganwala.

Boundaries.

The area now to be described is only a small portion of the larger plateau, called by Mr. Wynne in his Memoir on the Salt-Range,[1] the "Eastern Plateau," which extends along the top of the range for a great distance towards the west, and it is quite possible that large deposits of coal may exist in that direction, besides those already worked at Pidh and Dandot; but so little has yet been done in searching the intervening ground, though indications of coal have been met with in several places, that this larger area may be left out of account at present. A zone of broken and hilly ground, due to sharp folding and faulting of the rocks, rising abruptly from the western edge of the alluvial flat on which Ara is situated, conveniently divides the coal-field from the larger plateau on the west, while on the north it is bounded by a broad and deep ravine, which cuts down into beds underlying the coal-bearing rocks. On the south it is bounded by the long line of scarp overlooking the plains of the Jhelum valley, and extending for about 5 miles from east to west; and to the north-east by a tract of very hilly country, occupied by highly inclined beds of sandstone and clays, higher in the series than the nummulitic limestone overlying the coal-bearing beds, so that the latter in this direction quickly become buried to an unworkable depth.

Previous notices.

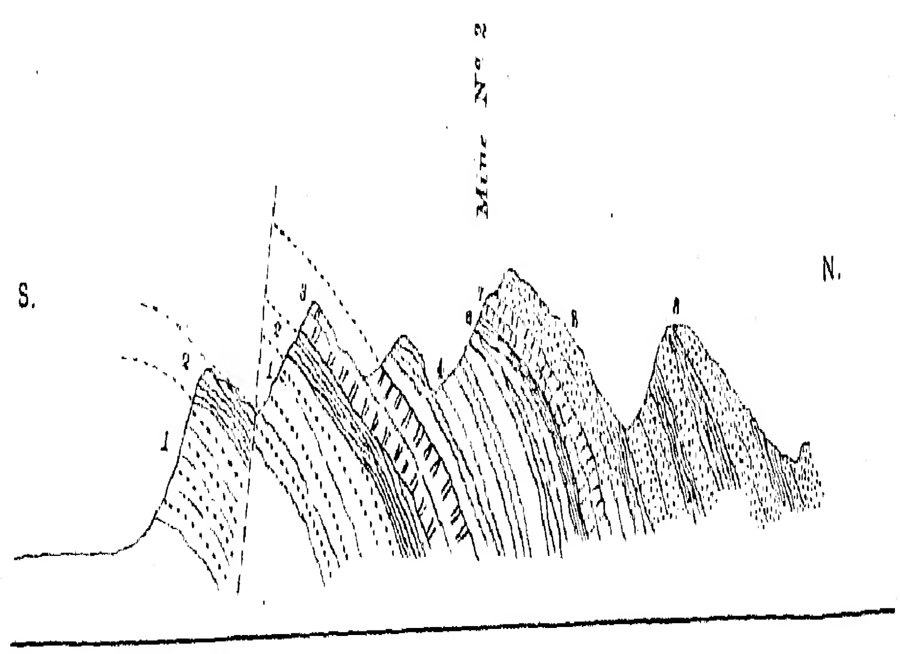
Although it is only quite recently that a serious attempt has been made to open out the coal seams in this field, the fact of the existence of coal here has been known for many years. It appears to have been first brought to notice by Dr. Fleming in 1853 and was reported on by Dr. Oldham in 1864. Dr. Oldham estimated the total quantity of coal available at 16,20,000 maunds, or between 50,000 and 60,000 tons; but there is little doubt that a considerable quantity of coal, which was not included by Dr. Oldham in his estimate, as he considered that it lay at too high an angle to be profitably worked at any rate below the level at which it could be reached by horizontal adits, can be extracted, if proper precautions are taken in opening out the mines.

The coal of this locality is mentioned by Mr. Wynne in his Memoir on the Salt-Range above cited. He quotes from the report of Dr. Oldham, and gives a section of the coal seam and associated rocks at the point referred to above, *viz.*,

[1] Memoire, G. S. I., Vol. XIV.

La Touche.

Sketch Sections across the Bhaganwala Coal field



Section No. 1.

Referen

8 *Tertiary Sandsto*

7 *Nummulitic Limes*

6 *Coal bearing bed*

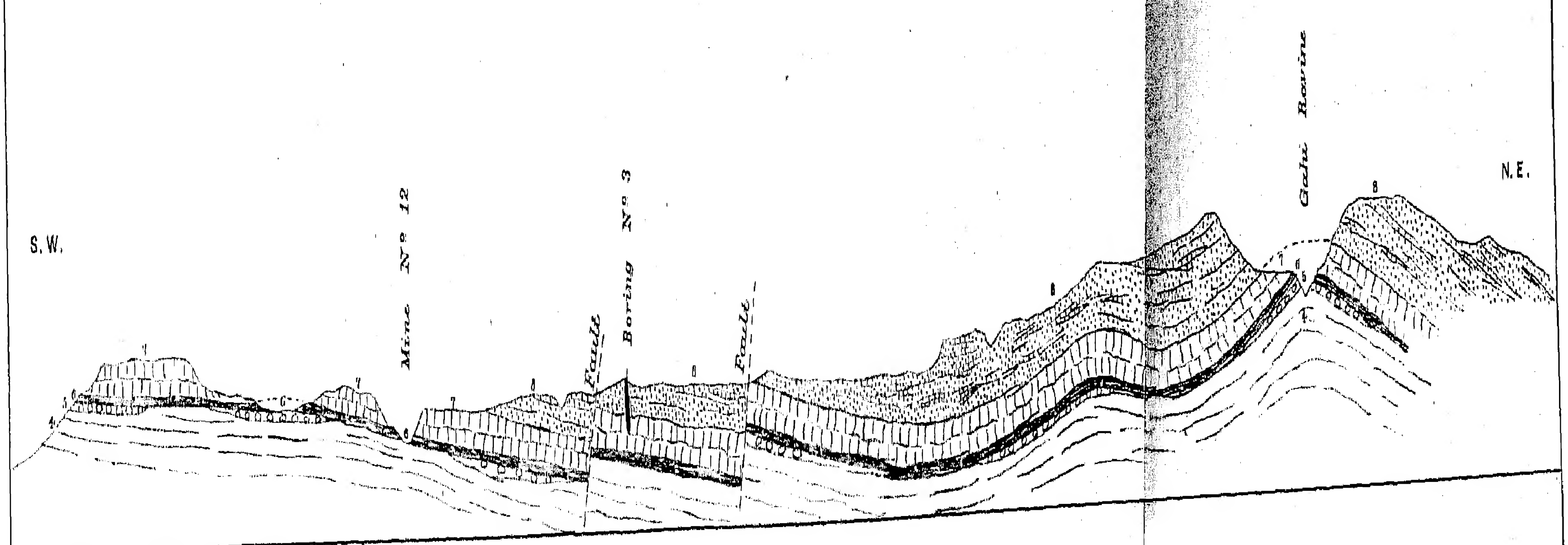
5 *Boulder bed*

4 *Salt Pseudomorph*

3 *Magnesian Sandst*

2 *Silurian Shale*

1 *Purple Sandstone*



Section No. 2.

Lithographed & Printed at Geological Survey Office.

Lithographed & Printed at Geological Survey Office.

Scarp above Mine No. 7 —— Bhaganwala Coal-field where the beds lie at a considerable angle.[1] He does not seem to have been acquainted with the coal at the other point where it is now being worked, at mine No. 7, where the beds are almost horizontal, though both he and Dr. Oldham state that the outcrop may be traced for 2 miles. Probably the outcrop of this good coal at No. 7 was at that time concealed by talus.

Since the publication of Mr. Wynne's Memoir in 1878, nothing appears to have been done to prove the capabilities of the field for many years, except that a number of holes were dug into the outcrop by native contractors, who of course took the coal wherever it was most easily to be got, without any regard for the future, and if they had been allowed to continue in that fashion, might in time have done irreparable damage. Some 2,000 tons is said to have been removed in this way. But in 1892 Mr. Luckstedt, Executive Engineer, Manager of the Dandot Colliery, submitted a report, in whtch the total quantity of coal was estimated at 10 million tons, and of this 6 millions were said to be available. This estimate was so largely in excess of that made by Dr. Oldham, and, as pointed out by Dr. King, Director, Geological Survey, rested upon such slender evidence, that it was felt advisable, before sanctioning the expense necessary to provide better communication with the railway than the present system of pack animals, that some further evidence should be collected, if possible, supplemented by borings, to prove the existence of coal or otherwise at points where it could not be reached by drifts from the outcrop. Accordingly, the present detailed survey of the field was undertaken. While it was in progress Mr. Luckstedt furnished another report, in which the total amount of coal is estimated at 20 millions of tons. This report will be discussed further on.

Plan of the coal-field.

The best available map of the district, on the scale of 1 inch = 1 mile, not being sufficiently detailed to allow of geological boundaries, outcrops, etc., being laid down upon it with accuracy, a large-scale plan of the field was prepared by Mr. Dallas Edwards, Assistant Superintendent, Geological Survey, during the past working season. A reduced copy of the plan, which was surveyed on a scale of 6 inches = 1 mile, is attached to this report. The advantages of making such a plan as this at the same time that the geological survey is being carried on are obvious. The boundaries of the different formations and other geological features can be inserted on the plane table, as the survey proceeds, with an accuracy not obtainable when an enlargement from a small-scale map, made without any reference to geological details, is the only one available.

Geological structure. (See Sections 1 and 2, plate I.)

The geological structure of the rocks is not very easy to describe, as the forces which have determined it appear to have acted from two or more directions, whether simultaneously or at different periods, and the result is somewhat complicated. At the eastern end of the field the rocks are tilted up at a high angle, apparently forming the northern limb of a great anticlinal, the southern limb and crown of which have been removed by denudation. As we proceed westwards the anticlinal becomes broader and flattened, as it were, spreading out into a series of gently undulatings, anticlinals and synclinals, which occupy the space between the highly inclined rocks at the southern edge of the range and the northern edge of the coal-field. Great

[1] Memoirs, G. S. I, Vol XIV, Pl. XIV, p. 138.

denudation has taken place, so that a deep gap has been formed between what is now the southern edge of the coal-field and the edge of the hills, a large area of what may have been productive coal-bearing beds having been removed. Although the rocks are seldom quite horizontal over that part of the field which has escaped denudation, yet they dip either to the north or south at very low angles, having generally sufficient inclination to render drainage of the mines, when it shall be necessary, a matter of little difficulty.

Faults.

Faults are neither numerous nor of great extent in this field. Such as do occur are marked on the plan, and it will be seen that they nearly all run in a northerly direction, starting from the southern scarp, and soon die out, so far as can be seen, on the surface of the plateau. The longest can be traced for about 1,500 yards from the edge of the scarp, near and to the east of the Railway bungalow, and appears to have a throw of about 50 feet at most. This and some of the others appear rather to be very sharp folds accompanied by faulting, than ordinary faults, but the result is the same, so far as the relative position of the beds on either side of them is concerned.

Formations represented.

The formations which we have to deal with are very few in number, since the coal occurs at only one well-defined horizon, and the rocks below that horizon need not be noticed. A general vertical section through the beds shown on the plan is given below :—

In descending order.

	Maximum thickness. Feet.	Inches.
Nahan sandstones and clays, thickness variable, sometimes absent	...	...
Nummulitic limestone	160	0
Yellow and dark grey shales	14	0
Coal	7	0
White sandstone with pebble bands	50	0
Olive shales and clays with boulders of crystalline rocks . .	20	0
Salt pseudomorph zone, red and grey shales	...	...

Nahan sandstones.

Only the lowest beds of this formation are represented in the coal-field. They consist of soft grey sandstones interstratified with red or purple shales and clays, and with irregular pebbly bands from 1 to 8 feet or so in thickness. The composition of the beds varies horizontally a good deal, so that the section passed through in a boring at one point may be very different from that at another. The lowest beds contain pieces of silicified wood, also fragmentary bones and teeth, mixed with pebbles of quartzite and other crystalline rocks. They also contain what appear to be pebbles of the underlying limestone, but the latter is very nodular, and these apparent pebbles may be merely nodules mixed with the sandstone while it was still soft and not really rolled pebbles. No sign of unconformity can be detected between the sandstones and underlying rock. The sandstones have been greatly denuded within the limits of the field, and often removed entirely, patches remaining here and there as outliers, but to the north-east of the Ara plain these patches coalesce, increasing to a thickness of several hundred feet, so that the underlying rocks are only exposed where deep ravines have cut through the whole series.

Nummulitic limestone.

The scarped outcrops of limestone which form such a conspicuous feature in the Salt-Range are of considerable importance as a guide to the position in which indications of coal should be looked for, because the limestone everywhere overlies the coal-bearing bed, and it is, indeed, to the softness of the latter, coming immediately beneath the hard limestone bands, that the aforesaid scarps are due. As represented in this coal-field the limestone has lost much of the thickness and solidity which it displays further to the west, as at Dandot, and even within the limits of the field its thickness diminishes from about 160 feet on the west to less than 50 feet on the east, while beyond the limits of the plan it thins out entirely within no great distance, if traced along the outcrop.

A section of the limestone at mine No. 12 gives, in descending order:—

		Feet.	Inches.
Nodular limestone	about	20	0
Solid and very hard limestone	"	15	0
Nodular limestone with partings of shale and clay	"	25	0
Solid hard limestone	"	6	0
Nodular limestone with partings of clay	"	10	0
Nodular limestone with bands of shale and clay	"	36	0
Solid and very hard limestone	"	7	0
Nodular limestone	"	26	0
Nodular limestone with partings of clay and shale	"	14	0
Shaly limestone	"	5	0
TOTAL		164	0

The want of homogeneity in the limestone has been found to be a serious drawback in the attempts made to bore through it, at any rate with the steam boring machine, for though the tool cuts through the hard bands readily enough on reaching the soft clays and shales it becomes clogged, and even if any progress is made, fragments of the shale frequently fall from the sides of the hole, and cause the tools to become jammed, a difficulty that it has not yet been found possible to surmount.

Coal-bearing beds.

Immediately underlying the limestone are found the coal-bearing beds, consisting of dark-bluish grey shales passing down into carbonaceous shales or sandstones and coal. The maximum thickness of the shales is not more than 14 feet, and it is often less, a circumstance which is greatly in favour of mining operations here as compared with Dandot, where the shales above the coal reach a thickness of 40 feet. Another advantage here is that a band of hard sandstone is frequently found between the coal seam and the shales, affording a good roof to the workings. Beneath the coal-bearing beds is a strong band of white sandstone, often stained yellow or brown by oxide of iron. This also frequently contains strings of carbonaceous matter, and sometimes pebbles and boulders of crystalline rocks. Its thickness varies a good deal in different parts of the field.

The rocks which succeed this band need not be described here in detail, as though they afford some interesting points for discussion they have no connection with the subject of this report.

Distribution of the coal.

The evidence so far obtained as to the distribution of the coal in this field is of two kinds; 1st, that afforded by natural outcrops; and 2nd, that afforded by the drifts and mines which have been put in at numerous points along the outcrop.

1. Outcrop indications.

Beginning at the western end of the long southern scarp, which stretches in an unbroken line for a distance of about 5 miles from mine No. 12 to the east of mine No. 1, the following sections may be observed :—

Section No. I. (see Plan), Mine No. 12—

		Feet.	Inches.
Limestone (see page 18)	about	164	0
Yellow shales		2	0
Dark grey shales		5	0
Carbonaceous sandstone		1	9
Sandstone band		0	6
Coal		1	0
White sandstone		...	...

Proceeding from this point along the left bank of the ravine, the outcrop of the beds beneath the limestone is much concealed by talus, but where visible, the rock is a coarse yellow and white sandstone, the shales apparently being absent; nor is there any trace of carbonaceous matter. Where the outcrop bends sharply to the east, the following section is seen :—

Section No. II—

Limestone	...
Shales	about 3 feet seen.
White sandstone much stained with iron	" 40 "

No good section of the rocks between the limestone and sandstone is exposed along this part of the scarp up to drift No. 9, but where the shales are visible they are not carbonaceous.

Section No. III Drift No. 9—

	Feet.	Inches.
Limestone	...	...
Carbonaceous shale	5	0
White sandstone	54	0
Pink sandstone	18	0
Grey shales	...	...

Again, between this and drift No. 8, there is much talus, but a clear section is exposed at the mouth of the latter drift beneath the bungalow, and close to the road from Ara to Bhaganwala.

Drift No. 8—

		Feet.	Inches.
Limestone		...	...
Shales	about	4	0
Carbonaceous shale		1	0
White sandstone very much stained at top		...	...

To the east of the road a little carbonaceous shale shows at intervals, but no good sections are exposed till near drift No. 7 A. In a gully about 500 feet west of this drift the section is—

Section No. IV—

	Feet.	Inches.
Limestone	...	...
Shales	10	0
Ferruginous sandstone	0	6
Slightly carbonaceous sandstone and shale	1	0
White sandstone	...	...

At about 75 feet to the west of the drift the coaly stuff has increased to 2 feet 4 inches, and at the mouth of the drift the section is—

Drift No. 7 A—		Feet.	Inches.
Limestone		...	...
Sandy marl with many bivalves		1	4
Yellow shale		3	0
Dark grey shale		7	0
Sandstone	about	0	6
Carbonaceous shale and *coal*		2	0
White sandstone		...	...

Beyond the drift the carbonaceous band dies out again, being about 1 foot 6 inches thick at 100 yards from it. The ground is then again covered by talus, and no good sections are seen until the spur overlooking mine No. 7 is reached. From this point to mine No. 6, a distance of about a mile and a quarter, clear sections are freely exposed. A photograph of this portion of the scarp is attached, (Plate II) which gives a good idea of its general aspect. No coal or indications of it are seen, however, until a point is reached about 300 yards west of mine No. 7, where about 2 feet of carbonaceous sandstone appears at the base of the shales beneath the limestone (Section No. V). This band of carbonaceous sandstone gradually increases in thickness, and the proportion of coal it contains becomes more considerable up to mine No. 7, where the section is—

Mine No. 7—		Feet.	Inches.
Limestone	about	100	0
Shale		11	0
Sandstone band		0	7
Coal		5	3
White sandstone		...	...

To the east of the mine the coal thins out again, until at about 200 yards distance the seam is represented by a band of grey sandstone with strings and nests of coal. Beyond this there are no signs of coal, or only very slight indications, for a considerable distance, to near drift No. 6 B. Here there is another lenticular band of coaly shales and sandstone. Where first seen, the coaly layer is 1 foot 3 inches thick, increasing to 2 feet 9 inches at about 12 yards further on, and continues with about the same thickness, but very irregular, to some 50 yards beyond the drift. Talus then covers the outcrop to near mine No. 6.*

At the mouth of mine No. 6 the section is—

	Feet.	Inches.
Limestone	...	...
Shale and clay	8	0
Coarse sandstone with nests of *coal*	1	0
Sandy coal	4	0
White sandstone	...	...

* Mr. Luckstedt in his second reportspeaks of a "line of erosion" about 1,200 feet wide as occurring in the scarp between mines Nos. 7 and 6, but I could not detect anything of the kind, nor could I see the "false bedding" he mentions in the lowest portion of the nummulitic limestone, though I looked for it carefully, as such a structure in the limestone, considering the mode of origin of the latter, would be worth studying.

Beyond this again the rocks are hidden by talus, but at 450 yards from the mine a section is exposed—

Section No. VI—

	Feet.	Inches.
Limestone	...	...
Brown clay	3	0
Soft sandstone with strings of *coal*	1	0
Hard sandstone	1	2
Soft sandstone, slightly carbonaceous	0	10
White sandstone	...	...

A little further on the whole of the rocks are concealed beneath a great slip, which has covered the hill-side with a confused mass of blocks of the Nahan sandstone from above. Where they appear again to the east of the slip no indications of coal are seen up to and upon the col dividing the drainage towards Bhaganwala from that into the Bunhar river; but they appear again near the head of the ravine on the east. At first there are two bands of coaly stuff from 10 inches to 1 foot thick, separated by sandstone. The shales above the coaly band are of a bright red colour, as though they had been burnt. Continuing along the side of the ravine the rocks are somewhat concealed by talus. Occasional indications of coal are seen as at section No. VII, where there are 15 inches of sandy carbonaceous clay, but sometimes the place of the seam is taken by a pebbly band of sandstone. It then begins to thicken gradually to about 3 feet at mine No. 5. Here the rocks begin to bend over with a dip of about 30° to the north. The seam may be traced continuously, and at the same time improving in quality, beyond mine No. 4, where the thickness is 3 feet 2 inches, down to the bottom of the ravine. At this point the section is—

Mine No. 3 W—

		Feet.	Inches.
Base of Nahans	Soft grey sandstones, weathering red	...	...
	Light green and brown marly clay, with nodules of limestone	3	0
Limestone, very nodular, with partings of clay		50	0
Limestone with small nodules		9	0
Shelly bed		4	6
Sandy limestone		1	0
Yellow marly bed with selenite in cracks		1	0
Coal		7	0
Sandstone		21	0
Clays, light green		10	0
Green shales with much selenite		13	0
Red shales		...	

Dip N. 10° E. at about 50°.

The coal seam continues up the hill-side to the south with an average thickness of about 4 feet and down to the ravine in which mine No. 1 is situated. At the bottom of this ravine the section is—

Mine No. 1—

	Feet.	Inches.
Nahan sandstone	...	...
Limestone	20	0
Purple shale	2	0
Dark-coloured sandstone	6	0
Coal	4	6
Sandstone	16	0
Green clays and shales	10	0
Red shales	...	...

Half-way up the hill on the south bank of this ravine a trial drift has been put in, but without finding coal. The section at the mouth of the drift is—

Section No. VIII—

	Feet.	Inches.
Limestone	18	0
Purple clay	2	0
Dark-grey and white sandstone	8	0
Slightly carbonaceous sandstone	2	0
Carbonaceous sandstone	3	3
White sandstone	8	0
Greenish clays and shales	15	0
Red shales	...	...

At the top of the hill, the furthest easterly point shown on the plan, all traces of coal have disappeared. It will be noticed that the limestone is very much attenuated in these latter sections, as compared with its thickness at the western end of the field, and at a short distance further east it thins out entirely.

Section No. IX—

	Feet.	Inches.
Grey Nahan sandstone	...	...
White nodular limestone	2	0
Yellow limestone, very fossiliferous	14	0
Purple shale with a band of clay at top	2	0
White sandstone	10	0
Red shales	...	...

Besides this long line of outcrop along the southern edge of the field, the drainage from the plateau has in more than one place cut through the formations above the coal-bearing beds, and we are thus enabled to form an opinion as to how far the coal seam extends to the north and east. The ravines in which the beds are thus exposed are the Rai ravine, to the east of Ara village, the Gahi ravine running east from the village of Dhamiala, and the Sikki ravine, which extends along the northern edge of the field.

Rai ravine.

In the Rai ravine the rocks beneath the Nahan sandstones are exposed over a considerable area as an inlier, the outcrop of the coal-bearing beds forming a narrow, continuous band on both sides of the ravine. Several good sections are exposed, especially on the north bank, but on that side there are no indications of coal whatever, the place of the coal seam being taken by shales. On the south bank a section at the mouth of Drift No. 10 gives :—

	Feet.	Inches.
Limestone	...	...
Grey shales	4	0
Ferruginous conglomerate mixed with clay, containing quartz pebbles	2	0
White sandstone with strings of *coal* and coaly stuff lining cracks	8	0
Fine yellow sandstone with pebbles	3	0

At the mouth of the drift some distance further to the east, marked Geological Survey Drift on the plan, which I had put in at this point because it was opposite to mine No. 7 on the southern outcrop, and it was important to discover how far the good coal in that mine extends in a northerly direction, the section is—

	Feet.	Inches.
Limestone	...	...
Shales	about 10	0
Yellow sandstone	1	6
Carbonaceous sandy shale	1	0
White sandstone	...	...

There is no "seam of weathered coal, 18 inches thick," here, as stated by Mr.

Luckstedt, but, as is so often the case in this field, the sandstone which occupies th place of the coal is irregularly carbonaceous.

In the bottom of the ravine, where the rocks dip below the level of the strear bed, at drift No. 11, there is no good section to be seen, both banks being mor or less covered by talus, but just within the mouth of the drift there are about 3 fee of shale at the base of the limestone, overlying sandstone, in which there are n traces of coal.

Gahi ravine.

In the Gahi ravine also a small closed area of the rocks beneath the limeston is exposed, but with the same disappointing results, a regards indications of coal, as in the Rai ravine. At onl one point could I find any traces of carbonaceous matter, and I had a cutting made here as the outcrop was obscured by talus. At a distance of 30 feet in, this gives the following section:—

Section No. XI—

	Feet.	Inches.
Limestone	...	...
Yellow shale	2	0
Slightly carbonaceous sandy band, very irregular	0	6
Soft white sandstone and clay	1	6
Dark-grey shales	...	...

Wherever at other places in this ravine the rocks between the limestone and the greenish-grey shales of the boulder bed are exposed, they consist of yellow and pink sandstones, even the shales which usually occur at this horizon being absent.

Sikki ravine.

Along the southern bank of the Sikki ravine the outcrop is exposed for more than a mile, but that of the coal-bearing beds is generally concealed by talus from the limestone above. At one point there are some indications of coal, and here a drift (No. 14) has been put in. The section at its mouth is—

Drift No. 14—

	Feet.	Inches.
Limestone	...	...
Marl	2	0
Carbonaceous sandstone	4	6
White sandstone	6	0
Boulder bed	...	...

Further to the west, near the village of Sikki, the following section was measured:—

Section No. X—

	Feet.	Inches.
Limestone	...	...
Shales	4	0
Ferruginous sandstone	2	6
Concealed by talus	6	0
Soft purple sandstone	3	0
Pebbly band	4	6
Yellow sandstone	8	0
Boulder bed	...	...

Conclusions to be drawn from evidence afforded by outcrops.

In considering the evidence afforded by the natural outcrops of the beds, as detailed above, it must be borne in mind that, although the outcrop is to a great extent concealed by talus, and the evidence is therefore to a similar extent imperfect, yet it is seldom that an interval of more than a few hundred feet of talus-covered ground separates points at which the beds are more or less well exposed, in the numerous small gullies which furrow the sides of the scarps. Therefore the cumulative evidence derived from such a large number of sections becomes more worthy of acceptance. Moreover, in those cases where good coal does occur, as at mines Nos. 7 and 1 to 3 W, it shows distinctly at the outcrop, and the seam may be traced almost continuously on either side of the points of greatest development, gradually thinning out as we recede from those points, until at last it disappears entirely, or is replaced by coaly stuff imbedded in sandstones or shales. Thus we are justified in drawing this conclusion from a study of the outcrops alone, that the distribution of coal is extremely irregular, and that it would be very unsafe to form an estimate of the quantity of coal that may exist within the area under consideration, from such evidence, taken by itself.

Evidence afforded by the drifts.

The drifts that have been put in at various points along the outcrops may be conveniently divided into two groups, *viz.*, those situated in the narrow neck of coal-bearing rocks at the eastern end of the field, from No. 1 to No. 7, including the drifts in the Rai ravine, and those situated in the western portion of the plateau, Nos. 7 A to 12 on the southern outcrop, and No. 14 in the Sikki ravine on the north.

Drifts in eastern portion of coal-field.

Taking first those in the eastern portion of the field, it should be noted that these are the only places from which coal of good quality has yet been procured. Drifts Nos. 1 to 5 are all on a continuous band or seam of coal, which may be traced, as above described in treating of the outcrops, for a distance of nearly a mile along the strike of the beds, and having an average thickness of about 4 feet. Nos. 1 and 3 E are driven from either side of a ridge, and meet in the middle of it, having a total length of 1,380 feet. The centre pit No. 2, driven from the highest point of the same ridge down the dip of the beds, meets the other two about half-way through the ridge, and continues beyond them to a distance of over 300 feet from the outcrop. Thus the continuity of the seam in this area has been fairly well proved. The thickness varies from 3 feet 9 inches to 7 feet, and 5 feet may be taken as a fair average.

No. 3 W is driven along the strike of the beds on the bank of the ravine opposite No. 3 E, to a distance of about 300 feet from the outcrop, and shows the seam reduced in thickness from 3 feet 6 inches at the outcrop to 2 feet 9 inches at the farthest point reached. A branch drift is also being put in at right angles to this in the direction of the dip, but it has not proceeded far, having been stopped for the present by water. Three feet may be taken as an average thickness for the coal affected by this drift.

Nos. 4 and 5 were driven to a distance of only 100 feet from the outcrop, and I have no information regarding them.

Drift No. 6 starts in about 4 feet of coaly sandstone, in which the coal and sandstone are disposed in thin, alternate layers. Further in the seam becomes thinner, but of better quality, and at 240 feet from the outcrop there are 2 feet 4 inches of good coal.

Between this and drift No. 7 one or two drifts have been put in at points where there are indications of coal, but they are now blocked up, and I have no information regarding them.

Drift No. 7 was started in good coal, about 5 feet thick at the outcrop, and extends in a northerly direction for about 500 feet, still in good coal of the same thickness. It has been opened out as a mine, and a considerable amount of coal has been worked out from either side of the main drift. The seam varies in thickness from 2 feet 9 inches on the west side of the main drift to between 4 and 5 feet on the east, and a thickness of 4 feet 6 inches may be taken as an average throughout the area proved by it.

In the Raí ravine three drifts have been put in, all on the southern bank. Of these No. 10 extends to a distance of 180 feet from the outcrop, in the shales below the limestone, but without finding any traces of coal. No. 11 is driven at the lower end of the ravine, where the rocks are brought down by a dip of about 20° to the level of the bottom of the valley. It extends to about 170 feet from the outcrop, and shows about 3 feet of shale underlaid by sandstone, in which there are occasional strings of coal, but no coal is found in the shales.

In the drift between these, which I had put in at this point as being opposite to mine No. 7, and which extends to about 200 feet from the outcrop, a similar section is shown, there being some 10 feet of shales beneath the limestone, without a trace of coal, underlaid by sandstone in which strings of bright coal, up to an inch or so thick, are occasionally found. And it is evident that the seam of good coal 5 feet thick, in mine No. 7, must die out in this direction, as it does along the outcrops on either side of that mine. Mr. Luckstedt, it is true, asserts that there is no prospect of reaching the coal of mine No. 7 within a distance of 400 or 500 feet from the outcrop in the Rai ravine, as, according to him, the whole of the southern side of the ravine is a slipped mass. But, apart from the fact that there is no evidence of such a general slip at that distance from the outcrop, even if it had occurred, it is inconceivable that it should have utterly destroyed the coal, and left the soft shales, in which the coal should be found, intact. In this drift there is a small fault or hitch at 110 feet from the mouth, bringing down the limestone, but the section is not affected by it; and the drift has been continued far beyond it, without meeting with any improvement. At drift No. 11 there is certainly no question of a slip, as the beds dip below the level at which denudation can have affected them, and are in an exactly similar position to that which they occupy further along the strike, at mine No. 3 W; and there is no reason whatever why the coal, if it originally existed at both these points, should have disappeared at one of them and remain at the other. These drifts, in my opinion, prove conclusively that the coal does not extend continuously from the southern outcrop to the Rai ravine, but thins out somewhere in the interval; and so far from agreeing with Mr. Luckstedt, I say that we have as yet no evidence, and there is no reason for thinking that the seam extends even to within 500 feet of the mouths of drifts in that ravine.

Drifts in the plateau.

Drift No. 7 A shows near the outcrop a thickness of 2 feet 7 inches of sandy coal, *i.e.*, a band consisting of thin alternating layers of bright coal and sandstone. At 70 feet in this dwindles to about a foot of the same stuff, then thickens again to 3 feet at the end of the drift, 200 feet from the outcrop.

Drift No. 8 is now closed, but Mr. Luckstedt states that it extends for 120 feet from the outcrop, and that the 1 foot of carbonaceous sandstone exposed at the mouth does not improve further in. He accounts for this by saying that a fault runs about 300 feet to the east of the drift in a northerly direction. The fault is certainly there, but I do not see how it could have affected the thickness of the coal, supposing that it was originally greater at this point. Faults are of common occurrence in most coal-fields, but beyond altering the relative positions of the seam on either side of them, they have little or no effect on the thickness of the coal, except along the actual plane of dislocation, where the rocks are sometimes crushed, and I know of no instance where a seam has been affected in such a manner, at so great a distance as 300 feet from the fault, as to reduce its thickness to such an extént as Mr. Luckstedt imagines.

Drift No. 9 is also now stopped up, but was apparently no more promising than No. 8.

Considerable importance must be attached to the indications afforded by mine No. 12, for assuming for a moment that Mr. Luckstedt is correct in attributing the general absence of signs of a thick seam of coal along the outcrop to slipping and other dislocations of the strata, this is just the place where we ought to find that thick seam in full force. For at this spot, not only is the scarp of recent formation lying as it does close to the head of a small ravine in which there is a perennially flowing stream of water, but there are no slips or faults anywhere in the vicinity, by which on his hypothesis the seam, supposing it had originally existed, could have been destroyed. Yet, on the one hand, in spite of the freshness of the outcrop, no thick seam of good coal shows in it, and on the other, although the drift has been pushed to a distance of over 250 feet from the outcrop, nothing like a continuous seam of good coal has been met with. The place of the seam is occupied by a band of carbonaceous sandstone and shale, varying in thickness from 1 foot 7 inches to about 4 feet. The sandstones usally contain thin strings of coal of good quality, sometimes thickening to a band about a foot thick, but useless as fuel, from the amount of foreign matter inseparable from it. Some of the so-called coal from this mine was tried in the engine of the steam boring machine, but it would not keep alight in the furnace.

The same remarks apply to the only drift that has been put in on the northern side of the field, No. 14. Here also the scarp above the outcrop is not very high, and there are no signs of slipping or other dislocations anywhere near the drift. It extends to a distance of about 200 feet from the outcrop, always in carbonaceous sandstone with the strings of bright coal which are such a common feature in the sandstones that so frequently occupy the place of the coal seam in this field.

It may be objected that the non-occurrence of good coal in these two drifts may be a mere accident, owing to an unfortunate choice of position, but seeing that both of them were put in where they are solely because of the comparatively promising indications of coal at the outcrop, that argument can hardly be considered as valid.

If these two drifts, in conjunction with No. 7 A, 8, and 9, prove anything at all, they prove that a continuous seam of coal, 3 or 4 feet in thickness, does not underlie the whole of the plateau,—that is, over by far the greater part of the area coloured as productive of coal on Mr. Luckstedt's maps; and the conclusion drawn from the evidence afforded by the outcrops,—*viz.*, that the distribution of coal is extremely irregular—is thus quite borne out by that of the drifts. Still, however, it is quite possible that coal in large quantities may exist beneath the plateau, but until its existence has been proved, it is quite out of the question to take such hypothetical coal into calculation, when speculating upon the total quantity obtainable from the field.

I may mention here that my colleague Mr. Middlemiss, who had been rather sceptical as to whether any correct inferences could be drawn from a study of the outcrops, was convinced after seeing the two drifts, Nos. 12 and 14, of the truth of the conclusions I had come to regarding the irregularity of the coal seam.

Causes of irregularity in distribution of coal.

This irregularity in the distribution of the coal may be due to either of two causes,—*viz.*, either that the coal was originally deposited in limited areas, or that subsequently to the deposition of the coal bed over the whole area it was irregularly denuded. From the manner in which the seam, wherever there is good coal, can be seen passing horizontally into carbonaceous shales and sandstones, I am inclined to think that the first of these causes is sufficient to account for the facts, and that the coal was formed in detached pools or marshes of limited extent, the banks of which are represented by the barren ground intervening between the different productive areas. I have, moreover, not been able to find any good evidence of erosion subsequent to the deposition of the coal, except that in some cases the sandstones overlying it contain what appear to be fragments of coal; and as the period following that in which the coal was formed seems to have been one of rather rapid depression, as evidenced by the appearance of the limestone at no great distance vertically above the coal horizon, it is likely that the beds were quickly covered by shales and sandstone, and were thus protected from denudation.

Age of the coal.

A few obscure casts of fossils, principally gasteropods, have been found in the sandstone layers immediately above the coal at mine No. 7, not sufficiently well preserved to determine the age of the beds, but there can be little doubt that they belong to the nummulitic group. It is remarkable, however, that the coal frequently contains specks and nests of fossil resin, which is characteristic of the coals of cretaceous age in Assam, and in that part of the country serves to distinguish them from the newer tertiary coals.

Borings.

Before the present investigation was undertaken, it was pointed out by the Director of the Geological Survey that borings would have to be put down on the plateau, to prove the existence or otherwise of coal beneath it; and all that I have seen of the conditions under which the coal occurs has convinced me that several borings should be made. The distance to be sunk in any borings made on the plateau need not be more than 300 feet or so, and at many points would be much less, whereas if it is proposed to continue driving from the outcrop until the plateau is thoroughly proved, many thousands of feet of barren rock may have to be passed through, before any coal is struck; and on the score of expense alone it seems to me that a serious effort should be made to carry out those borings at any rate which have been started during the past six months, down to the coal horizon. Two of these were partly sunk with the aid of the steam boring machine belonging to the Geological Survey, which does its work excellently so long as hard and homogeneous rocks have to be passed through, the average rate of progress being about 3 feet per hour in the sandstone, and over 1 foot per hour in the hard limestone. But the latter contains bands of soft shale and clay, which it has been hitherto found impossible to bore through with the machine. These borings are being proceeded with by hand, as the soft beds present no obstacle to that method, but in the harder limestone bands progress is extremely slow. A third boring is being sunk by the aid of the machine, and so far has proceeded satisfactorily, but it remains to be seen whether similar soft bands will be met with, as in the other two borings.*

Quantity of coal available.

In making an estimate of the quantity of coal obtainable from the Bhaganwala field, the foregoing considerations will have shown that we are justified in taking into account only those areas in which the existence of workable coal has been actually proved, and it will be noticed that these are just the areas in which good coal appears at the outcrop, *viz.*, along the scarp from mines Nos. 1 to 5, at No. 6, and No. 7. In no other instance has any of the drifts proved the existence of good coal, nor have the indications of its presence at the outcrop been found to improve further in. As far as regards the areas above referred to, I have satisfied myself that Mr. Luckstedt's figures, as given in his second report, are reliable, and I calculate the available quantity of coal as follows:—

(*i*) Mines Nos. 1, 2, and 3 E.

These may be taken together, as they are practically one and the same mine.

Estimated average thickness of seam .	= 5 feet.
Area actually proved	= 384,000 square feet.

$$\text{Quantity of coal} = \frac{384{,}000 \times 5}{30} = 64{,}000 \text{ tons.}$$

To this may be added, according to the depth, measured along the dip, to which the mines can be worked, for each 60 feet in that direction, or an addition of 96,000 square feet to the area,

$$\frac{96{,}000 \times 5}{30} = 16{,}000 \text{ tons.}$$

Supposing, for instance, that it is found feasible to work the mine to a depth of about 2,000 feet along the dip, below the bottom of the ravines on either side. And I think that such a depth would be quite practicable, for it is not likely that any great influx of water would be met with, considering the climate of the locality.

* Since the above was written, this boring, No. 4 on the plan, was stopped, as far as the machine was concerned, by a soft layer in the limestone at a depth of 150 feet from the surface. About 45 feet of the limestone had then been bored through, and I calculated that about 70 feet more remained before the coal-bearing bed would be reached. Should it be found impossible to carry any of these borings down to the coal horizon, I recommend that one or more shafts should be sunk, say, close to borings Nos. 3 and 4. These would no doubt cost more than the drifts per foot, but probably not much more, and the distance to be passed through in order to settle the question of the existence of coal beneath the plateau would be so very much less in the case of shafts than in that of drifts from the outcrop, that the cost of the former would be a mere trifle as compared with that of the drifts. Moreover, in case good coal is found beneath the plateau, shafts will have to be sunk in order to ventilate the mines, so that the expenditure on them will not have been wasted.

Assuming, then, that the coal retains its thickness to that depth, we should have a total quantity of about 600,000 tons of coal available from this mine alone.

(ii) Mine No. 3 W—

Estimated average thickness of seam . . . . . =3 feet.
Area actually proved . . . . =64,800 square feet.

$$\text{Quantity of coal} = \frac{64,800 \times 3}{30} = 6,480 \text{ tons.}$$

It is a question how far the seam extends along the strike beyond the area proved, since where the beds are again exposed in that direction, in the Rai ravine, they contain no coal, but it may be assumed that it continues to at least 1,000 feet from the mouth of the mine. This would give for every 60 feet of depth, measured as before, along the dip, an additional area of 60,000 square feet,

or, $\frac{60,000 \times 3}{30}$ . . . . =6,000 tons of coal.

Assuming, as before, that the coal extends to a depth of 2,000 feet along the dip, and that it can be worked to that depth, this would give a total of 200,000 tons.

Adding the portion which it may be assumed can be worked out along the strike beyond the area actually proved, *i.e.*, over an area of 240,000 square feet, which gives—

$\frac{240,000 \times 3}{30}$ . . . . =24,000 tons

we get a total of about 230,000 tons of coal available from this mine.

(iii) Mines Nos. 4, 5, and 6.

These mines have not yet been opened out sufficiently to furnish any reliable data on which an estimate can be founded; besides which Nos. 4 and 5 are so much closer to what appears to be the original limit of the basin in which the coal was formed, as to render any speculation, regarding the distance to which the coal may extend from the outcrop, extremely hazardous; while No. 6 appears to be in a small detached basin, very little of which has been actually proved to contain good coal.

(iv) Mine No 7—

Estimated average thickness of seam . . . . . =4 feet 6 inches.
Area actually proved . . . . =120,000 square feet.

Quantity of coal proved $= \frac{120,000 \times 9}{30 \times 2}$ . . . . . . =18,000 tons.

Here again it is not known how far the seam extends in a northerly direction, as it does not appear in the sections exposed in the Rai ravine, at a distance of 3,750 feet from the mouth of the mine; nor is it known how far it extends laterally on either side of the area proved. Assuming, however, that it extends half-way towards the Rai ravine, with an average breadth of 500 feet, an area of 817,500 square feet will be added to that already proved, which gives—

$\frac{817,500 \times 9}{30 \times 2}$ . . . . =122,625 tons.

Adding the amount actually proved, we have in round numbers 140,000 tons available from this mine.

Adding together the whole of these amounts, it appears that 88,480 tons of coal have been actually proved, and that a reasonable estimate of the coal obtainable from the three mines referred to gives a grand total of 970,000 tons, or, say, one million tons, of coal. From this amount quite 25 per cent. should be deducted to allow for waste, on account of the frequent interbedding of the coal with thin layers of sandstone, and of the remainder a large proportion will be slack coal; but this, it is stated, can be sold at a profit.

General conclusions.

The conditions under which the coal is found, as regards roof and floor, and thickness of the seam, are such that nearly the whole of the amount estimated above should be easy of extraction, under a proper system of mining, and except at the eastern end of the field, and that only when the mining is carried below a certain depth, no pumping will be required to drain the mines. On the whole I consider that though the quantity of coal estimated for is by no means proved, yet there is a reasonable prospect of sufficient coal being obtainable, and under favourable conditions, as to make it quite worth while to improve the existing communications with the railway at Haranpur in the manner detailed in Mr. Luckstedt's reports.

Mr. Luckstedt's reports.

It will be seen from the foregoing that my estimate of the coal available differs considerably from that formed by Mr. Luckstedt, whose estimate amounts to 20 million tons; the reason being that I cannot agree with him in including the very large area coloured as coal-bearing on his map, until some more decided evidence than is at present at our disposal can be brought forward to justify the inclusion of that area. Mr. Luckstedt begins his argument by asserting that "it is a mining axiom that a coal seam cannot abruptly vanish, and that the continuation of a seam that has been worked up to the boundary of a district may be safely assumed." Where Mr. Luckstedt got this "axiom" from I do not know, but from the use of the word "district," I suspect that it refers entirely to the conditions under which seams of coal occur in England, where coal estates are divided into districts, and it may be presumed that where coal has been proved in adjoining estates and districts that it will be continuous between them. But the seams in the coal-fields of this country are not as a rule so continuous in thickness for great distances as they are in the coal-fields of England, and numerous examples might be cited, even in fields of Gondwana age, where the seams do thin out from a workable thickness to one of a few inches or so, if not abruptly, using the word in its strict sense, yet within a few yards. And in fields of nummulitic age, such as this of Bhaganwala, the thinning out of seams, just as they are seen to do here, is the rule rather than the exception. I have seen it in the Jammu coal-field, in those of the Khasia Hills in Assam, and even the enormously thick seams of Upper Assam are not continuous for anything like the distance to which the rocks, in which they occur, extend.

Mr. Luckstedt says again that, if the seams were deposited in detached basins, we should have signs of the approach to the edge of such basins in the appearance of littoral deposits containing pebbles, in line with the coal seams. But it is not at all necessary that such deposits should contain pebbles; in fact, considering the conditions under which the coal was formed, it is hardly likely that pebbles would occur. Their presence would depend on the distance of the nearest hills, in which solid rocks capable of being formed into pebbles occurred, and supposing that the coal was formed under some such conditions as at present exist in Sylhet, and the Sunderbunds, the absence of pebbles is easily accounted for. But the replacement of the coal seam by sandstones and shales, as so frequently happens here, is precisely what we should expect if the coal had been formed under some such conditions as I have supposed, and is in itself an indication that it was laid down in pools or marshes of limited area.

The "axiom" quoted by Mr. Luckstedt is, he says, "based on the laws of sedimentation, by which coal and its associated shales can only be deposited during a prolonged period of great quiescence." However true this may be of the continuous seams to which the "axiom" refers, the facts of the case here seem to point in the opposite direction, *viz.*, that the period of coal formation with which we are dealing was one of rather rapid change. Within a thickness of less than 50 feet of strata, we have several diffierent rock bands, each of which denotes a more or less abrupt change of conditions, and a glance at the sections given above will show that each of these bands varies greatly in thickness at different points. First we have the boulder bed, denoting the presence at no great distance of rocky hills with rapid torrents descending from them; then the white sandstones, showing that the hills were at a greater distance, though the occasional presence of strings and beds of large boulders, imbedded in the sandstone, shows that the area was not beyond the reach of torrents. After this the coal beds and shales, which were probably deposited on a flat plain, far removed from any hills, with frequent depressions or marshy spaces in which an abundant vegetation grew, and traversed by sluggish streams unable to move anything but the finest sand and silt. Lastly, the whole was submerged beneath the waters of the sea, the sudden alteration from shales to limestone showing that the depression was rapid. I can hardly imagine a case in which the evidences of a rapid change of conditions could be more clear.

It would be waste of time to criticise seriously Mr. Luckstedt's geological reasoning, if it were not that its introduction into his reports gives them an air of plausibility, which might impose on those whose acquaintance with geology is slight. To take one or two instances in which his reasoning might be modified by a little more study. He evidently thinks that a "geological basin" has some connection necessarily with the present configuration of the country, as where he says that "the Bhaganwala field lies at the south-west limit of a well-defined geological basin, of which the Salt-Range, the outer Himalayas, the Jhelum and the Indus form the boundaries." These mountains and rivers have nothing to do with the limits of the basin, which, as a matter of fact, extends far beyond them. Then, again, he says, "The (proving of the) existence of coal is a work of purely geological character . . . . To search for coal among rocks the age of which was not known would of course be fruitless." Does he think that it was necessary that the age of the coal measures in Bengal, for instance, should be determined before the existence of coal there was proved, or that three hundred years ago the geological age of the strata about Newcastle and Bristol, from which "sea coal" was sent to London, was known? Or is it possible that he is labouring under the now ancient delusion that all coal seams are of one and the same geological age? Supposing, as might have been the case, that none of the coal seams in Bengal appeared anywhere at the surface, but that the geological age of the rocks had been ascertained by other evidence, that knowledge would of itself have *prevented* any search for coal being made in those rocks. For at the time the Bengal coal-fields were being opened out, no other coal-bearing strata of that particular age were known.

The fact is that geology has nothing to do with the existence of coal at all. There *may* be several millions of tons of coal lying beneath the plateau at Ara, but if it is not there; no "mining axioms," or geological reasoning, good or bad, will put it there. Its existence can only be proved by a rigorous search, and I have already stated my reasons for thinking that this search can best be carried out by means of borings or shafts. Mr. Luckstedt, assuming the existence of a 4-feet seam of coal over the whole area, thinks that borings will be of little use, and, of course, if that assumption were correct, there would be no object in making them, since the depth of the seam from the surface at any point could be calculated from the observed dips, in case it was required to sink shafts for mining purposes.

Finally, supposing that the amount of coal obtainable from the mines at the eastern end of the field is even half only of what I have estimated above, it will take some 20 years, with a regular output of 2,000 tons a month, before it is all worked out; and the expenditure necessary to construct a branch line from Haranpur would be amply justified. In the meanwhile there is plenty of time to carry out a thorough search on the plateau, and if a large area of coal is found there, the output can be enormously increased, without fear of the coal-field becoming exhausted for many years to come.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 18.—ENDING 31ST JANUARY 1894.

Director's Office, Calcutta, 31st January 1894.

In November last, a slight modification of the disposition list of the Staff became necessary owing to an urgent call for inspection of the collieries in the Salt-Range and at Warora, where the percentage of accidents was considered excessive. The newly-appointed Inspector of Mines for India not having then arrived, it was judged expedient to depute Dr. Noetling for this work, he having had the necessary experience at thin-bedded coal on the Continent. He has reported since on the Dandot and Bhaganwalla Collieries, and is now at Warora.

2. Mr. James Grundy, the Inspector of Mines, reported his arrival at Calcutta on the 14th December, and was placed with the Director of the Geological Survey, through whom he communicates with the Government of India. After some necessary delay in arranging procedure and interviewing the Calcutta Agents of several Mining Concerns, he left early in January, and entered on the examination of the Bengal coal mines.

3. The Director proceeded on tour in Burma on the 28th of December, and returned to headquarters on the 31st of January. He visited the Thingadaw coal-field, and the auriferous tract of Wuntho. At the Thingadaw coal-field, which is worked at present by an incline colliery at Letkobin, the various coal outcrops were

examined under the guidance of Mr. T. H. Ward, the Agent and Manager. There are two kinds of coal which appear to belong to two separate members of the Chindwin series, the lower and better coal occupying a rather restricted area at Letkobin and Kesobin, but the further extensions of this group will have to be explored by boring, primarily between those places and the Irrawaddi bank; while it is not improbable but that larger areas of the same measures may be tapped over a considerable extent of this part of the Irrawaddi tract, though at some depth, as the country is opened up in the progress of coal development. At present, however, progress is considerably handicapped, if not on the eve of being retarded for a time, by the laying down of coal from Bengal in the Rangoon market, the present low price of which would undoubtedly be raised were the Burma development so restricted. In other words, it would almost appear as if a ring had been formed in the Rangoon market to choke off the Burma output of coal, at a price which cannot for long be profitably kept so low as now rules.

4. The Wuntho region is undoubtedly auriferous to a certain extent, having been worked by surface washings in a fitful manner for a long time past, but its development in any such productive way as has lately been prophesied, is entirely dependent on a more prominent occurrence of vein or reef matrix than has been met with so far: the matrix exhibited up to the present time being merely a sporadic occurrence of small and discontinuous strings and narrow ledges of auriferous and pyritous quartz in which there is some free gold, among strongly and deeply weathered schists. Exploration and some prospecting have been made, but these are still only in an initial stage; no large reefs are yet known, and the few indications of increase in the size of the veins met with point to a decrease in their gold-bearing aspect.

5. Just at the close of the last three months, an enquiry which is full of promise of most interesting geological results is being taken up by the Survey in connection with the gigantic landslip which took place in Garhwal last September; and Mr. Holland has been deputed for this work. As yet there is only a demi-official account of the occurrence from the Public Works Department of the North-West Provinces, but it is as well to record now what is known of it from the very interesting memorandum given by Colonel R. R. Pulford, R.E., Superintending Engineer 2nd Circle, Provincial Works, Lucknow, who visited the scene of what he has designated as the "Gohna Slip."

6. It appears that the site of this *debacle* is up the valley of the Bihri Ganga, a tributary of the Alaknanda, some 80 miles over mountain and valley, due north of Naini Tal. The bed of the river is about 5,000 feet, and the hill on the right bank, from which the mass fell, has a height of about 9,000 feet above sea-level. On the 22nd of September, a tremendous mass of rock material was detached, leaving an almost perpendicular section of hill face 4,000 feet high. The force of the fall carried the rocks and *débris* from the right bank, right across the valley of the river and half-way up the steeply scarped hill on the left bank; after which the mass settled down again in the river bed forming a dam with a big slope up against the hill on the left bank; the consequence being that there is now an appearance as if a portion of the dam had been formed by a big slip from the steeply scarped hill of this side of the valley also. Further slips which took place during heavy rain in October have piled up the dam on the right bank against the hill on that side, so that the top of the dam has a large depression in the centre

some 150 feet or more, between two sloping mounds of rocks and smaller *débris*. The dam itself is a very massive affair, being largely composed of enormous masses of rock, some of which are calculated to be more than a thousand tons in weight. There is, in addition, a very large admixture of smaller detritus and broken rock, and a thick layer of impalpable powder which gives the whole place the character of being covered with white clay dust, which Colonel Pulford likens to the country about Vesuvius after an eruption. The dam may be taken roughly to be 900 feet high, 2,000 feet broad at the top, and 1,100 feet at base along the valley, and 3,000 feet long at top, and 600 feet at bottom across the valley. The bed of the river slopes at about 250 feet in the mile; and the depth of water in the newly-formed lake on the 13th and 14th December was 450 feet, the water then rising at the rate of 8 inches a day, though the flow of water in the mountain rivers was then at its slackest. Colonel Pulford writes as follows, on the probable future rise of water and the ultimate condition of the dam :—

"The present amount of water running into the lake is roughly about 260 cubic feet per second. During the winter rains there will be the addition due to a 12 inches fall over 84 square miles, which is the area drained by the river above the dam. The increase due to the snow-melting may be put at 2,120 cubic feet per second.

"Taking these several additional sources of supply into account, there seems every reason to suppose that the rise of water in the lake will be as follows :—

"Area of lake at present equals roughly 1 square mile—

"(*a*) Rainfall of 12 inches over 84 square miles $= 5{,}280^2 \times 1 \times 84$ cubic feet, which for one square mile of lake gives a rise of 84 feet.

"(*b*) In addition to rainfall there will be rise due to the present rate of inflow of, say, 8 inches per day up to date of snow beginning to melt, say, 1st April 1894. Up to that date, therefore, the rise in lake due to ordinary inflow will be 8 inches $\times$ 110 days $= 73$ feet. Up to 1st April 1894, therefore, the total rise will be 84 feet $+$ 73 feet $=$ 157 feet, leaving a margin of $350 - 157 = 193$ feet from water-level to top of dam. Now the rate of rise due to snow-water influx will be eight times that due to the present ordinary flow of the river, since the floodmarks show that during snow-melting (as above stated) the river flow is 2,120 cubic feet per second, whilst present flow is 260 cubic feet per second. This, it is seen, gives a rise of 8 inches daily; and hence the rise to snow-melting may be put at 8 $\times$ 8 inches $=$ 64 inches, or as the area of the lake will be increasing and slopes of hillside are about 35°, we may put this rise at 48 inches, or 4 feet per diem. Hence it will require $\frac{193}{4}$ days $=$ 48 days after 1st April 1894 for the lake water to rise to the top of the dam. The date of this event may therefore be placed at about the middle of May 1894. As to what will take place when the water passes over the dam, it is difficult to speak with any approach to certainty. The first rush of water will necessarily be very severe, and I think that at least 250 feet or so of the dam at the top will gradually be carried away. After that it may possibly happen that the main portion of the dam will get thoroughly jammed and consolidated together so as to form a permanent lake with a natural outfall over the big rocks forming the dam."

Colonel Pulford also adds an account of a previous occurrence of the like kind :—

"A few years ago a very heavy flood was caused in the same river Birhi Ganga and Alaknunda by a heavy landslip falling into a lake which had been formed some 8 or 9 miles higher up the valley than the present slip. The lake was called Gudyar Tal, and had been in existence for many years; probably it had been formed originally by a similar slip to the one at Gohna. The result of the heavy slip falling into the lake was that the entire basin was filled up and the water forced over the dam which held it up down into the bed of the stream. This occurred in 1869 during the rains, and the results were very disastrous. A large number of pilgrims and others were drowned, and the lower part of Srinagar Bazar was washed away, and the lower end of Nand Pryag bridge was washed away. In addition the bridge at Chamoli, wnich is 12 miles below Gohna, was destroyed. Many of the bridges now up were not erected at the time of this heavy flood. They tell me that all trace of the former lake has been obliterated, and the channel is now very much like the other watercourses near it."

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894.

SUBSTANCE.	For whom.	Result.
One specimen of coke	H. MACLEOD, Bengal Coal Co., Ld., Calcutta.	Proximate analysis with calorific power and sulphur determination.
One specimen of quartz schist with iron pyrites.	F. T. VERNER	Assayed for gold.
One specimen of chlorite schist with copper pyrites.	KILBURN & Co., Calcutta.	Analysed for copper.
One specimen of quartz with iron pyrites.	H. C. MILLER, District Engineer, E. I. R., Howrah.	Assayed for gold.
One specimen of coal, from Japan.	H. MACLEOD, Bengal Coal Co., Ld., Calcutta.	Prozimate analysis with calorific power.
One specimen of coal, from the Ramnagar quarry, Barakar.	MAHARANI HARA SUNDRI DAVI, Searsole, Rajbati.	Proximate analysis with calorific power.
One specimen of coarse river sand consisting chiefly of quartz, spinel, garnet, magnetic iron, bits of slate, and mica.	BALMER, LAWRIE & Co., Calcutta.	Assayed for gold.
One specimen of quartz, with iron pyrites, from the "Rees Reef," Pahardiah.	A. MERVYN-SMITH, Oriental Prospecting Syndicate, Ld., Calcutta.	Assayed for gold.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
A specimen from the bed of the Atrai River, Joyganj, Dinajpur District, supposed to be peat.	W. C. MACPHERSON, I.C.S., Officiating Director, Department of Land Records and Agriculture, Bengal.	*Quantity received, 15lbs.* Moisture . . . 20·06 Volatile matter, exclusive of moisture . . 30·16 Fixed carbon . . 10·06 Ash . . . . . 39·72 100·00 Does not cake. Ash, reddish brown.
One specimen of "Blanket sands," and one specimen of quartz with chlorite schist and iron pyrites, from Chota Nagpore.	A. MERVYN-SMITH, Oriental Prospecting Syndicate, Ld., Calcutta.	Assayed for gold.
One specimen of coal .	GILLANDERS, ARBUTHNOT, & Co., Calcutta.	Proximate analysis with calorific power and sulphur determination.
A specimen found in the Garhwal District, supposed to be molybdenite or sternbergite.	W. R. PARTRIDGE, I.C.S., Deputy Commissioner, Garhwal.	Carbonaceous shale (graphitic).
A specimen of limonite crystals from Chaibasa, supposed to be manganiferous.	A. W. WALKER, Chaibasa, Singbhum.	Tested for manganese.
A specimen "from an old pit (in the transitions) Nawanagari, Sihaol Tahsil, Rewah State, close to rich iron-ores" for indication of any other metal.	P. N. BOSE, Geological Survey of India.	Tested for gold—contains none.
Two specimens for examination.	S. B. BOSS, Geologist to the Nepal Government, Nepal.	= Iron pyrites, and artificial glass.
A packet of "stones found in an old ruby mine near Papun, Salween District, Tenasserim," for report.	HARRY L. TILLY, Secretary to the Financial Commissioner, Burma.	Small fragments of spinels and garnets of kinds often found associated with rubies, and as often not so found. In themselves they indicate nothing of value.
Specimens from the Karharbari coal-field, for examination.	W. SAISE, Manager, E. I. R. Co.'s. Collieries, Karharbari, Giridih.	*Karharbari Coal-field.* Fine-grained olivine dolerite. *Karharbari coal-field. Intrusive Lower Seam = Dyke No. 5 or Jogitand dyke of Hughes Memoirs. Geological Survey of India, Vol. VII, 239.* Biotite amphibole peridotite. *800 ft. above main seam.* Olivine dolerite. *Ranigang coal-field.* Calcareous and micaceous sandstone.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		Raneeganj Coal-field. Calcareous and micaceous sandstone. *Raneeganj Coal-field.* Quartz-schist with green muscovite and eyes of calcite. *Rock from Bhal Hill.* Consists of quartz and felspar crystals with small quantities of brown felsitic, or even glassy matrix with microlites like the matrix of a rhyolite. The quartz crystals show distinct signs of secondary enlargement, the older grains being full of bubbles and bands of inclusions. The rock appears to be a felspathic grit which has been partially fused. *Raneeganj Coal-field, Raneeganj* A. *series, Balrooi seam horizon.* Decomposed "mica-trap" probably originally mica-peridotite. B. *Intrusive in Karharbari Lower seam.* Decomposed "mica-trap." C. *Karharbari Coal-field.* Slightly micaceous sandstone with angular quartz-crystals and ferruginous cement. D. *Karharbari Coal-field, Lower seam.* Micaceous sandstone with angular quartz crystals. E. *Karharbari Coal-field.* Clay.
Specimens of rocks from Bellary.	R. BRUCE FOOTE, late Geological Survey of India.	*In the Pass south of Halakandi, Bellary.* $\frac{8}{788}$ *26-1-86. Slide 1195.* Epidiorite, approaching hornblende schist. Actinolitic hornblende, quartz-felspar, mosaic and magnetite. S. G. 2·97. *Kudatami, Bellary.* $\frac{8}{787}$ *1-2-86. Slide 1196.* Olivine-augite-enstatite-biotite-anorthite rock. The dusty magnetite present is a result of alteration principally of olivine-serpentine also in small quantities; otherwise the rock has a fresh appearance. Olivine in rounded grains is the oldest constituent; plagioclase-felspar (basic varieties) the youngest; the intermediate minerals are not so easily determined. Enstatite, slightly pleochroic. S. G. 3·14.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		West of Tekkalkota, Bellary Taluq. $\frac{8}{788}$ *13-12-86. Slide 1197.*
		Grey rock approximating granite in composition, but quartz and felspar crystals have been smashed into a schistose mosaic with production of fine mylonitic structure. S. G. 2·68.
		From a "neck," Dewurruguddu Id. Falls of Kistna, Raichur Doab. $\frac{8}{708}$ *21-2-88. Slide 1198.*
		Quartz and felspar in felsitic base, which has turned red by oxidation of the iron. S. G. 2·52.
		Black hill, West of Maski, Raichur Doab. $\frac{8}{801}$ *13-2-88. Slide 1199.*
		Diorite with large porphyritic crystals of hornblende. Rock considerably altered with formation of epidote. S. G. 3·03.
		Inlier South of Manur, Bellary Taluq. $\frac{8}{808}$ *15-3-88. Slide 1200.*
		Quartz-diorite. Quartz in part secondary, clear granules. Kaolinized felspars some at least plagioclase. Green hornblende and a green pleochroic mica, sphene in considerable quantity. Iron ores as magnetic granules. S. G. 2·81.
		Near Yemmigamer, Bellary Taluq. $\frac{8}{810}$ *20-3-88. Slide 1201.*
		Quartz-diorite. Felspars highly kaolinized. Epidote in small quantities. Green hornblende and a chloritic mineral; magnetite practically absent. S. G. 2·85.
		Hill, South of Kurnool District. $\frac{8}{817}$ *30-11-88. Slide 1202.*
		Granulite with quartz, orthoclase, pleochroic mica, hornblende, sphene and plagioclase. Fine-grained granular, in places granitic in structure. S. G. 2·67.
		Tornagal Hill, Hospett Taluq, Bellary. $\frac{8}{814}$ *6-4-88.*
		Hornblende granite with porphyritic crystals of orthoclase. S. G. 2·71.
		South of Nilgunda, Harapanahalli Taluq, Bellary. $\frac{8}{823}$ *17-12-89.*
		Pyroxenite approaching eucrite. S. G. 3·22.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894.—contd.

SUBSTANCE.	For whom.	Result.
		Yenkatampalli, 6 miles east of Uravakanda Guti Taluq, Anantapur. $\frac{9}{408}$ *29-1-85.*
		Fine-grained diorite approaching aphanite. S. G. 3·07.
		Mudkalpenta, South-East Valley, Sandur, Bellary. $\frac{9}{382}$ *20-3-86. Slide 1219.*
		Aphanite. S. G. 3·05.
		South-West of Uravakonda, Guti Taluq, Anantapur. $\frac{9}{407}$ *23-1-85. Slide 1214.*
		Large rounded crystals of orthoclase and plagioclase embedded in a microgranitic aggregate of quartz, felspar, hornblende and occasional sphenes. S. G. 2·69.
		Dyke East of Uparhally, Hospett Taluq, Bellary. $\frac{9}{427}$ *3-3-86. Slide 1218.*
		Augite-diorite, fine-grained. Identical with many of the dark-coloured dykes of Southern India. S. G. 3·03.
		Daroje, Hospett Taluq, Bellary. $\frac{9}{410}$ *23-4-85. Slide 1216.*
		Aphanite, with highly kaolinized, porphyritic crystals of felspar. S. G. 3·19.
		Devadura spur, Sandur Hills, Bellary. $\frac{9}{444}$ *25-3-86. Slide 1234.*
		Rock composed principally of quartz and felspar, some of the latter being plagioclastic. Micrographic intergrowths are common. Brown patches of iron oxide occurring in large quantities may be the remains of some original ferro-magnesian silicate; calcite has been formed in fairly large quantities. Isolated crystals of pyrites. S. G. 2·60.
		South of Hurina, Haddgalli, Bellary. $\frac{9}{480}$ *16-4-86. Slide 1205.*
		Micro-granulitic aggregate of quartz, felspar, hornblende, garnet, and possibly some other minerals. Banding displayed. Nature of original rock unknown. S. G. 2·94.
		Halakandi Pass, Bellary. $\frac{9}{464}$ *26-1-86. Slide 1206.*
		Augite-andesite-olivine-free basalt. Crystals of colourless augite and plagioclase set in a fine-grained matrix of magnetite, augite felspar, and possibly vitreous material. S. G. 3·03.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		West of Halakandi, Bellary. $\frac{8}{461}$. *27-1-86. Slide 1207.* Hornblende schist.
		West by South of Yettan Budihal, Bellary. $\frac{8}{468}$. *21-1-86. Slide 1208.* Epidiorite. Large crystals of green hornblende in microgranular matrix of quartz and felspar with granular sphene, (?) rutile magnetite and colourless (?) augite. S. G. 2·98.
		Karigatta Hill, East of Seringapatam Id., Mysore. $\frac{8}{88}$. *15-2-87. Slide 1211.* Diorite-felsite: felsitic base with porphyritic crystals of plagioclase, hornblende (partially converted to epidote and chlorite), sphene and magnetite. S. G. 2·62.
		Ram Drug, Alur Taluk, Bellary. $\frac{8}{485}$. *21-1-87. Slide 1212.* Hornblende-granitite with sphene and pleochroic mica. S. G. 2·66.
		Verupur Hill, Bellary Taluq, $\frac{8}{702}$. *13-12-87. Slide 1213.* Augite-syenite. Augites green and slightly pleochroic with green hornblende. Considerable quantities of plagioclase amongst the smaller crystals, hence approaches a diorite. S. G. 2·81.
		Close to road between Permadavanhalli Bungalow and Joladarathi, Bellary Taluq. $\frac{8}{178}$ and $\frac{8}{174}$. *30-11-86. Slides 1210, 1221, 1222* "Blotchy diorite." Highly decomposed porphyritic diorite in which epidote, calcite, chlorite, kaolin and quartz have been formed as secondary minerals. S. G. of $\frac{8}{178}$ = 3·02; S. G. of $\frac{8}{174}$ = 2·79. Specific gravity necessarily variable in different specimens.
		Mudikalpenta, South-East Valley, Sandur, Bellary. $\frac{8}{447}$. *20-3-86. Slide 1220.* Decomposed aphanite. S. G. 3·03.
		South of Nilgunda, Harapanahalli, Taluq Bellary. $\frac{8}{828}$. *17-12-89. Slide 1233.* Pyroxenite, approaching eucrite.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
Rocks from the Khojak Range.	C. L. GRIESBACH, Geological Survey of India.	*A.—Main mass of Range north of the Gwajsha defile, South-East of Khwaja Amran.* Granitic in structure. S. G. 2·64. Composed of *orthoclase* much kaolinized and often in form of microcline. *Quartz* frequently intergrown with the orthoclase forming imperfect micro-graphic structure. *Plagioclase*-felspars, often zoned by successive growths of increasing acidity. *Biotite* in small crystals generally as nest-like aggregates. *Magnetite* generally with the biotite. *Sphene* very rare. Minerals given in order of approximate proportions. The rock may be named *Biotite-Granite* approaching granitite (= Granitite of Rosenbusch). *B.—Near boundary between A and "Trap-belt," Gwajsha defile, south-west of the Khwaja Amran.* Granitic or micro-granitic in structure, beautifully micro-graphic in places. S. G. 2·68. The rock approaches A. in composition, but is slightly more basic and contains less potash-felspar. Biotite is present in larger quantities, but still in small bunches, and in the plagioclase crystals, granules of epidote have been developed in considerable quantity from the kaolinized felspar. Magnetite is also present and more rarely sphene. A rock with this mineral composition and structure might occur as a dyke-like extension from a main mass like A.=Granitite approaching quartz-diorite. *C.—Near South-West end of the ridge of A. Gwajsha defile, South-West of Khwaja Amran.* Granitic to micro-granitic in structure, and occasionally micro-graphic. S.G. 2·72. More basic than B. with more plentiful development of biotite and plagioclase. Apatite is present also in large numbers of minute acicular crystals. Granular magnetite and sphene more abundant. The quartz often in micro-graphic intergrowths with the felspar. Plagioclase almost invariably zoned, the cores of more basic material being generally kaolinized. Rock =Quartz-biotite-diorite. *D.—From main mass of "Trap-belt" near C. Gwajsha defile.* Granitic in structure approaching granulitic. S. G. 2·89.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		Hornblende decidedly the most abundant constituent. Pleochroism, $\mathfrak{a}$=yellowish-green, $\mathfrak{b}$ = grass green $\mathfrak{c}$=blue green. Plagioclase in zoned crystals is the next most abundant mineral. Biotite, quartz, magnetite and sphene in smaller quantities. Epidote and calcite occur as the result of secondary alteration.=Diorite.
		NOTE.—The biotite in all four of the above rocks shows the same kind of greenish pleochroism. The differences in mineral composition might easily be obtained in rocks derived from the same magma at different periods of consolidation.
		E.—From outer margin of the "Trap-belt," Gwajsha defile.
		The main mass of the rock resembles an epidiorite or a rock formed as the result of decomposition and slight crushing of D. The plagioclase-felspar crystals are highly kaolinized, but still show their lamellar twinning. The hornblende and biotite have contributed to the formation of chlorite, but fragments of the original minerals still preserve their optical characters sufficiently for recognition. But there are streaks and patches of brown material with small granular augites and magnetites in a fine-grained groundmass like that of a basaltic andesite, and the patches being very ill defined they suggest partial re-fusion of the rock in some manner not explainable from the hand specimen alone. Veins of calcite and granular quartz have been produced *since* the above changes took place in the rock.
		F.—From the outer margin of the "Trap-band," Gwajsha defile.
		Development of pistacite (epidote) in a rock similar to D. or E. Calcite and granular quartz have developed also as the result of secondary action with the epidote. Acicular actinolite, magnetite, etc., occur as relics of the original rock. S. G. 3·16.
		G.—From margin of "Trap-belt," Gwajsha defile.
		Highly crushed aggregate of quartz, felspar and biotite with small quantities of magnetite. Some of the felspar is orthoclastic and the rock might very well be simply a crushed form of a type either identical with or closely related to A.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		H.—From the margin of the "Trap-belt," Gwajzha defile.
		A brecciated and crushed microgranitic rock approaching A in composition but very much more finely grained. Ferruginous material cementing the fragments. Cracks produced *since* brecciation and cementation have been in-filled with calcite.
		I.—From margin of "Trap-belt," Gwajzha defile.
		Diorite containing patches of fine-grained rock like those in E. Epidote occurs in small quantity. The rock seems identical with E, and it must have been in this rock that the epidote of F was produced.
		L.—Margin of "Trap-belt" and Gwajzha pass.
		Granular aggregate of plagioclase, (?) orthoclase, quartz, magnetite and a decomposed ferro-magnesian silicate, probably biotite. Origin of rock doubtful, probably igneous.
		K.—From margin of "Trap-belt," Gwajzha defile.
		Finely laminated and decomposed rock, possibly orginally similar to L.
		M.—From margin of "Trap-belt," Gwajzha defile.
		Foliated variety of D, E, or I. Now in the form of a hornblende-schist.
		N.—From grit-beds North-East margin to the Khwaja Amran mass of igneous rocks.
		A composite grit in which the grains are cemented and available crevices in-filled with calcite. Grains imperfectly rounded; many of them seem, however, to have been attacked by the infiltrated carbonate of lime, or to have been deformed by pressure. The minerals and rocks are of comparatively low specific gravity—averaging about 2·65; and isolated fragments of heavy minerals are absent. Quartz fragments with bands of inclusions like those of plutonic rocks are common and might of course have been derived from any granite or quartz bearing crystalline rock. Fragments of plagioclase, orthoclase, felspar occur as isolated grains; but most of the felspar occur as constituents of rock fragments. Flakes of biotite are mostly changed in part to chlorite.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, duringthe months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		Of the rock fragments there are fairly fresh specimens of a rhyolite with bipyramidal and corroded quartz crystals, a considerable amount of plagioclase amongst the felspathic constituents, and colourless and coloured mica in a felsitic or vitreous matrix showing distinct flow-structures and imperfect spheralitic and axiolitic aggregations of microlites. A rock of this type might very well be a volcanic representative of the granitite A. There are also fragments of andesites, bits of diorites with similar developments of epidote, rare pieces of granophyre (micrographic intergrowths of quartz and felspar); but nothing distinctly basic in character; in fact the grit seems composed of fragments of the rocks A to M, together with pieces of volcanic origin, possibly representative of that series.
		O.—From the volcanic grit-beds North-East of the Khwaja Amran mass.
		The fragments are sub-angular to rounded as in the former case; but although calcite is again present in infilling cracks, the cementing material is much more ferruginous in character and some of the granules appear to be ferruginous clay with cracks infilled with calcite like minute septarian nodules. Whilst granules of quartz are present in this grit it is by no means so plentiful as in the case of N, and the rock granules are moreover almost wholly of the dioritic series with considerable display of epidote. The average specific gravity of the fragments is 2·71, and thus as might be expected heavier than those of N. Some of these are distinctly foliated.
		P.—From the shaley portion of the grit-beds North-East portion of the Khwaja Amran mass.
		Compact mass of calcareous clay with minute quartz grains.
		Q.—Nummulitic limestone close to the base of "Kojak" shales, near Spintizha.
		(Not further examined).
		X.—From the "trappoid" beds in the Chehiltan range, West of Quetta.
		Small fragments of quartz, quartzite, and intermediate igneous rocks (diorites and andesites); limestone and mica-plates are cemented with argillaceous material. Cracks are filled with calcite which has infiltrated into all available crevices.

Notifications by the Government of India during the months of November and December 1893 and January 1894, published in the "Gazette of India," *Part II.—Leave.*

Department.	No. of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	Remarks.
Revenue and Agricultural Department.	No. $\frac{2837}{220}$, dated 24th November 1893.	W. B. D. Edwards, Assistant Superintendent, Geological Survey.	Furlough on Medical Certificate.	4th November 1893.	...	...

Annual increments to graded officers sanctioned by the Government of India during November and December 1893 and January 1894.

Name of Officer.	From	To	With effect from	No. and date of sanction.	Remarks.
Dr. F. Noetling, Palæontologist, Geological Survey.	700	750	1st October 1893.	Revenue and Agricultural Department No. $\frac{2770}{213}$, dated 8th November 1893.	
C. S. Middlemiss, Deputy Superintendent, Geological Survey.	660	700	1st November 1893.	Revenue and Agricultural Department No. $\frac{2820}{217}$, dated 22nd November 1893.	

Notifications by the Government of India during the months of November and December 1893 and January 1894, published in the "Gazette of India," *Part I.—Appointment, Confirmation, Promotion, Reversion and Retirement.*

Department.	No. of order and date.	Name of Officer.	From	To	Nature of appointment, etc.	With effect from	Remarks.
Revenue and Agricultural Department.	No. $\frac{114}{35}$, dated 12th January 1894.	Dr. H. Warth.	Officiating Superintendent, Government Central Museum, Madras.	Deputy Superintendent, Geological Survey.	Substantive, permanent.	4th December 1893.	

Postal and Telegraphic Addresses of Officers.

Name of Officer.	Postal address.	Nearest Telegraph Office.
T. W. H. HUGHES	On furlough.	
C. L. GRIESBACH	Loralai . . .	Loralai.
R. D. OLDHAM	On furlough.	
P. N. BOSE	Rewa	Rewa.
T. H. D. LATOUCHE	Sukkur . . .	Sukkur.
C. S. MIDDLEMISS	Jalarpet . . .	Jalarpet.
W. B. D. EDWARDS	On furlough.	
P. N. DATTA	Bhandara . . .	Bhandara.
F. H. SMITH	Harnai . . .	Harnai.
F. NOETLING	Calcutta . . .	Calcutta.
HIRA LAL	Calcutta . . .	Calcutta.
KISHEN SINGH	Babar Kach . .	Babar Kach.

DONATIONS TO THE MUSEUM.

FROM 1ST NOVEMBER 1893 TO 31ST JANUARY 1894.

A small specimen of quartz, from the Elephant Rocks, Shevaroy Hills, Salem District, Madras.

PRESENTED BY THE DISTRICT FOREST OFFICER, SALEM.

A block of steatite, from the Marble Rocks, Jubbulpore; and another from Kanheri Village, Bhandara District, Central Provinces.

PRESENTED BY THE OFFICIATING REPORTER, ECONOMIC PRODUCTS TO THE GOVERNMENT OF INDIA.

Hercynite, in small fragments, from Chinnamalai, Erode Taluk, Coimbatore District.

PRESENTED BY H. WARTH, OFFICIATING SUPERINTENDENT, GOVERNMENT CENTRAL MUSEUM, MADRAS,

A cut specimen of fine-grained sandy shale, and two of fine-grained sandstones, from Indrajurba, near the Damuda River, Hazaribagh District.

PRESENTED BY N. BELLETTY.

Two large pieces of Columbite; a large block showing junction of very coarse mica granite with mica schist; and decomposed iron ore, from the Dattoo Mines, Pannanore Hill, Nawadih, East Indian Railway.

PRESENTED BY H. H. FRENCH.

A specimen of quartz, with iron pyrites and gold, from the "Rees Reef," Pahardiah, Chota Nagpore.

PRESENTED BY T. F. VERNER.

Large specimens of Pumice, from Cardamum Island, Laccadives.

PRESENTED BY SURGEON-CAPTAIN A. W. ALCOCK, M.B.

ADDITIONS TO THE LIBRARY.

FROM 1ST OCTOBER TO 31ST DECEMBER 1893.

Titles of Books. *Donors.*

AGUILERA, *Jose G.*, and ORDONEZ, *Ezequiel.*—Datos para la Geologia de Mexico. 8° Pam. Tacubaya, 1893. THE AUTHORS.

BLACKENHORN, *Dr. Max.*—Beiträge zur Geologie Syriens die Entwickelung des Kreidesystems in Mittel-und Nord-Syrien. 4° Cassel, 1890.

BOYD, *R. N.*—Coal Pits and Pitmen. 8° London, 1892.

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CASARIEGO, *D. Enrique Abella Y.*—Descripcion Fisica, Geologica y minera en Bosquejo de la Isla de Panay. 8° Manila, 1890. THE AUTHOR.

COOKE, *Josiah P.*—Elements of Chemical Physics. 8° London, 1886.

COTTEAU, PERON and GAUTHIER.—Echinides Fossiles de L'Algerie. Fasc. 6-9 4° Paris, 1880-1883.

DALL, *William Healey.*—Republication of Conrad's Fossils of the Medial Tertiary of the United States. 8° Philadelphia, 1893.

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DAUBREE, *A.*—Application de la Méthode experimentale au Role Possible des Gaz Souterrains dans L' Histoire des Montagnes Volcaniques. 8° Pam. Paris, 1892.

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GARDNER, *J. S.*—Iron work from the earliest times to the end of the Mediæval period. 8° London, 1893.

GEIKIE, *James.*—Fragments of Earth Lore. 8° Edinburgh, 1893.

GEIKIE, *Sir Archibald.*—Text Book of Geology. 3rd Edition. 8° London, 1893.

HOERNES, *Dr. Rudolf.*—Erdbebenkunde. 8° Leipzig, 1893.

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Annals and Magazine of Natural History. Vol XII, Nos. 70-72. 8° London, 1893.

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"	"	IIb,	"	8—10.
"	"	III,	"	8—10.
" CI,	"	I,	"	1—6.
" "	"	IIa,	"	1—5.
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G. I. C. P. O.—o. 31 D. G. Survey.—12-3-94.—

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1894. [May.

Note *on the* Chemical qualities of petroleum *from* Burma; *by* PROFESSOR DR. ENGLER (*Karlsruhe*). (*Translated by* DR. FRITZ NOETLING, G.S.I.)

According to the localities, four different kinds of petroleum were received, *viz*:—

(1) Petroleum from Yenangyat.
(2) " " Kodoung.[1]
(3) " " Twingon.
(4) " " Minbu.

The quantity not being sufficient to permit of photometric investigations, the petroleum was chiefly examined with regard to specific gravity and the products of fractional distillation.

The whole character of the oil, particularly the relation between the specific gravity and the boiling point of the single fractions, proves with some certainty, that the oil from Burma chiefly consists of hydrocarbons of the $C_n H_{2n+2}$ group; napthenes could be discovered in small quantities only. The oil from Minbu forms however an exception, because it probably contains, besides the first mentioned hydrocarbons, a larger quantity of napthenes ($C_n H_{2n}$); the comparatively speaking liquid quality of fractions of a high boiling point seems to favour this supposition.

I.—Petroleum from Yenangyat.

1. From well No. 15.

Colour: Greenish brown in thin films, green by reflected light.
Specific gravity, 0·8214 at 30° C.
Melting point, 26° C.
Begins to boil at 130° C.

Fractional distillation.[2]

Oil distilling—		
Below 150° C.	17·8 vol. °/₀	Specific gravity ranging from 0·765 to 0·850.
Between 150° C. and 175° C.	8·0 " "	
" 175° C. and 200° C.	7·9 " "	
" 200° C. " 225° C.	8·6 " "	
" 225° C. " 250° C.	9·2 " "	
" 250° C. " 275° C.	7·7 " "	
" 275° C. " 300° C.	8·0 " "	
" 300° C. " 400° C.	30·8 " "	
Loss	2·0 " "	

[1] Kodoung and Twingon form the central and northern parts of the Yenangyoung oil field.—*Trans*

[2] All the analyses have been carried out with Engler's Normal distillation apparatus (*vide* Chemisch technische Analyse, von J. Post. II. Aufl. Bd. 1, p. 277).

All fractional products below 300° C. smell only slightly, are of water white colour, and do not fluoresce. At a temperature of 10° C. paraffin crystallises from the fraction 275° to 300°.

The fractional products above 300° C. have a gradually intensifying yellow colour, and congeal to a firm crystalline mass at the ordinary temperature.

Fraction	300° to 325° C. melts at	18° C.
"	325° to 350° C. " "	24° C.
"	350° to 375° C. " "	36·5° C.
"	375° to 400° C. " "	40° C.

The last-mentioned fractions of high boiling point could be used for the manufacture of lubricating oil and paraffin wax.

Crude oil of this type yields—

Light oil (flashing point below 150° C.) .	17·8 vol. °/₀	of 0·765 specific gravity.
Illuminating oil (ditto from 150° to 300°)	49·4 " "	" 0·820 " "
Lubricating oil and paraffin wax . .	30·8 " "	" 0·838 " "

About ⅔ of the fraction below 150° C. could be added to the illuminating oil without lowering its flashing point to a dangerous degree; thus the total percentage of illuminating oil could be raised to about 60°/₀

2. Analysis of a mixed sample.

Specific gravity	0·8160.
Melting point	27·5° C.
Boiling point	120° C. to 125° C.

Fractional distillation.

Oil distilling—

Below 150° C.	18·6 vol. °/₀	Specific gravity ranging from 0·755 to 0·845.
Between 150° C. and 175° C.	17·9 " "	
" 175° C. " 200° C.	9·1 " "	
" 200° C. " 225° C.	7·7 " "	
" 225° C. " 250° C.	8·8 " "	
" 250° C. " 275° C.	8·5 " "	
" 275° C. " 300° C.	7·6 " "	

The qualities are the same as those of the oil from well No. 15. The fractions above 300° gradually become more yellow in colour, begin to smell, and congeal according to the following table:—

Fraction	300° C. to 325° melts at	21·5° C.
"	325° C. " 350° " "	24° C.
"	350° C. " 375° " "	37·5° C.
"	375° C. " 400° " "	40° C.

The qualities of these heavier oils are the same as those of oil from well No. 15. A mixed sample of oil from Yenangyat would therefore yield:—

Light oil (flashing point below 150°) . .	18·6 vol. °/₀	of 0·755 specific gravity.
Illuminating oil (ditto from 150° to 300°)	49·6 " "	" 0·816 " "
Lubricating oil and paraffin wax . .	28·3 " "	" 0·837 " "

The percentage of illuminating oil could however be raised up to 60 °/₀ by adding a part of the lighter oils.

II.—Petroleum from Kodoung.

Colour: Fine reddish brown in thin films, fluorescing green by reflected light.

Specific gravity	0·8726 at 32° C.
Melting point	31° C.
Boiling point	135° to 140° C.

Fractional distillation.

Oil distilling—

Below 150° C.	4·3 vol. °/₀	Specific gravity ranging from 0·755 to 0·875.
Between 150° C. and 175° C.	3·4 „ „	
„ 175° C. „ 200° C.	3·8 „ „	
„ 200° C. „ 225° C.	4·6 „ „	
„ 225° C. „ 250° C.	7·9 „ „	
„ 250° C. „ 275° C.	8·4 „ „	
„ 275° C. „ 300° C.	10·7 „ „	

The distilled oil is nearly water white; from 200° upwards the oil shows a distinct, although not unpleasant smell. Above 300° the colour changes to yellow and fractions congeal at the ordinary temperature.

Fraction 300 to 325° C.	melts at 13° C.
„ 325 „ 350° C.	„ „ 26° C.
„ 350 „ 375° C.	„ „ 31° C.
„ 375° „ 400° C.	„ „ 34° C.

The fractions from 350° to 375° amount to about ⅜ of the total quantity of oil boiling between 300° to 400° C., and could be used for the manufacture of lubricating oil and paraffin wax.

Crude oil of this type yielded—

Light oil (flashing point below 150° C.)	4·3 vol. °/₀ of 0·755 specific gravity.
Illuminating oil (ditto from 150° to 300°)	38·8 „ „ „ 0·849 „ „
Lubricating oil and paraffin wax	50·4 „ „ „ 0·895 „ „

Without any danger the light oils may be added to the burning oil proper, thus raising the total percentage of burning oil to about 42 vol. °/₀, but the specific gravity of this oil would be so high as to require specially constructed lamps in order to prevent the smoking.

III.—Petroleum from Twingon, well No. 15.

Colour: Reddish brown in thin films, fluorescing green by reflected light.

Specific gravity	0·8653 at 32° C.
Melting point	31° C.
Boiling point	130° to 135° C.

Fractional distillation.

Oil distilling—

Below 150° C.	5·5 vol. °/o	}	Specific gr ranging 0·755 to
Between 150° C. and 175° C.	3·1 „ „		
„ 175° C. „ 200° C.	4·0 „ „		
„ 200° C. „ 225° C.	5·6 „ „		
„ 225° C. „ 250° C.	6·4 „ „		
„ 250° C. „ 275° C.	9·3 „ „		
„ 275° C. „ 300° C.	10·4 „ „		

The fractions show the greatest similiarity with those from Kodou difference exists with regard to the smell. Fractions above 300° are so nary temperatures, except the fraction 300—325°, which is semi-solid.

Fraction 300° to 325°	melts at	14° C.
„ 325° „ 350°	„ „	23° C.
„ 350° „ 375°	„ „	33° C.
„ 375° „ 400°	„ „	33° C.

As with the Kodoung oil the fraction 330° to 375° forms the largest of the total, and can be used for the manufacture of lubricating oil a wax.

Crude oil of this kind yielded—

Light oil (flashing point below 150° C.)	5·5 vol. °/o	of 0·755 specific
Illuminating oil (ditto from 150° to 200° C.)	38·8 „	„ 0·843 „
Lubricating oil and paraffin wax	48·7 „	„ 0·888 „

If the light oils be added to the illuminating oil, which may be do any danger, the percentage of the latter can be raised to about 40 vol. must, however, be burnt in specially constructed lamps, owing to its hig gravity.

IV.—Petroleum from Minbu.

Colour: In thin films, dirty brown; reddish brown without fluorescence by refl

Specific gravity,	1·00213	at 30° C.
„ „	1·005	„ 25° C.
„ „	0·984	„ 50° C.

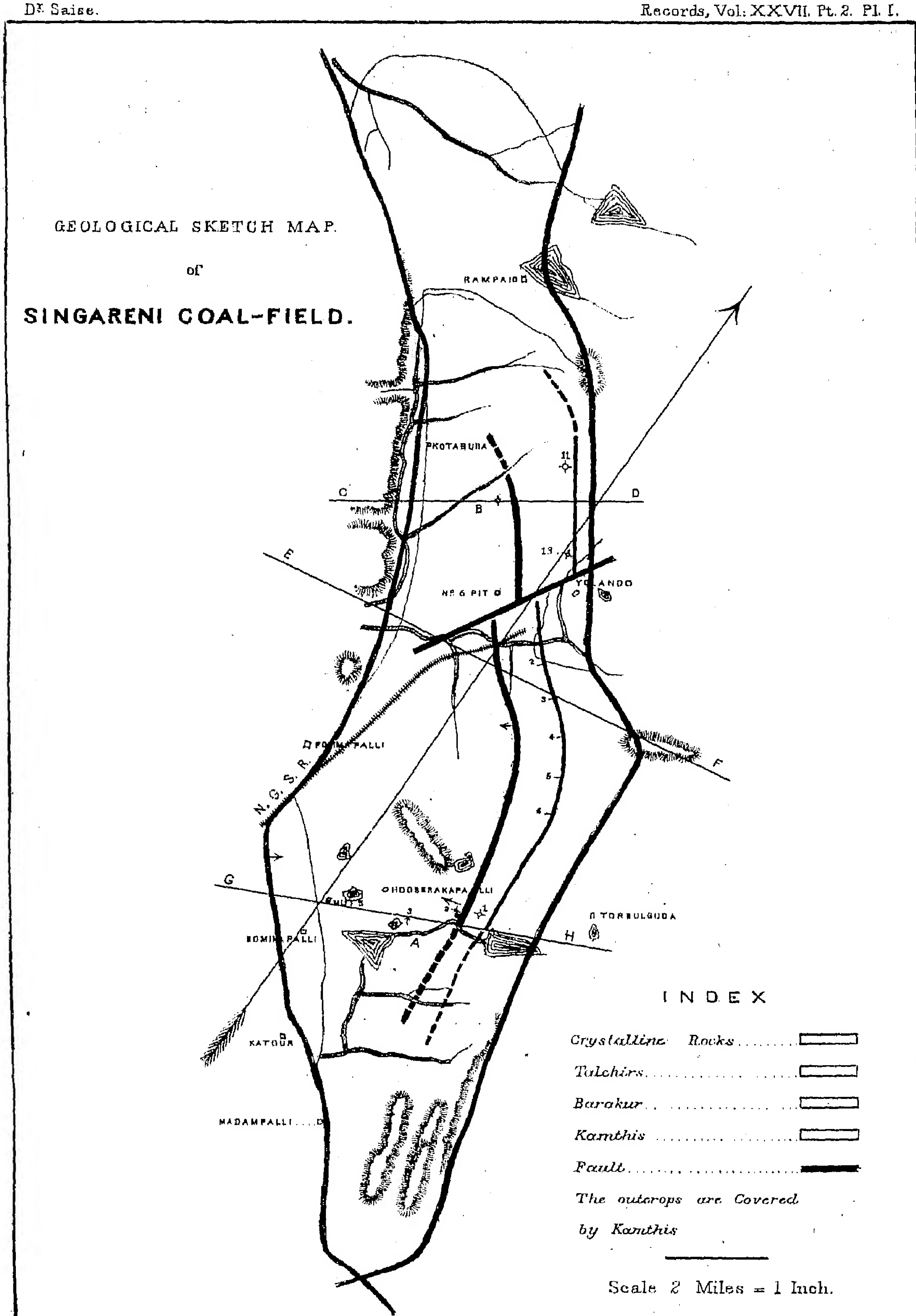
On account of the remarkable viscosity of this oil the melting point be determined. It is, however, liquid at the ordinary temperature. Bo only water distills; it only begins to boil at 300°, and therefore contain stituents from which illuminating oil could be manufactured.

Fractional distillation.

Below 300° C.	2 vol. °/o (water).	
Between 300° C. and 325° C.	8·3 „	„ of 0·920 specif
„ 325° C. „ 350° C.	49·7 „	„ „ 0·938 „
„ 350° C. „ 375° C.	18·7 „	„ „ 0·972 „
Balance about	21 „	

Unlike fractions of the other oil-samples boiling above 300°, those

Dr. Saise. Records, Vol: XXVII. Pt. 2. Pl. I.



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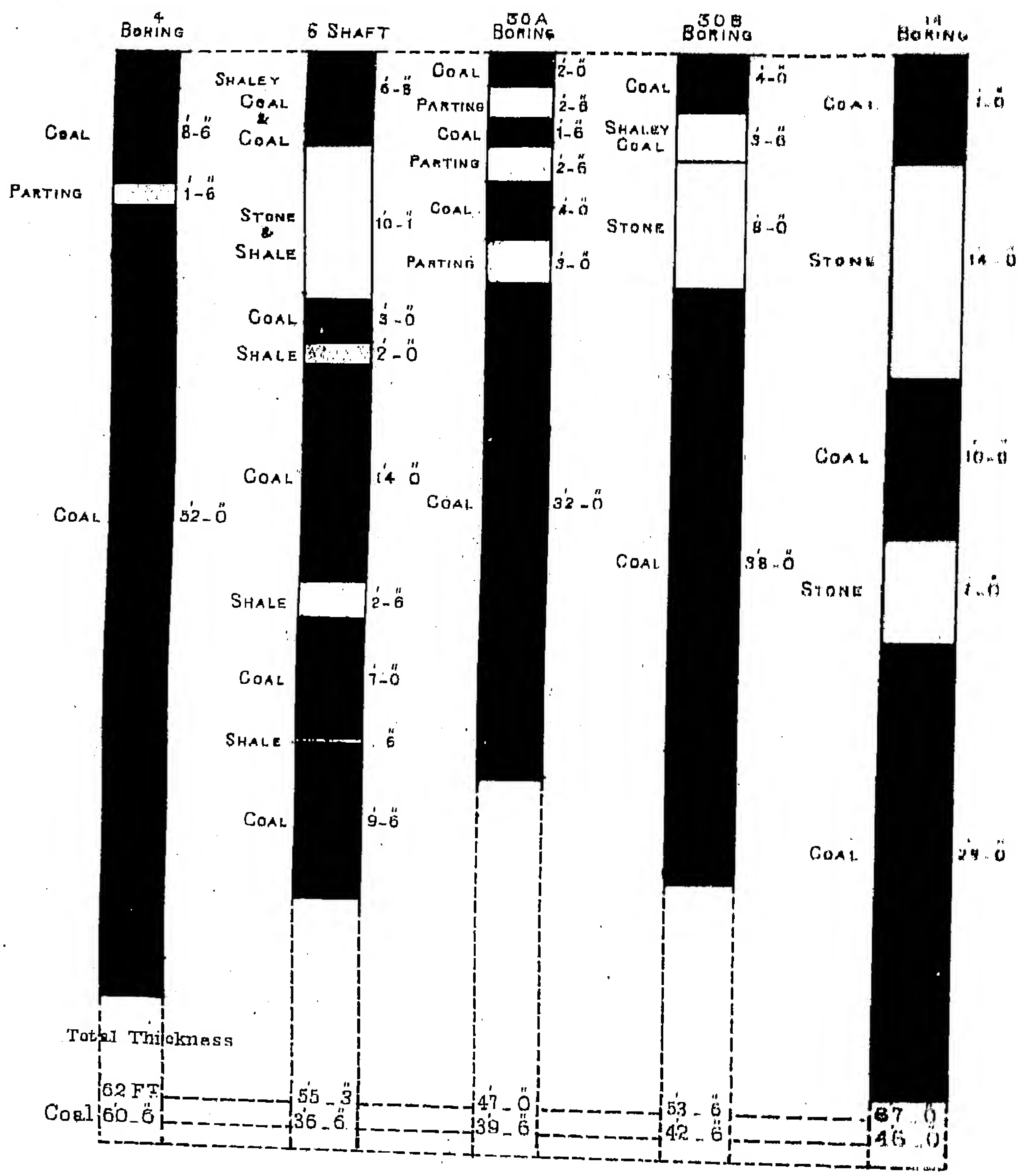
SINGARENI COAL-FIELD

SECTION OF THE SEAMS

That go to make up the

THICK COAL

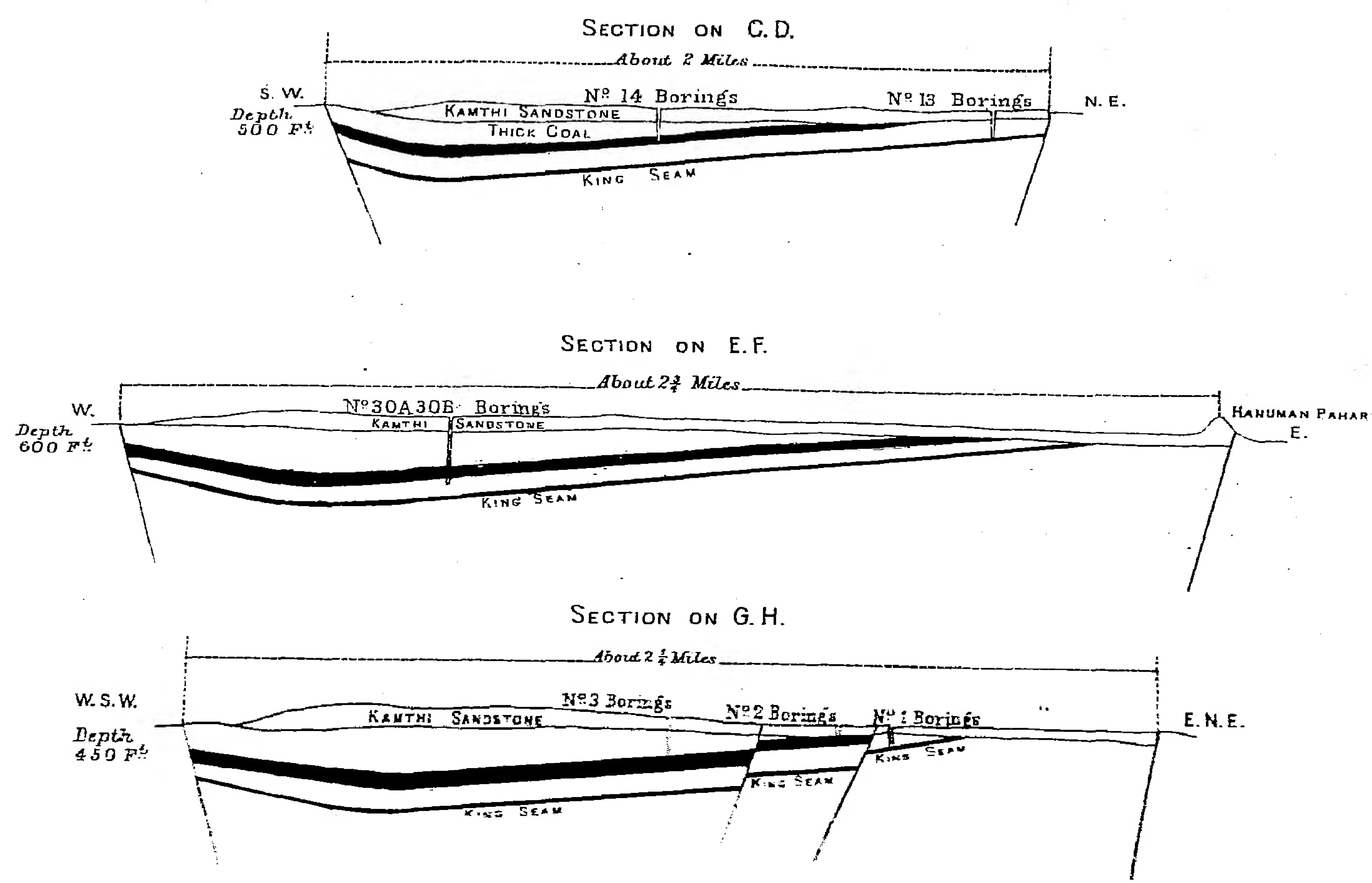


Average Thickness of Seam 56 ft. 10 In.

" " Coal in Seam } 45 Feet.

Scale 16 Feet = 1 Inch.

Lithographed & Printed at Geological Survey Offices



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SINGARENI COALFIELD DIAGRAMMATIC SECTIONS ILLUSTRATING GENERAL STRUCTURE OF THE FIELD

Minbu oil are all liquid at the ordinary temperature, of a brown colour, and resemble in this respect the high-boiling fractions of the petroleum from Baku, which chiefly consist of napthenes.

The subjoined table will show the composition of various samples of crude oil from Upper Burma with regard to their economic value :—

	Light oils (below 150° C.)	Illuminating oil (150° to 300° C.)	Lubricating oil and paraffin wax.	Remainder and loss.
I Petroleum from Yenangyat Well No. 15.	17·8 vol. °/₀	49·4 vol. °/₀	30·8 vol. °/₀	2 vol. °/₀
I " " " (mixed)	18·6 " "	49·6 " "	28·3 " "	3·5 " "
II " " Kodoung . .	4·3 " "	38·8 " "	50·4 " "	6·5 " "
III " " Twingon . .	5·5 " "	38·8 " "	48·7 " "	7 " "
IV " " Minbu . .	...	...	76·7 " "	21·3 " "*

It must be specially noted that the oil samples I, II, and III while being of a viscous character at ordinary temperatures, contain a high percentage of lighter oils especially illuminating oil. Up to now I have never found similar oils, which being of the same consistency, contain such a high percentage of illuminating oil.

Note *on the* Singareni Coalfield, Hyderabad (Deccan). *By* WALTER SAISE, D.Sc., F.G.S., Manager, East Indian Railway Collieries.† (With map and 3 plates of sections.)

The original note on this field is to be found in the Records, Geological Survey of India, Vol. V, Part 2 of 1872, where Dr. W. King's discovery of the coalfield is announced.

The borings made by the Nizam's Government and the working of an extensive colliery by the Hyderabad (Deccan) Company, have resulted in information which enables a corrected map of the field and a section of the measures, as well as sections showing the structure of the field to be issued.

The coalfield is an elongated patch, 13½ miles long, and 3½ broad in the widest part. The long axis runs approximately north-north-east and south-south-west.

The formations consist of, in descending order :—

Kamthis.
Barakars.
Talchirs.

The character of these are fully described in Dr. King's paper ; the only point to be noted is the marked unconformity of the Kamthis on the Barakars. The

* 2 vol. °/₀ water.

† Dr. Saise while reporting on this coalfield last year for the Hyderabad (Deccan) Mining Co., Ld., made the accompanying map and sections, to which, at my request, he has obligingly added this note, and now permits of their publication in the Records.— *Ed.*

seams of coal crop right up against the overlying Kamthis, and at these outcrops the coal is damaged and useless, shewing that the outcrops were weathered before the Kamthis were deposited. The boundaries of the field are faulted except at the north where the Talchirs lie naturally on the older rocks.

The preservation of the coal-measures between trough faults is characteristically Indian. The Ranigunj, Jherriah, and Karharbari Coalfields are similar instances.

The Barakars are faulted against the older rocks wherever exposed, and the Kamthis also. As the Kamthis are younger than the Barakars, this appearance is to be explained by the fact that disturbances tend to follow old lines of fracture, and the same faults that defined the extent of the Barakars and Talchirs also defined at a later date the general area of the Kamthis.

Seeing that the coalfield lies between the Gneiss and the Vindhians, I should be inclined to suspect a line or lines of fracture between these formations as the leading cause of the preservation of this patch of coal-measures.

The plate of the correlations shows that there are several seams besides the *King Seam.*

The thick coal seam is made up of many bands. It has not been opened out or explored to any extent. An assay of part of the thick coal gave the following percentages—

Fixed carbon	52·5
Volatile matter	34·5
Ash	13·0

The *King seam,* which is of uniform quality, is the best in the field and is being extensively worked. The composition is :—

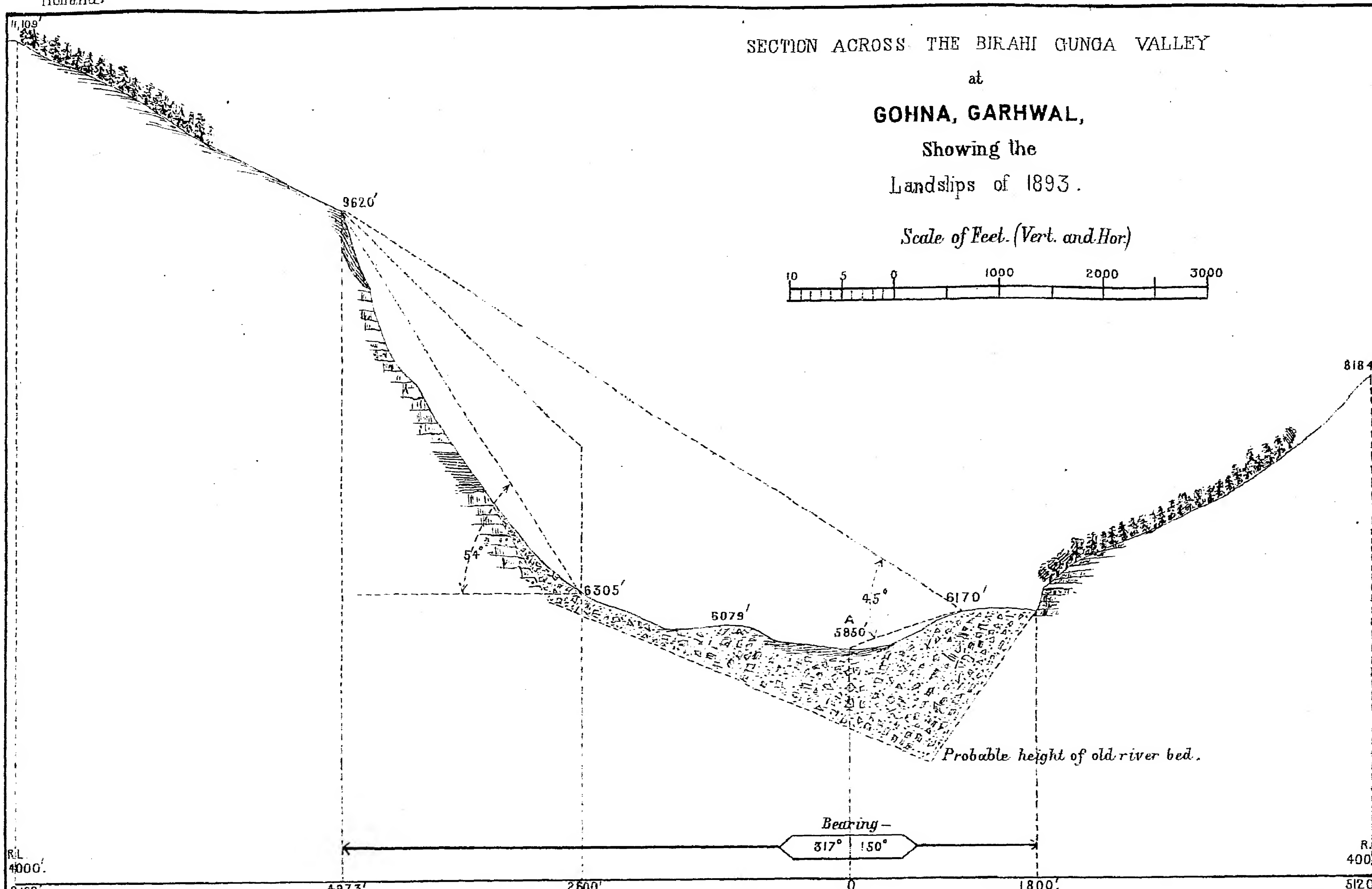
Volatile matter	25·25
Fixed carbon	56·50
Moisture	7·60
Ash	10·65

It is a good steam-coal but will not coke.

Sections measured by me varied from 3 feet 9 inches to 6 feet in thickness. In this variation it agrees with Indian seams. Allowing 4 feet 9 inches as the average thickness, and taking the area of this seam at 9 square miles, there are, after allowing 20% for wasteage, 36,000,000 tons left to be gotten.

The other seams will no doubt receive attention in time to come.

Holland.



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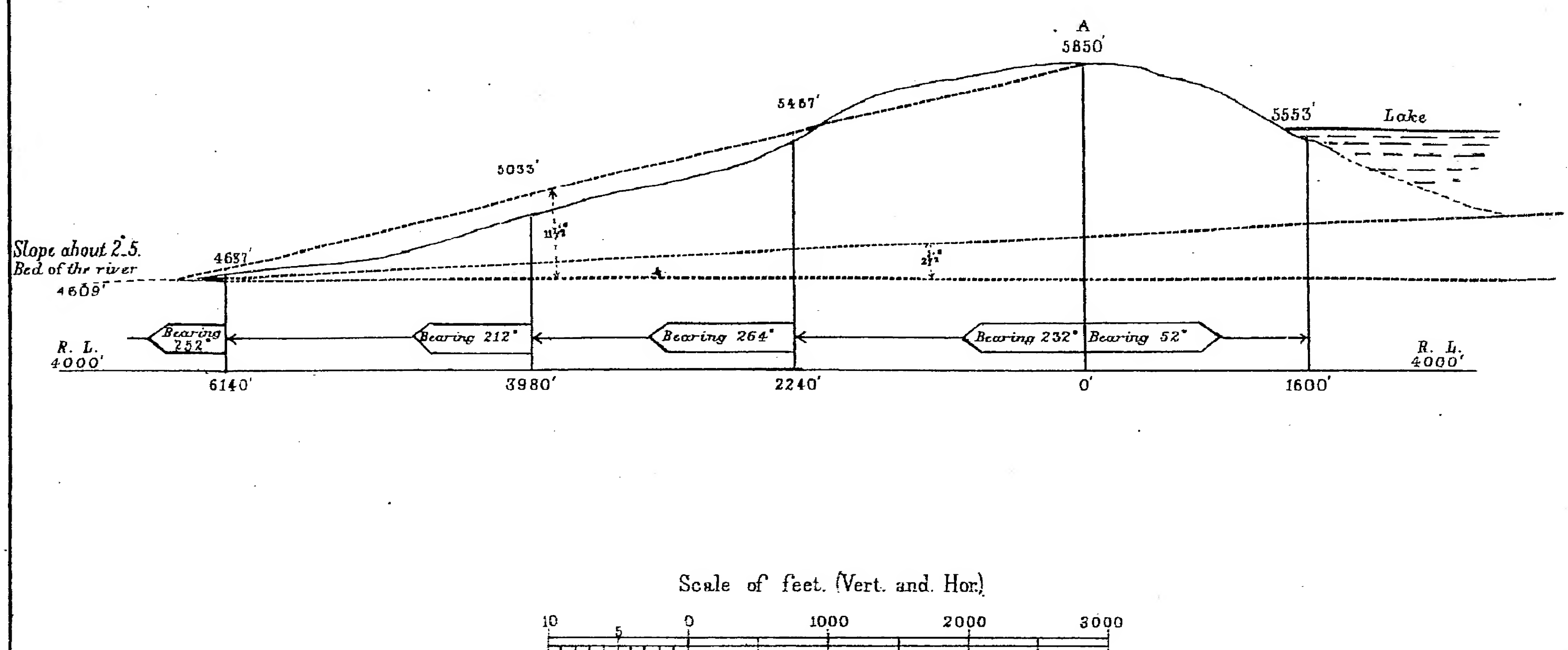
SECTION ALONG THE BIRAHI GUNGA VALLEY
at
GOHNA, BRITISH GARHWAL.



Scale of feet. (Vert. and Hor.)

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GEOLOGICAL SURVEY OF INDIA.

T.H.Holland.

Rocords. Vol. XXVII. Part 2. Pl. 4.

Survey of India Offices, Calcutta, May 1894

VIEW OF GOHNA TAL, FROM EDGE OF THE DAM.

T.H.Holland.

Records. Vol.XXVII.Part 2.Pl.5.

Photo-etching.

Survey of India Offices, Calcutta, May 1894.

Report *on the* Gohna Landslip, Garhwal. *By* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Geological Survey of India.* (With 5 plates and 2 maps).

CONTENTS.

INTRODUCTION.

1. The observations recorded in this note were made during a journey to Gohna, Garhwal Himalayas, in February and March, 1894—five months after the landslip, and when the lake formed by the barrier fallen across the Birahi Ganga valley had risen to within 290 feet of the top of the dam.

During the course of this investigation I have received most valuable help from Lieutenant-Colonel R. R. Pulford, R.E., Superintending Engineer, Mr. G. J. Joseph, Divisional Engineer of Kumaon, and especially from Lieutenant S. D'A. Crookshank, R. E., who is now stationed at Gohna in charge of the survey and works.

The lake will be full and will overflow the barrier about the middle of August. Means for recording by instantaneous photographs the effects of the water on the dam are being carefully arranged by the Government of the North-Western Provinces.

I. GEOGRAPHICAL AND GEOLOGICAL FEATURES.

(1) GEOGRAPHICAL.

2. Gohna in British Garhwal (lat. 30°-22′-18″ N., and long. 79°-31′-40″ E.) is a small village in the valley of the Birahi Ganga, a river running westward and joining, at a point 8 miles west of Gohna, the Alaknanda, one of the principal tributaries of the Ganges. The village is about 130 miles north of Naini Tal, and by the road which follows the valley of the Alaknanda, it is 160 miles from Hardwar.[1]

3. The bed of the Birahi Ganga, sloping at about 2½°, is at Gohna 4,600 feet above sea-level and is the bottom of a narrow gorge with steep, and sometimes precipitous, sides. The gentler slopes are grass-covered, and higher up clothed with evergreen oak, fir and rhododendron. In the more open parts of the valley a small amount of cultivation is carried on by the few inhabitants of the small groups of houses dignified even by the name of villages. The river basin, which is 20 miles long and 9 miles wide, is bounded on the north and east by a snow-clad ridge rising to 21,286 feet. A considerable portion, therefore, of the water of the river is derived from the melting snows, and it consequently receives its greatest supply during the warmer months. The area of the basin east of Gohna, and consequently the area draining into the lake which has been formed by the landslip, is about 90 square miles.

(2) GEOLOGICAL.

4. The quartzites and associated crushed diorites and ash-beds, which prevail from Adbadri to north of Chamoli, give place on entering the gorge of the Birahi

[1] The journey can now be made on pony back by the following routes, which I give for the convenience of visitors:—

D.B. = Dâk bungalow, or inspection bungalow.

(1) *Viâ* Naini Tal.

	Miles.	
Naini Tal	0	D. B.
Ratighat	8	D. B.
Bamshaon	10	D. B.
Dwarahat	14	D. B.
Gonain	10	D. B.
Lohaba	14	D. B.
Adbadri	10	—
Karnprayag	12	—

(2) *Viâ* Najibabâd.

	Miles.	
Najibabâd	0	D. B.
Kotdwara	18	D. B.
Daramundi	12	D. B.
Banghât	12	D. B.
Adwani	12	D. B.
Pauri	10	D. B.
Srinagar	7	D. B.

(3) *Viâ* Hardwar.

	Miles.	
Hardwar	0	D. B.
Rikikech	16	—
Bijni	13	—
Mahadeo	9	—
Bayasghât	10	—
Deoprayag	13½	—
Bibarkoti	16	—
Srinagar	13½	—

Srinagar	0	
Dungripant	9	—
Rudrprayag	12	—
Kotki	9	—
Karnprayag	12½	—

Karnprayag	0.	—
Nandprayag	10m.	—
Chamoli	7m.	—
Gohna	13m.	—

The highest point on the route is the Pannuakhal pass, 7,010 feet, between Lohaba and Adbadri.

Ganga to black carbonaceous and pyritous shales, dolomitic marls, pyritous dolomités, dolomitic limestones with chert, and smaller bands of talc and talc-schist.

The quartzites are sometimes coarse-grained (7 miles from Adbadri on the Karnprayag road) with films of a sericitic mineral, or talc, more often compact and porcellaneous in appearance, and grey, green or cream-coloured (Nandprayag to Chamoli). Their enormous thickness, painfully evident to the pedestrian, their petrological characters, the interbedded "greenstones," and their association with the dolomitic series of the Birahi Ganga valley recall Mr. Oldham's descriptions and specimens of the Bawar quartzites, and the similar rocks described by Mr. Middlemiss in his route-traverse from Jaunsar through Tiri to British Garhwal.[1]

5. Between Karnprayag and Nandprayag these quartzites exposed on the road-side have a general dip 45°—60° E.-N.-E. About a quarter of a mile N. E. of the junction of the Mandakini and Alaknanda rivers at Nandprayag, mica-schist, talcose schist and biotite-gneiss are exposed in order, with planes of foliation dipping in the same direction, and apparently lying on the quartzites. Continuing in the northerly direction the dip becomes less and ultimately, at 3 miles north of Nandprayag, the beds are almost horizontal, whilst in the next mile they are found dipping in the S. E. direction with exposures in the inverse order—biotite-gneiss alcose schist and mica-schist, with quartzites apparently dipping under them.

It would at first sight seem that in this syncline the quartzites are older than the gneiss and schists, dipping uniformly under them. Whilst this *may* actually be the true order it is possible that we have here a case parallel to, but not co-extensive with, the remarkable instance described by Mr. Middlemiss in Western Garhwal, where he has shown the anomalous position of younger beds to be due to the destruction of a sigma-flexure by the development of a thrust-plane or reversed strike-fault, as in the parallel cases described by Professor Lapworth and the Scotch Gelogical Survey in the North-West Highlands.[2]

6. The specimens of diorites and "greenstones" which I have collected from the beds associated, and probably interbedded, with the quartzites are evidently the same as those which have been described in detail by Mr. Middlemiss.[3]

7. The carbonanceous shale and dolomite series are crumpled about in the most irregular fashion and sometimes even inverted. A striking instance of inversion has been exposed by a small slip in the gorge 3 miles west of Gohna. All the beds, whether shaley or dolomitic, are charged with pyrites, cubes of which in the dolomites are seen to be distorted by pressure. The decomposition products of this mineral reacting on the hydrocarbons of the carbonaceous shales have given rise to the sulphuretted hydrogen emitted by the numerous evil-smelling springs below Gohna. In this, and in ways shown below, pyrites has contributed to the cause of the mischief at Gohna.

8. The dolomites and dolomitic limestones are grey or cream-coloured, sometimes as massive as those at Naini Tal and sometimes well-banded. It is interesting

[1] R. D. Oldham. *Rec., Geol. Surv., Ind.*, Vol XVI (1883), p. 193.
C. S. Middlemiss, *Ibid*, Vol. XX (1887), p. 28.

[2] Lapworth, *Geol. Mag.*, dec. II. Vol. X (1883), p. 337. Report on the recent work of the Geological Survey in the N. W. Highlands of Scotland, *Quart. Journ. Geol. Soc.*, Vol. XLIV (1888), p. 378.

[3] *Rec. Geol. Surv., India.*, Vol. XXI (1888), p. 11.

to record the occurrence of a curious structure strikingly like that of specimens from the Deoban limestone in Jaunsar and Sirmur;[1] also in similar rocks from Kúlú,[2] from Kumáon,[3] and from the Gandgarh range in Hazára.[4]

In appearance this structure recalls the concentric growth of the Lower Palæozoic *Stromatoporoidea*, but sections which I have made show no structure which could be safely referred to an organic origin, and it is possibly only due to concretionary action.

9. It is interesting to note that although these so closely resemble one another, that from Deoban is in a limestone almost free of magnesia, that from the Hazara area is a dolomitic limestone, whilst that from Gohna is a dolomite in which the carbonates of lime and magnesia give about the same molecular ratios. All these specimens contain small quantities of phosphates; those from Deoban and Gohna less than that from Hazára. The specific gravity increases naturally with the percentage of magnesia:—Deoban, 2·67; Hazára, 2·74; Gohna, 2·82.

An *analysis* of the Gohna rock gave—

Insoluble residue	1·355
Ferric oxide,[5] alumina and phosphoric acid . .	1·225
Carbonate of lime	53·875
Carbonate of magnesia	44·780
	101·235

Specific gravity of the fragment analysed, 2·83.

Specimens of the *banded rock* at Gohna have a specific gravity of 2·75, and on chemical examination I find the dark bands in the rock are dolomite, whilst the lighter bands are limestone. In one bed the dolomite is curiously spotted, due to amygdaloidal cavities arranged along the bedding planes and partially filled with calcite. As the cavities are only partially filled, hand-specimens of the rock have a specific gravity as low as 2·56.

10. Although the specimens from Deoban exhibiting the pseudo-organic structure happen to be limestones, Mr. Oldham has recorded dolomites also in the same area. There is also a massive dolomite at Naini Tal associated with the purple shale series of Mr. Middlemiss, and probably of the same system as that at Gohna and again in Hazára. Although the correlation of these beds in different parts of the Himalayas, based for want of fossils on purely lithological grounds, is naturally insecure, one cannot help recalling the similar association of unfossiliferous slates, quartzites, carbonaceous shales and dolomites described by Mr. Mallet near Baxa in the eastern Himalayas.[6]

[1] R. D. Oldham, *Rec. Geol. Surv., Ind.*, Vol. XXI (1888), p. 133.

[2] C. D. Sherborn, *Geol. Mag.*, 3rd dec., Vol. V (1888), p. 255. Mr. Sherborn compared the general characters of the structure to those of certain similar American specimens described under the name of *Cryptozoon proliferum*. Prof. H. A. Nicholson, who examined the Kúlú specimen, was inclined to attribute it to an organic origin, quoting a similar case described by M. Dupont from the altered Devonian limestones of Belgium under the name *Stromatactis* (*ibid*, p. 257.)

[3] J. McClelland, *Journ. As. Soc., Beng.*, Vol. III (1834), p. 628.

[4] Specimens collected by A. B. Wynne, G. S. I., in 1878 at Kora-na-durrah, and preserved in the Geological Museum, Calcutta. No. 79-118.

[5] The iron occurs in the rock mostly in the ferrous condition. This result should consequently be slightly lower.

[6] *Mem. Geol. Surv., Ind.*, Vol. XI (1874), p. 33.

II. THE LANDSLIP AND LAKE.

11. From the account of the villagers there seem to have been fields along the sloping portion of the gorge near Gohna on both sides of the river, whilst the hill they speak of as Maithána—the one which fell—rose almost vertically above the slope on the north side of the river (*plate II*). Two years ago there was a small slip between Maithána and Gohna village. On the 6th of last September (1893), and towards the close of the rainy season, two falls took place, damming back the river to form a lake. Falling continued for three days with deafening noise and clouds of dust which darkened the neighbourhood and fell for miles around, whitening the ground and tree-branches like snow. Further slips occurred at subsequent intervals after heavy rain; and at the time of my visit in March a day's rain or fall of snow was always succeeded by falls,—blocks of several tons came bounding from ledge to ledge for more than 3,000 feet over the broken hill face with a low rumbling noise and the production of clouds of dust. The part which fell was a spur of one 11,109 feet high; but except on the edge of the precipice, where pieces could be pushed over with the foot, I found no cracks in the hill. The rocks exposed on the cliff-front, as shown in Plate I, are crumpled and faulted in a complicated manner and with varying dip; but on the west side of the slip the dip is towards the valley at a lower angle than that of the precipice, the average inclination of which is 54°. The mass of broken material which fell stretches for 2 miles along the river valley, and rests against the cliff of similar rocks on the opposite side a mile away. On the higher mounds, from which the mud has been washed away, large masses, sometimes weighing hundreds of tons, of crumpled dolomitic limestones are seen pitched in obliquely and shot out like a pack of cards, whilst blocks hurled a mile away against the opposite cliff have knocked down numbers of trees. In the first fall, at any rate, the hill must have pitched forward and not have slipped down in the usual fashion of smaller slides. The second main fall now stands as a heap of irregularly piled blocks weighing from about 30 tons down to ordinary hand-specimens.

12. The surface of the dam exposed in early March was 423 acres; but it is gradually being submerged on the eastern side by the rising lake. A section *along* the valley from the bed of the river on the west to the edge of the lake on the east slopes at an angle of 11½° on one side and 10° on the other, from a point 5,850 feet above sea-level, or 1,200 feet above the bed of the river at Gohna. As the river bed slopes at about 2½° the dam must be about 850 feet thick at the point referred to. A section *across* the valley shows the broken rock rising as two mounds on the south side to a height of 6,186 feet, and on the north side to 6,305, where it ends at the foot of a talus sloping at about 40° up to the broken cliff-front of the mountain (see Plates II and III). The mounds on either side consist of large masses of rock, whilst the shallow valley between is covered with a thick layer of fine mud probably washed down from the higher levels.

13. The lake in the beginning of March was 2¾ miles long, 1 mile wide at the widest part and covered 370 acres. It is rising at the rate of about 6 inches per day; but with the melting of the snows in the hot season the rise will be more rapid. When full it will, unless a cutting is made, overflow at the point referred to as 5,850 feet above sea-level; and the stream, rushing down an incline of 11°, will rapidly cut with increasing head a channel in the mud and loose stones, which cover that portion

of the dam, until its speed is checked by the reduction of slope and the exposure of large blocks of dolomite which must occur below at no great depth. It is impossible from mere inspection to estimate the thickness of the soft mud, but from the rain which has fallen since last September gullies 20 and 30 feet deep have been cut on the western slope of the dam exposing large quantites of small stones and blocks of a few tons in weight. If, as I anticipate, the rapid erosion becomes arrested before 100 feet has been cut there will be preserved above a lake 3¼ miles long and 1½ mile wide, whose destruction by gradual erosion of the dam and silting up of the basin, though a matter of time geologically considered short, will be sufficiently slow for what historically may be called a permanent lake. The lake view from the dam is the crowning charm of scenery typically Himalayan and wild: the steep mountain slopes, partially clad with fir, evergreen oak and gorgeously-flowered rhododendron, slope steeply down on either side to the blue-green waters of the lake, whilst to the east Tirsúl and two associated peaks rising over 20,000 feet, with snow-clad slopes and glaciers, form the back-ground of the picture.

14. Doubtless at several places in the Himalayas, lakes have in the recent past been formed by landslips, filled, and afterwards cut through by their own streams. Mr. Oldham has described the very interesting case of Turag Tal near Gonain in Almora District, which was formed behind a barrier of slipped limestone 250 feet high. The level of the alluvium in the lake is now within 50 feet of top of the barrier, so the age of the lake is measured by the time required to deposit alluvium to a thickness of 200 feet.[1]

15. Whilst the steep slope of the mountains around the lake at Gohna add greatly to the beauty of the view, they are unfortunately a source of danger to the lake itself on account of their liability to follow the example of Maithána and slide down displacing proportionately large bodies of water. At one spot, a little to the south-west of the dam and half-way to Durmi, where the dolomites dip in the direction of the steep slope towards the lake, the hill side may at any time slide into the lake. In 1869, higher up the same valley, a small lake, Gudyar Tal, having been formed in the same way by a landslip became suddenly nearly filled with a second slip accompanied by displacement of a body of water which flooded the valley of the Alaknanda and washed away part of Srinagar, 78 miles below. That this, sooner or later, will take place is a certainty; but when, it is impossible to say. The very size of the lake, however, will be a safeguard against high floods. Supposing, for instance, the permanent lake to have an area of 500 acres—I don't think it will be less—and a slip of 12,500,000 cubic feet occurred—the maximum possibility near the south-east corner of the dam. Then the water in the lake would rise $\frac{12,500,000}{500 \times 43,560} = \frac{12,500,000}{21,780,000} =$ nearly 7 inches. There are, however, one or two steep precipices on the north side of the lake which I could not examine and which might probably give larger slips. As such an occurrence is most likely to take place after a long season of rain the rivers will already be flooded and unable to carry any extra supply. I would suggest, therefore, to the engineers, the advisability of strengthening and raising the sides of the final outlet at the dam to receive a sudden rise of a few feet and the high waves which would follow a fall, such as I anticipate, into the lake. Careful determination by contours of the steep slopes on the northern

(1) *Rec. Geol. Surv., India*, Vol. XVI (1883), page 164.

side of the lake would give means for estimating the maximum possibilities of such slips.

16. Fears have frequently been expressed concerning the danger of the dam bursting under the hydrostatic pressure of the water accumulating in the lake above. The sections and map accompanying this note should be sufficiently convincing to any engineer; but to remove any doubt concerning the security of the barrier, its strength may be conveniently compared by a simple calculation to the actual hydrostatic pressure which it will have to resist before overflow occurs:—

The point referred to above as 5,850 feet above sea-level is approximately in the centre of the dam and lies in its weakest section. To make the problem as simple as possible, we may consider a section through this point, one foot thick and 1,000 feet deep—an estimate well beyond the maximum depth of the water in the lake.[1] Such a section will contain:— $\frac{1,000}{2} \times (2 \times 1000 \times cotan.\ 11^\circ) =$ 5,144,600 cubic feet of material. Now, the dam is composed principally of dolomite, varying in specific gravity from the pure material of 2·83 to blocks charged with iron pyrites up to a specific gravity of 3·61. There is also an admixture, in smaller quantities, of pyritous shale (averaging 2·79), and in still smaller quantities of talc (2·78); but pyritous dolomite is in large excess. Taking 2·8 as a very safe estimate for the average specific gravity of the dam, the weak section referred to will weigh—

$5,144,600 \times 2{\cdot}8 \times 62{\cdot}5 \div 2,240 = 401,922$ tons. Further, when the overflow is about to take place, the horizontal hydrostatic pressure against the section will be: $1,000 \times (\frac{1,000}{2} \times 62{\cdot}5) \div 2,240 = 13,950$ tons.

The weight of the section is thus $\frac{401,922}{13,950} =$ nearly 29 times the horizontal pressure of the water. Supposing this section to be free of friction from the sides and only offers the resistance estimated by its own co-efficient on a bed of the same material. Now, the angle of repose of a dolomitic talus on the dam is, as stated before, about 40°, which would imply a co-efficient of friction of 0·839 (*tan.* 40°). The section would thus require about four-fifths of its own weight to move it; that is to say a pressure of $\frac{401,922 \times 4}{5} = 321,536$ tons. But as the maximum horizontal pressure of the water will only be 13,950 tons, the weakest section of the dam is *at least* 23 times the necessary strength. This estimate would, of course, be still higher, if we took into consideration the weight of the thousands of tons of dolomitic blocks which rise on either side the weak section and point of overflow. Finally, the enormous pile of rubbish, weighing quite 800,000,000 tons and lying in a valley nearly one mile wide, would, if shifted, become jammed into a gorge only 500 feet wide.

III.—CAUSE OF THE LANDSLIP.

17. It is easy to trace several causes, which have been for sometime conspiring to the one end of bringing about the catastrophe that has been attended with such serious consequences at Gohna.

18. Among these the principal, or more correctly the one which gave facilities for the action of all the others, is the dip of the strata towards the gorge.

(1) Since the above was written, Lieutenant Crookshank has sounded the lake obtaining 512 feet as the greatest depth. As it is still 265 feet from the top of the dam, its maximum depth will be 777 feet.—*T. H. H., May 2nd, 1894.*

Plate I shows the complicated manner in which the beds are crumpled in this area. At the same time it will be noticed that over Gohna village, the dip of the dolomites in the south-east direction increases, until in Maithána itself the beds are inclined in the face of the cliff at an angle of about 45°—50°, and consequently large platey surfaces are exposed by the fall. As the dip of the rocks is here greater than the angle of repose of dolomite or shale-slabs, sliding would naturally take place when necessary facilities are presented. As long as the slope of the surface does not exceed in angle the dip of the strata, there is no danger of a slip; but when, as in this case, the foot of the slope is undermined by the action of a river and springs, the average slope of the surface is increased and there is a tendency for the beds lying between the line of slope and the line of dip to slide off. If the beds are well cemented and only subject to the influence of their own weight, the surface-slope may greatly exceed the dip (and the angle of repose) before sliding commences.

The influence of the dip of the strata in fashioning the surface slope is also well-illustrated in the Cheddar valley in England. The river has cut a gorge approximately in the direction of the strike of the carboniferous limestone, which dips on both sides of the river at an angle of 15°—24° S. The south side of the gorge is an almost perpendicular cliff 400 feet high, whilst on the north side the slope is only slightly greater than the dip of the beds, which are constantly, though gradually, slipping down as the river is deepening its valley. Thus, whilst an almost perpendicular cliff is safe on the south side in which direction the rocks dip, there is a perpetual slipping on the north side, and no slope greater than the angle of repose of the loose blocks would be safe.

19. In the landslip at Gohna not only was the support removed by undermining at the foot of the slope, and loosening of the beds, but the beds were impelled outwards by a series of changes following as a natural consequence of the processes which destroyed the originally compact nature of the strata. These causes combined, taking advantage of the stratigraphical facilities, precipitated the mass of material which now dams back the Birahi Ganga. Taking these causes in order we have—

(1). *Those producing a loosening of the strata.*
- (*a*) Dolomitization.
- (*b*) Solution by atmospheric waters.
- (*c*) Reduction of co-efficient of friction by water.

(2). *Subsequent changes impelling strata in the direction of least resistance.*
- (*a*) Expansion of products on oxidation and hydration.
- (*b*) Changes of temperature.
- (*c*) Hydrostatic pressure.

20. *Loosening of the strata.*

(*a*) *Dolomitization.*—The change of ordinary limestone into dolomite (which has only been partially effected at Gohna, see section 9, p. 58) on account of the lower molecular volume of magnesium carbonate, is accompanied by an increase of specific gravity from about 2·73 to 2·83, and consequently corresponding decrease in volume. The vesicular and jointed characters of many dolomites are probably thus caused, although the visible effects may often be prevented by pressure; but even under conditions of pressure, dislocations once produced offer facilities for subsequent agencies as, for example, removal by solution, or introduction of other minerals like iron pyrites with which the Gohna rocks are highly charged.

21. (*b*) *Solution by atmospheric waters.*—Besides the mere solution along joint and bedding planes—a process inevitable wherever atmospheric waters circulate amongst such rocks—minerals like iron-pyrites become decomposed and the products of oxidation and hydration act as solvents for the production from dolomite of sulphates of lime and magnesia which are carried away, at once or ultimately, in solution. Except for these changes combined, I should find it difficult to explain the amygdaloidal cavities in the dolomite referred to in section 9; and apart from such an unusual manifestation of their effects as these cavities, there is no doubt of the rocks being loosely jointed and channelled in numerous directions. The large cavities and "swallow-holes" described by Mr. Middlemiss in the dolomites of Naini Tal are examples of the changes brought about by the agencies here referred to.[1]

22. (*c*) *Reduction of the co-efficient of friction by water.*—The co-efficient of friction of *damp* clay is about 1·0, corresponding to an angle of repose of 45°. The co-efficient of friction of *wet* clay varies from 0·25 to 0·31, corresponding to angle of repose 14°—17° (Rankine). The effect, therefore, of water on a soft bed of shale is equivalent to lubrication, and doubtless this has occurred in the shales which underlie the dolomites in the cliff at Gohna. After the season of heavy rain, which preceded the landslip, the mountain must have been saturated with water, and even now small springs issue from different parts of the slope (see section 11). The disastrous landslip at Naini Tal towards the end of the rains of 1880 illustrates this fact.[2] The mass of slush forming the foot of the slip sloped at an angle of 15° up to where the old Victoria Hotel stood; from there the drier debris formed a steeper slope of 25°.

A similar illustration is afforded by the well-known landslip region of South Devon and Dorset between Sidmouth and Lyme Regis. There the porous cretaceous beds resting on the impervious clay-beds of the lower Lias, Rhœtic and Red Marl, and dipping gently towards the sea, have been pushed over the slippery wet clays by a hydrostatic pressure which must have been only a small fraction of the weight of the beds.

(*2*) *Subsequent changes impelling strata in the direction of least resistance.*

23. The direction of least resistance in this case is of course towards the gorge, and any sufficient impulse could only be manifested by movement in that direction. The smallest movement thus becomes a positive contribution to the final condition for a slip.

24. (*a*) *Expansion of products on oxidation and hydration.*— The sulphuric acid produced by the oxidation of pyrites would, under pressure and high temperature, decompose the carbonates of lime and magnesia, and form either anhydrous or partially hydrated sulphates, which would expand on subsequent more complete hydration before final removal. This action taking place in small cracks would give rise to the production of a number of wedges to dislocate the rocks.[3] Although I have mentioned this as one of the causes which brought about disruption of the originally more compact rocks, I should not imagine that in the present instance the effects were very serious. Gypsum the final product of the action of

[1] Middlemiss. *Rec. Geol. Surv., Ind.*, Vol. XXIII (1890), page 220.
[2] R. D. Oldham. *Rec. Geol. Surv., Ind.*, Vol. XIII (1880), page 277.
[3] See also Middlemiss, *Rec. Geol. Surv., Ind.*, Vol. XXIII (1890), page 221. Calcareous tufa and gypsum near Naini Tal.

sulphuric acid and water on carbonate of lime nevertheless occurs in illustration of the statement.

25. (*b*) *Changes of temperature.*—The expansion accompanying the rise of temperature during the summer can only be manifested in the direction of least resistance, and as there is no tendency to return on subsequent contraction during the low winter temperatures, the result is a gradual " creep " in the direction of the valley. In the Garhwal Himalayas, mountains of the height of those at Gohna are for sometime covered with snow and frequently subjected to a freezing temperature, the surface rocks at any rate will therefore suffer the usual effects of frost.

26. (*c*) *Hydrostatic pressure.*—From the upper edge of the slip the hill rises at the back to a height of 11,109 feet,—a rise of 11,109—9,620 = 1,489 feet in half a mile. As the strata dip in this direction at a slightly steeper angle than the surface slope, there is every facility for rain water sinking through to exert a hydrostatic pressure due to a column increasing from 1,489 feet to about 1,489 + 5,000 = 6,489 feet in height. As the slip took place towards the end of the rainy season, there is every reason for including this among the causes which combined brought down the side of Maithána.

27. Before closing this note it may be of interest to the general reader to be reminded of the fact that the folding of the Himalayan range having continued to times geologically recent, if not still in action, there has resulted a condition of strain frequently manifesting and relieving itself by earthquakes, and of steep slopes with rushing torrents, frequently resulting in landslips. When subsequently the inequalities of level have been sufficiently reduced by denudation, the slopes will be more stable, rivers less violent and the scenery tamer—a condition of affairs exemplified by the more geologically old-fashioned peninsular portion of India. Water, the great agent of denudation, has, we have seen, by its chemical and physical action, been the cause of the landslip at Gohna, and we have still to look for the effects of the potential energy accumulating in the lake.

IV.—EXPLANATION OF PLATES.

MAP I.—Gohna landslip and lake, giving contours at 100 feet vertical intervals. Scale 1,000 feet = 1 inch. Reduced principally from the survey of Lieutenant S. D'A. Crookshank, R.E. The small map in the corner is from Atlas sheet No. 66, N. W., showing the limits of the basin draining into the Gohna lake. Scale 4 miles = 1 inch.

MAP II.—Map showing the position of Gohna and routes from Hardwar, Nazibabad and Naini Tal (see section 2). Scale 8 miles = 1 inch.

PLATE I.—Sketch of Maithána—the broken hill—showing the elevations and bearings of the principal points along the north side of the gorge. Sketched from the south side of the dam at an elevation of 6,170 feet (see Map I).

PLATE II.—Section across the Birahi Gunga valley and the landslip through 5,850 feet point (A) on the dam (See Map I. and section 12).

Photo-etching. Survey of India Offices, Calcutta, April [illegible]

PLATE III.—Section along the valley from the old river-bed below Gohna to the lake (see Map I and section 12).

PLATE IV.—View looking up the valley (eastwards) from the edge of the lake, 290 feet below overflow point. Tirsúl (23,406 feet) and two associated peaks over 20,000 feet form the back-ground. Photographed March 10th, 1894.

PLATE V.—View from camp near Durmi looking eastwards. The village of Durmi on the right will be submerged before overflow occurs (see Map I). Photographed March 10th, 1894.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 19.—ENDING 30TH APRIL 1894.

Director's Office, Calcutta, 30th April 1894.

The association of the Survey with the Geological Survey of Austria and the geologists of that country, which practically began with the appointment of the first Palæontologist, Dr. Ferdinand Stoliczka, and was distinguished in 1873 by the presentation to the then Director, Dr. T. Oldham, and Dr. Stoliczka of gold medals by the Emperor of Austria, has again been marked by a like gracious bestowal of gold medals on the present Director of the Survey and Mr. Superintendent C. L. Griesbach, C.I.E., in recognition of their services in connection with the carrying out of the scientific expedition undertaken in 1892, at the suggestion of the Imperial Academy of Sciences at Vienna, to the central regions of the Himalayas, as well as generally in assisting the palæontological researches of Austrian Savants in India. This medal is figured on the annexed plate.

Mr. Grundy, the Inspector of Mines in India, has, during the last three months, continued an admirably close inspection of the Bengal collieries; in which it is gratifying to note that he has experienced very earnest co-operation on the part of the Agents and Managers of the mines. His seasons' work in Bengal will be shortly closed, when his office will return to Calcutta. The inspection of the Warora Colliery, which had been arranged for before Mr. Grundy's arrival in India, was finished by Dr. Noetling after his inspection of the collieries in the Salt-Range, Punjab.

It is as well to state here that during this inspection Dr. Noetling eagerly seized the opportunity afforded him of continuing the scientific work of the Department. He visited the lower palæozoic outcrops of Bhaganwala, Khussak and Khewra, whence he was able to bring away a valuable and sufficiently typical collection of the *Olenellus* and *Neobolus* fauna which should clear off much of the obscurity still shrouding the definition of the Cambrian strata of the Salt-Range. Since his return to Head-Quarters at the end of February, he has been engaged in his proper work at the tertiary fossils of Burma, including the marine fossils from Minbu and Yenangyat which show, so far, that this lower miocene fauna has to a large extent a community of facies with the tertiaries of Sumatra and Java and those of Western India, though the facies of the latter is the stronger. He is also preparing a memoir on the vertebrate remains from Yenangyoung.

Mr. Holland returned from his inspection of the Gohna landslip in Garhwal, a report on which appears in the current records; and he has just proceeded to Naini-Tal to take part in an enquiry by the Department of Public Works of the North-Western Provinces into the condition of certain landslips in that neighbourhood.

At the end of March, the Director visited Giridih under the guidance of Dr. Walter Saise, Manager of the East Indian Railway Collieries, in connection with the excellent survey of the coal-field lately completed by the latter gentleman, on the conclusions derived from which the new Jubilee pit on the southern edge of the field is being sunk to a depth of 650 feet. This will be the deepest coal pit yet put down in India, and it will bear witness to the admirable reasoning and series of test borings whereby Dr. Saise was enabled to arrive at an approximate estimate of the immense quantity of coal yet stored up in this outlier of the main Ranigunj area of the Bengal coal tract, which is calculated to yield an output of 600,000 tons per annum for the next 138 years. The want of newer geological maps of these coal-fields, than those which were prepared, on the only available scale at the time, for the particular memoirs published in 1863 and 1870, is becoming more and more felt; and when so much has been done in the way of helping towards this end as has been quietly accomplished by Dr. Saise in a map, on the scale of $2'' = 1$ mile with sections, of the Giridih coal-field which has been laid before the Board of the East Indian Railway Company, and which is to be presented to the survey for publication; it would seem as if the time had fully come for the formation of a committee of Bengal Colliery Managers to move in the preparation of a revised and enlarged map of the Ranigunj coal-field. The Colliery Managers would appear to have quite sufficient data before them in the way of borings and shaft sections which, combined with their local knowledge, should enable them to contribute materially to the production of a lasting standard work of this kind. An initiatory step might be made by supplying Managers with copies of the latest revenue and other maps of their districts, on which each gentleman could enter all the data at his disposal according to some settled scheme of geological and mining delineation. The Geological Survey Staff is all too limited for such an undertaking, but by judicious co-operation with a committee of the kind indicated, a great deal might be done to effect the desired end. With experienced and long-tried Managers to choose from, an excellent committee might be formed; while the project might also receive additional energy and influence from the Indian Mining Association in Calcutta, which is the official representative of the coal owners of Bengal.

A visit was also made to the belt of metalliferous rocks of the Transition Series in Chota Nagpur, on which for the last few years considerable but almost futile energy has been expended in an attempt at gold production; in view of taking up the mineral survey of the country during the next field season. It was sufficiently evident that the relations of the Transitions themselves, and the association of the metalliferous veins (which are cupriferous, or lead-bearing, or auriferous, as the case may be, in certain zones) occurring in them, should now be worked out in some detail, if only to afford guidance in any further endeavours which may be made in the way of production; while our mineralogical and geological study of the Transitions will help towards the complete correlation of them with those of Chhattisgarh further westward, and perhaps also with the Dhárwárs of Southern India.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of February, March, and April, 1894.

SUBSTANCE.	For whom.	Result.
1 Specimen of iron ore, from Khochipura, near Pokhra, Sihaol Tahsil, Rewah State.	P. N. Bose, Geological Survey of India.	*Specular iron.* *Quantity received*, $1\frac{3}{4}$ lbs. Contains 21·40 per cent. of iron (Fe) = 30·57 per cent. of ferric oxide (Fe_2O_3).
1 Specimen of coal, from the Sarakdi Colliery, Asansole.	N. A. Hodges, Howrah.	Proximate analysis, with calorific power.
1 Specimen of coal, from Raneeganj.	John Chambers & Co., Singaram Valley Coal Concern, Calcutta.	Proximate analysis, with calorific power, and sulphur determination.
2 Specimens of quartz, with iron pyrites and galena, from Chota Nagpur.	John Martin, Calcutta.	Assayed for gold.
3 Packets containing duplicate assay beads, for weighment and parting.	C. M. P. Wright, Wuntho, Upper Burma.	Weighed, parted and calculated to the ton.
4 Specimens of limestone, for analysis.	Kilburn & Co., Calcutta	Analysed for insoluble residue; ferric oxide and alumina; carbonate of lime; and carbonate of magnesia.
1 Specimen of coal, from Laikha, Southern Shan State, Burma.	The Revenue Secretary to the Chief Commissioner, Burma.	*Lignite.* *Quantity received*, 32 lbs. Moisture . . . . 14·40 Volatile matter, exclusive of moisture . . . 41·00 Fixed carbon . . . 36·60 Ash . . . . . 8·00 100·00 Does not cake, but sinters slightly. Ash—light buff.
1 Specimen of coal, from Darjeeling District.	Finlay Muir & Co., Calcutta.	Proximate analysis.
1 Specimen of quartz, with iron pyrites and galena, from Chota Nagpur.	John Martin, Calcutta.	Assayed for gold.
1 Specimen of coal, from the North Cachar Hills, Assam.	Finlay Muir & Co., Calcutta.	Proximate analysis.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of February, March, and April, 1894—contd.

SUBSTANCE.	For whom.	Result.
Dolomite, with pseudo organic structure in hand specimen, from Gohna landslip, Garhwal.	Thomas H. Holland, Geological Survey of India.	S. G.=2·83. Insoluble residue . . . 1·355 Ferric oxide, alumina, etc. . 1·225 Carbonate of lime . . . 53·875 Carbonate of magnesia . . 44·780 101·235
Specimen of quartz, with iron pyrites, from Pardiah, Chota Nagpur.	A. Mervyn-Smith, Oriental Prospecting Syndicate, Ld., Calcutta.	Assayed for gold.
Specimen of galena, with quartz and iron pyrites, from Maingays Island, Mergui Archipelago.	Lieutenant E. J. Beaumont, R.I.M., Calcutta.	Yielded on assay:—74·33 per cent. of lead and 12 oz. 14 dwts. 19 grs. of silver to the ton of lead.
	C. S. Middlemiss, Geological Survey of India.	*Block, E. face of Sankaridrug Hill, Trichengode Taluq, Salem District.* Banded and finely granular aggregate of diopside, quartz, felspar, garnet (pink), and a highly refracting, highly-doubly-refracting, colourless (in section) mineral, with very imperfect and seldom-developed cleavage in one direction. Estinctions 27° to the cleavage: probably chondrodite. *E. face of Sankaridrug Hill.* Massive garnet (colophonite?) pink in section, with granular diopside, calcite and quartz in bands. Large quantities of minute and doubly-refracting crystals of possibly the same minerals are scattered through the mass of garnet. The association of calcite and diopside recalls the coccolitic crystalline limestones, and in the present instance they appear to be the results of alteration of the garnet. S. G. of mass=3·43.
3 Specimens of minerals, from the Sirmur State, sent by the Raja of Sirmur, for determination.	J. S. Gamble, M.A., Director, Imperial Forest School, Dehra Dún.	1. Iron pyrites. 2. Common garnet in rhombic dodecahedra. 3. Muscovite, with fragments of felspar and quartz attached, evidently part of very coarse granite.
A specimen of rock, found in the vicinity of the reserved forests of the Darjeeling Division.	C. A. G. Lillingston, Deputy Conservator of Forests, Darjeeling.	A zeolite allied to laumontite.
A mineral, found close to Simla, for examination.	E. M. Johnstone, Octagon Cottage, Simla.	Iron pyrites ($Fe S_2$). If in large quantities, may be used for source of sulphur in sulphuric acid manufacture. Waldie and Co., Cossipore, uses this material for this purpose.
"Two sorts of rock, from Munjerabad, Mysore," for examination as to whether it is *laterite* or not.	J. Walter Leather, Agricultural Chemist to the Government of India, Dehra Dún.	1. Quartz probably from a coarse-grained granite now kaolinized. 2. Lithomarge like that of the Nilgiris, Pulnis, etc., the result of decomposition of a crystalline micaceous rock at a high level, over 2,000 feet.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of February, March, and April, 1894—concld.

SUBSTANCE.	For whom.	Result.
Specimens of stones, from Shamsunderpore, Bankura District, believed to be sapphires, for determination.	Raja Sourindro Mohun Tagore, C.I.E., Pathuria Ghata Raj Bati.	Almandine spinels. S. G. = 3·614. H. = 8·0. Isotropic. Specimens, waterworn.
A small piece of mineral found in the neighbourhood of the Jabalpur Pottery Works.	Burn and Co., Calcutta.	Barytes (heavy spar).
A substance found in Naini Tal, as an efflorescence on the surface of the soil, for determination.	C. H. Holme, Executive Engineer, Naini Tal.	Crude sulphate of alumina and iron, result of the decomposition of iron pyrites.
A specimen of nummulitic limestone from the Panir Tunnel, for determination of the white stuff in the stone.	F. E. Robertson, Calcutta.	Calcium sulphate = Alabaster.

Postal and Telegraphic addresses of Officers.

Name of Officer.	Postal address.	Nearest Telegraph Office.
T. W. H. Hughes	On furlough . . .	...
C. L. Griesbach	Pishin	Pishin.
R. D. Oldham	On furlough . . .	...
T. H. D. LaTouche	Sukkur . . .	Sukkur.
P. N. Bose	Calcutta . . .	Calcutta.
C. S. Middlemiss	Ootacamund . .	Oatacamund.
P. N. Datta	Bhandara . . .	Bhandara.
T. H. Holland	Naini Tal . . .	Naini Tal.
W. B. D. Edwards	On furlough . . .	...
F. H. Smith	Harnai . . .	Harnai.
F. Noetling	Calcutta . . .	Calcutta.
Hira Lal	Naini Tal . . .	Naini Tal.
Kishen Singh	Quetta . . .	Quetta.

DONATIONS TO THE MUSEUM.

FROM 1ST FEBRUARY TO 30TH APRIL 1894.

A specimen of galena, with quartz and iron pyrites, from Maingays Island, Mergui Archipelago.

PRESENTED BY LIEUT. E. J. BEAUMONT, R.I.M., CALCUTTA.

A large specimen of quartz, with iron pyrites and gold, from No. 3 shaft, Anundpur, Singbhoom, Chota Nagpore.

PRESENTED BY V. L. REES (J. MACKILLICAN & CO., AGENTS, ORIENTAL PROSPECTING SYNDICATE, LD., CALCUTTA).

Five specimens of quartz with iron pyrites and gold, from Chonkpazat Mine, Mawnaing Township, Katha District, Upper Burma.

PRESENTED BY C. M. P. WRIGHT, WUNTHO, UPPER BURMA.

ADDITIONS TO THE LIBRARY.

FROM 1ST JANUARY TO 31ST MARCH 1894.

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" Census of India, 1891. General Report. Flsc. London, 1893.
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ERRATA.

RECORDS, VOL. XXVII, PART 3.

The Giridih (Karharbari) Coal-field.

Page	87,	line 1,	from top,	for *Plates* read *Maps*.
,,	87	,, 1	,,	and for *III* read *I*.
,,	87	,, 13	,,	for *section* read *section on EF*.
,,	87	,, 19	,,	for *Plan* read *Map*.
,,	87	,, 23	,,	for *inclines* read *incline*.
,,	87	,, 38	,,	for *VII* read *VI*.
,,	88	,, 7,	from bottom,	for *100* read *200*.
,,	89	,, 10,	from top,	omit *three*.
,,	89	,, 16,	from bottom,	parenthesis to be placed after *numerously* and omitted after *Seam*.
,,	91	,, 6,	from top,	for *Dikes* read *Dykes*.
,,	94	,, 13,	from top,	for *are* read *is*.
,,	95	,, 13,	from top,	for *rubbed* read *robbed*.
,,	95	,, 14	,,	omit *off*.
,,	95	,, 26	,,	for *square* read *shot*.
,,	97	,, 9,	from bottom,	for *8* read *3*.
,,	97	,, 6	,,	for *VII* read *VIII*.
,,	99	,, 13	,,	for *women*), *Santas* read *women and Santals*).

Plate VII,	for figure	*1*	read	*6*.
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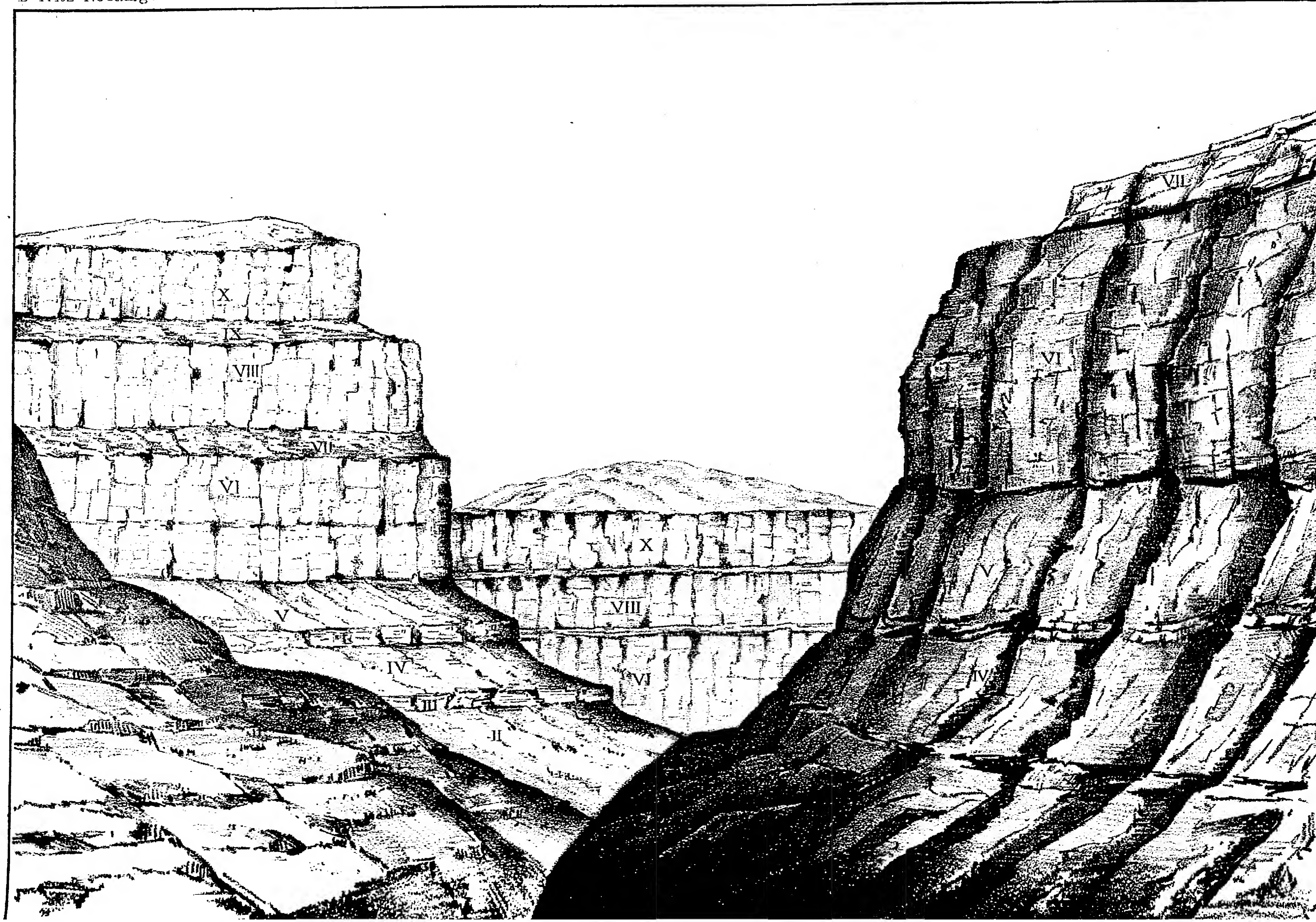
Dr Fritz Noetling.

Records, Vol: XXVII. Pt. 3. Pl. I.



RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1894. [August.

On the Cambrian Formation *of the* Eastern Salt Range. *By* DR. FRITZ NOETLING, F.G.S., *Palæontologist, Geological Survey of India.* (With a Plate.)

It is one of the strange features in the Geology of the Salt Range, that the strata belonging to the older palæozoic age have for a long time been misapprehended, although they form petrographically as well as palæontologically a conspicuous series in the eastern part of the range. While visiting the country during the season 1893-94, I had the good luck when studying a section near Baghanwalla to discover after a long search the first authenticated fossils in the Magnesian sandstone. Besides Baghanwalla, I was able to study the development of the Cambrian formation at several other localities between that place and Khewra, which has put me in the position to give a further contribution towards its interpretation, which to a certain degree must modify the views hitherto held. I regret that I am unable to give a description of the interesting fauna which I collected, but in accordance with the views of the Director of the Survey it has been decided to send the fossils to Dr. Waagen at Vienna, who is still engaged on the description of the Salt Range Fossils found hitherto, in order to enable him to give a more detailed and concise description of this fauna. The way some Cambrian fossils were originally included by him, among those of carboniferous and permo-carboniferous age, and the manner in which the question of the Cambrian fauna has eventually got mixed up in the discussion of the geological results of the study of the younger palæozoic fauna, tend by no means to render the whole matter intelligible to the student of Salt Range Geology. I therefore feel obliged, before communicating my own observations, to review the whole state of this question.

I.—Historical Summary.

Mr. Wynne[1] mentions for the first time the existence of pre-carboniferous rocks in the Salt Range, which according to the fossils they contained, were considered of Silurian age. Mr. Wynne specially states "on the strength of Dr. Waagen's determination, who was able to free the internal aspect of a few of the valves, so as to enable them to be determined as belonging to two species of *Obolus* and *Siphonotreta*," that the "Obolus shales" as they were thenceforth called, were considered to be of Silurian age. The late Dr. Stoliczka was apparently of the same opinion as regards the generic position of these fossils (*ibid*, page 68).

[1] Geology of the Salt Range in the Punjab. Mem. Geol. Surv. of India, vol. xiv, page 86.

Professor Waagen, however, in his subsequent book on the Productus Limestone[1] has abandoned the view previously held by him; and in the preface even strongly combats the view of the Silurian age of the "Obolus," or, as he now calls them, the "Neobolus" shales. Professor Waagen after having particularly laid stress upon the intimate connection of the "Pseudomorphic Salt-crystal Zone," the "Magnesian sandstone," and the "Neobolus bed," a view which is perfectly correct as we shall presently see, continues: "We can fairly say this group follows immediately below upper carboniferous beds, and must thus be of lower carboniferous age. I cannot see anything unreasonable in these deductions; and among all possibilities these seem to me again and again the most probable ones. The palæontological facts are decidedly in opposition to the view of these beds being Silurian, not a single species or even genus being identical, and the geological facts, without straining them in any way, can be interpreted so as to let these beds appear as of carboniferous age."

I fully agree with Dr. Waagen as to the appearance of the fossils, the chief forms of which belong to genera decidedly different from *Obolus*; and that, failing the presence of further fossils of a decisive character, the Silurian age of the Obolus shales was no longer above every suspicion. On the other hand, I cannot help noticing the close relationship of the new genus *Davidsonella* with the genus *Obolella*, Bill. I must confess that I think the genus *Davidsonella* is so closely related to *Obolella*, if not identical altogether, that I would have preferred to have it included in that genus; and weighing the evidence thus at hand, I would have preferred to consider the Obolus shales of Silurian, rather than of Carboniferous age, for which view there was more support, palæontologically as well as stratigraphically, than for the latter one. Palæontologically, on account of a genus from the family of the Trimerellidæ, closely related to, if not identical with, *Obolella*; stratigraphically, because the close connection between the Magnesian Sandstone group, the Pseudomorphic Salt-crystal group, and the overlying rocks of undoubted carboniferous age is nowhere so well developed as Professor Waagen assumes it to be, and as subsequent observations have proved.

It is greatly to be regretted that the subsequent discoveries were not made in time, so as to allow Professor Waagen to amend his views regarding the age of the Neobolus shales before the publication of Vol. IV of the SALT-RANGE FOSSILS containing the "Geological Results"; otherwise he would not have been obliged to modify on page 51 ff. his views expressed on page 45, where he says: "The name introduced by Mr. Wynne for this group was simply "Silurian": I cannot accept this name on several grounds. Firstly, the fossils occurring in the group, though exhibiting a rather old-looking habitus, cannot, either generically or specifically, be identified with Silurian forms: then even if the beds should yet be proved to be of lower palæozoic age, they could never be taken as equivalent to the Silurian in general, but could no doubt only represent a small part of it; they are most intimately connected with the next following Magnesian sandstone, the Silurian age of which is also rather doubtful.

"The fossils found up to the present in the group give no decisive evidence, but there is some hope that a new search in these beds will furnish more extensive materials. Pending such new and better information, I abstain here from

[1] Palæontologia Indica, Series xiii, Salt-Range Fossils, vol. i. Productus Limestone Fossils.

reuttering my formerly expressed opinion that these beds were lower carboniferous.

"In the meantime it will be most advisable to give these beds a neutral name as "Dark shaly zone" or "Neobolus beds."

Dr. Waagen's modification on page 54 is as follows :—

"With regard to the lower series, there has been detected in the meantime not only the great discordance, which cuts just through the middle of the division, but just while I write these lines I have a letter from Dr. Warth announcing the discovery of Trilobites in the Neobolus beds—specimens which seem to be nearly related to *Conocephalites*. Thus it is no longer possible that the beds below the great unconformity which are of Permian and topmost Carboniferous age, should form one series with the more recent strata above that unconformity, and, therefore, the Lower Series (Productus Limestone) of former times will have to be cut up into two."[1]

The discovery of the Trilobites in the Neobolus shales made a fresh discussion of the age of that group necessary and on page 91 ff. Professor Waagen gives his final views as to the division and age of the pre-carboniferous rocks. He divides the Lower Palæozoic series into two groups in descending order, *viz.*:

2. Magnesian Sandstone group	3 Red shaly zone (Salt-crystal Pseudomorph Zone of Wynne).
	2 Magnesian sandstone.
	1 Dark shaly zone (Neobolus beds).
1. Purple Sandstone group	4 Upper Purple Sandstone.
	3 Rock salt and red gypsum group.
	2 Grey gypsum group.
	1 Lower Purple Sandstone.

Professor Waagen further remarks, that the most important of these sub-divisions, from a palæontological point of view, is the Neobolus bed, but that "the demarcation of the sub-group is not very easily drawn, though its lower limit against the Purple sandstones of the preceding group is somewhat better defined than the upper one towards the Magnesian sandstone."

A list of fossils, chiefly Brachiopoda, is then given, numbering nine species altogether; to which is added the description of the species collected by Dr. Warth numbering 2 species of Trilobites, 2 Gastropods and 1 Brachiopod, thus bringing the number of the fossils found in the Cambrian of the Salt-Range to 14 species altogether.

In connection with this fauna the age of the strata is discussed, and Professor Waagen eventually (after having remarked that the head of a Trilobite, which had been found by Mr. Middlemiss at Khussak in beds *above* the Brachiopoda strata of the Neobolus beds, undoubtedly represented an *Olenellus*) adopts the following sequence of the faunas as represented in the Cambrian formation of the Salt Range:

4. Olenus fauna.
3. Paradoxides fauna.
2. Olenellus fauna.
1. Neobolus fauna.

[1] By a misprint this passage says exactly the opposite of what the author wanted to express; the beds *below* the great unconformity are not of Permian, but of older age. If we, however, substitute the word "above" for the word "below" and further on read: "with the strata below that unconformity" instead of "with the more recent strata above that unconformity"; the author's views become quite clear.

I regret to say that I cannot agree with Professor Waagen in this view of the sequence of the faunas, which, quite apart from the palæontological, is certainly not borne out by the facts from a stratigraphical point of view, as I shall point out later on.

As it appeared that the exact locality where Dr. Warth had first found the trilobites could not be traced again; a party, consisting of Mr. Middlemiss and Mr. Datta, went up to the Salt Range to verify Dr. Warth's find. Mr. Middlemiss was lucky enough to find at Khussak fort hill, besides other fossils, some exceedingly well-preserved Brachiopoda and numerous fragments of Trilobites. Mr. Middlemiss[1] has given an exceedingly clear and correct section through the Neobolus shales at Khussak, locating the beds containing fossils in such a distinct way that they can be easily recognized again.

II.—The Geological Division of the Cambrian Formation.

My time being rather limited, I devoted my attention chiefly to the study of the fossiliferous Neobolus shales, with no further object originally, than my own information; but when in the course of these studies I found that the Neobolus shales were intimately connected with the Purple sandstone below, and the Magnesian sandstone above, I extended my investigations to these two groups also. As I had not, however, sufficient time to spare, I could not go into such details regarding the last two groups as I have done with the Neobolus beds; and the sections presently described deal chiefly with the structure of this series, and to some extent with that of the Magnesian sandstone, while no details are given regarding the Purple sandstone. However, one of the principal facts I elicited was, that there exists no sharp well-defined boundary between the Purple sandstone and the Neobolus beds (see section in Khewra gorge), the dark red or Purple sandstone passing gradually by light coloured passage beds into the Neobolus beds. This proves that there is no justification for dividing the lower Palæozoic Series of the Salt Range into two distinct or equally important groups. Of course the Purple sandstone will always have to be separated from the Neobolus beds; but I do not think that the two-fold division can be upheld. I, therefore, propose the following sub-division of the Salt Range Cambrian, in descending order:—

4. Bhaganwalla group, or Salt-crystal pseudomorph zone.
3. Jutana group, or Magnesian sandstone.
2. Khussak group, or Neobolus beds.
1. Khewra group, or Purple sandstone.

The whole formation might be called the Punjab Province of the Cambrian formation.

1. The Khewra group or Purple Sandstone.

There still remain some most interesting problems in the Geology of the Salt Range connected with this group; but not having studied its features in detail, I do not venture to express a decided opinion. All I can say is that from what I have seen, I fully agree with the hypothesis promulgated by Mr. Middlemiss,

[1] Records, Geol. Surv. of India, vol. xxiv, page 24.

regarding the quasi-intrusive nature of the salt-marl; and that I thus no longer consider it as an inseparable member of the series of sedimentary rocks forming the Cambrian strata of the Salt Range. I do not want to dwell here on the origin of the salt-marl, this hypothesis having been so ably discussed by my colleague, Mr. Middlemiss; all I desire to say is, that having accepted the above hypothesis as a most probable one, the salt-marl must be excluded from the series forming the lower part of the Cambrian formation in the Salt Range.

Professor Waagen distinguishes four sub-divisions in his Purple sandstone group, one of which has already been eliminated, namely, the Salt-marl. As regards the other three, I agree with Mr. Middlemiss, who is of the opinion that Professor Waagen's so-called lower Purple sandstone might much more easily be explained as an inversion of the overlying Purple sandstone. There remain, therefore, only the two upper members of Professor Waagen's sub-divisions; as to the lower of which I am not in the position to give a definite decision regarding its existence, because, as already pointed out, I have not so carefully studied the Purple sandstone group as those higher up. Until further evidence is to prove the contrary, we may therefore assume that the Khewra group consists of two divisions, the upper of which is formed by the "Purple Sandstone Group" of Wynne.

For details regarding this group I must refer the reader to Mr. Wynne's able memoir on the Geology of the Salt Range. All I can say here is that I frequently found ripple marks, and that it seems to me that the Purple Sandstone gradually thins out towards west. It is certainly not so well developed in the western as in the eastern part of the Salt Range. So far no fossils have been discovered.

Mr. Wynne states that the thickness of the Purple Sandstone varies from 200 to 400 feet.

2. KHUSSAK GROUP OR NEOBOLUS BEDS.

The series immediately following the Khewra group has, from the earliest times, attracted the attention of the geologists working in the Salt Range, not only on account of the marked way in which the dark shales of this group contrast with the dark red of the Purple sandstone below, and the light cream or ochre colour of the Magnesian sandstone above, but also because they are, whatever their real age may be, certainly the oldest formation in the Salt Range containing fossils.

The Khussak group consists of a series of more or less light cream-coloured Dolomites or Dolomitic sandstones in thin layers, alternating with thick beds of dark purple to black shales. The latter being generally preponderating, the appearance of this group is that of a dark-coloured band running along the slope of the hills, and distinctly visible at a great distance. It is intimately connected with the Khewra as well as with the Jutana group, although its boundaries are always well and sharply defined. Mr. Wynne states that the thickness of this group varies from 20 to 150 feet. There is no doubt that the Khussak group reaches its chief development in the eastern part of the Salt Range, where it attains its greatest thickness, and then gradually thins out towards west. I was unfortunately unable to visit those localities west of Khewra, where the Khussak group begins to die out; and the study of the conditions in this part must be left to the future. It will be highly interesting to follow the gradual changes of the Khussak group from east towards west, but for the purposes of that we must first study its typical development in the eastern part of the Salt Range. The detailed sections which I give further on have proved that the Khussak group may be divided into five sub-divisions, which, although their local development varies greatly, are easily recognisable as such from the position which they invariably hold in the sequence of the beds, and from their fossils. These five sub-divisions are in descending order :—

V. ZONE OF OLENELLUS SP.—Dark compact shales thinly bedded, and subcocretionary, micaceous, but not glauconitic, containing numerous specimens of *Brachiopods* probably belonging to the family of *Trimerellidæ*, and fragments of *Trilobites*, probably belonging to the genus *Olenellus* at some localities; at others dark purple soft sandy shales without any fossils. Thickness 15 to 18 feet.

IV. ZONE OF NEOBOLUS WARTHI.—Thin bedded purple sandy and micaceous shales, full of *Neobolus warthi* Waagen. Thickness appoximately 15 feet. This zone is separated from the preceding one by a band of hard glauconitic sandstone of about 2 feet in thickness, which, notwithstanding its small thickness, is very constant.

III. UPPER ANNELID SANDSTONE.—A series of hard cream-coloured sandstones, flaggy and glauconitic, alternating with soft dark and shaly layers. Thickness about 40 feet. According to Mr. Middlemiss, the top layer of this sub-division contains many "broken shells" at Khussak fort hill, which I, however, could not discover again.

II. ZONE OF HYOLITHES WYNNEI.—Dark purple shales with green patches, lumpy and very brittle. Thickness about 10 feet. Contains numerous specimens of *Hyolithes wynnei* Waagen, besides *Neobolus* (?) sp. and fragments of small *Trilobites*.

I. LOWER ANNELID SANDSTONE.—A series of hard cream-coloured glauconitic sandstones, alternating with darker shaly partings or soft sandy beds. Except one isolated specimen of *Hyolithes* and some bi-valves, the name of which is not known to me, no other fossils have so far been discovered. The sandstone, however, is full of those worm-like traces, which are considered as the tracks of annelids. Approximate thickness about 50 feet.

Zone V varies very much in its petrographical aspect, and at such places where it is typically developed as on the west side of the Bhaganwalla ravine, the southern slope of Khussak Fort Hill, or the western branch of Khewra glen, it forms two beds of dark shale separated by a light cream-coloured micaceous shale. The dark shale is hard, sub-concretionary, thinly bedded and contains numerous fossils, which to my knowledge are the same in both layers.

When not typically developed as in the eastern branch of Khewra glen, or the north slope of Khussak Fort Hill, or Bhaganwalla Fort Hill or numerous other places, it consists of soft dark purple sandy shales containing no fossils. The most striking instance of this facial development may be seen at Bhaganwalla, where on the right side of the ravine, this zone shows its typical development, while just opposite on the other side it shows its abnormal facies. We must therefore suppose that at the time of its deposit, at some particular parts a dark clay was deposited which formed the habitat of a fauna though small in species, numerous in individuals, while at other places a sandy soft clay of dark purple colour was deposited which presented unfavourable conditions for the existence of this fauna.

The different facial development of this zone is a good deal responsible for the erroneous view of the sequence of the faunas as given by Professor Waagen. Professor Waagen was not in the favourable position of having his palæontological conclusions supported by a carefully-worked-out section, he having only such vague terms as "glauconitic sandstone" or "dark shales" to guide him; and it is only too natural, that without knowing their relative position a mistake would occur. It is to be regretted that the first observer, Dr. Warth, was unable to specify the position of the strata in which he found the Trilobites, otherwise this misunderstanding would never have occurred.

I have now to deal with the distribution of the fossils, as determined by Professor Waagen, throughout the subdivisions into which I have divided the Khussah group. I confess that this is rather risky, and I am quite prepared that one or another mistake will take place, but considering that Professor Waagen constructed the sequence of the faunas in the Khussak group on the fossils as determined by him, I must take the risk.

However we have the following facts to guide us:—

1. *Neobolus warthi*, Waagen and the closely related form *Neobolus wynnei*, Waagen do not from what we know at present ascend higher than zone IV. They may probably occur in the lower subdivision, but to my knowledge *Neobolus warthi* characterises zone IV.
2. *Olenellus* sp. is restricted to zone V at the top of the Khussak group.

On page 92 of his memoir, Professor Waagen gives a list of fossils, stating that they come from the dark shales at the base of the group. They are the following species:—

1. *Discinolepis granulata*. Waagen.
2. *Schizopholis rugosa*. Waagen.
3. *Neobolus warthi*. Waagen.
4. " *wynnei*. Waagen.
5. *Lakhmina linguloides*. Waagen sp.
6. " *squama*. Waagen sp.
7. *Lingula kiurensis*. Waagen.
8. " *warthi*. Waagen.
9. *Fenestella* sp. indet. Waagen.

Altogether nine species. I refrain from expressing my views as to their specific independence, but I think that even Professor Waagen will agree with me that the *Dictyonema*-like fossil can no longer be considerd a *Fenestella*. From personal examination of these fossils I can however fix their position so far that I am convinced that they do not come from zone V, the character of the rock still adhering to them proves that they must come from one of the lower zones, most probably from zone IV.

As regards the fossils mentioned on page 104, the following are from the glauconitic sandstone:—

Olenus (?) *indicus*. Waagen
Trilobites gen. et. sp. indet.
Hyolithes khussakensis. Waagen.

All I can say is that, to judge from the character of the rock, these fossils may come from any horizon in the zones I to III, even IV; most probably from zone III; they certainly do not come from zone V.

As regards the fossils from the dark concretionary shales, *viz.*:—

Conocephalites warthi. Waagen.
Trilobites gen. et sp. indet.
Hyolithes wynnei. Waagen.
Orthis warthi. Waagen.

we may at once say that the term "dark concretionary shales" is as ill-chosen as possible, and would lead to serious misunderstandings. *Hyolithes wynnei* is imbedded in a rock of purple colour, differing in no way from that in which the first-named fauna of brachiopods was discovered. The other three forms come, certainly from a light coloured rock, and Dr. King's doubts as to the exact horizon of *Conocephalites warthi* Waagen are fully justified. If my views are correct *Hyolithes wynnei* is chiefly found in zone II, although it may ascend higher up, while *Conocephalites warthi* and the two other forms may come from any of the bands of cream-coloured glauconitic sandstone that occur in zones I to III.

Now the result of this criticism is, that the faunas do not exist in the sequence as depicted by Professor Waagen; if we still adhere to the combination as given by him, the sequence of the faunas in descending over would be—

Neobolus fauna,
Olenus fauna,
Conocephalites fauna,

if we take the Trilobites as the representatives of the respective faunas. We would therefore have quite the inverted order in nature from that given by Professor Waagen on page 106, where he gives the sequence of the faunas as—

4. Olenus fauna.
3. Paradoxides fauna.[1]
2. Olenellus fauna.
1. Neobolus fauna.

Now we further know that whatever their respective sequence may be, all the three faunas; Neobolus, Olenus, and Conocephalites are *below* the Olenellus fauna, and the real sequence of the faunas would be in descending order.

4. Olenellus fauna.
3. Neobolus fauna.
2. Olenus fauna.
1. Conocephalites fauna.

Such a succession of faunas in the lower Cambrian would however be against all experience if we suppose that the Conocephalites fauna represent the Paradoxides fauna, and if *Olenus* (?) *indicus* is really an *Olenus*. As we however know for certain that

(*a*) the fauna in zone V, as represented by the Oelnellus fauna, forms the top of the Khussak group;
(*b*) the Neobolus fauna (zone IV) is older than the Olenellus fauna;
(*c*) That the two *Trilobites* determined as *Olenus* (?) *indicus* and *Conocephalites warthi* must come from beds that are either older than the Neobolus fauna (zone IV), or at the outside contemporaneous with it

[1] Professor Waagen considers the Conocephalites fauna as the equivalent of the Paradoxides fauna of Europe.

we must come to the conclusion that the two Trilobites, determined as *Olenus* (?) *indicus* and *Conocephalites warthi*, do not belong to the genera they are supposed to do, and that the two faunas, if they really exist as such, represent a perfectly different horizon from what they were supposed to do by Professor Waagen. Here we will have to wait for future discoveries to throw some light on this rather vexed question.

All that we can say with certainty for the present is, that at the top of the Khussak formation a fauna occurs, which is most likely the equivalent of the Olenellus fauna of other countries, while for those faunas below it, no representative can be found in the Cambrian strata of other countries.

Professor Waagen's view that the strangeness of the fauna of the Neobolus shales may be explained by the fact that it is older than any other Cambrian fauna, is therefore fully confirmed by the above arguments, only not quite exactly in the way he was led to conjecture. Until proved otherwise, the following species as representatives of the Neobolus fauna must therefore be considered as some of the earliest forms of animal life, *viz.*:—

Neobolus warthi, Waagen.
Neobolus wynnei, Waagen.
Hyolithes wynnei, Waagen.

Besides which there existed undoubtedly a rich fauna of various species of annelids which left their traces in the shape of various tracks on the surface of the sandstones.

3. THE JUTANA OR MAGNESIAN SANDSTONE GROUP.

No more unfortunate name could have been selected for this group than "Magnesian sandstone." According to the analysis of its author, Dr. Fleming,[1] it is a dolomite with an admixture of quartz sand. A specimen of Magnesian sandstone will resemble any other rock but "sandstone." The term Magnesian sandstone having however been adopted in all the papers dealing with the geology of the Salt Range, it would be inopportune to change it now.

The Jutana group is naturally divided into five subdivisions, which, although of nearly the same petrographical habitus, are easily distinguished from a long distance even. The subdivision is produced by the occurrence of shaly, thinly laminated beds which easily weather and crumble to pieces, thus forming gently inclined sloping terraces between the bold cliffs below and above. The sketch of Jutana glen (see Plate I) gives a very fair idea of the natural appearance of this group.

Hitherto the Jutana group has been considered unfossiliferous, except the highly doubtful specimen of *Sigmodus dubius*, Waagen, which, in all probability does not come from the Magnesian sandstone at all: I was, however, lucky in discovering the *first fossils* which certainly prove the faunistic connection of the Jutana group with the older Khussak group.

When going up the Bhaganwalla ravine, I noticed that the surface of a thin band of hard limestone was covered with some fossils; unfortunately I could, only secure without blasting, a fairly-sized piece; this, however, was sufficient to prove that they represented a species of the genus *Stenotheca*. On my return, comparing

[1] See Wynne's memoir, page 88.

it with other species, I could not help noticing the great likeness with *Stenotheca rugosa, var. aspera, Billings.*[1] If my view is correct, this species would form a proof for the lower Cambrian age of the Magnesian sandstone.

Besides this form, I found in a thin bed of rather hard clay, resembling very much the dark shales of the Olenellus-zone, but being of light brown colour, about 50 feet above the base of the Magnesian sandstone, some brachiopods, in one of which I think I recognize a *Lingulella.* Another one resembles very much *Schizopholis rugosa, Waagen,* but I leave it to Professor Waagen to confirm these views or not. Anyhow it seems to me that the lower part of the Magnesian sandstone group at least must also be considered of lower Cambrian age.

As already pointed out, the changes in the composition of the rocks produce a natural division in this series; in descending order we may distinguish the following subdivisions, as coming in numerically over the five zones given in page 76 :—

X. UPPER MAGNESIAN SANDSTONE.—The same as the middle Magnesian sandstone, and forming like that a bold cliff : thickness 30 to 40 feet.

IX. UPPER PASSAGE BEDS.—Petrographically apparently the same as the lower passage beds, and like those forming a gentle slope : thickness about 15 to 20 feet.

VIII. MIDDLE MAGNESIAN SANDSTONE.—A series of thickly bedded grey dolomite forming bold inaccessible cliffs : thickness about 60 feet.

VII. LOWER PASSAGE BEDS.—A series of thinly bedded laminated sandy dolomite alternating with beds of greenish clay; the planes of the sandstone are sometimes micaceous and covered with tracks of annelids. Approximate thickness 20 to 25 feet. The outcrop generally forms a gentle slope.

VI. LOWER MAGNESIAN SANDSTONE.—This subdivision may again be divided into two parts; the lower one consisting of thinly bedded layers of dolomite or sandy dolomite, separated by thin layers of clay, and terminating in a bed of brown hard clay, which contains brachiopods, although not very frequently. In the lower parts pisolitic beds are frequently met with, and on the plane of one bed at least, *Stenotheca* sp. is pretty common. The upper portion consists chiefly of thickly bedded dolomite of grey colour. The lower part sometimes forms a sort of a slope, while the upper part stands out in a bold cliff. Approximate thickness 100 feet.

The above division can be recognized everywhere in the eastern part of the Salt Range, but it seems that already at Khewra the subdivision X, the upper Magnesian sandstone, has disappeared. Anyhow I could not trace it in section I, described in detail below. Now whether it really did not exist in that part, or whether it has been denuded afterwards is a question that must remain open for the present. As we know that the Magnesian sandstone gradually disappears towards the west, it is not quite improbable that the Upper Magnesian sandstone, as noticed near Bhaganwalla or Jutana, has already disappeared at Khewra. It would be highly interesting to follow the continuation of the Magnesian Sandstone west of Khewra, and to record in detail the changes that take place in its structure. I am fully convinced that this would result in some remarkable discoveries.

4. THE BHAGANWALLA GROUP OR SALT-CRYSTAL PSEUDOMORPH GROUP.

With reference to this group, I must refer the reader to Mr. Wynne's and Professor Waagen's papers, as I have not devoted much time to its study, but

[1] Charles D. Walcott. The fauna of the lower Cambrian or Olenellus zone. United Stetes Geological Survey, Tenth Annual Report, 1888-89, page 617, fig. 3.

several things seem to me beyond doubt. It is certainly most intimately connected with the Magnesian sandstone below, the flaggy layers can hardly be distinguished from the dolomite below. It is further certain that it dies out rapidly to the west and although still well developed at Khussak, it has nearly disappeared near Khewra. No fossils have yet been found in this group.

I may here mention that at Khussak the top beds of this group have been worked up in such a way by the boulder clay that boulders are kneaded into it, while flakes of the Bhaganwalla group have been taken up and imbedded in the boulder clay. No further instance is required for the striking unconformity above the Bhaganwalla group, which was first noticed by Mr. Oldham.[1]

III.—DETAILED SECTIONS.

Section I. In Khewra glen, just above the masonry wall damming up the valley, western branch, in descending order.

17. *Magnesian sandstone*, thickly bedded, standing out in a bold cliff, approximately 60 feet.
16. „ very shaly and thinly bedded, forms a sloping escarpment 20 feet
15. „ thickly bedded and shaly towards the base, about 100 feet, forms a conspicuous cliff.
14. *Dark blue hard shales*, micaceous, but not glauconitic; thinly bedded, to some extent concretionary; thickness about 15 feet. *Obolella* (?) sp. rare.
13. *Cream-coloured sandstone*, hard and flaggy in thin beds, 2 feet in thickness.
12. *Dark purple shales*, occasionally with green patches; brittle and lumpy, very sandy glauconitic only to a small degree; 15 feet in thickness. *Neobolus warthi* Waagen, very common.
11. *Light cream-coloured sandstone*, very glauconitic; formed by a series of harder beds alternating with softer layers, terminating in a well-defined bed of about 2¼ feet in thickness of very hard cream-coloured Magnesian sandstone. Total thickness about 20 feet.
10. *Dark purple shales*, lumpy and very brittle; very glauconitic; numerous tracks of *annelids*; 10 feet in thickness.
9. *Dark purple sandstone*, with lighter patches, micaceous and very glauconitic, 4 feet.
8. *Cream-coloured sandstone*, with purple patches, very glauconitic, 15 feet.
7. *Dark greyish-green sand*, with purple patches, 20 feet; the clayey beds getting thicker towards the top, where they alternate with irregular layers of cream-coloured sandstone, which become honeycombed or cellular where exposed.
6. *Greyish green sandy shales*, 15 feet, the same as No. 4, but dark purple patches occur frequently.
5. *Dirty green, coarse sand*, 2 feet 10 inches.
4. *Greyish-green sandy shales*, 12 feet 3 inches in thickness. The shale is thinly bedded, and consists chiefly of thin layers of brittle sandstone alternating with equally thin beds of clay. Numerous impressions of *Annelid*-marks on the sandstone.
3. *Light coloured conglomerate*, 2 feet in thickness.
2. *Greyish-green shale*, 2 inches in thickness, which is followed by,—
1. *Purple sandstone* in thick beds, approximately not less than 200 feet in thickness; the top layers gradually get lighter and eventually change into a cream-coloured coarse layer which terminates the purple sandstone.

[1] Records, Geological Survey of India, Vol. xix.

Owing to the inaccessibility of the cliffs, the upper part of the section could not be measured, and the thickness of the different strata is only given approximately.

The various beds, of which the above section consists, which form a bold cliff in the upper part of the Khewra glen, can be divided into three larger groups, representing in descending order—

C. Magnesian sandstone	approximately	180	feet	in thickness.
B. Neobolus shales	"	140	"	"
A. Purple sandstone	"	200	"	"

The above three members of the Cambrian formation of the Salt Range are so clearly visible from a long distance even, that they cannot possibly be mistaken, and although if examined closely, they gradually pass into each other, there is not the slightest doubt as to the actual boundaries.

It now remains to be seen whether we are able to trace well defined sub-divisions in the above section. As regards the purple sandstone or Khewra group, I did not try to sub-classify it, but as regards the Khussak and Jutana group (Neobolus shales and Magnesian sandstone), some exceedingly well defined sub-divisions can be marked out.

In the Jutana group we can distinguish three subdivisions, *viz.*, in descending order :—

VIII. Middle Magnesian sandstone hard and thickly bedded; thickness about 60 feet.

VII. Shaly intermediate layer, with numerous annelid-tracks, about 20 feet.

VI. Lower Magnesian sandstone, shaly and thinly bedded in the lower, thickly bedded in the upper part; forms a bold cliff. Thickness about 100 feet.

In the Khussak group we can distinguish five sub-divisions, which are well defined and which can be seen from a long distance, by either forming bold cliffs or gently sloping escarpments. In descending order, the subdivisions are as follows :—

V. Dark black shales ; zone of *Olenellus* sp. Thinly bedded and sub-concretionary; micaceous but not glauconitic. Forms a gently sloping terrace. Thickness about 15 feet.

IV. Dark purple shales, lumpy and brittle, zone of *Neobolus warthi, Waagen* ; thickness 15 feet, separated from No. 5 by a bed of cream-coloured sandstone (Nos. 12 and 13 of the above section).

III. Glauconitic sandstone. A series of more or less flaggy, hard cream-coloured, glauconitic sandstones, alternating with clayey layers. Thickness about 20 feet. No fossils except annelid marks.

II. Dark purple shales, lumpy and brittle, micaceous ; 10 feet ; no fossil remains except annelid-tracks; generally forms a gently sloping terrace. No. 10 of the above section.

I. Glauconitic sandstone, a series of cream-coloured sandstones which are slightly darker towards the base, alternating with softer sandy layers of generally darker colour. Thickness about 50 feet, excepting annelid-tracks, no organic remains. Includes in the above section the beds from No. 2 to 9 inclusive.

Section 2. In Khewra glen, just above the masonary wall damming the valley, eastern branch.

In the eastern branch of the Upper Khewra glen, the Jutana group can be studied a little more in detail, as owing to the northerly dip the strata composing this group were brought within reach. As the beds forming the Khussak group (Neobolus shales) are exactly the same as in the western branch of the glen, except that bed V (dark shales upper layer) is more like bed IV in its petrographical habitus, it is unnecessary to reiterate them again. The Jutana group consists of the following beds in descending order :—

5. *Cream-coloured hard dolomite*, in thick beds ; forms always bold cliffs.
4. *Thinly bedded, flaggy, cream-coloured dolomite*, with numerous tracks of annelids on the parting planes, separated by thin layers of greenish clay: generally forms a gently sloping terrace.
3. *Cream-coloured hard dolomite* in thick layers, separated by thin beds of greenish clay. No fossils. Thickness about 70 feet.
2. *Dark shale*, pretty hard, thinly bedded and sub-concretionary; contains *Linguella* sp.[1] in small numbers. Thickness 1 foot 6 inches. This bed forms such a distinct parting in the lower magnesian sandstone, that, notwithstanding its very small thickness, it can be seen from a long distance.
1. *Cream-coloured hard dolomite*, in thin flaggy layers separated by thin layers of greenish clay. Thickness 25 feet.

Section 3. At Khussak Fort Hill, Southern Slope.

The lower part of this section could not be studied in detail, owing to the steepness of the slope which rendered it inaccessible. Mr. Middlemiss' section V forms the top of this section ; in descending order :—

12. *Magnesian sandstone*, in thin beds.
11. *Dark, hard shale*, thinly bedded and sub-concretionary, with numerous specimens of *Obolella* (?) sp. and fragments of *Trilobites*. Thickness 3 feet 8 inch.
10. *a.* Dark grey, streaky, soft sandstone thinly bedded, thickness 1 foot 4 inch.
    b. Light grey, thinly laminated, micaceous sandstone, in which darker streaks alternate with lighter ones, 3 inches.
    c. Dark brown coloured, thinly laminated, micaceous sandstone, which gradually passes into the next bed ; thickness 3 inches.
9. *Dark shale*, thinly bedded, but hard and fissile; micaceous, contains fragments of *Olenellus* sp. and *Obolella* (?) sp. Thickness 2 feet 9 inch.
8. *Glauconitic shale*, ·6 inch.
7. *Glauconitic sandstone*, thinly laminated, ·4 inch.
6. *Glauconitic, soft sandstone*, alternating with layers of hard, cream-coloured sandstone. Thickness 4 feet.
5. *Glauconitic sandstone*, very hard, 0·4 inch.
4. *Dark purple shales* alternating with flaggy layers of cream-coloured sandstone. *Annelid*-marks very frequent. Thickness 5 feet.
3. *Dark purple shale*, with green patches, very micaceous, soft. Thickness 8 feet, *Neobolus warthi*, Waagen common.
2. *Cream-coloured sandstone*, alternating with irregular layers of purple clay, terminating in a bed of hard sandstone.
1. *Purple sandstone*.

In the above section, beds Nos. 3 and 4 represent No. IV in the subdivisional grouping of the Khussak group which here has about 13 feet thickness ; the sandstone parting between Nos. IV and V has 5 feet 2 inch in thickness, and then follows group No. V, the dark fossiliferous shales which have an aggregate thickness of 8 feet 3 inch, represented by the beds from No. 9 to No. 11.

Section 4. At Khussak Fort Hill, Northern Slope.

Although this section has been described in detail by Mr. Middlemiss, it will

[1] The determination of this form is doubtful. I refrain, however, from anticipating Dr. Waagen's views.

be useful to give it here in detail, so as to make comparison with other sections more easy. In descending order :—

11. *Magnesian sandstone.*
10. *Dark purple shale*, soft, lumpy and thinly bedded ; capped by a bed of cream-coloured sandstone. Thickness 10 feet.
9. *Cream-coloured sandstone*, firm in the middle, but shaly towards the basis, and alternating with clayey layers. Thickness 7 feet.
8. *Dark purple shale*, with green patches ; very glauconitic and micaceous ; contains numerous specimens of *Neobolus warthi* Waagen. Thickness 24 feet.
7. *a. Hard cream-coloured sandstone*, alternating with thin soft layers ; thickness 8 feet 6 inch.
   b. Dark sandy shale ; ill seen ; thickness 3 feet.
   c. A series of cream-coloured sandstone, alternating with thin clayey beds, terminating with a bed of hard cream-coloured glauconitic sandstone. Thickness 8 feet.
   d. Dark purple shale ; thickness 3 feet.
   e. Hard cream-coloured sandstone 4 feet.
6. *Dark purple and green shales*; contains *Hyolithes wynnei* Waagen, and fragments of Trilobites.
5. *a. Cream-coloured, flaggy sandstone*; thickness 3 feet.
   b. Dark purple and green shales ; thickness 2 feet.
   c. Thinly bedded cream-coloured sandstone ; thickness 3 feet.
   d. Lumpy, dark purple and green shale, 0·6 inch.
   e. Hard flaggy, cream-coloured sandstone ; thickness 7 feet.
   f. Dark soft shale, 1 foot.
   g. Cream-coloured glauconitic sandstone; thickness 3 feet.
4. *Dark purple shaly sandstone*, alternating with harder beds ; thickness 30 feet.
3. *Cream-coloured, glauconitic sandstone*, alternating with thin beds of greenish clay ; thickness 10 feet.
2. The same as before ; ill seen ; not measured.
1. *Purple sandstone.*

Comparing the details of Mr. Middlemiss' section, with that given above, it will be noticed that we differ sometimes, but I do not think this of great importance, because as soon as several of the beds are taken as a whole it will be seen that we fully agree as to the sequence of the strata.

In the above section ; Nos. 2 to 4 represent Mr. Middlemiss' series of "pale cream-coloured, thin-bedded sandy layers with shaly partings and irregular mottlings of hardened purple clay, glauconitic and micaceous." No. 5*a-f*, all the strata above this, but below his Lower Gallery B ; No. 6 represents the Lower Gallery B ; No. 7*a-e*, all the beds above that but below the "thin bedded purple sandy and micaceous shales"; No. 8 represents the "thin bedded purple sandy and micaceous shales" ; No. 9, the beds between this and the following stratum ; No. 10, the thin bedded purple shales, inclusive of passage beds.

With the greatest ease we recognise in this section the five subdivisions of the Khewra Section ; subdivision I, includes beds Nos. 2 and 3 ; subdivision II, bed No 4, subdivision III, beds 5 to 7, subdivision II, beds 8 and 9, subdivision V, bed No. 10. I need not go into details regarding Mr. Middlemiss' section, the five subdivisions will be easily recognised in his section, but still more so if his sketch of Khussak Fort Hill is looked at, where they will be distinguished at the first glance.

If we now compare the two sections of Khussak Fort Hill, it will be noticed that they materially differ in the development of subdivision V. We can easily identify subdivision IV and the band of cream-coloured sandstone which separates it from subdivision V, but the latter shows a totally different development. Mr. Middlemiss has not expressed himself quite clearly in which way his section V correlates with section IV, but if I interpret his section on plates 1 and 2 correctly, he thinks that the dark shales containing the rich fauna of Brachiopods and Trilobites are superimposed on the "thin bedded purple shales" above B_8, or in other words that they are not represented in his section IV. The examination of the Khussak group, as developed at Bhaganwalla and Khewra, has however proved that this view cannot be maintained, but that Mr. Middlemiss' beds C and C_1, the dark fissile shales, are only a facial development of the "thin bedded purple shales" with which they are correlative.

Section 4. At Bhaganwalla Ravine, Western Branch.

The wild gorge just above the village of Bhaganwalla, shows some beautiful sections through the strata from the Purple sandstone upwards; and hardly a better place could be selected for the study of the structure of the Salt Range, as some model flexures can be studied here in all their details. As however the sides of the ravine are either exceedingly steep or covered with debris from the Magnesian sandstone, it has not always been possible to give the exact thickness of each single bed, and in this regard the following section lacks in accuracy; however I think that this is not of very great importance, as in this paper I chiefly want to demonstrate the sequence of the strata composing the Cambrian formation of the Salt Range, in order to give a reliable stratigraphical basis for the description of the fossils. In descending order:—

13. *Dolomite* in thick beds.
12. *Dolomite*, flaggy, in thin layers which are very brittle.
11. *Dolomite*, thickly bedded. Thickness 150 feet.
10. *Greenish grey soft shale*, well defined; containing Brachiopods (*Lingulella ?* sp.) in small numbers. Thickness from 6 inch to 1 foot.
9. *Dolomitic sandstone*, in thin flaggy layers, some of which are pisolitic, in the beds near the base is a bed full of *Stenotheca* sp. Thickness 50 feet.
8. *Dark blue shale*, hard and sub-concretionary; contains the same fossils as No. 6, but in smaller numbers.
7. *Grey micaceous sandstone*, alternating with dark clayey streaks, 3 feet.
6. *Dark black shale*, hard and sub-concretionary; contains a large number of *Obolella* (?) sp. and *Olenellus* sp. Thickness 4 feet.
5. *Flaggy cream-coloured glauconitic sandstone*, alternating with thin beds of dark shale.
4. a. *Dark purple shales*, with green patches, soft and lumpy; contains numerous specimens of *Neobolus warthi* Waagen.
   b. Bed of hard cream-coloured sandstone.
   c. Dark purple shales, thinly bedded.
   d. Band of hard cream-coloured sandstone.
3. *Dark purple shales*, thinly bedded.
2. *A series of thin bedded hard flaggy cream-coloured sandstones*, alternating with beds of softer sandstone or clay.
1. *Purple sandstone.*

In the above sections the five subdivisions of the Khussak group are not so readily seen, owing probably to the incompleteness of the section directly above the purple sandstone; subdivisions Nos. V and IV can be recognized by the fossils; we know that bed No. 4 containing *Neobolus warthi* must represent subdivision

IV; then follows the separating bed of sandstone, while beds 6 to 8 represent group No. V; beds 3 *a-d.* must represent subdivisions II and III, while bed 2 represents the lower glauconitic sandstone. The chief interest remains in the fact that subdivision V is developed exactly in the same way as at Khussak Fort, on the right bank of the ravine, while just opposite on the left bank it shows exactly the same development as on the northern slope of Khussak Hill.

The Giridih (Karharbari) Coal-field, *with notes on the* labour and methods of working coal. *By* WALTER SAISE, D.Sc. (Lond.), F.G.S., A.R.S.M., Mem. Inst. Civ. Engineers, Manager, E. I. R. Collieries.

The Giridih (Karharbari) Coal-field.

As every one speaks of this coal-field as the Giridih Coal-field and of the mines as the Giridih Collieries, this name is suggested as a permanent title. Previous references to this field are:—

Dr. McLelland in 1850.
Dr. T. Oldham in 1852 and again in 1867.
Mr. David Smith report to Government of India in April 1857.
Mr. T. H. Hughes, Memoirs, Geological Survey of India, Vol. VII, 1871.
Dr. O. Feistmantel, Ser. XII, Vol. III, Palæontologia Indica, 1879.
Dr. Walter Saise, N. E. Inst. of M. and M. E., Vol. XXX of 1880.
Dr. O. Feistmantel, Ser. XII, 1 Suppl. Palæontologia, 1881.

The map and sections were made for the information of the Board of Directors, East Indian Railway Company, and they are placed at the disposal of the Geological Survey of India for general information and permanent record.

The field is in the hands of a few owners, but its general structure which has been thoroughly worked out, is interesting and should be a guide to explorers in other coal-fields where similar problems may be presented.

The field took its name from the Mouza Karharbari which occupies only a part of the coal area. It is situated in the Giridih Sub-Division of Hazaribagh and is connected with the East Indian Railway chord line by a branch from Madhupur to Giridih, 24 miles long. From Giridih station several branch lines serve the companies occupied in mining.

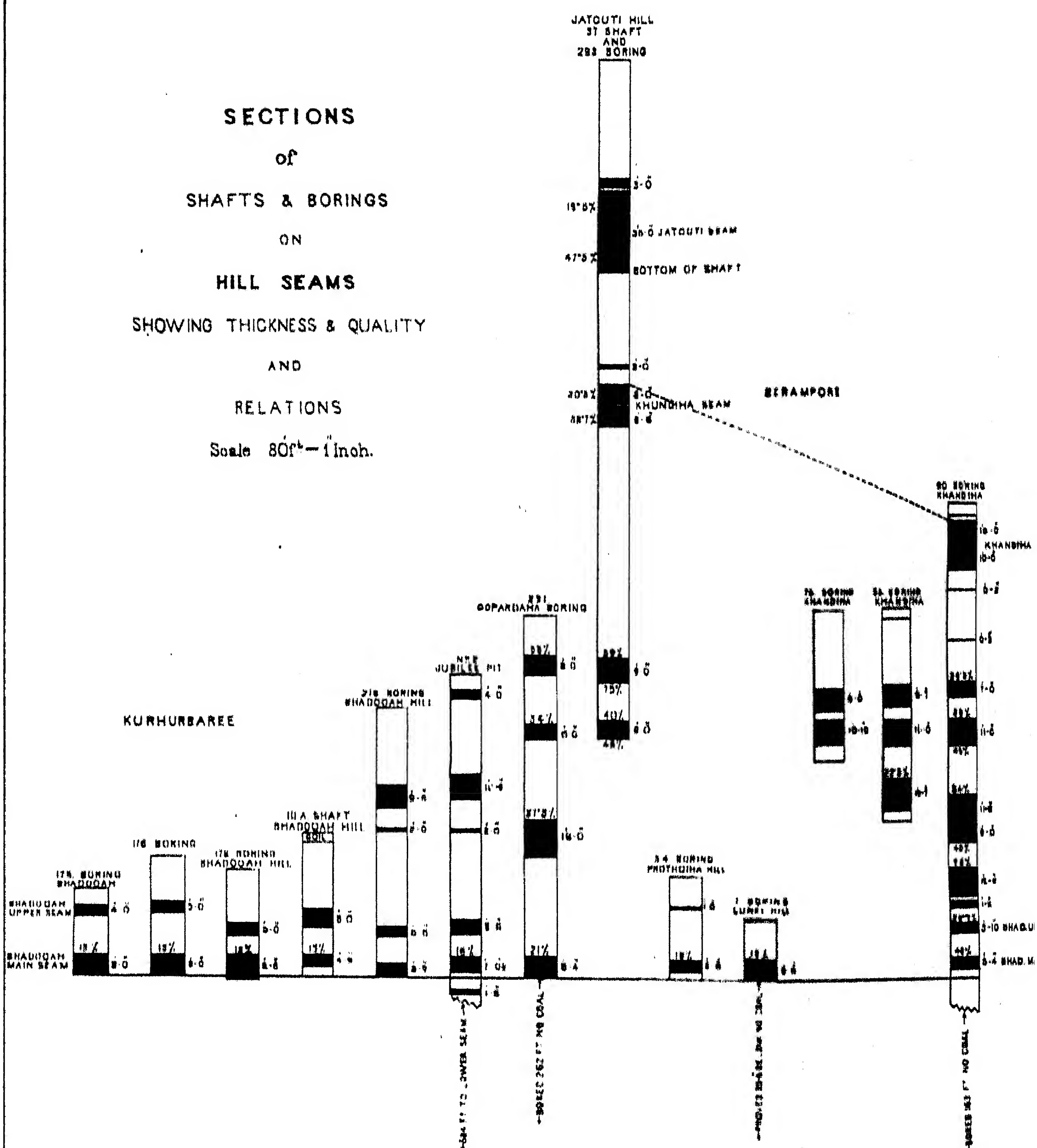
1.	Branch line to	Karharbari	Colliery,	E. I. R.
2.	Ditto	Serampur	ditto	ditto.
3.	Ditto	Kuldiha	ditto	Bengal Coal Co.
4.	Ditto	Karharbari	ditto	Raniganj Coal Association.

All of these are shown on the plan.

The coal-field has an area of 11 square miles, of which 3⅓ square miles are of the Talchir group, or unproductive measures, and 7 square miles are of the Barakar group, the balance is the area of the two inliers of Metamorphic rocks. The Barakar series contains the lower seam over its whole extent.

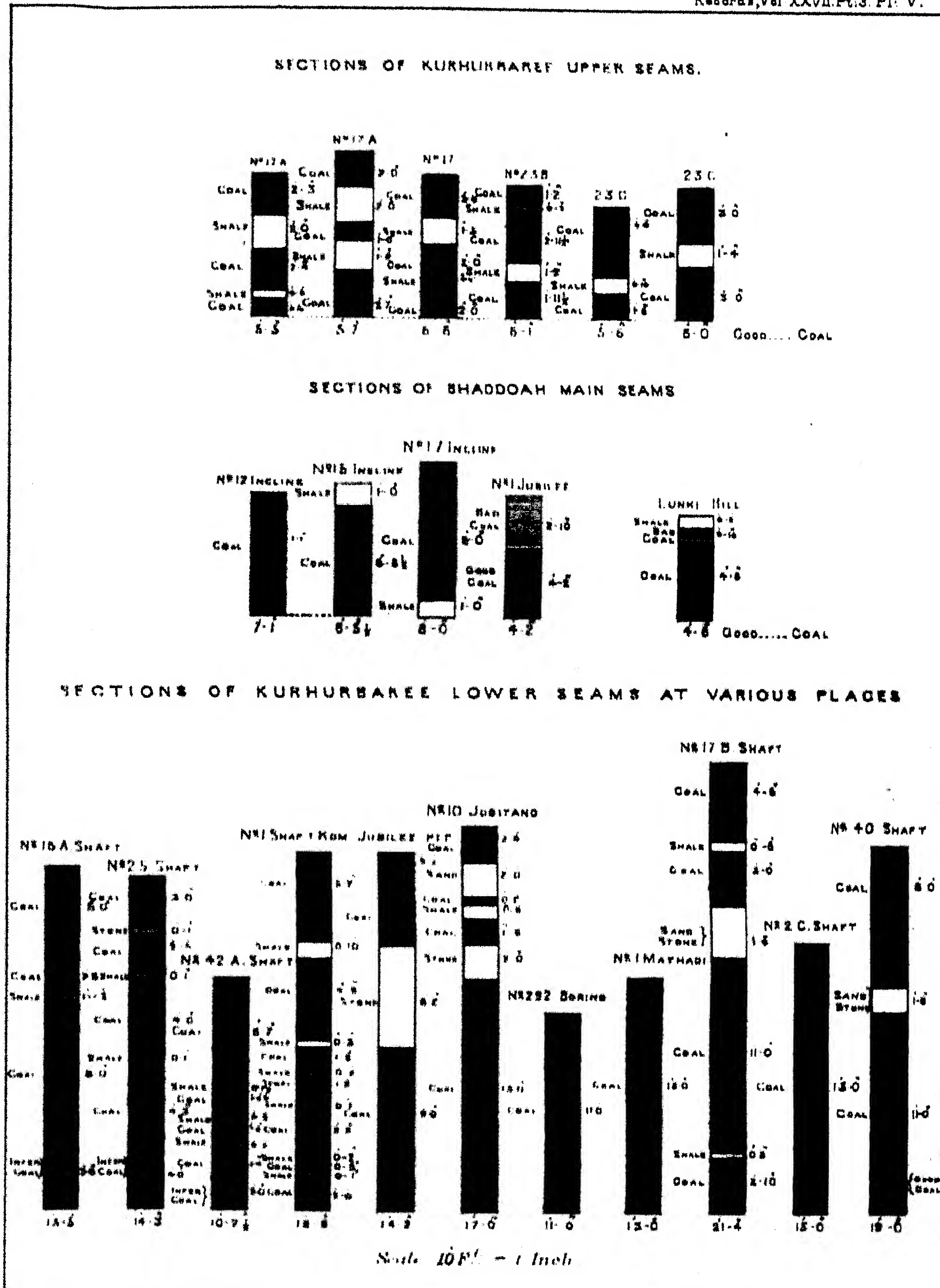
SECTIONS of SHAFTS & BORINGS ON HILL SEAMS SHOWING THICKNESS & QUALITY AND RELATIONS

Scale 80ft — 1 Inch.



Dr Saise.

Records, Vol XXVII. Pt. 3. Pl. V.



Lithographed & Printed at Geological Survey Office

Dr. Saise. Records, Vol. XXVII. Pt. 3. Pl. VI.

fig. 1.

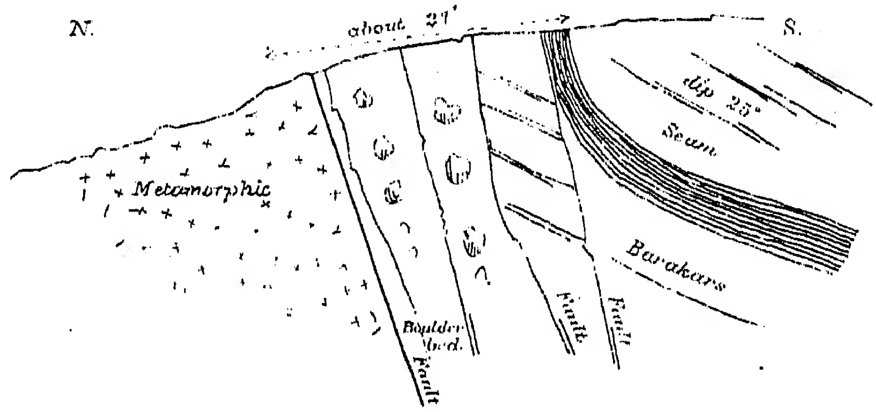


fig. 2.

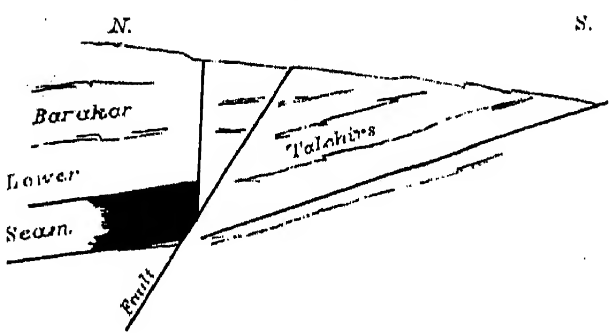


fig. 3.

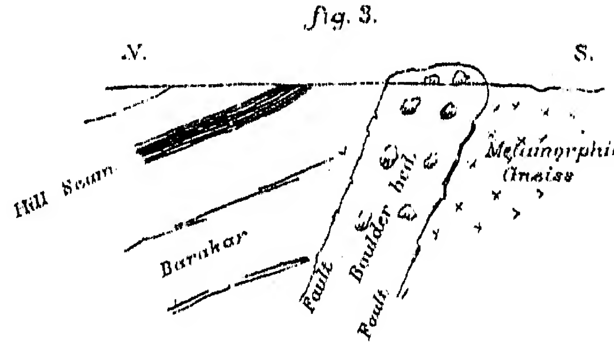


fig. 4.

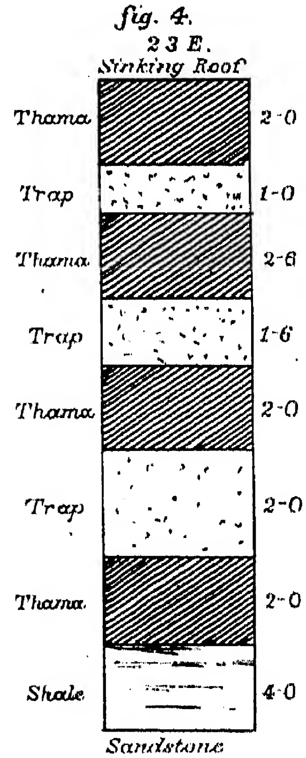


fig. 5.

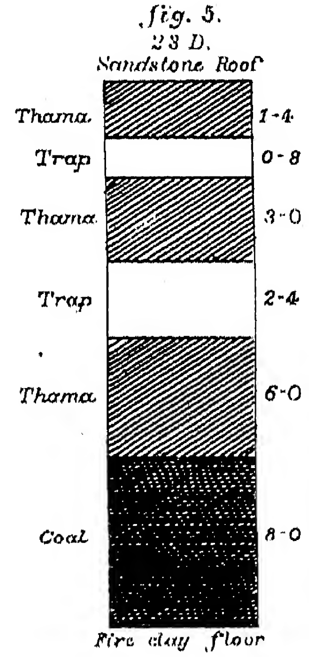


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fig. 1.

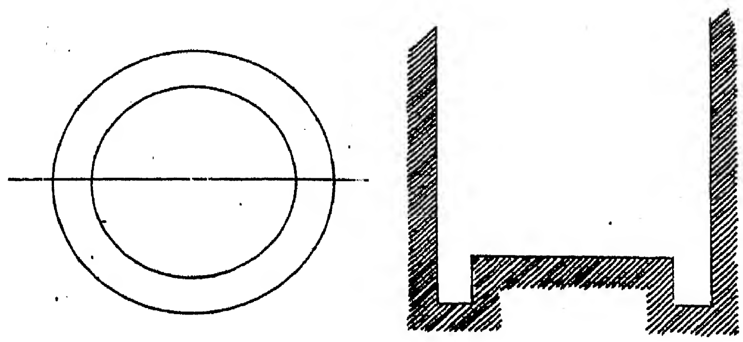


fig. 4.

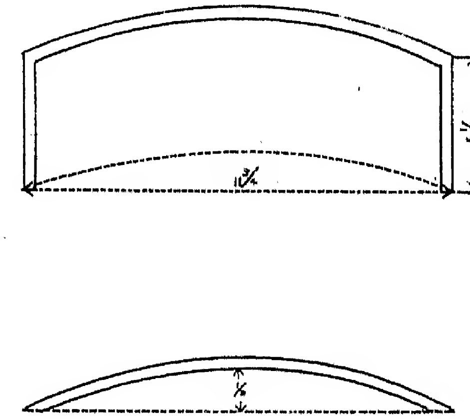
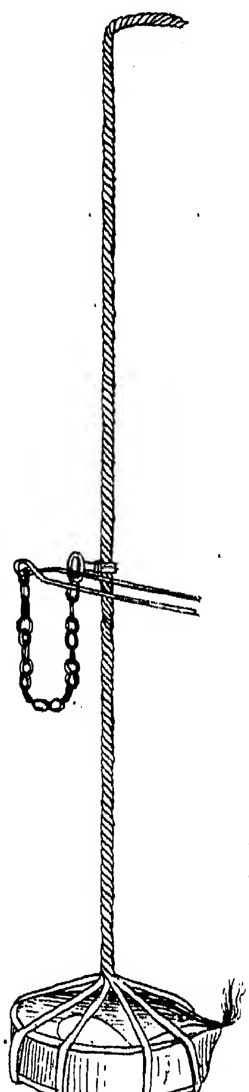


fig. 5
CHERAGH USED WITH CASTOR OIL



QUARTER SIZE

fig. 2
UNIVERSAL PICK

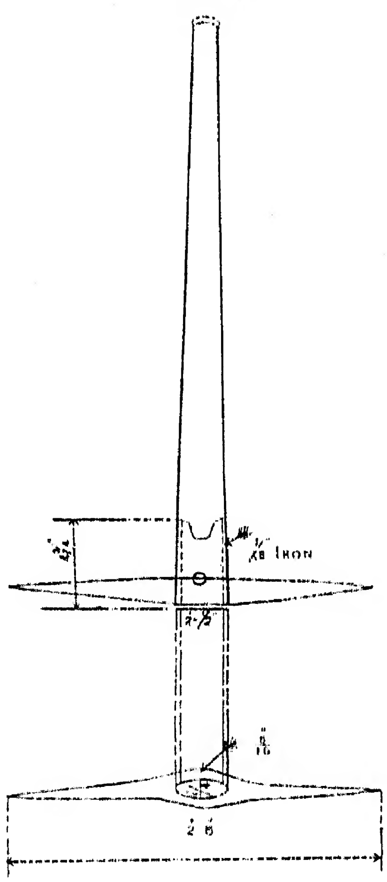


fig. 3.
MINER'S PICK

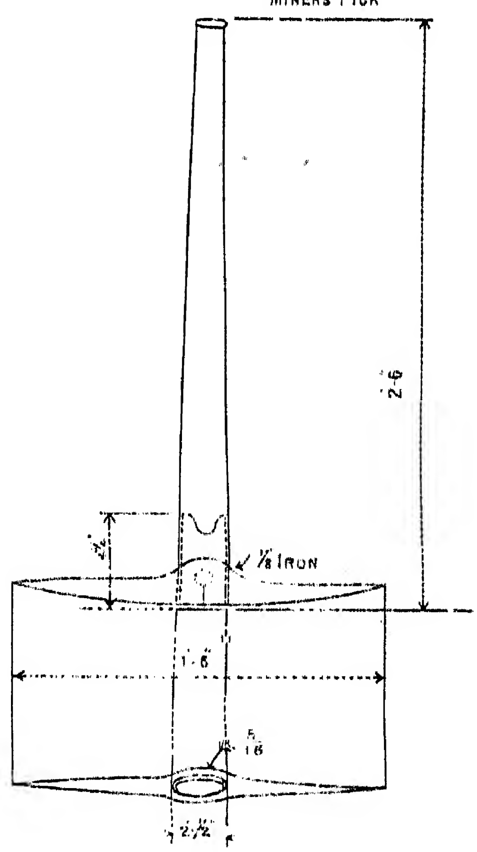
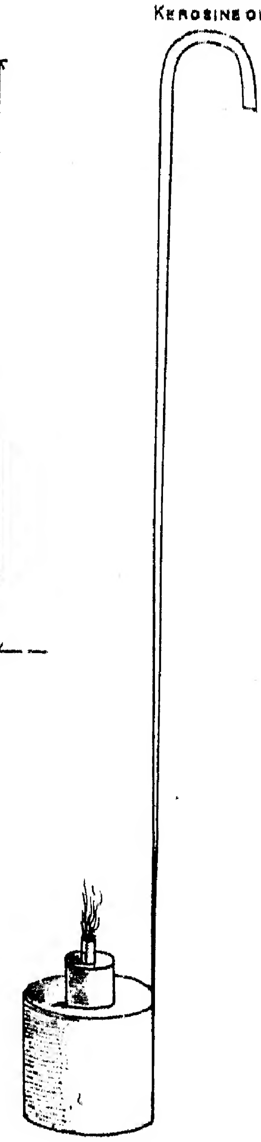


fig. 6.
DEBIA OF TIN FOR KEROSINE OIL



QUARTER SIZE

Lithographed & Printed at Geological Survey Office.

A glance at the surface maps, Plates I and II, and the cross sections (Plate III accompanying this report) will shew that the field is contained between two or more parallel or nearly parallel faults which trend W. N. W. and E. S. E. On the east of the field there is a natural boundary as determined by working and borings of the Raniganj Coal Association. West, at Bayra, at Mathadih and Jogitand there are small extents of natural or unfaulted boundary. In the main, however, the boundary is faulted. Starting at Bayra we find the fault running eastwards and throwing the Karharbari lower seam down to a depth of 450 to 500 feet. The fault is accompanied by intrusions of trap which have seriously affected the seam for some distance from the fault. Towards Giridih the boundary, for a time faulted, and then natural, turns through Mowlichua and Kuldiha and then bends suddenly to the east and runs towards Dandidih. From Kuldiha to Dandidih the boundary is faulted, the lower seam being about 200 feet in depth (*see* Sketch Section Plate II).

In the Geological Memoir on the Karharbari Coal-field this ground is called barren; *see* page 35 of Karharbari Coal-field, Vol. VII, Art. IV.

Here and there on the surface, patches of Talchirs (not shewn in the plan on account of the scale) exist. A good example is seen in an incline made by the Bengal Coal Company into a seam of coal (*see* plan II at N). The excavation exposes the metamorphic talchirs and coal seam all faulted as in sketch (Pl. VI, fig. 1). At Dandidih the boundary turns back and a curiously complicated bit of faulting is seen for some distance. At P an example of faulted boundary is well seen in Baboo's inclines. This incline is opened in Talchir shales and exposes the seam, as in sketch, fig. 2, faulted down to the north.

A large portion of the eastern boundary is apparently natural until we reach the southern fault at Choonka. Passing to the west along this fault we find two patches of the lower seam, *viz.*, at Choonka and Domahani exposed to-day. Along the rest of distance the lower seam lies at depths varying from 200 feet to 1,000 feet.

The thick seams cropping out at Khundida, Kope, Jatcoti, Lopsadih and Oopardaha Ghâts are not representatives of the lower seam as mentioned in page 33 of the Geological Memoirs on the Karharbari field, but belong to the highest beds of the coal-field.

Along the southern boundary, as along that on the north from Kuldiha and Dandidih, there are small patches of Talchirs brought up by the fault. At Oopardaha is a good section in the Khakoo Nuddi.

A ridge of the boulder bed crosses the stream and separates the metamorphics from the Barakars as in sketch Pl. VII, fig. 3. On to the west the lower seam re-appears at Satighat not quite naturally, but with Talchirs underlying it. From thence to Ramnuddi and Dhobidih going eastward the boundary is concealed by a fault. At Ramnuddi it is natural for a short distance and then faulted. The fault forming the boundary there (from Ramnuddi through Moheslundih to Jogitand) continues past the escarpment of the hills Bhadduah and Lunki and appears to run into the faults which define the eastern boundary at Dandidih and Buriadih. The boundary turns from Jogitand where it is natural across Mathadih (faulted) to Bayra where it is natural and joins the northern fault at the starting point of this description.

COAL SEAMS.

The seams of coal, of which there are many, see Plate VI, may be grouped thus :—

1. Hill seams.
2. Karharbari seams.

The first group to claim attention comprises the Hill seams so-called, because they were first noticed, and worked in the Bhaddoah and Lunki Hills which form a distinctive physical feature of the coal-field. It must not be supposed that because they are called Hill seams they do not occur elsewhere. They sink into the plains on the south and the lowest of them is at Khundiha, 200 feet in depth. There are four distinct areas in which these seams occur, and they can be seen in the skeleton plan, Pl. II, prepared to shew the structure of the field without the topography which obscures the details. From east to west they are :—

On the east—

1. Khundiha, Kope, Pruthdee hill, Lunki hill, about 400 acres.

In the centre of field—

2. Bhadooah and Agdonih and Baniadih, about 230 acres.
3. Keri hill.

On the west—

4. Jatcoti hill and Oopardaha and Lopsadih Ghâts, about 283 acres.

Pl. III shews the sections of strata in these areas and the coal seams that occur.

These are many in number and great in thickness, though in the borings where proved are not all good. The ash varies from 13 per cent. to 55 per cent. The amount of ash is given in that section. The two Bhaddoah seams, which lie at the base of these seams, have long been known, and the lower or Bhaddoah main seam has been extensively worked by the Bengal Coal Company and East Indian Railway. For many years 50,000 to 60,000 tons were raised from this seam. The coal is easy working and the roof good. Cropping out in the hill sides, the mines were easy of access for new and inexperienced labour ; and many hundred of the coal-cutters were trained in this seam. The Bhaddoah seams occupy the whole of the areas shewn, the overlying thicker seams only occupy a portion on the south. The sections in Pl. III shew that at Khundiha there is a total thickness of 80 feet in these seams. At Agdonih 33 feet and at Jatcoti hill 96 feet. It is probable that some good coal will be found in such a thickness. The smallest and largest amount of ash in each seam is figured in Pl. III. The relations of the Hill seams to the underlying Karharbari seams, and the way they crop out in the hills and sink to the south under the plains are exemplified in the sheet of sections across the coal-field.—*Vide* Pl. I. These sections are drawn to a small scale, so the Pl. II is drawn to 100 feet=1 inch to give detailed sections of strata on the lines of Section A.B. C.D. E.F., and G.H.

Below the Hill seams come what I have called the Karharbari seams, *viz.*, the upper and lower seams. The lower seam exists in workable thickness over the whole of the coal-field, but the upper seam is only found workable on the north of the anticlinal at Bhandaridih, Chaitadih, and Mowlichooah. The lower seam extends over the whole of the Barakars which cover a space of 7 square miles. It is uniformly good, specimens from Sati Ghât, Ramnuddi Mathadi, Jubilee Pit (600 feet deep), 16A on the east and from 23D on the north being of the same quality. The coal is softer in some places than others, and where the seam thickens as it does towards the east up to as much as 30 feet in thickness, the lower part of the seam is poor. There is, however, seldom less than 12 feet of excellent coal,—the finest steam coal in India. The general section of the field, Pl. IV, shews many seams below the Hill seams; they are 4 feet thick and less, and it is not to be expected that they will receive much attention until the lower seam becomes scarce. They are useful as guides in boring and sinking.

It will be seen that the three greatest depths to the lower seam are at or about boring 90 where main seam is probably about 800 feet deep.

	Feet.
At Jubilee Pit, No. 1	700
Jatcoti Hill, No. 37 shaft	980
Oopardaha Ghât, No. 291 boring . . .	736

The topography and features of the field are not here described, as there is nothing to add to former memoirs. For the same reason a detailed description of the various beds of the Talchirs and Barakars is omitted.

TERMINOLOGY; TALCHIR—BARAKARS PREFERRED TO TALCHIR—KARHARBARI BEDS.

It will be observed from the surface map that all the rocks below the Karharbari lower seam are classified as Talchirs and all above as Barakars. This is a return to the classification of Mr. Theo. H. Hughes in his Memoir published in Vol. VII of the Memoirs of the Geological Survey.

The proposal made by Dr. Feistmantel in 1879 and 1881 to consider part of the coal-bearing strata as more allied to the Talchirs than the Barakars, and to call them Talchir-Karharbari beds appears to have been made on insufficient grounds. The chief grounds were the rarity of *Vertebraria indica* (though later they were found to be present numerously in the lower seam) and the presence of large numbers of *Gangamopteris* in the Karharbari upper and lower seams (1, 2, 3 of Geological Survey).

It should be noted that the Hill seams (No. 4) were left to the Barakar subdivision, although *Gangamopteris* is found—it is said rarely. Apart from the fact that the Karharbari upper and lower seams being of fine quality were opened out in many localities and extensively worked, these seams contain shale which preserve fossil plants. There was therefore every likelihood of finding an abundant flora.

The Hill seams have been less worked and the strong sandstone roof rarely preserves fossils. The shales, too, when present are micaceous and fossil imprints are indistinct. Further, these seams have not been worked, except the Bhaddoah seam, and fossils were for the above reasons few and far between. The fact that *Gangamopteris* has been recognised in the Hill seams (No. 4 burnt, see Vol. III of Geological Survey, Palæontologia Indica) and that *Vertebraria indica* is numerous in the lower seam points to a connection between them.

Since the above proposal was made a shaft has been sunk through the Hill seams down to the lower seam, and the sandstones, 600 feet thick, shew no alteration from top to bottom. There is certainly no reason on physical grounds for taking any point in the 600 feet of strata and classifying the rocks above as Barakars and those below as Talchir-Karharbari beds. The lower seam forms, however, a division between two very dissimilar series of rocks, *viz.*, those lying above it and those lying below. The sandstones, and they predominate, are all alike above the lower seam and are different to those lying below in colour, grain and texture. The evidence of the mineral character of the strata is strongly in favour of grouping all the coal-bearing strata together, and the palæontological evidence is too weak to upset this view. The strata from the top of the Hill seams down to the lower seam are all known. They are chiefly sandstones, all of the same character and contain few beds of shale and other rock. Below the lower seam, at the Mathadih end of the field, there are peculiar greenish, yellowish loose sandstones, altogether unlike the sandstones overlying the lower seam. At the Serampore end of the field the lower seam rests on the blue Talchir shales.

Besides the inadequacy of the evidence for including some of the coal seams with the Talchirs, it is also a great convenience to have some solid land mark like the lower seam as the boundary between the two series—one altogether without coal and rich in shales, and the other rich in coal and poor in shales. For these reasons the lower seam and its rock floor are taken as the lowest beds of the Barakars, all below being considered Talchirs. In this coal-field there are no examples of overlap of Talchirs by the Barakars, indicating unconformability Sandstones thin out and disappear in a few hundred feet and re-appear in as many. For example, the thickness of sandstone between the Karharbari lower and upper seams and Serampore near 16 A shaft of the East Indian Railway is over 400 feet. At 40 shaft Karharbari Colliery it is 150 feet. Similarly, the 9 feet of sandstone separating the two divisions of the lower seam at 16 A sinking dies out in less than 300 feet. The disappearance of the Talchir sandstone in places is parallel to the above examples and indicates only a want of material at the period of deposition at that particular point and does not mean unconformity and all that such a term implies.

The Talchirs exist all over the coal-field. Of this there can be no doubt, as wherever the lower seam comes to-day, the Talchirs are found, and all round the boundary, as described above, the boundary faults have brought up patches of the Talchirs. The total thickness of the whole of Talchirs, where best developed at the Sookmed nuddi, east of Buxidih, cannot be more than 300 feet. The greatest thickness of Boulder bed is 22 feet, and yet we meet these beds all over the field. This is a proof that there was no period of erosion between Talchirs and Barakars in this field. The difference between the conditions of deposition of the beds of Talchirs and Barakars is, however, great and the different facies of the two groups justify their separation.

Faults and Dykes.

Faults are numerous and are sometimes of great throw in the coal-field. They run more or less parallel to the boundaries of the field. They die out rapidly and increase in throw rapidly. The same fault sometimes dips to the north and a short distance away it turns to south. Faults occur in the lower seam that do not exist in the upper; and the throw of a fault in the lower seam is greater than in the upper seam. This indicates that faulting takes place along old lines of fracture. No cases of reverse faulting have been observed in this field. All the faults can be read by the usual rule that the dip or hade of the fault shows the direction of dislocation.

Dikes are not shown on the map, partly because they are laid down in the map in Vol. VII of Memoir, and because they would crowd the plan with too many details. The existence of dykes on the surface does not indicate the extent to which the seams are damaged which they traverse. A dyke that crosses the seam vertically on its way upwards damages only a few feet. As a rule, the greatest damage is done when the trap intrudes into the seam coking and charring thousands of tons of coal and yet never showing on the surface of the ground.

Two examples are here given from the lower seam (Pl. VI, figs. 4, 5):—

23 E. Sinking.		23 D	
	Roof.		Sandstone roof.
Jhama	2-0	Jhama	1-4
Trap	1-0	Trap	8
Jhama	2-6	Jhama	3-0
Trap	1-6	Trap	2-4
Jhama	2-0	Jhama	6-0
Trap	2-0	Coal	8-0
Jhama	2-0		
Shale	4-0	Fire-clay floor.	
Sandstone	...		

Jhama is the native term for coked or charred coal. It is interesting to note that natives have got to understand the relations of dyke matter to the burnt coal.

The traps in the above examples are mica peridotites.

There appear to be two or three kinds of trap in the field and a bed just under the Khundiha seam that looks like tuffa. As Mr. T. H. Holland of the Geological Survey has this matter in hand, no more is said here on the subject. An interesting chapter will doubtless be the result of his investigations.

One point seems worthy of attention, and that is the probability that the faulting that formed the field contributed at great depths to the production of the trap. An interesting example of a boulder brought up in a trap dyke right through the Talchirs into the Karharbari lower seam was found in 23 B shaft. The boulder was about 3 feet in diameter and was from the metamorphic rocks underlying the coal-field.

Economic Summary.

The main source of mineral wealth of the field is the lower seam which is of uniformly good quality and considerable thickness. The quantity of ash in the coal varies from 3·5 per cent. to 12 per cent., but the average composition may be taken as under:—

Fixed carbon	66·84
Volatile matter	24·42
Ash	9·15
Specific gravity	1·35

The coal cokes easily, both in open kilns and in closed ovens, both of which are at work in the coal-field. The outturn of coke is not inconsiderable and probably amounts to 30,000 tons per year, which quantity finds a ready sale and is used largely on the East Indian Railway. The foundry coke made from this seam is very dense and will not float in water. The excellent steaming power of the coal may be seen from the results of its use by the East Indian Railway Company. The high speed of the mail service by the chord line shews that the fuel is good.

The area occupied by the lower seam is 7 square miles or 4,485 acres exactly. The average thickness of this seam is 15 feet 4 inches (see Plate V). The quantity of coal in this seam is therefore 112,836,712 tons.

The upper seam is also a coal of excellent quality but of limited extent. It will be seen in the shaft and boring sections that except on the north of the anticlinal in the area drained by 23D shaft of the East Indian Railway Company, it is so thin as not to attract attention. The composition of this coal is as under:—

Fixed carbon	60·46
Volatile matter	28·11
Ash	11·96
Specific gravity	1·33

This seam is worked over an area of 150 acres. In Plate V, it will be seen that the average thickness is 6 feet. This means a tonnage of 1,452,600 tons. The seam will be exhausted in about five years' time.

The Bhaddoah main seam, formerly extensively worked, is now left unworked.

The following are two analyses of the seam where it was largely worked:—

Fixed carbon	61·03	61·45
Volatile matter	25·37	20·46
Sulphur	0·80	...
Ash	13·60	18·08
The specific gravity is	...	1·40

This seam is not so persistent in quality as the Karharbari upper and lower seams. It extends over 913 acres but we may take only 400 acres to allow for variations in quality. The average thickness is 6 feet (*vide* Plate V). This means a tonnage of 4,083,840 tons.

Of the rest of the hill seams it is difficult to form a conclusion. The total average thickness, excluding Bhaddoah main seam, is 66 feet, and this over an area of 200 acres, which is probably the total area covered by these thick seams, there would be 22,461,120 tons. As much of this is bad, it would not be wise to take all this into account in computing the available coal in the field. Much of it, however, contains 20 per cent. to 25 per cent. of ash only, and this can be worked and sold especially in times of heavy demands. The coal can be cheaply worked and sold cheap. It is proposed therefore to consider that a quarter of this amount is available or 5,615,250 tons.

Summing up, we have coal in—

	Tons.
Lower seam	112,836,712
Upper seam	1,412,600
Bhaddoah main seam	4,083,840
Other Hill seams	5,615,250
	123,988,402

For faults, trap, intrusions, and loss in working allow 25 per cent		30,997,100
		92,991,302
	Tons.	
Already raised from 1857 to December 1893	9,358,000	
Probably lost in working	1,000,000	
		10,358,000
		82,633,302

The present output from this field is about 600,000 tons per annum. At this rate the life of the field may be taken at 138 years.

Amount of coal owned by East Indian Railway Company. The East Indian Railway Company own 3,341 acres of the Barakar series and the quantity of coal in the lower seam and upper seam is—

	Tons.
Lower seam	84,055,064
Upper seam	1,452,600
TOTAL	85,507,664
Less 25 per cent. for faults, traps, dykes and loss in working	21,376,916
NET	64,130,748
Deduct—already worked	5,858,000
	58,272,748

which, at an output of 400,000 tons per annum, means a life of 145 years. The lower and upper seams only are taken into account as the hill seams will not work to the high standard required by the Locomotive Department of that Railway.

In 1861, in his paper on the Ranigunj coal-field, Mr. W. T. Blanford describes the method of mining in that field. This may be taken as typical of the system in vogue in India at that time; so it may be as well to describe the methods in use in the year 1894 in the Karharbari Coal-field. It will show that in 33 years considerable advance has been made in mining methods and appliances.

Owners. The field is owned by the East Indian Railway Company, the Bengal Coal Company, the Ranigunj Coal Association, the Equitable Coal Company, and a few native owners.

Collieries. There are no open workings and very few shallow ones. Inclines are still used to let the men walk to their work even when the working places are 500 feet deep from surface. The miner and his wife like the comparative freedom that follows from this mode of ingress and egress as compared with shafts when people can only be raised when coal winding ceases. Efforts are therefore made to preserve these incline roads, as it is a matter of importance to please the miners.

Pits or shafts. These vary in depth from 80 feet to 650 feet and are of varying sizes from 10 feet to 14 feet diameter. In the East Indian Railway collieries the favourite shape is elliptical and the sizes are 15 × 13 and 13 × 11. The number of shafts in the field is large, but sinking is not expensive and the shaft never requires lining except near the surface or in a faulted stretch of ground. The faulted nature of the field has also increased the number of shafts, as Indian stone-cutters are first-rate sinkers but slow drifters, and it is a quicker job to sink a pit than to cut a fault in cases where coal is shallow. Shafts are sunk by natives who have learnt to use dynamite and electric firing; the average rate of sinking has risen to about 15 to 30 feet a week.

Methods of drawing coal.

Coal is drawn out of shafts in cages in iron and wooden tubs holding from 8 cwt. to 12 cwt. each. Nearly all shafts are fitted with guides of rope or rails or wood, and handsome pit-heads of lattice iron work or teak wood have taken the place of the gin pillars of 20 years ago. Winding engines vary from direct acting (Bengal Coal Company) to second motion engines, and no gins are now at work in the field for raising coal. There are still a comparatively large number of shafts at which small quantities of coal are raised, but the increasing depth of new winnings will lead in a few years to concentration of output to fewer shafts; and machinery capable of pulling out 400 to 500 tons per day will be required.

Coal is also hauled out by hauling-engines, the roads being of 1′ 9″ gauge and number of tubs hauled in a journey 6 to 8.

Draining.

Is done by powerful pumps—15″ plunger sets—12″ lifting and 9″ lifting and Tangye's specials. The East Indian Railway Company has a pumping engine, by Hathorn Davey, that raises 1,200 gallons per minute from a depth of 420 feet.

Carriage of coal.

The broad guage (5′ 6″) line is carried into each of the three Companies' collieries to a convenient spot—where coal is loaded into main line wagons. Metre gauge and smaller lines are in use for conveying coal to these wharves.

Gas.

The mines are free from gas. One or two explosions have occurred, but as kerosine oil was used in the places, it is not conclusive that the explosion was due to fire damp and not to kerosine oil.

Ventilation.

Ventilation is good, the number of shafts making it easy to create and maintain air currents. There are many furnaces in the coal-field for ventilating purposes.

Temperature.

The mines are pleasant, the average temperature being about 80° F., but as the temperature in the shade on the surface rises to 112° F. in the hot weather, this is not excessive.

Sending coal underground.

Underground the coal is loaded into tubs by women and lads, and the tubs are in cases pushed by the same persons to the shaft or else led by horses. Self-acting inclines for rise coal and hauling engines for dip are in common use. The guages of underground tramways vary from 1′ 9″ to 2′ 0″ and the rails from 15 to 19 ℔ per yard. The underground tubs are of iron or steel, or wood with steel wheels 9″ or 12″ diameter.

SYSTEMS OF WORK.

The general system in use is the pillar and stall. The pillars are of varying size, from 12 feet square, in thin seams with strong coal and strong roof, to 100 feet square in the thick seam with soft coal and strong roof. The galleries are usually

10 feet or 12 feet in width. In the thick coal only the upper 7 feet is worked first, the bottom coal being left to strengthen the pillars. The tramways are all laid on the bottom coal and this leads to the inconvenience that when the bottom of the seam is cut up, the coal has to be carried up to the tram line. The pillars are worked out and the following is a description of the methods adopted to suit varying sizes of pillars and qualities of coal and roof.

Taking thin seams first. The coal has been divided into pillars of from 12 to 20 feet square in a seam 6 feet to 10 feet thick, the coal being strong and the roof good. The galleries vary from 12 to 15 feet in width and were cut without any special trouble; and the roof being good, accidents were very unfrequent. In taking the pillars out the system has been to set chocks 10 feet square (of dressed timber) as in sketch (*vide* Plate VII, fig. 6). The row of pillars, three or four only, are then rubbed off until a small stump of 4 feet square is left. The chocks are then taken out. These stumps are valuable indicators of weight, as their cracking foretells a fall, and as the roof is very solid, the fall is always heavy, and violent air-blasts occasionally cause accidents. When the indicators give notice (*boli-deta*, as natives say), the work is stopped on the next row of pillars until the roof is safely in.

In thin seams.

In some mines, the section is as under. (See Plate VII, figs. 7, 8.)

The 10 feet seam has been cut up into pillars and when they are taken out the object is to get the 2 feet 6 inches of coal overlying it—this being a solid bed, two pillars are taken out in one operation. The band of stone, 2 feet to 3 feet thick, between the coal seams is jointed, and all the cleats in the coal run through it.

The two pillars are cut out until there are two stumps, 6 feet square each, and the place is timbered with props 3 feet apart and with several 10 feet square chocks, when the stumps are reduced to 6 feet, square holes are bored in them and charged with dynamite and prepared fuses and detonators, and cotton-wick, soaked in kerosine, fastened on the fuses. The timber is then drawn by two Europeans, the cotton-wick is lighted by torches at end of long bamboos and the stumps blown out. The band of stone and roof coal fall. The main roof being thus newly exposed, is generally good, and after careful sounding it is generally found possible to load up all the fallen coal without timbering.

The above system is also applied to the upper seam when it has the section shewn in Pl. VII, Fig. 9. The 4 feet is sub-divided into pillars and the top coal is dropped in the goaf and loaded out.

When the main roof has fallen, a row of pillars or a rib 10 ft. thick of the roof is left to take the broken edge and a new face started as in fig. 10, Pl. VII.

In the following section (Figs. 11, 12, Pl. VII) the coal has been divided into pillars in each seam from 20 feet to 40 feet square by roads, from 10 feet to 12 feet in width. The pillars in the upper division are exactly over those in the lower division. The roads were first driven in the upper division and boreholes put through at the junctions of the roads as a guide to the coal-cutters in the bed below. These holes are used as guides in setting cogs or chocks when pillars are to be taken out, so that each cog in upper bed is directly over one in the lower.

In thick seams.

The places are well timbered in each seam and then the pillars, one or two at a time, are reduced to 6 feet square. The timber is then drawn in each bed commencing in the upper bed. One row of props is drawn in upper bed and then one in the lower, until all the timber that can be safely got is taken out. The roof soon follows the timber drawing and the 6 feet square stumps left give early notice of a weight.

As many as three divisions have been worked this way. It was found on trial that the coal could not be gotten in the goaf, as described in previous case—roof followed too quickly, so the whole of the sub-divisions were worked into pillars, pared down, and the stumps *d* blown out and remainder of coal falls.

In the thick seams, varying from 12 feet to 22 feet of coal without partings and with a solid sandstone roof 30 feet thick up to next parting, the following system has been in use.

The seam is divided into pillars in the upper part of the seam, the floor being left solid so as not to weaken the pillars. The pillars are from 30 feet to 100 feet square. When the time comes to take out the pillars, a row of five or six, either diagonally or in a line, is taken and the bottom coal is cut up all round each of them.

If the coal is strong, they are undergone in the lowest part as in sketch (Fig. 16, Pl. VII). A road or jenkin is driven through the pillar towards the goaf. The half pillar next the goaf is undercut and timbered with props, except two knobs B and B, 4 or 5 feet square. The timber is then drawn and these knobs blown out and the top coal dropped and loaded up. The remaining half of the pillar is got by widening out the jenkin as at C, timbering with 5 feet props 3 feet apart.

Where the pillars are crushed and old the pillars are taken out in a line. The bottom coal is cut along Gallery A.B. C.D. and A.H., B.G., C.F., and D.E. Slices are then taken off the pillars as in sketch (Figs. 13, 14, Pl. VII), commencing at the top of pillar until all is removed. Chocks of 10 feet squared timber and roller (round props 7 inch diameter) are put up where needed.

Sometimes, in fact, always, until the main roof starts to work, the whole of the coal can be taken out. After a heavy fall of main roof a row of pillars or half pillars is left against the broken edge as in sketch (Fig. 15, Pl. VII). Several rows can then be taken out completely. The pillars then left afford valuable indications of coming weight, and each morning before work and hourly through the day the officials listen for the cracking of these indicators.

Some falls are very heavy—400 feet × 150 feet in area and about 30 feet in thickness. They cause heavy blasts of wind which put out all the lights in the mine and sometimes blow out doors and stoppings. When the indicators give warning of an approaching fall, all work people are stopped until the fall is down and all quiet. Sometimes the stoppage of work lasts a week.

Where the roof breaks up readily in consequence of shale or thin coal bands over the main coal, another system is in vogue, see fig. 17, Pl., VII. The pillars are split as at A. and galleries widened out, timbering as required until two knobs 6 feet square are left on goaf edge. The timber is drawn and these knobs blown out and roof dropped.

New system of work.

An important modification has been in work for a few years, the principle of which is not to divide the coal into pillars in any of the seams, but to divide the area to be worked to any particular shaft into large blocks or districts by roads driven to the boundary of the district and then to take the coal out. By this system the danger of losing a large area of pillars by creep is altogether avoided. The very strong roof over the Karharbari lower seam is very liable to creep and the thickness of the seam and friability of the coal greatly assists this movement.

In a seam 18 feet thick, the system is as in sketch, fig. 18. A series of faces *en echelon* are each 100 feet in length. Two pillars, 40 feet × 30 feet are cut out as shewn in sketch, fig. 19 in the floor of the seam, the roads forming them being 10 feet wide. These roads are made 5 feet 6 inches high. The pillars are then pared off until there are three stumps 6 feet square, two of them being in the corner pillar next the goaf, and one in the other pillar. Props are set 3 feet to 4 feet apart all over the place. When all is ready the props are drawn and the stumps or knobs being blown out, the roof coal falls and is loaded out. The roof being freshly disclosed is good and does not fall for weeks. When a main fall occurs a rib is cut off about 10 feet thick, the full height of the seam. This steadies the roof and indicates the coming of the next main roof fall. See sketch fig. 20.

This system has so many distinct advantages that it will probably supersede the pillar method altogether. There is no fear of fire; there is no area of pillars to creep and there is no worry about watching pillars to prevent miners robbing them and reducing their size and strength; and if a fire occurs the mine is not lost, as a few stoppings will shut the district off, whereas in pillars and stall workings the mine is practically all roads.

In sinking, the jumper is used of 1¼ steel octagonal. The shorter ones are pointed and used for cutting and dressing sides. The long ones are chisel-ended for drilling holes. These crowbars or *sabels* or jumpers vary from 6 feet to 12 feet in length. The coal measure sandstone is easy to sink in and fairly rapid progress can be made.

There are two systems of sinking. One is to cut a trench (or *khanja*) round the edge, and in this way defining the size and shape of the shaft (Pl. VIII, fig. 1). This trench is cut 2 feet deep and in it water collects. The holes are bored to blow off the core left and powder or dynamite used for the purpose. This is a slow process, but it leaves the sides of shaft perfect.

The other and quicker method is to blow out the centre of shaft by sumping shots fired simultaneously and then to blow off the sides until full size of shaft is reached. By this means 4 feet a day can be done, but the sides of shaft are rough and require constant examination during the progress of sinking. The sinkers have got used to dynamite and electric firing and understand that during a thunder-storm it is unsafe to charge the holes for electric blasting.

The same jumpers are used for underground work even in making overhead holes, the drill and hammer have never come into general use. In coal cutting the picks used are shown in sketch (Pl. VIII, figs. 2, 3). Fig. 2 shows the 3lb Hardy Universal pick a great favourite in India, and fig. 8 a pick used largely in East Indian Railway collieries. The helves are made of sâl wood, and the picks and handles are supplied to the miners by the colliery owners. The rest of his tools are *kamcha*, a piece of bent sheet iron, see sketch (Pl. VII, fig. 4) for scraping with both hands the slack and dust together to load into the root or bamboo basket in which it is carried to the tub or tram. This *kamcha* is preferred to the shovel even when the tub is close to the face. With the *kamcha* a person works sitting or squatting, only rising when basket is full to empty it into the tub, whereas with a shovel he has to stand and use it.

LIGHTING.

Where castor oil is burnt as in the East Indian Railway collieries, the miners use a lipped earthenware *chiragh* or lamp 3″ diameter. This is supported by a wire suspender, see sketch (Pl. VIII, fig. 5). A length of fencing wire is stolen or begged, and the strands at one end opened out and passed round the earthenware *chiragh*. Some of them have a wire chain with tongs attached to trim the wicks. This lamp will stand on the floor, or can be hung against a prop or on road side. The lamp is first soaked in water when new to prevent absorption of oil on first day of use. A little cotton waste is laid from the lip inwards and oil dropped on the wick. As oil burns up it is replaced from the store. The *chiraghs* never have much oil in them, so that in case of accident little is wasted.

Where kerosine oil is used, tin lamps "*dibia*" are in use. One is shewn in the sketch (Pl VIII, fig. 6). The kerosine oil is kept and carried in beer or wine bottles. The flame from this oil is smoky and disagreeable, and in mines with limited ventilation must be dangerous. The writer remembers a case where, against the rules, some pump men used kerosine oil and upset the oil on the water they were engaged in pumping. It there either exploded or simply lighted, but it burnt two men severely and it was reported as an outburst of gas. Enquiry showed it to be kerosine oil.

Labour.—The greatest misconception exists regarding the labour employed in this coal-field.

The *Bawris*, who were introduced some twenty years ago to teach the local labour, have to a large extent left and taken their bad habits with them.

The labour is composed of:—

1. *Mahomedans.*—Julas, etc., about . . .	30°/₀
2. *Hinduized aborigines.*—Ghatooars, Kahars, Dosadhs, Masahurs, Tooris Chamars, Rajwars and Bawris.	60°/₀
3. Aborigines, Kols and Santals . . .	10°/₀

A list of the various castes is given at the end, and those interested in such matters can get full information as to the social and religious customs of these people from that excellent publication, "The tribes and castes of Bengal by H. Risley."

These people make good steady miners, are not given to excessive drinking, are mostly well-to-do, and the majority are not dependent wholly on mining, but cultivate plots of land and own cattle.

The various companies have attracted labour by easy leases of land.

As cultivation (rice) takes only a few months of the year (3 months), the rest of the time can be spent in colliery work. Most of the miners, the writer knows, can do without colliery work for many months together, and they are in an incomparably better position than miners in England, who have not yet gone beyond, and some have hardly reached a living wage. As long as the Indian miner sticks to his cultivation and declines to become a collier only, he has a good time before him, as he can fix his own terms of wages and period of work. There are few or no quarrels between employers and labour; one finds that the men are dissatisfied by their non-appearance at work and then negociations take place.

The labour is paid weekly either on Saturday evenings or Sunday mornings.

This is a point to be noticed, as in the Ranigunj and Jherriah Coal-fields the payments are made daily. Wages are always paid in cash and, except in cases of contractors, the truck system is unknown. Even amongst contractors the "truck" system is a modified one. It consists in providing food from a certain shopkeeper who puts the price on a bit. This system is in vogue among the new arrivals who have not settled down comfortably, or to the few unfortunates who never can save.

Wages.

Payment to miners is made by the tub or tram or bucket, and varies according to nature of the coal and the system of work. For cutting coal in the solid and on pillars the rates vary from 2 annas 6 pies to 4 annas per bucket or tram for large coal, and 6 pies to 9 pies per bucket or tram for small coals. In dropped coal the rate for small and large is the same, *viz.*, from 1 anna 6 pies to 1 anna 9 pies per bucket or tram, as the coal has simply to be loaded up. These prices include leading to either shaft bottom or to some station in the mine. This depends on the size of the mine.

The average wages of miners is R1-1-0 per head per gang per week. Thus a man and his wife alone will earn R2-2-0 per week. Three members of a family count R3-3-0 for their total earnings per week. This is excellent pay compared with wages in the district and is better than daily wage work on the surface which is 2 annas 6 pies per day per man and 1 anna 6 pies per day per woman. The chief charm of the coal cutters' position is that he has not to work to time. He gets up early, attends to his own affairs, has a good square meal and goes to work at 8 A.M. At 4 P.M. he is out again to wash and go home. Daily labour works to the bell or whistle, and is in harness from 6 A.M. to 6 P.M. with intervals for rest. Wages are so good that the main body of coal cutters never work on Mondays. They take all the other holidays they can, but they are willing to sacrifice some holidays if work be emergent and coal wanted badly. The wages of coal cutters decide the rest of the wages paid; coal cutters get the best wages ; stone cutters and sinkers come next. The latter, however, prefer the cleanliness of stone work to dirty coal getting. Ordinary labour is the worst paid.

Bazaar.

The main source of food supply and of news of friends and relatives is the big Whitty-bazaar founded by the East Indian Railway Company : over 30,000 persons resort weekly on Sundays to this bazaar to buy food and gossip ; and never a stroke of work is done on Sundays in the Karharbari Coal-field.

Every article from a small tooth-comb (a favorite requisite of women), Santas feeding bottles (the Indian mother has learnt its use), slate pencils, Manchester goods, shoes : in fact everything the people want and don't want can be purchased here. It is not too much to say that the founding of this bazaar did more to settle labour than anything that was done ; and making it a Sunday bazaar gave the rest of the week to work.

At this bazaar the people lay in their weekly wants and the women (who receive the pay from their husbands) give a share to their men and Sunday sees a good deal of drinking, but there are few sots and few cases of ruin to families through drink.

Education has taken root in this coal-field ; and over 1,500 children attend schools where they receive a thorough but elementary education. The demand for educated men is on the increase, as mining sirdars and foremen are now expected to write reports on their work as in English collieries. Rules for signalling conduct of the mines etc., can be seen posted up in the field and if the men themselves cannot all read them they are pleased to hear their children do so.

Lists of castes engaged in collieries in the Giridih (Karharbari) Coal-field.

MAHOMEDANS—

1. Julahas.
2. Pathans.
3. Sheikhs.
4. Kalal.

HINDUS AND HINDUIZED ABORIGINES—

1. Brahmans. } Superior posts.
2. Kaisthas and Kaiths } Superior posts.
3. Ghatowars or Bhuiyas.
4. Kahars.
5. Moosahars (also called Bhuiya)—not to be confounded with 3.
6. Dosadhs.
7. Chamars.
8. Toories.
9. Bawris.
10. Rajooars.
11. Gopes or Goalas (4 castes).
12. Moholis.
13. Coomars.
14. Burhis.
15. Koeris.
16. Dhoby.
17. Hazam or Nowa.
18. Morrick.
19. Teli.
20. Beldar.
21. Pasi.
22. Sonar.
23. Lohars.
24. Sundi.
25. Poojahar.
26. Kurmi.
27. Malla.
28. Hari.
29. Gosae.
30. Halowai.

ABORIGINES—

1. Santals.
2. Kols.

CHRISTIANS—

1. Europeans.
2. Native Converts.
3. Do. (Santals and Kols).

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On the Occurrence of Chipped (?) Flints *in the* Upper Miocene of Burma. *By* DR. FRITZ NOETLING, F.G.S., *Palæontologist, Geological Survey of India.* (With a Plate.)

While engaged in mapping out a part of the Yenangyoung oil-field my attention was particularly directed to the collecting of vertebrate remains, which are rather common in certain strata around Yenangyoung. One of the most conspicuous beds, palæontologically as well as petrographically, is a ferruginous conglomerate, upwards of ten feet in thickness. This bed may be distinguished a long distance off as a dull-red band, running, in a continuous line, across ravines and hills. Besides numerous other vertebrate remains, such as *Rhinoceros perimense*, etc., one of the commonest species is *Hippotherium antelopinum* Caut. and Falc. of which numerous isolated teeth can be found.

While stooping to pick up the fine lower molar which is figured in the accompanying plate, my attention was drawn to some curiously shaped flints partly imbedded in the ferruginous conglomerate. Next to the molar just mentioned, I found the fine specimen figure 2, —; and on looking further about I found about a dozen or so of other flints, some of which are figured on the same plate.

Before discussing the geological position in which these flints were discovered, it will be useful to describe shortly their appearance. As regards their general shape, we may distinguish three types, *viz.*:—

(*a*) Irregularly shaped flat flakes.
(*b*) More or less triangularly shaped flakes.
(*c*) A rectangular flake.

(*a*) *Irregularly shaped flakes.*—These are generally flat, more or less square flakes, up to about 40 mm. in length, which are thicker in the centre than near the edges; edges sharp and cutting. Flakes of this kind are frequently found.

(*b*) *Triangular flakes.*—These show a roughly triangular shape; one side being generally flat, the opposite one being more or less rounded, so that a cross section has an irregular triangular or wedge-shaped outline. The lateral edges are straight, sharp and cutting; figures 3, 4 and 5 show good samples of this kind; particularly figures 3 and 4. Figure 5 is particularly remarkable, it shows that the upper face must have been produced by the repeated chipping off of thin flakes.

(*c*) *A rectangular flake.*—I found only one specimen of this kind, in fact it was through this specimen that my attention was directed to these flints. It is of a somewhat irregular rectangular shape and slightly curved; the length being 45 mm., the breadth 20 mm., both faces are roof like, so that a rhomboidal section is produced. The two long edges run nearly parallel and are sharp and cutting. This flake affords particular interest in as much as the two faces must have been produced by an action, which is difficult to explain by natural causes. Let us consider the convex face first; it will be seen that one side is smooth, apparently produced by the chipping off of a single flake, while the other side shows that at least four smaller flakes have been chipped off at a right angle to the first one. The concave face which is however much damaged at one side must have been produced by the chipping off of two longitudinal flakes.

The shape of this specimen reminds me very much of the chipped flint described in Volume I of the Records, Geological Survey of India, and discovered in the Pleistocene of the Nerbudda river, the artificial origin of which nobody seems to have ever doubted.

As regards the geological position in which these flakes were found, I mentioned above that they were imbedded in a ferruginous conglomerate. It remains now to be explained what position this bed holds in the sequence of the tertiaries near Yenangyoung. According to my researches, which will be published in detail at a later period, three distinct groups can be distinguished in the Yenangyoung tertiaries, namely, in descending order :—

3. GROUP C.—Consisting chiefly of light coloured, yellow sandstones or soft yellow sand-rocks with hard silliceous concretions, alternating with beds of light brown clay. Silicified wood very common, besides fragments of terrestrial and fresh-water animals. Measured thickness not less than 4,620 feet.

2. GROUP B.—Consisting of brown and red sandstones and light brown clays, containing numerous crystals of selenite, and locally countless numbers of *Batissa crawfurdi*, Noetl., terminating in a bed of ferruginous conglomerate with numerous remains of terrestrial animals, among which *Hippotherium antelopinum*, Caut. and Falc., and *Rhinoceros perimense* preponderate; chipped flints locally not rare. Measured thickness of the whole group 1,105 feet.

1. GROUP A.—Consisting of a series of blue clays alternating with beds of grey sandstone, which contain locally large quantities of petroleum. Fossils are scarce, but such as have been found consist chiefly of true salt water fossils with some rolled fragments of bones and some teeth of terrestrial animals. Thickness not less than 1,000 feet.

It is apparently quite clear that this succession of strata exhibits the gradual change from true marine strata, deposited somewhere near a coast, through estuarine deposits as represented by the strata containing *Batissa crawfurdi*, Noetl. to fresh water deposits containing the remains of terrestrial and fresh water animals as represented by Group C. A superficial examination of the vertebrate remains shows that the fauna is nearly identical with that of the Siwaliks, or in other words, that Group C (probably inclusive of Group B) must be of upper miocene if not pliocene age. We must therefore claim either pliocene or at the latest upper miocene age for the ferruginous conglomerate in which the chipped flints have been found. But whatsoever their particular age be, it is certain that a considerable amount of time must have lapsed since the deposit of a series of strata of more than 4,620 feet thickness, containing numerous genera of animals which are now-a-days either entirely extinct, or at least no longer living in India, which rests upon it.

Having now described the geological position of the strata in which the chipped flints were found, there still remains the question to be discussed whether they were really found *in situ*, or not. To this I can only answer that to the best of my knowledge they were really found *in situ*, and that I most probably would not have discovered them, if I had not stooped to pick up the molar of *Hippotherium antelopinum*, figure 6. The exact spot where the flints were found is marked on my geological map of the Yenangyoung oil-field with No. 49 and is situated on the steep eastern slope of a ravine, high above its bottom, but below the edge in such a position that it is inconceivable how the flints should have been

brought there by any foreign agency. There is no room for any dwelling place in this narrow gorge, nor was there ever any; it is further impossible from the way in which the flints were found that they could have been brought to that place by a flood. If I weigh all the evidence, quite apart from the fact that I actually dug them out of the bed, it is my strong belief that they were *in situ* when found.

As to their nature whether artificial or not, I do not want to express an opinion; all I can say is, that if flints of this shape can be produced by natural causes, a good many chipped flints hitherto considered as undoubtedly artificial products are open to grave doubt as to their origin.

EXPLANATION OF PLATE.

Fig. 1. Rectangular flint flake, top view.
Fig. 1*a*. ,, ,, ,, lower view.
Fig. 1*b*. ,, ,, ,, side view.
Fig. 2. Triangular flint flake, top view.
Fig. 2*a*. ,, ,, ,, lower view.
Fig. 2*b*. ,, ,, ,, side view.
Fig. 3. Triangular flint flake, top view.
Fig. 3*a*. ,, ,, ,, lower view.
Fig. 3*b*. ,, ,, ,, side view.
Fig. 4. Triangular flint flake, top view.
Fig. 4*a*. ,, ,, ,, lower view.
Fig. 4*b*. ,, ,, ,, side view.
Fig. 5. Triangular flint flake, top view.
Fig. 5*a*. ,, ,, ,, ower view.
Fig. 5*b*. ,, ,, ,, side view.
Fig. 6. Left upper molar of *Hippotherium antelopinum*, Caut. and Falc. Twice the natural size.

Note *on the* Occurrence *of* VELATES SCHMIDELIANA, Chemn. *and* PROVELATES GRANDIS, Sow *sp.*, *in the* Tertiary Formation *of* India *and* Burma. *By* DR. FRITZ NOETLING, F.G.S., *Palæontologist, Geological Survey of India*. (With 2 Plates.)

While describing a number of fossils collected by me in the Upper Tertiary formation of Burma, near Minbu and Yenangyat, some further specimens which had been collected on the eastern slopes of the Arrakan Yoma, near the village of Napeh, about 40 miles west of Minbu, were presented by Mr. Way, Engineer in-Chief, Aeng Pass Railway, to the Geological Department. No particulars were given about the geological position of these fossils, but from my knowledge of the country I think that they come from strata older than those containing the marine fauna of Minbu and Yenangyat. The most characteristic and at the same time numerous among these fossils, was one kind that I recognized at once as belonging to the genus *Velates*, Mont. Now, considering the important position this genus holds in the Tertiary formation of Western India, where it is restricted to the Ranikot and Khirtar group, having its chief development in the latter,[1] I thought it advisable to compare the specimens from Burma with those from Western India, in order to establish the identity or to prove their difference. If identical, a most important fact would be established in regard to the correlation of the Tertiary strata of Burma and Western India. We know that *Velates schmideliana* does not reach beyond the Khirtar group in Sind; if therefore the species from Burma were identical with that from India, the important fact would be proved that the beds containing *Velates schmideliana* in Burma would be equivalent to the Ranikot or Khirtar group in Western India, most probably to the latter one, and therefore the whole series of the strata above that bed would represent the equivalents of the Nari, Gaj and Manchhar groups. Thus a most important step in the knowledge of the Tertiary formation of Burma would be gained—a fact which cannot be under-estimated, because the fossil here in question can be easily recognized in the field, and the geologist working in the remote jungly hills skirting the Arrakan Yoma would always have a guide to lead him, when the thickness of the jungle hides the closed sequence of the strata.

It was with this object in view that I took in hand the examination of the specimens from Burma, at the same time comparing the Indian *Velates schmideliana* with a typical specimen from Europe in order to make sure as to their identity. On taking up the subject I found almost at once that there exist in Western India two genera which at the first sight might easily be confused; the one is represented by a typical *Velates*, the other by the new genus *Provelates*, which resembles a cast of *Velates* so closely that I am perfectly certain that it has frequently been mistaken for it.

In fact the mistake begins almost immediately with the description of Tertiary fossils from India; in 1840 James de Carle Sowerby[2] mentions a fossil as *Neritina grandis* from Wagé-Kí-pudda, in Cutch, which he describes as follows: "Short, conical, smooth; spire concealed; aperture very large; base convex, its margin rounded. Diameter 3 inches; height $1\frac{1}{2}$ inch. This resembles *N. schmideliana*, but has a larger aperture in proportion and a less eccentric apex, it is also higher. The specimen is little more than a cast, and does not exhibit the edge of the inner lip, but still it shows the attachment of the ligament projecting from the lower surface, and that the aperture occupied more than half the base."

Now we have, in the Survey Museum, from Sind several specimens of a shell which are undoubtedly identical with *Neritina grandis*, as we shall presently see, but which are certainly different from *Velates schmideliana* with which they have been identified by Messrs. d'Archiac and Haime.[3] The specimens figured and described by them undoubtedly represent a true *Velates*, but this form is not identical with *Neritina grandis*, Sow., as the authors supposed.

Before going however into the details of the description of the Indian forms, it will be useful to recall the characters of the type *Velates schmideliana*, Chemn. sp.,

[1] Distribution of the fossils described by Messrs d'Arch. and Haime, Memoirs, Geological Survey of India, Vol. XVII, 1880, page 205.

[2] Transactions of the Geological Society, 2nd ser., Vol. V, plate XXIV, fig. 9.

[3] D'Archiac and Haime, Desc. des Anim. foss. du groupe nummulitique de l'Inde, page 278, plate XXV, fig. 3.a, 4, 5, non. plate XXVII, fig. 1, b.

and then starting from this form to examine how the Indian types can be compared with it.

VELATES SCHMIDELIANA, Chemn. sp.

1786. *Nerit. schmideliana*, Chemn. Conch. Cab., Vol. 9, page 130, plate 114, figs. 975, 976.

1810. *Velates conoideus*, Denys de Montfort, Conchyl. Syst., Vol. II, page 354.

1853. *Nerita schmideliana*, D'Archiac and Haime, Desc. des. Anim fossil. du groupe nummulitique de l'Inde, page 278, plate XXV, fig. 3, 3a, 4, 5, non. plate XXVII, fig, 1, 1b, 1c.

As a list of synonyms is given by d'Archiac it is useless to repeat it here. The chief character of the shell consists in the feature that the last whorl expands suddenly and rapidly in such a way as to form an enormous body chamber, and by producing an enormous callosity on the spire, which partly envelopes the earlier whorls. The last whorl is therefore conical in shape, the apex of the cone being represented by the spire, the base by the aperture; its shape might perhaps be compared with a Phrygian cap. The surface of the last whorl is covered with fine irregular striæ of growth, which in the peripheral part run parallel to the circumference, that is to say, they form complete circles, while in the central part they form only semi-circles. The outline of the early shape is always more or less marked by a deep furrow, running obliquely from the centre towards the lower edge of the last whorl; the base of the last whorl is sub-orbicular, and formed by a broad and inflated callosity which is supported from inside by a strong septum; the aperture is semi-circular; the inner lip deeply denticulated, the outer lip sharp.

It is therefore clear that for the specific differences we must chiefly look to the shape of the last whorl; we have therefore to examine the Indian specimens whether they show any marked differences from the type specimens in that regard or not. The genus *Velates* has been found in the Indian Tertiaries at the following localities:—

1. Kharguzani hill near Laki (Sind), Khirtar group.
2. Two unknown localities in Sind.
3. Napeh in Upper Burma.

The best preserved specimens are those under No. 1, then follow those from Burma, while those under No. 2 are casts which in all probability belong to the genus *Velates*; the latter may be disposed of at once, not only because the exact locality and position where they were found are unknown, but also because as casts no fair idea can be formed as to their original shape. It remains therefore a question to be decided in the future whether they may perhaps represent a new species or not.

As regards the specimens from Khargurzani hill, they are tolerably well preserved, but none of them shows the base or the aperture sufficiently well; this is rather unfortunate, as it may be supposed that the character of the aperture differs in both species. For the present we must leave it to the future to decide this; but as regards the outer side of the last whorl, I cannot detect the slightest difference between the Indian and the French specimen; so unless some very distinguishing features would be brought to light as regards the feature of the aperture, we must consider the Indian form identical with *Velates schmideliana*, Chemn.

The specimens from Burma were apparently somewhat roughly handled and also exposed for a long time to weathering, but all the same I cannot discover any difference either in shape or surface sculpture of the last whorl. Neither does the aperture which can be fairly seen in some of the specimens exhibit any different characters. We must therefore consider that the Burma species is also identical with *Velates schmideliana*, Chemn.

However, in order to show that not only the external features agree, I have measured two specimens from France, five from Burma, and five from India, the dimensions of which are given in the subjoined table.

	Diameter of last whorl.	Length of last whorl.	Height of last whorl.[1]
French type specimens.	75 mm.	90 mm.	56 mm.
	75	85	51
Indian specimens	62	?	39
	45	?	29
	56	65	38
	52	62	?
	49	60	?
Burma specimens	62	78	45
	51	68	41
	?	88	58
	83	?	59
	57	?	44

If we reduce these figures to a common denominator, we find that in the two French specimens the proportions are—

Diameter	:	Length	:	Height.
5	:	6	:	3·6
5	:	6	:	3·3

The proportions of the Indian specimens are as follows:—

5	:	?	:	3·3
5	:	?	:	3·3
5	:	6	:	3·3
5	:	6		
5	:	6		

And in the Burma specimens:—

5	:	6·5	:	4
5	:	7	:	4
?	:	6·5	:	4
5	:	?	:	4
5	:	?	:	4

We see therefore that the French type and the Indian specimens agree very well as regards the proportions of the last whorl; the specimens from Burma seem however to differ a little, inasmuch as the last whorl is a little longer and a little higher. Now I do not want to lay too much weight on this fact, particularly as regards the height, because it will be seen from the above figures that it varies considerably even among specimens of the same locality; this might only be expected if we consider that the callosity of the base varies much in thickness; on the other hand, it would be of greater importance if the circumference of the last whorl as seen from above, would be elliptical instead of sub-orbicular as with the type *Velates schmideliana*; if we, however, examine *Velates schmideliana*, we find that at some

[1] This includes the visible part of the spire.

time of its life the last whorl was also of elliptical circumference; now the largest specimen from Burma, which is unfortunately damaged, had apparently a sub-orbicular circumference, and unless it is proved by comparing numerous specimens of the various types that the Burma type differs materially in the shape of the last whorl from the others, we must consider it as identical with the Indian form and the French type specimen *Velates schmideliana*, Chemn.

The area of distribution of this remarkable species is therefore much wider than was supposed by d'Archiac: from France, it ranges through Italy, Egypt, Persia, Cutch, Sind, as far as Western Burma, or, roughly speaking, from 0° Long. to 94° Long; and as to our knowledge, *Velates schmideliana* is restricted to the same limited horizon in the early Tertiaries, we may say indeed, that at one time during the Tertiary era, *Velates schmideliana* was distributed over an area extending over at least one-quarter of the globe in length without however reaching beyond a certain northern latitude.

After having proved the identity of the Indian types of *Velates* with the well-known European species, it now remains to turn our attention to the *Velates*-like shell, that has been mistaken for *Velates* itself. As I have sketched the history of this form in the beginning of this paper it now remains to describe and fix the new genus.

Order: Prosobranchiata, Cuv.
Sub-order: Aspidobranchiata, Cuv.
Family: Neritidae, Gray.
Genus: Provelates, Noetling.

Spire invisible, perfectly involved by the last whorl, which is of a considerable size, and of sub-conical shape, separated on the upper side by a deep furrow which runs from the apex to the posterior end of the aperture, representing the suture; aperture, large semi-lunar, outer lip sharp, inner lip not perfectly known, but apparently callous and probably not denticulated; not quite covering a deep umbilicus. Shell thin, and covered with fine striæ of growth which become rather effaced on full grown specimens but which are very regular on young ones.

So far as known for the present this genus is restricted to the Khirtar group.

The only species known is *Provelates grandis*, Sow[1].

Mr. Blanford collected this species in the gorge of the Baran River (Sind), from where figures 6 and 7 came; figures 8 and 9 come from the hills east of Trok in Kohistan, where it was collected by Mr. Fedden. The younger specimens resemble very much an ordinary Natica, only that the suture becomes indistinct and as if it were covered with a second layer of shell substance. The largest specimen measures 54 mm. from the edge of the outer lip to the opposite side, while its height was not more than 26 mm.

Full grown specimens, particularly when they have partly lost the shell, resemble in appearance very much casts of *Velates schmideliana*, but they may always be distinguished by the large aperture which was not denticulated, and the traces of an umbilicus; if the casts which I have mentioned above really represent casts of *Velates schmideliana*, then the latter would be distinguished by having the last part of the last whorl partly separated from the former whorls and the traces of a denticulated

[1] *Neritina grandis*, Sow., Transact. of the Geol. Soc., 2nd ser., vol. V, plate XXIV, fig. 9.

inner lip. On both specimens there exists a sharp ridge at that place where in the *Provelates grandis* the limit of the callosity is marked on the earlier whorls, but inasmuch as there is a similar sharp ridge on the *inside* of the last whorl of *Velates schmideliana*, where it forms the continuation of the perpendicular septum on the lower part of the callosity, which naturally must leave the same mark on the cast, we are left as before in the dark regarding the identity of these casts. Of course the whole question could be decided at once if I could manufacture a cast of *Velates schmideliana;* but unfortunately my material does not allow this, so we shall have to wait until a favourable opportunity arrives for doing so.

EXPLANATION OF PLATES.

PLATE 1.

Fig. 1.	*Velates schmideliana*,	Chemn. sp.	Sables inférieures,	Cuisse Lamotte,	upper side.
Fig. 1*a*.	"	"	"	"	left side view.
Fig. 1*b*.	"	"	"	"	base.
Fig. 1*c*.	"	"	"	"	last whorl & spire.
Fig. 2.	*Velates schmideliana*,	Chemn. sp.	Khirtar Group,	Kharguzani Hill (Sind),	upper side.
Fig. 2*a*.	"	"	"	"	last whorl & spire.
Fig. 2*b*.	"	"	"	"	left side view.
Fig. 3.	*Velates schmideliana*,	Chemn. sp.	Khirtar Group,	Napeh (Burma),	left side view.
Fig. 3*a*.	"	"	"	"	upper side.
Fig. 3*b*.	"	"	"	"	base & aperture.

PLATE 2.

Fig. 1.	*Velates schmideliana*,	Chemn. sp.	Khirtar Group,	Napeh (Burma),	left side view.
Fig. 1*a*.	"	"	"	"	upper side.
Fig. 2.	"	"	"	"	upper side.
Fig. 2*a*.	"	"	"	"	left side view.
Fig. 3.	*Provelates grandis*,	Sow. sp.	Khirtar Group	(Gorge of Baran river),	upper side.
Fig. 3*a*.	"	"	"	"	left side view.
Fig. 3*b*.	"	"	"	"	base.
Fig. 4.	*Provelates grandis*,	Sow. sp.	Khirtar Group,	Gorge of Baran river,	upper side.
Fig. 4*a*.	"	"	"	"	left side view.
Fig. 4*b*.	"	"	"	"	base
Fig. 5.	*Provelates grandis*,	Sow. sp.	Khirtar Group,	Truk (Kohistan)	upper side.
Fig. 6.	"	"	"	"	upper side.
Fig. 6*a*.	"	"	"	"	sculpture enlarged.
Fig. 7.	*Velates schmideliana*,	Chemn. sp. (?) cast,	Khirtar group (?)	Sind,	upper side.
Fig. 7*a*.	"	"	"	"	lower side.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 20.—ENDING 31ST JULY 1894.

Director's Office, Calcutta, 31st July 1894.

DR. WILLIAM KING, B.A., D.Sc., F.G.S., late Director of the Geological Survey of India, obtained his early Geological training amongst the Permian rocks and the coal-measures of Durham and Northumberland, and afterwards whilst as student at Queen's College, Galway, amongst the crystalline rocks and the carboniferous limestone of that part of Ireland, in all of which he had the teaching and guidance of his father, the eminent Professor William King.

He graduated in the Queen's University in Ireland in 1854 and completed the course of Civil Engineering in his College. He was selected for the Geological Survey of India by Dr. Oldham, then Director, and joined his appointment in Calcutta on the 4th March 1857. In May of that year he proceeded to Madras with the first geological surveying party for Southern India under Mr. H. F. Blanford and ultimately became Superintendent for the survey in that Presidency in 1868. The greater part of his field-work was in Southern and Central India, and he was engaged in joining up his surveys in the latter province with the geological maps of the western parts of Chota Nagpur, when, in 1887, he was ordered to proceed to Calcutta to take over the Directorship from Mr. Medlicott.

He is the author of numerous valuable papers dealing with the Geology of India, chiefly of the southern and central parts of it, for a complete list of which I refer to the "Bibliography of Indian Geology," compiled by Mr. Oldham and published in 1888,—and the pages of the subsequent "Records."

Dr. King retired from the Directorship of the Department on the 16th of this month and was succeeded by Mr. Griesbach, the senior Superintendent, Mr. Hughes being incapacitated in consequence of a serious accident which took place some time ago.

Mr. Griesbach.
Mr. Smith.
Lala Kishen Singh.

The field-work in Baluchistan under Mr. Griesbach as Superintendent, with Mr. F. H. Smith and Lala Kishen Singh, was continued to about the middle of June, and the result of this season's work is a large addition to the geologically explored area of Baluchistan, being chiefly parts of the southern extension of the Sulaiman range with the Mari hills adjoining, the Western Zhob valley and parts of the Kojak range with patches left unexplored during the previous season in the Quetta District. One of the most interesting facts elucidated, consists in the establishment of the geological age of the Kojak shales and their eastern prolongation into the Zhob, which by their fossil contents are now shown to be intermediate in age between upper cretaceous and upper eocene, and to form a more or less continuous facies closely associated with a variety of igneous rocks.

Mr. Smith has gone on short privilege leave and Lala Kishen Singh on a year's furlough.

Mr. Oldham.

With the sanction of the Secretary of State, Mr. Oldham was specially deputed, whilst on furlough in Europe, to study certain oil-fields in the province of Galicia in Austria-Hungary, and it is to be hoped that the experience which he has thus gained may lead to a more successful search for productive oil-wells in India.

Mr. Middlemiss.
Dr. Warth.

The Madras party, consisting of Mr. Middlemiss and Dr. Warth, returned into recess in Ootacamund and Bangalore respectively to prepare reports on the past season's work. Dr. Warth, however, will be recalled to Calcutta for the remainder of the recess season to assist in the arrangement of the Museum at head-quarters.

Mr. Bose.
Mr. Datta.

The officers engaged last season in Central India, Messrs. Bose and Datta, have returned some time ago into recess; the former has gone on three months' privilege leave, whilst the latter has prepared his progress report on the last season's work.

Mr. LaTouche.

The trial-boring at Sukkur was continued under the superintendence of Mr. LaTouche; the depth, when last reported, reached some 500 feet, where many difficulties are being encountered owing to the nature of the strata reached, which are soft shales with much gypsum in veins and nests. Bituminous traces have been observed, which might be a hopeful sign, if it were not known that the middle eocene strata into which the boring descends are often full of bituminous matter in the neighbouring area of Baluchistan, without in the majority of cases showing any oil-supplies.

Mr. Grundy.

Has returned to Calcutta where he has since been engaged in drawing up his report on the inspection of mines in India during the year ending on the 30th June, which is finished and has been printed.

Dr. Noetling.
Mr. Holland.
Lala Hira Lal.

After finishing his report on the Gohna landslip and the condition of the hill-sides of Naini Tal, Mr. Holland returned with Lala Hira Lal to head-quarters to continue his studies of Indian rocks. Lala Hira Lal has now availed himself of three months' privilege leave.

Dr. Noetling is engaged on important palæontological work, the result of which will be published in the "Records" and "Memoirs."

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July 1894.

Substance.	For whom	Result.
1 Specimen of quartz, with iron pyrites and fine gold, from the Chowkpazat mine Mawnaing Township, Katha District, Upper Burma.	C. M. P. Wright, Wuntho, Upper Burma.	Assayed for gold.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July 1894—continued.

Substance.	For whom.	Result.
3 Specimens of limestone, from Rourkela quarry, Bisra quarry, and Sonna quarry.	Thomas Skone, Amda, Singbhum.	Analysed for:— Insoluble residue. Ferric oxide and alumina. Carbonate of lime. Carbonate of magnesia.
1 Specimen of coal, from the Jherria coal-field, Manbhum.	Finlay Muir & Co., Calcutta.	Proximate analysis.
2 Specimens of manganese ore, from the Central Provinces.	P. N. Datta, Geological Survey of India.	1. *Braunite*, from Beemasoor peak, Chicklah, Chandpur Pargana, Bhandara. *Quantity received*, ½ lb. Moisture (hygroscopic) . ·04% Manganese (Mn) . . 63·71% Phosphoric acid (P_2O_5) . 2·24% 2. *Braunite*, from Kuchee, 1 mile S. by W. of Silora on the Kunhun River, Chindwara. *Quantity received*, 1 lb. Moisture (hygroscopic) . ·26% Manganese (Mn) . . 53·25% Phosphoric acid (P_2O_5) . 2·10%
1 Specimen of coal, from an outcrop in Jammú Territory.	Charles Tickell, Director of Public Works, Jammú and Kashmir State, Srinagar.	Proximate analysis.
1 Specimen of powdered sand, from Rajmehal, and 1 of powdered quartz, from Mihijam.	Voigt & Co., (Pioneer Glass Manufacturing Co., Ld.,) Calcutta.	Silica percentage determined.
2 Specimens of coal, from Cachar.	Grindlay & Co., Calcutta.	Proximate analysis.
4 Specimens of decomposed crushed quartz-rock, from Mr. Watson's Estate in the Tavoy district.	H. M. S. Mathews, Offg. Director of the Department of Land Records and Agriculture, Burma.	No. 1. Quantity received . 24 lbs. ,, 2. ,, . 22 lbs. ,, 3. ,, . 19 lbs. ,, 4. ,, . 9 lbs. Contains no gold.
1 Specimen of coal, from the Jherria coal-field, Manbhúm.	H. H. Macleod, Bengal Coal Co., Ld., Calcutta.	Proximate analysis, with calorific power.
1 Specimen of coal.	H. A. B. Evatt, Calcutta.	Proximate analysis.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July 1894—concluded.

Substance.	For whom.	Result.
2 Small stones, from Shamsanderpur, Bankura District.	Raja Saurindra Mohan Tagore, C. I. E., Patharia Ghata Rajbati.	*No. 1.* Spinel-Ruby. *No. 2.* Zircon.
1 Specimen of clay.	E. G. Barton, District Engineer, B. N. Ry. Co., Ld., Purulia.	Refractory nature tested.
5 Specimens of rocks, for determination.	G. A. Savielle, Executive Engineer, B. B. & C. I. Railway, Mount Abu.	*No. 1. Chambal.* Fine-grained glomero porphyritic basalt. *No. 2. Sipra.* Fine-grained basalt. *No. 3. Dulet Danta.* Quartzite. *No. 4. Kalisind.* Quartzite. *No. 5. Hinga Moi.* Slightly calcareous clay.
5 Specimens of minerals for determination.	Wm. Farquhar, care of Post Office, Bombay.	*No. 1. Khetri, Rajputana.* Steatite. *No. 2. Khetri, Rajputana.* Impure Erubescite and Pyrite. *No. 3. Oodeypur Territory, Chota Nagpur.* Plumose amphibole and quartz. *No. 4. Tavoy, Burma.* Galena. *No. 5. Ceylon.* Moonstone.
A specimen from Hazaribagh for determination.	Balmer, Lawrie & Co., Calcutta.	Hornblende-schist.

Notification by the Government of India during the months of May, June, and July 1894, published in the "Gazette of India," *Part I.—Appointment, Confirmation, Promotion, Reversion and Retirement.*

Department.	No. of order and date.	Name of officer.	From	To	Nature of appointment, etc.	With effect from	Remarks.
Revenue and Agricultural Department.	$\frac{2058}{14}$ Surveys, dated 20th July 1894.	C. L. Griesbach.	Superintendent, Geological Survey of India.	Director, Geological Survey of India.	Substantive, permanent.	17th July 1894.	...

Notification by the Government of India during the months of February, March, and April 1894, published in the "Gazette of India," *Part I.—Leave.*

Department.	No. of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	Remarks.
Revenue and Agricultural Department.	$\frac{1952}{129}$ Surveys, dated 13th July 1894.	H. B. W. Garrick, Artist, Geological Survey of India.	Furlough.	15th July 1894, or subsequent date.	...	...

Notification by the Geological Survey of India during the months of May, June, and July 1894, published in the "Gazette of India," *Part II.—Leave.*

Department.	No. of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	REMARKS.
Geological Survey Department.	1034, dated 7th May 1894.	P. N. Bose, Offg. Superintendent, Geological Survey of India.	Privilege.	1st June 1894.	...	...
Do.	1497, dated 7th July 1894.	F. H. Smith, Assistant Superintendent, Geological Survey of India.	Do.	25th July 1894, or subsequent date.	...	...
Do.	1533, dated 19th July 1894.	T. H. D. La-Touche, . Offg. Superintendent, Geological Survey of India.	Do.	18th July 1894.	...	...

Postal and Telegraphic addresses of Officers.

Name of Officer.	Postal address.	Nearest Telegraph Office.
T. W. H. Hughes	On furlough	...
R. D. Oldham	On furlough	...
T. H. D. LaTouche	On privilege leave	...
P. N. Bose	On privilege leave	...
C. S. Middlemiss	Ootacamund	Ootacamund.
P. N. Datta	Calcutta	Calcutta.
T. H. Holland	Calcutta	Calcutta.
W. B. D. Edwards	On furlough	...
F. H. Smith	Quetta	Quetta.
F. Noetling	Calcutta	Calcutta.
Hira Lal	On privilege leave	...
Kishen Singh	On furlough	...

DONATIONS TO THE MUSEUM.

FROM 1ST MAY TO 31ST JULY 1894.

Meteorite (stony), weighing 8617 grammes, fell about 4 P.M. on Wednesday, 9th May 1894, in village BORI, Lat. 22°, Long. 78° 6″ East, about 12 miles N.-E. of Badnur, Betul District, Central Provinces.

SENT BY COL. J. W. MACDOUGALL,
Deputy Commissioner, Betul.

Three specimens of Cobalt ore; one of Steatite, and one of impure Erubescite and Pyrite, from Khetri, Rajputana; one specimen of Plumose amphibole and quartz, from Oodeypur Territory, Chota Nagpur; one specimen of Galena, from Tavoy, Burmah and one specimen of moonstone, from Ceylon.

PRESENTED BY WM. FARQUHAR.

Several specimens of spinels, from Shamsunderpur, Bankura District.

PRESENTED BY RAJA SAURINDRA MOHAN TAGORE, C.I.E.,
PATHARIA GHATA RAJBATI.

ADDITIONS TO THE LIBRARY.

FROM 1ST APRIL TO 30TH JUNE 1894.

Titles of Books. *Donors.*

BLAKE, *J. F.*—Annals of British Geology, 1890-91-92. 8° London, 1894.

BRONN, DR. *H. G.*—*Klassen* und ordnungen des Thier-Reichs. Band II, Abth. II., lief 9—10 and IV, lief 33—35. 8° Leipzig, 1894.

KLEIN, DR. *H. J.*—Jahrbuch der Astronomie und Geophysik. Jahrg. IV, 1893. 8 Leipzig, 1893.

LYALL, SIR *Alfred.*—Asiatic Studies, religious and social. 8° London, 1884.

Paléontologie Française 1re. serie, Animaux Invertebres. Terrains Tertiaries, Eocene, Echinides. Tome II, livr. 32. 8° Paris, 189.

SUESS, PROF. *Ed.*—The future of Silver. 8° Washington, 1893.

PERIODICALS, SERIALS, ETC.

American Geologist. Vol. XI, Nos. 3—4 and XIII, No. 2. 8° Minueapolis, 1894.

American Journal of Science. Vol. XLVII, Nos. 279—281. 8° New Haven, 1894.

American Naturalist. Vol. XXVIII, Nos. 327—329. 8° Philadelphia, 1894.

Annalen der Physik und Chemie. Namen register, 1874—1893. 8° Leipzig, 1894.

Annalen der Physik und Chemie. Neue Folge, Band LI, heft 3-4; and LII, heft 1-2 8° Leipzig, 1894.

Annales de Geologie et de Paleontologie. Livr, 12—13. 4° Palerme, 1894.

Annals and Magazine of Natural History. 6th series, Vol. XIII, Nos. 76—78. 8° London, 1894.

Athenœum. Nos. 3463—3476. 4° London, 1894.

Beiblätter zu den Annalen der Physik und Chemie. Band XVIII, Nos. 3—5. 8° Leipzig, 1894.

Title of Books. *Donors.*

Chemical News. Vol. LXIX, Nos. 1789—1802. 4° London, 1894.
Colliery guardian. Vol. LXVII, Nos. 1732—1745. Fol. London, 1894.
Geological Magazine. New series, Decade IV, Vol. I, Nos. 4—6. 8° London, 1894.
Indian Engineering, Vol. XV, Nos. 12—25. Flsc. Calcutta, 1894.
Industries and Iron, Vol. XVI, Nos, 1104—1117. 4° London, 1894.
Journal of Geology, Vol. II, No. 1. 8° Chicago, 1894.
London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science. 5th series, Vol. XXXVII, Nos. 227—229. 8° London, 1894.
Mining Journal. Vol. LXIV, Nos. 3054—3067. Fol. London, 1894.
Natural Science. Vol. IV, Nos. 24—25. 8° London and New York, 1894.
Nature. Vol. XLIX, Nos. 1271—1284. 4° London, 1894.
Neues Jahrbuch für Mineralogie, Geologie und Palæontologie. Band I., heft 2—3. 8° Stuttgart, 1894.
Oil and Colourman's Journal. Vol. XV, Nos. 164—166. 4° London, 1894.
Palæontographica. Band XL, lief. 5—6. 4° Stuttgart, 1894.
Palæontologische Abhandlungen. Neue Folge, Band II, heft 3. 4° Jena, 1893.
Petermann's Geographischer Mittheilungen. Band XL, Nos. 3—5. 4° Gotha, 1894.
THE EDITOR.
Scientific American. Vol. LXX, Nos. 8—21. Fol. New York, 1894.
Scientific American. Supplement. Vol. XXXVII, Nos. 947—960. Fol. New York 1894.
The Indian Engineer. Vol. XIX, No. 363 to XXI, No. 376. Fol. Calcutta, 1894.
Tschermak's Mineralogische und Petrographische Mittheilungen. Band XIII, heft 6. 8° Wien, 1894.
Zeitschrift für Krystallographie und Mineralogie. Band XXIII, heft 1—2. 8° Leipzig, 1894.
Zeitschrift für praktische Geologie. Jahrg. 1893, heft 1—12; and 1894, heft 1—4 and 6. 4° Berlin, 1893-1894.

GOVERNMENT SELECTIONS, REPORTS, ETC.

BOMBAY.—Bombay Gazetteer. Vol. XXVI. 8° Bombay, 1894. BOMBAY GOVERNMENT.
„ Selections from the Records of the Bombay Government. New Series, Nos. 274—275. Flsc. Bombay, 1893. GOVERNMENT OF BOMBAY.
INDIA.—Annual Statement of the Trade and Navigation of British India with Foreign Countries and of the coasting trade of the several Presidencies and Provinces for the years ending 31st March 1887 to 1892. 4° Calcutta, 1887—1892. GOVERNMENT OF INDIA.
„ Census of India, 1891.
General Tables, Vol. II. Flsc. London, 1894.
REVENUE AND AGRICULTURAL DEPARTMENT.
Mysore, Vol. XXV, Parts I—II. Flsc. Bangalore, 1894.
RESIDENT, MYSORE.
N.W.-Provinces and Oudh, Vols. XVI to XVIII. Flsc. Allahabad, 1894.
REVENUE AND AGRICULTURAL DEPARTMENT.
„ General Report on the operations of the Survey of India Department for 1892-93. Flsc. Calcutta, 1894. SURVEY OF INDIA DEPARTMENT.

Title of Books. *Donors.*

INDIA.—List of Civil Officers holding Gazetted appointments under the Government of India in the Home, Legislative, Foreign and Revenue and Agricultural Departments, corrected to 1st January 1894. 8° Calcutta, 1894.
HOME DEPARTMENT.

" Indian Meteorological Memoirs. Vol. VI, Part 1. 4° Calcutta, 1894.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

" Monthly Weather Review. November 1893 to February 1894. 4° Calcutta, 1893-1894.
METEOROLOGICAL REPORTER TO THE GOVERNMENT OF INDIA.

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Note on the Geology of Wuntho *in* Upper Burma, *by* FRITZ NOETLING, PH.D., F. G. S., *Palæontologist, Geological Survey of India, with a map.*

Geographical features.—The area described in the following pages comprises part of the Wuntho sub-division of the Katha district in Upper Burma. It extends, roughly speaking, between Htygaing on the Irrawaddi, and the Mu valley; in its eastern part only low hills rise from the surrounding plains, but in its western part the large massive of the Maingthong hills form a tract of approximately 75 miles in length.

The Maingthong hills, which I partly examined begin near Lat. 23° 45′ and Long. 90° 20′ near the junction of the Daungyu Choung with the Mu river. From this point the hills extend in a nearly northerly direction, the tract widening out gradually till it reaches its greatest breadth of 30 to 35 miles near Lat. 24° 5′.

It may be said to be limited by the broad valleys of the Mu and its tributary the Nam-Maw in the west, but its eastern boundary is less sharply defined. In the southern part the broad Wuntho valley forms the boundary, but further towards north the low hills to east come quite close up to the central massive forming for some distance a low watershed between the Meza and Mu river. North of these low hills the eastern boundary is again well defined being formed by the broad valley of the Meza river.

The highest point in this hilly tract is Maingthong hill (5,510 feet), the south-western spurs of which have been geologically examined.

The Toung-thon-lon (5,565 feet) at Lat. 24° 56′ and Long. 95° 52′ may possibly form the northern continuation of the Maingthong tract, but it was not visited.

Geological features.—I can only give a rough outline of the geological features of this area, owing to the almost unsurmountable difficulties, which the dense, nearly impenetrable jungle places in to the way of geological researches. Here and there a rock protrudes from under the thick vegetable mould which everywhere covers the ground. But nothing can be seen of the dip and strike of the strata. The trained eye, however, learns very soon to judge from the difference of the surface soil, whether a change in the nature of the underlying rocks has taken place. For instance, it is always easy to distinguish whether there are tertiary strata or diorite *in situ* below the surface soil, but the exact boundary lines must be guessed at. Even the valleys afford little opportunities for the geologist, owing to the impenetrable jungle.

As far as I could ascertain only eruptive rocks take part in the formation of the Maingthon hill tract whilst the surrounding low hills to the east, south and west of the eruptive mass consist of miocene beds, both of the lower or Chindwin and the upper or Irrawaddi group. Older formations occur only close to the Irrawaddi river, where the low ridge which runs almost due north, near Htygaing, is formed by mica schists, with an easterly dip; some traces of metamorphized carboniferous limestone may be seen on the eastern side of the ridge which forms the watershed between the Meza and Mu river, the crest of which is formed by an extensive serpentine dyke.

A.—ERUPTIVE ROCKS.

1. *Quartz Diorite.*—The rock which is chiefly developed in the Maingthong hill tract is a crystalline rock which from its outward appearance must be placed between granitites and quartz diorites.

So far as it is known the quartz diorite occupies chiefly the central part of the tract; it is well seen on the road from Wuntho to Pinlebu, between the villages of Myelin and Hethat, that this is so may be seen on the footpath which leads from Wuntho to Myelin, but the locality where I found it best developed is the Tayawchoung, a feeder of the Yu river; here enormous masses may be seen in rounded forms covering the slopes.

There is sufficient reason to believe that the quartz diorite is not only developed in the shape of a central mass, but that numerous dykes radiate from the centre, which show a considerable difference from the central mass; such a vein may be seen in the Nam-Maw ravine east of Mawteik where it undoubtedly penetrates the black rock (aphanite). Occasionally veins of white quartz may be seen in the diorite, but so far as I know they are not metalliferous.

2. In close connection with the diorite occurs a hard black rock which is developed either in homogenous masses or is well stratified. This mode of occurrence may be seen in the Nam-Maw ravine, east of Mawteik; after having passed Mawteik where a truly intrusive rock of the trap type can be seen, an exceedingly hard dark rock forms the bed of the river; for about half an hour this rock may be traced without any apparent change being noticed, excepting occasional fissures; then the rock disappears beneath the jungle, and when it crops out again, it is apparently of the same type, but now well stratified. The strike is 45° N. E.-S.W. and the dip 45° W. It is crossed by a system of jointing, running 340° N. N.-W.-S. S. E. and dipping 62° E.

Mr. Holland describes this rock as follows:—A compact bluish-green rock breaking with a semi-conchoidal fracture, studded with minute grains of magnetite pyrites and pyrrhotite, the last-named minerals occurring also in irregular patches. Specific gravity 2·86. Under the microscope the rock presents the characters of a volcanic agglomerate rather than an ordinary lava or a dyke rock. Fragments of plagioclase felspars, hornblende and augite in all stages of decomposition are mixed with opaque grains of magnetite and pyrites in a microlithic groundmass. It contains a trace of gold but not enough for estimation.

Mr. Holland further remarks that only the occurrence in the field can decide exactly the origin of the rock, but from the microscope alone it seems to be a consolidated volcanic ash.

Mr. Holland's supposition is perfectly correct; when I first discovered this rock it struck me at once as not being of truly sedimentary origin, although being perfectly stratified. In fact the bedding goes so far that the grains and patches of magnetite pyrites run parallel to it. My first idea was that this must be a consolidated volcanic ash, very probably deposited in water. At all events under this circumstance the hard bluish rock mentioned above is also a cemented and hardened volcanic ash on the top of the stratified beds.

This hardened volcanic ash may be seen all along the outskirts of the Maingthong hill tract forming particularly the surrounding region; I first noticed it near Padeingon, about 15 miles in a straight line north of Wuntho, and from there I traced it all along the lower hills which form the outskirts *viâ* Pinlon, Kyaungon, as far as Wuntho; on the road from Wuntho to Pinlebu between the 7th and 8th mile where there are extensive old gold-diggings, this hardened volcanic ash shows, according to Mr. Holland, exactly the same composition as that from Mawteik which is not less than 28 miles in a straight line distant from that place. Here the simultaneous occurrence of the stratified and the non-stratified beds can also be seen, and the first are apparently the lower; a sample of the non-stratified rock exhibits the following characters:—A coarser grained rock than that from Mawteik, presenting the characters of a compact and altered agglomerate. There is a considerable development of epidote at the expense of the decomposing felspathic material which is in large quantities. Fragments of amygdaloidal andesite are occasionally found included and undergoing the general decomposition. Specific gravity 2·884. I need hardly add that it also contains numerous specks of magnetite pyrites.

To me it seems most probable that the diorite and the volcanic ash are in generic connection, although this has not been actually proved yet; the probably sub-marine diorite eruptions were accompanied by large showers of ash which form now these pseudo-sedimentary rocks. Undoubtedly, subsequent eruptions produced dykes, which intruded into the surrounding ash masses and these dykes chiefly attract our attention. They were of two types—one, closely allied in composition to the diorite; the second, chiefly consisting of felspathic quartz which contains a more or less considerable quantity of auriferous pyrites.

(*a*) *Pyritic veins* (*auriferous.*)

The known pyritic veins are only found on the eastern side of the Maingthong hill tract, but I have not the slightest doubt, that subsequently they will be found at other places within the ash-girdle. Beginning from the north the following localities are known where these veins occur:—

1. Gwegyi.
2. Toungni near Padeingon.
3. Chouk-paza-doung, close to Padeingon.
4. Theindoo-choung, near Pinlon.
5. Mayutha.

All these places are quite close to each other, the distance from Mayutha to Gwegyi being not more than 12 miles in a bee-line. So far as it has been observed the veins do not run in any particular direction, but I may be wrong here. Anyhow the small holes in which the veins were exposed, did not permit a definite opinion; only when their extent is known, can this question be decided. The veins naturally vary in thickness, as well as in the quantity of pyritic ore which they contain. The thickest vein which I have seen is that of Toungni; the ore contained a comparatively small quantity of pyrites; on assay it yielded 4 dwt. 15 grs. of gold to the ton. The ore from Chouk-paza-doung which occurs in a vein of about 9 to 12 inches in thickness is much richer in pyrites, but it yielded only 1 dwt. 7 grs. of gold.

At Pinlon, of which Mayutha is probably only the continuation, the vein is about 4 inches in thickness, but consists nearly throughout of pyrites. On assay it yielded only a trace of gold, although there is seemingly a connection between the quantity of pyrites and gold contained in the ore; that is to say, the richer in pyrites the poorer in gold, this supposition requires however a great deal more confirmation before it can be accepted.

However it is not only the quartz veins to which the occurrence of auriferous pyrites is limited, much more frequently it is largely dispersed in small crystals through the ash; in fact we may say the occurrence in veins is only a concentrated form of the occurrence of the auriferous pyrites in the ash. Pinlon offers a good example of this; as above mentioned, there is a comparatively thin vein of pyrites traversing the volcanic ash, which itself shows not race of pyrites, at a distance of about 200 yards from the above place the ash, however, shows numerous small pyritic crystals and old diggings prove that the natives have been working here for gold. Typical localities of the second mode of occurrence of the pyrites are—

1. Gotama hill near Wepone, north of Wuntho.
2. Kyoukpyu, between the VII and VIII mile on the road from Wuntho to Pinlebu.
3. Nam-Maw east of Mawteik, Pinlebu Sub-division.

Besides the above there are undoubtedly numerous other places; for instance the frequent occurrence of crystals of pyrites in the streams near Gyodoung (north of Wuntho) prove that it must be found west of that place.

(*b*) *Galeniferous veins* (*argentiferous*).

Besides the pyritic ore there occurs on the western side of the Maingthon hill tract a galeniferous vein of Cerussite under very similar circumstances. The first locality where I found it is called Kaydwin (Kay-lead, dwin-mine) situated in the ravine of the Nam-Maw, east of Mawteik and still further to the east from the place where the pyritic ash had been observed. As far as I was able to ascertain without making extensive diggings it is a vein of, as Mr. Holland describes it, an igneous rock of the aphanite group being composed principally of lath-shaped plagioclase felspars, hornblende, and relics of augites with considerable quantities of granular magnetite. The whole rock has been considerably decomposed; epidote has formed and veins of other products of decomposition occur. The strike of the vein is apparently N. N. E.-S. S. W.; but owing to the unfavourable position of the outcrop this could not be ascertained. The thickness varies, but in the average it is not less than 4 feet. The cracks of this vein are filled with veins of Cerussite, which forms thin layers encrusting the rock. According to Mr. Holland it yielded 69·1 per cent. of lead and 33 oz. 16. dwt. 4 grs. of silver to the ton of lead.

Following up the direction of the strike in a south-westerly direction at a distance of about six miles in a straight line, another locality called Mawkwin exists where the natives have been digging for lead. The mode of occurrence being the same, it is undoubtedly that this place represents the southern continuation of the Kaydwin outcrop.

(*c*) *Salt springs.*

Another most remarkable occurrence within the area of the volcanic ash on the western side of Mainthong hill tract, is that of salt springs.

They are usually found in the bed of the streams where the brine oozes out from the rock. Such places are :—

Kyatngat in the Nammaw ravine.
Kaydwin " " "
Taungmaw " " "
Natdaw " " "
Mangyi " " "
Mawkwin in the Tayaw ravine.
Senan " " "
Sagyin
Magyibin
Kya-wut-maw
Sinsamaw
Zibinmaw
Nayaungbinmaw
} Nam of stream unknown, but close to the above.

If the situation of these salt springs is fixed on the map it seems that they occur along a line which runs about north-north-west and that they are chiefly found at such places where the erosion of the streams has cut across it. It is therefore highly probable that these salt springs follow a line of fault, which seems in the main to run parallel to the Cerussite vein.

B.—THE YOUNGER FORMATIONS.

Maingthon hill tract is surrounded on all sides by tertiary strata, which in no way differ from those observed elsewhere in Burma. Yellowish soft sandstones and brown clays form the upper beds, and blue clays with ferruginous concretions, and grey sandstones, are predominant in the lower part. The tertiary strata come up quite close to Maingthon hill tract; in fact, they form part of it, and on its western side they compose the lowest spurs. Whether there is a line of disturbance between the tertiaries and the eruptive centre is difficult to say.

On the western sid^ the older tertiaries or Chindwin group may be traced for a long distance; these beds are of small thickness comparatively, and form a narrow band which skirts the central massiv; it is followed by the upper tertiaries, the Irrawaddi sandstone, which is easily recognizable by its characterstic escarpments, facing east; there is no doubt that the Irrawaddi sandstone extends to the west as far as the Chindwin.

The general dip of the tertiaries is towards west.

On the eastern side the Chindwin sandstone has not been observed yet, but there is every reason to believe that it may yet be found. General dip towards east.

The way in which the tertiaries follow the contours of the central massiv convinces me that they were not only deposited along it, but that they once covered it entirely. The older eruptive massiv was only laid bare by the same action which resulted in the folding of the tertiaries. Once laid open to denudation the softer tertiary strata were of course washed away easier than the hard diorite. As a result of this denudation the central diorite massiv protrudes in the form of a high, hilly tract from the surrounding low-lands of tertiary age. On the eastern side there are numerous outcrops of coal seams, which, beginning north, run as follows :—

1. Choukpyachoung between Mansigale and Pinmu.

The coal is exposed in the bed of a small stream ; it forms two seams separated by a clayey parting ; the following is the section in descending order :—

7 Clay.
6 Shaly coal, 18 inches.
5 Brown soft clay, 12 inches.
4 Shaly coal, 10 inches.
3 Good hard coal, 3 inches.
2 Shaly coal, 3 inches.
1 Clay of unknown thickness.

The coal, except the thin layer of 4 inch, is of very inferior quality, brittle, and very shaly ; in fact, it can hardly be considered as more than a bituminous shale.

2. Tabawda-Choung a feeder of the Tayaw-Choung, about three miles south-west of Mansigale.

The coal seam crops out in a narrow, nearly inacessible ravine ; the seam dips west at an angle of about 10°. The following is the section in descending order :—

9 Clay.
8 Shaly coal, 14 inches.
7 Brown bituminous clay, 12 inches.
6 Shaly coal, 7 inches.
5 Good coal, 6 inches.
4 Shaly coal, 1 inch.
3 Good coal, 6 inches.
2 Shaly coal, ½ inch.
1 Bluish clay of unknown thickness.

The coal is of good quality, but not of sufficient thickness to pay working.

3. Milaunggon, east of Pinlebu.

Here an outcrop of coaly shale, apparently in disturbed position, may be observed ; it is absolutely of no commercial value.

4. Subokom, about the 34th mile from Wuntho.

The outcrop is found in the bed of a very narrow ravine, unfortunately much covered by jungle ; unless exposed by trenches, not much can be said about this out-crop ; but judging from the others, it is not very probable that it will prove of particular value. The seam dips west at an angle of apparently 10°. The following is the analysis of a sample of this coal :—

Moisture	7·68
Volatile matter	34·42
Fixed carbon	53·58
Ash	4·32

According to this analysis, the coal should form a very good fuel provided it exists in sufficient quantity.

5. Moungaw Stream, near Yuyinbyet village, south of Pinlebu.

Two outcrops can be seen here: the lower one is a seam of shaly, brittle coal of about two feet thickness imbedded in clay, the second shows a seam of 4 to 5 feet good coal covered by about 8 inch of shaly coal; the out-crop was unfortunately partly covered with water, which prevented further examination. Dip about 10° towards west. The following is the analysis of a sample of this coal:—

Moisture	6·60
Volatile matter	34·24
Fixed carbon	52·22
Ash	7·04

The coal is so exactly similar in composition to that from Subokom, that, considering the position of the two localities, it is highly probable that both belong to one and the same seam, of which the Moungaw out-crop is the southern continuation.

6. Wetabin-Choung, about 1 mile west of Engwe village on the Yu river.

I discovered only a seam of shaly coal here which closely resembled that of Milaunggon. However, another seam must be *in situ* in the same stream, which is hidden under the detritus, for fragments of good hard coal have been washed out and prove its existence higher up. According to the analysis it contained—

Moisture	8·28
Volatile matter	36·14
Fixed carbon	48·58
Ash	7·00

It is therefore in no way inferior to the coal of the above named two places.

C.—ECONOMIC VALUE OF THE MINERALS IN THE MAINGTHONG HILL TRACT.

1.—GENERAL CONDITIONS.

Before going into the details of the value of the minerals mentioned in Section B., it will be useful to discuss such questions first, which would apply generally to all mining operations in Wuntho, namely, accessibility, labour, water and fuel-supply.

As regards accessibility, there can be no doubt that the opening of the railway line to Wuntho has greatly facilitated mining enterprise in those parts of Burma. Without the railway, mining in such a country would be out of the question altogether; the forty odd miles from Htygaing, the nearest river station, to Wuntho, across a country which is a swamp for the greater part of the year, would never permit any mining enterprise. But even supposing the necessary tool and plant having safely arrived by rail at Wuntho, there still remains a good distance to be covered by carts. The pyrites mines are more favourably situated, the railway line running nearly parallel to the eastern spurs of the Maingthong hill tract; but there are still, in the most favourable case of Theindoo-choung and Mayutha at least 10 to 12 miles of very difficult country to be traversed by road; in the case of the other mines, the distance is greater still. It may be said, however, that, although the cost of transport is great, it would not be prohibitive in the case of the pyritic veins.

As regards the coal-mines, the nearest outcrop is 32 miles over a much broken country, from the railway station, a distance which in itself would render it an unprofitable undertaking to work these mines, considering the favourable position of the Kabwet colliery, which is open to communication either by river or rail. The lead-mines are still more unfavourably situated, there is a cart road from Pinlebu to Wuntho (at present, however, only practicable during the dry season); but beyond Pinlebu, communication is rather difficult; the total distance from the railway station to the Kaydwin being not less than 68 miles over very broken country, which in my opinion will enhance the cost of transport so much as to make it a most unprofitable concern even if the ore contained 33 ounces of silver to the ton.

With regard to labour, it may at once be said, that to rely on local supply would wreck any mining enterprise from the very beginning. Probably one or the other local coolie, attracted perhaps by high wages, will for some time work in a mine, but it is more than doubtful whether they would take up the work in any number, and, what is the most important point, would persevere in it. The population consists chiefly, if not entirely, of agriculturists, who are not likely to give up their comparatively easy work, which affords them a sufficient if not ample livelihood, with plenty of spare time. If they could be induced to take up working in a mine, they would most probably only do so during the off season, and return to the cultivation of their fields when their presence is required. Labour must therefore be imported at undoubtedly considerable expense, if ever mining operations were started in those parts of Burma. Finally, another point must not be overlooked; Wuntho, in fact the whole of the Maingthong hill tract, is an excessively unhealthy and feverish country, as I have experienced myself. The death-rate amongst the coolies would be sure to rise to such a point that exorbitant wages would have to be paid to the labourers to induce them to stay on. The sanitary conditions would undoubtedly improve immediately the jungles were being cleared and the coolies fairly housed, but at the beginning the death-rate would certainly be a high one. There is plenty of water all the year round, an important matter, if it were to come to the setting up of stamping batteries, and there would be no lack of fuel, at any rate within the first twenty-five years, the country being thickly stocked with wood.

To sum up, accessibility in all cases, except the coal and lead mines, fairly good. Water and fuel plentiful; local supply of labour next to none.

2.—VALUE OF THE MINERALS.

Having dealt with the general conditions, on which mining enterprise in Wuntho will depend, it remains to discuss the value of the different minerals which are likely to be exploited. These are—

1. Auriferous pyrites.
2. Argentiferous Cerussite.
3. Coal.
4. Salt.

1. *Auriferous Pyrites.*—It must be understood that all the gold found in the Maingthong hill tract has been derived from the decomposition of iron pyrites, whether gold be found in specks, in the surface soil, or in small grains inclosed in the quartz. The sooner it is understood that the gold found in the quartz is not primary, but a residue of a chemical process, *i. e.*, the decomposition of the

iron-pyrites, the more will the difficulties be realized which will have to be encountered when exploiting these auriferous ores. I do not doubt that at the outcrop of the pyrites-veins metallic gold has been found, although I did not find it myself; the Choukpaza lode for instance shows unmistakeable signs that its outcrop had been worked by some body and for some purpose, and if the natives state that this purpose was the extraction of gold this statement is probably correct. I have also no doubt that the same may be the case with other localities, for instance, Toungni near Padeingon or Gwegyi. But my opinion is, that I do not believe that the occurrence of metallic gold at the outcrop of these lodes will continue to any great depth. Sooner or later it will disappear, and be replaced by undecomposed iron-pyrites. Then the difficulty of dealing with a "refractory" ore will have to be faced. This is the point which I want to put stress upon. We have, therefore, to answer the question: does the iron-pyrites contain a sufficient percentage of gold, so as to make its extraction a profitable business? This may be answered with *no*, as far as our present knowledge enables us to form a judgment. The richest ore contained a little over 4 dwt. of gold to the ton; but although as small a quantity as 3 dwts. is sufficient to pay some of the Australian mines, it is hardly beyond a doubt that in Wuntho the expenses will be too high to make gold-mining a payable concern, unless a higher percentage of gold to the ton of pyrites ore could be proved. I quite believe that should gold-mining be really started some of the mines would pay a small dividend during a couple of years or so, but when the small supply of metallic gold, prepared in the chemical laboratory of nature, has been exploited, and when it comes to extract the gold from the pyrites, which holds it with an iron grip, every single one of the mining concerns will ingloriously break down. It may be argued that the natives have extracted gold at various localities in the Maingthong hill tract. True enough, and countless old and deserted diggings prove that they actually did, but it must not be forgotten that a native feels himself amply paid if he gets a few annas weight of gold after a month of hard work. The native does not employ expensive mechanical labour, and an equally expensive staff; a primitive pickaxe, a wooden shovel and a pan made on the spot, an ample supply of water is all he requires. With that outfit he sets to work, diligently, day per day; and when he thinks he has exhausted one place, he moves on to another. Small as his earnings may be there is no question that they sum up, if we suppose, that this work has been steadily going on for years and years. The gold which eventually comes to the market is perhaps the accumulated result of years of work. But if the same quantity were to be obtained within a short period of time, the working expenses would simply be higher than the value of the gold extracted.

2. *Argentiferous Cerussite.*—The results of the analysis prove that this is a highly valuable ore, and so far as I have observed there is a large quantity still available, but as I have already said, it must remain doubtful whether under the present conditions of railway communication and costly labour these ores could be worked profitably.

3. *Coal.*—According to the analysis the coal is of good quality; but not largely in excess of that from Kabwet or the Chindwin. It is in fact up to the average coal from the Burmese Territories, which makes a fairly good fuel, provided there is a sufficient quantity of it. But so far my examination of several localities

where such coal exists, does not warrant a very hopeful view, and in fact, except at one or two places, the seams are of wretchedly poor quality, consisting chiefly of coaly shale.

4. *Salt.*—In conclusion I may mention in few words how the natives utilize the salt springs. I have already stated that these springs are almost always found along the stream beds; and the natives have overcome the difficulty of obtaining a strong brine for evaporation in a most ingenious way. A fairly sized log of wood is hollowed out in the centre, and driven into the bed of the stream over the spring, whilst the space between this hollow cylinder and the rock is safely plugged with clay. A bamboo-wicker work is then placed round the wooden cylinder and the space between the two filled with clay, well rammed in; a few heavy boulders, on the top protect the clay from being washed away. The brine then rises in the wooden tube sometimes above the level of the surrounding stream. It is pumped out in the ordinary way by means of a pot, and then boiled down, in the way as described by me in a previous note on a salt spring near Bawgyo in the Shan States.

Preliminary notice *on the* Echinoids *from the* Upper Cretaceous System of Baluchistán, *by* FRITZ NOETLING, Ph.D., F.G.S., *Palæontologist, Geological Survey of India.*

The fine collection of fossils, which Messrs. Griesbach and Oldham have obtained from the cretaceous rocks of Baluchistán, contains, amongst others, numerous well-preserved *Echinoids*, several of which I recognised to belong to the genus *Hemipneustes* Agass. The occurrence of this genus seemed to indicate the existence of the étage *Danien* in Baluchistán—a fact which, if proved with certainty would be of considerable interest. The closer examination of the *Echinoids* has elicited some more interesting facts, which I publish now, because a considerable time must lapse before the examination of the whole fauna can be completed.

It is unfortunate that no figures of the new species can be given here, and, for the time being, the conclusions I base on the species mentioned below must be accepted in good faith, but I hope that the publication of the whole of the cretaceous fauna of Baluchistán will not be delayed much longer. On the other hand, I think that the results of the examination of the *Echinoids* will be of some assistance to the field geologists who are working now in Baluchistán, and it may be hoped that these notes will help to elucidate further facts concerning the development of the Upper Cretaceous system in Baluchistán.

From a paper in the "Records"[1] it appears that Mr. Oldham divides the strata below the Gházij beds (Eocene) into three groups, which in descending order are as follows:—

3. Dunghan group.
2. Belemnite beds.
1. Massive limestone.

An unconformable break is said to exist just above the Belemnite beds. It might then be expected that a considerable difference in the fauna of the Belemnite

[1] Geology of Thal Chótiali, Records, Geological Survey of India, Vol. XXV., P. 18.

beds and the Dunghan group would be met with, a view which had been fully borne out by the facts. However, Mr. Oldham, unfortunately, was led into a mistake, further elaborated in the 2nd Edition of the "Manual," p. 291, to assume that the Dunghan group contained an anomalous fauna, and that *Nummulites* were associated with cretaceous forms.

Mr. Oldham continues: "Under these circumstances it must remain an open question whether we are to regard the Dunghan group as oldest tertiary or newest secondary in age . . . If the top of the Dunghan group represents the lower limit of the tertiaries, we have to acknowledge an extreme abundance of the genus *Nummulina* in beds of cretaceous age; if the bottom, then the *Ammonoïdea* are represented in beds of tertiary age by several genera and species. A third interpretation is open, and probably it will prove the true one, that the Dunghan group represents the gap between the Secondary and Tertiary period in Europe."

Supposing Mr. Oldham's observations were correct, they would contain nothing new, because true *Nummulites* have been discovered in the Eastern Pyrenees in strata which have been considered by Mr. Seunes[1] as belonging to the étage *Danien*. These strata are said to pass gradually into limestones which contain large *Nummulites* (*N. perforata*).

It is to be regretted that Mr. Oldham advanced such far-reaching theories on palæontological evidence which cannot be considered as conclusive. I have examined the "*Nummulina*" of the Dunghan group in Mr. Oldham's collection, and have found that Mr. Oldham had mistaken a species of the genus *Orbitolites* for *Nummulina*, and as the form is a typical cretaceous genus, the anomaly disappears.[2]

Mr. Griesbach has lately been over the sections described by Mr. Oldham in the paper quoted, and has found that there are three distinct series of rocks represented in that part of Baluchistán; the lowest (Mr. Oldham's "massive limestone") contains a number of fossils, which I am now engaged in working out. I found that they chiefly belong to the genera *Macrocephalites*, Zitt., and *Perisphinctes*, Waag., and that several forms from Kach, such as *M. transiens*, Waag., and *M. polyphemus*, Waag., are represented amongst them. The "massive limestone" is therefore of jurassic age, and represents probably the Kelloway group.

Above the massive limestone follows a series of beds, which are distinguished by an abundance of specimens of *Belemnites*. Locally the *Belemnite* beds may be divided into various horizons, but it seems doubtful whether such horizons could be traced over more than a very limited area. The examination of these forms has proved, that the Belemnite-beds must be considered to be of Neocomian age.

Above the *Belemnite* beds follow the calcareous beds (locally often sandstones) which contain a rich fauna, amongst which the genera *Sphenodiscus*, Zitt., and *Orbitolites*, must be specially mentioned. These beds are also characterised by the widely distributed *Cardita beaumonti*, D'Arch., which in Sind also occurs in the uppermost Cretaceous.

[1] Seunes, Observations sur le Crétacé supérieur des Pyrénées occidentales, Bull. de la Soc. Géol. de France, 3rd ser., vol. xvii, p. 803.

[2] I need not dwell here on the controversy that has been going on for a long time regarding the age of Leymerie's étage Garumnien. It is sufficient to say that Mr. Leymerie tried to explain the presence of cretaceous Echinoids in the calcaires à *Micraster tercensis* by the theory of colonies—a view which might also be applied to the Dunghan group supposing the anomalous fauna existed.

Above the dark-brown *Sphenodiscus* beds follows the white limestone of the Eocene formation with true *Nummulites*.

From the foregoing remarks it seems clear that the *Sphenodiscus* beds represent that part of Mr. Oldham's Dunghan group which contains the cretaceous fauna together with the so-called "*Nummulina*."

The Echinoids which have been described in the following pages have been collected by Messrs. Griesbach and Oldham in the *Sphenodiscus* beds; none come from the massive limestone or the *Belemnite* beds, nor from the nummulitic limestone above. We are therefore in a position to ascertain with great accuracy the age of the *Sphenodiscus* beds.

The Echinoid fauna here described consists of 11 genera with 16 species, of which 8 genera are represented by one, three genera by two, and one genus by three species, *viz.* :—

1. *Cidaris suleimani*, spec. nov.
2. *Orthopsis perlata*, spec. nov.
3. *Cyphosoma sp.*
4. *Protechinus paucituberculatus*, gen. et spec. nov.
5. *Echinoconus gigas*, Cotteau.
6. *Holectypus baluchistanensis*, spec. nov.
7. *Pyrina ataxensis*, Cotteau.
8. „ *gigantea*,[1] spec. nov.
9. *Echinanthus griesbachi*,[1] spec. nov.
10. *Clypeolampas helios*,[1] spec. nov.
11. „ *vishnu*, spec. nov.
12. *Hemipneustes pyrenaicus*, Hébert.
13. „ *leymeriei*,[1] Hébert.
14. „ *compressus*, spec. nov.
15. *Hemiaster blanfordie*, spec. nov.
16. „ *oldhami*, spec. nov.

Out of the 16 species, 15 have been determined specifically, and only 1 generically; out of the 15 specifically determined species, 11 have been found to be new, but 4 could be identified with well-known species from Europe; these are—

Echinoconus gigas, Cotteau.
Pyrina ataxensis, Cotteau.
Hemipneustes pyrenaicus, Hébert.
„ *leymeriei*, Hébert.

I wish to say at once that among the 11 new species several show so close a relationship to other European species that it is quite probable that on actual comparison with the type specimens they may be found identical, and that the number of European species appearing in the cretaceous system of Baluchistán may in fact be much larger than stated above. However, the four species named have been recognised with great certainty, and we may therefore say that the Echinoid fauna of Baluchistán exhibits a most marked European character.

[1] The horizon of this species is not quite certain; Mr. Oldham, who has collected it, simply states from "Dunghan group"; from the state of preservation I think that it has been collected in argillaceous strata just above the *Belemnite* beds.

This feature appears still more remarkable if we take into consideration that these four species occur principally in the étage *Danien* of the Pyrenees. We are therefore fully justified in assuming, from the evidence of the Echinoids, that the cretaceous fauna of Baluchistán is of European type, and showing the closest relationship with the cretaceous fauna of the étage *Danien* of the Pyrenees. I admit that this is a somewhat startling result, and I must say that for some time I felt serious doubts as to its correctness, considering the great geographical separation; but after I noted down this fact, I came across Mr. Cotteau's note, "Sur un exemplaire du *Coraster Vilanovæ* provenant de Tersakhan (Turkestan)."[1] Mr. Cotteau, whose high authority on Echinoids will hardly be doubted by anybody describes in this a small echinoid, which had been presented to his brother by General Komaroff of the Russian Army. I quote here Mr. Cotteau's own words:—

"Cette espèce avait été dans l'origine considerée par M. Vilanova et par moi qui n'avais fait que suivre ses indications, comme éocène. De nouvelles observations ont demontré que la couche qui renferme le *Coraster Vilanovæ* doit se placer dans la Craie, à un niveau supérieur. La découverte de cette espèce faite récemment par M. Seunes dans la Craie supérieure des Pyrénées, ne laisse plus aucun doute sur l'horizon stratigraphique du *Coraster Vilanovæ*.

"La présence de ce petit Échinide, à une aussi grande distance des Pyrénées et de la province d'Alicante, est extrêmement intéressante et suffit pour établir que les dépôts de Tersakhan, dans lesquels il a été recueilli, font partie de la Craie supérieure, et que, suivant toute probabilité, les mers crétacés, qui recouvraient cette partie de la péninsule espagnol et des Pyrénées, se prolongeaient jusque dans le Turkestan."

There is other evidence of the probability that the cretaceous beds of Turkestán belong to the same area of deposition as those of Baluchistán, and if an Echinoid has been discovered in the former which is identical with a form which has hitherto only been found in the Upper Cretaceous system of the Pyrenees and Spain, it is by no means surprising that in Baluchistán several species have been found which are also identical with forms occurring in the cretaceous beds of the Pyrenees.

Mr. Cotteau's view that the sea in which the cretacous beds of the Pyrenees were deposited, extended to the Turkestán area, appears to be fully corroborated by the examination of the Echinoids from Baluchistán. In fact we might assume that the cretaceous sea in which this remarkable fauna lived had extended far to the south and certainly reached to Baluchistán.

If we turn our eyes further south-east and compare the Echinoids from the Arialoor group of Southern India with those from Baluchistán, we observe a most striking difference in the facies of the fauna and find that not a single species is common to both localities; in fact the whole composition of the Echinoid-fauna of Southern India differs greatly from that of Baluchistán, as will be seen from the following table. The following genera have been found in:—

	Baluchistán.	South-India.
Cidaris	X	X
Orthopsis	X	X
Cyphosoma	X	

[1] Bulletin de la Société Géologique de France, 3rd ser., Vol. XVII, p. 155.

	Baluchistán.	South India.
Pseudodiadema	.	X
Micropedina	.	X
Protechinus	X	
Salenia	.	X
Holectypus	X	X
Echinoconus	X	X
Nucleolites	.	X
Pyrina	X	
Cassidulus	.	X
Stigmatopygus	.	X
Botriopygus	.	X
Catopygus	.	X
Echinanthus	X	
Clypeolampas	X	
Hemipneustes	X	X
Holaster	.	?
Cardiaster	.	X
Epiaster	.	?
Hemiaster	X	X

We see, therefore, that out of a total of 22 genera which occur in the Arialoor group of Southern India and in the etáge *Danien* of Baluchistán, only five genera are common to both areas, namely,—

1. *Cidaris*,
2. *Orthopsis*,
3. *Holectypus*,
4. *Echinoconus*,
5. *Hemiaster*,

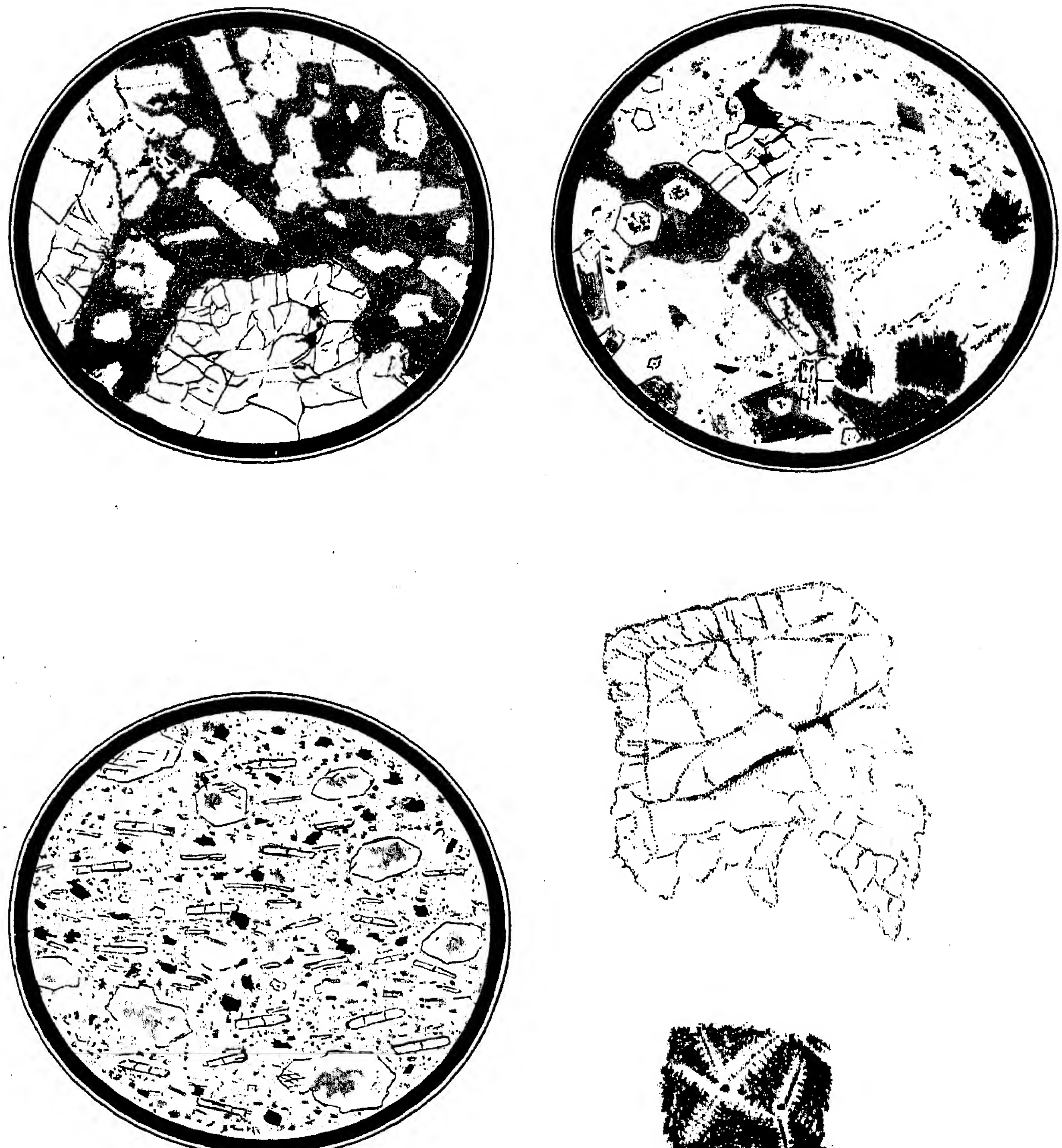
and probably also a sixth, the genus *Hemipneustes*; but the presence of the latter in Southern India is somewhat doubtful, because I base it on the supposition only that the ill-preserved *Cardiaster orientalis*, Stol., does not belong to that genus, but to *Hemipneustes*, as its poriferous zones indicate. Of the above-named five genera, four, *Cidaris*, *Hemiaster*, *Holectypus*, and *Echinoconus* are widely distributed genera, from which no conclusion can be drawn, and only *Orthopsis* may be said to be limited in its vertical distribution, and this genus, together with the probable *Hemipneustes*, would form the only connective links between Echinoid fauna of the upper cretaceous beds of Southern India and Baluchistán.

It may, however, be remarked that it would have first to be proved that the Arialoor group could be correlated with the *Sphenodiscus* beds in Baluchistán, before a comparison of their respective Echinoid fauna could be undertaken; in fact it might be assumed that such comparison is inadmissible if, as it is supposed, the Arialoor group represents the etáge *Senonien* in Southern India, whilst the *Sphenodiscus* beds can be correlated with the etáge *Danien*.

Mr. Lévillé,[1] however, has recognised the presence of the etáge *Danien* in Southern India, which he calls Ninyur group, and of which we must suppose that it was included in the Arialoor group, and therefore a comparison of the *Danien* in Baluchistán with the Arialoor group of Southern India may by no means be incompatible with the actual facts.

It must therefore be admitted that a large faunistic difference exists in the

[1] Bulletin, de la Société Géol. de France, 3rd ser., Vol. XVIII. 146.



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Echinoid faunas of the upper cretaceous systems of Baluchistán and Southern India—a difference which not only concerns the species but also the genera. This fact is the more striking if we consider the faunistic similarity between the upper cretaceous systems of Baluchistán and the Pyrenees.

The only inference which we are able to draw from this fact is that a great faunistic province extended from South-Western Europe towards Central Asia and Baluchistán—the cretaceous Mediterranean Sea,—and that this same province was separated by a land barrier from the sea, in which were deposited the cretaceous beds of Southern India; a view which has already been expressed by other writers, amongst them the late Dr. Neumayr.

On Highly Phosphatic Mica-Peridotites intrusive *in the* Lower Gondwana Rocks *of* Bengal, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Deputy Superintendent, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

1. Besides the fact that hitherto only one or two types of ultra-basic rocks have been described in India, a special interest attaches to the varieties of the rock described in this paper for the following reasons:—

1st,—It is irrupted as dykes and sheets coking the coal and baking the sandstones and shales of Damuda age in Bengal, thus occupying a position similar to that of its near relative, the diamond-bearing peridotite of South Africa, which breaks through the carbonaceous rocks of the Ecca beds and Kimberley shales—strata contemporaneous in geological age and agreeing partly in lithological characters with the coal-bearing Damuda series of India. That diamonds have originated by the action of peridotites on carbonaceous rocks seems to be a most natural conclusion from their frequent occurrence either in the igneous rock itself (South Africa), or in localities where peridotites are intruded into carbonaceous rocks (New South Wales, Western America). This similarity of conditions, therefore, in the Indian coal-fields is most suggestive.[1]

2nd.—The presence of biotite and anthophyllite amongst the leading constituents of this rock considerably limits the number of its relatives amongst the described peridotites of the world, whilst the quantity of apatite, amounting sometimes to over 11 per cent., makes it unique amongst igneous rocks. Whilst apatite is about the most widely distributed of all rock-forming minerals, I know of no case in which its proportion amongst the rock-constituents would entitle it to be regarded other than as an accessory, whilst in the peridotites it is comparatively scarce.

2. Mr. F. G. Brook-Fox called my attention to these rocks in 1892, and kindly brought specimens from Giridih and Assensole. Since that date I have followed up the subject during short holiday excursions to the coal-fields, principally in company with Dr. Saise, Manager of the East Indian Railway Company's collieries at Giridih, to whom I am indebted for some very interesting specimens and for generous assistance in many ways. I am indebted also to Professor Judd of the Royal College of Science, London, for having kindly examined the slides of the mica-peridotites from the Darjíling area and for correcting my determinations.

[1] *Cf.* H. Carvill Lewis, "On a diamantiferous peridotite and the genesis of the diamond," *Geol. Mag.*, dec. III, vol. IV (1887), p. 22; *Rep. Brit. Ass.*, 1887, p. 720. A. H. Green, "A contribution to the geology and physical geography of Cape Colony," *Quart. Journ. Geol. Soc.* vol. XLIV (1888), p. 239. The diamond-bearing peridotite of South Africa is, like the Bengal rock, associated with a series of intrusive sheets and dykes of dolerite, which appear to be the underground representatives of the great sub-aërial lava-flows forming the highest sub-division of the Stormberg beds (Green, *loc. cit.*, p. 255), and thus occupying a position corresponding to the Rajmahal traps of Bengal.

The analogy of the occurrence of diamonds in meteorites and in peridotites, their nearest terrestrial allies, has frequently been remarked (*vide* Daubrée, *Comptes Rendus*, vol. CX (1890), p. 18).

II.—PREVIOUS DESCRIPTIONS OF THE "MICA TRAPS."

3. Dr. W. T. Blanford seems to have been the first to record the occurrence of black mica in the dykes of igneous rock intersecting the Lower Gondwana beds of the Raniganj area, and although in 1860 he could have had no means for distinguishing the petrological characters of the two principal types of dyke-rocks intrusive in the coal-field, he distinguished two groups by their distribution amongst the stratified rocks, describing what he thought to be the older as almost invariably decomposed and soft, forming a red or yellow stone, frequently vesicular and with a habit of forming sheets in the coal and sandstones. From observations which have been greatly facilitated by mining operations since carried out in this and in the adjoining coal-fields, I find that the dykes which are soft, buff-coloured and vesicular at the surface can be traced in the mine-shafts to compact mica-apatite-peridotites, whilst the basaltic dykes, which can now be proved to be younger (*vide infra*, paragraph 14), display characteristic jointing and spheroidal weathering at the surface, with microscopic characters that are unmistakeable.[1]

4. In 1866 Mr. Hughes distinguished the mica-traps, which decomposed to yellow earth and occurred in narrow dykes in the Jherria coal-field, from the basaltic dykes of the same area.[2]

5. In 1867 Dr. V. Ball described a trap-dyke, crossing the Dámodar (Dámuda) north-east of Burobing in the Rámgarh coal-field, as decomposed and earthy similar to many seen in the Ániganj field.[3]

6. In 1868 Mr. Hughes recognised micaceous traps amongst the dykes of the Girídíh (Karharbárí) coal-field.[4]

7. In the Jaintí coal-field (Deoghur) Mr. Hughes distinguished in 1868—70 between the micaceous and the augitic types of dyke-rocks, remarking that the former are always in thin dykes, are more decomposed, and affect the sedimentary rocks to a greater extent than the latter—an observation which is confirmed by a microscopic study of the contact effects.[5]

8. The first microscopic examination of the so-called "mica-traps" was made in 1880 by Mr. F. Rutley of the Royal College of Science, London, who described specimens collected in the Girídíh (Karharbárí) coal-field by Dr. Saise. According to the extract from Mr. Rutley's note published in Dr. Saise's paper on the coal-field, the rocks were "micaceous traps very decomposed indeed, the felspar being replaced by carbonate of calcium." In one specimen he suspected the occurrence of olivine.[6]

9. In 1888 my colleague, Mr. P. N. Bose, described some mica-traps from Bara-

(1) "On the geological structure and relations of the Raniganj coal-field, Bengal." *Mem. Geol. Surv., Ind.*, vol. III, pp. 141—149. The great Salma dyke, for instance, to which Dr. Blanford referred as possibly a member of the younger group (p. 143), is an augite-plagioclase rock.

2 *Mem., Geol. Surv., Ind.*, vol. V, p. 322.

3 *Ibid.*, Vol. VI, p. 129.

4 *Ibid.*, Vol. VII, p. 239. Recently these and the other dykes of this area have been examined in detail by Dr. Saise and myself and will form the subject of a separate note.

5 *Mem., Geol. Surv., Ind.*, Vol. VII, p. 252.

6 *Trans. North Eng. Inst. Min. and Mech. Eng.*, Vol. XXX (1880), p. 13.

kar and Ráníganj under the names *kersanton* and *kersantite*.[1] From an examination of Mr. Bose's slides and specimens, together with a large collection of fresher rocks from this and other coal-fields in Bengal, I should not hesitate to class these rocks with a far more basic type.

III.—MODE OF OCCURRENCE.

10. Compared with the basaltic dykes of the same area, the mica-peridotite intrusions are very narrow, never, so far as seen in the Girídíh coal-field, exceeding about 3 feet in width; and this seems to be true also of similar intrusions in the associated fields.[2] From dykes of this width it can be traced down to minute veins ramifying in the most intricate manner, and even as thin films spreading between the separate columns in the zones of burnt coal which border the dykes (6·930).[3]

11. This rock frequently occurs also as sheets intruding along the beds of coal-bearing rocks—a habit noticed by Dr. Blanford to be so constant that he found it necessary to reassure himself that the igneous rocks were not interstratified lava-flows contemporaneous with the coal.[4] It has thus become to the coal-mine owners a more formidable pest than the larger masses of basalt which occur in vertical dykes.

12. A further mode of occurrence is exhibited in one of the mines of the East Indian Railway Company's collieries in the Girídíh field (Jogítánd shaft, No. 7). One of the galleries has been driven through a mass of peridotite 50 feet thick, and numberless veins from this are found ramifying in all directions and anastomosing amongst the coal-seams around. The other galleries of the mine have, however, only passed through narrow dykes of trap, and they show that the lateral limits of the large mass are, at any rate, within the area of the galleries. There is, therefore, a boss-like expansion in this locality.

13. Representatives of the same rock, with slight local variations in structure and mineral composition, occur in the coal-fields of Ráníganj and Barákar, of Jherria, of Deoghur, and probably of Rámgarh. It occurs also in the Darjiling coal-field also in sheets, with the usual contact-effects of intrusion.

Geological age.

14. According to Dr. Blanford, there is a much larger amount of trap permeating the Lower Damudas than the younger beds, and the sheets of igneous rock intruded into the former strata appear to be alone amongst the trap-rocks of the field which have been thrown by faults. The age of these rocks is, therefore, given as probably Damuda and possibly Lower Damuda.[5] Specimens which I identify with the mica-peridotite here described were collected by Mr. Bose and stated by him to be intrusive in the Raniganj series.[6] The uppermost members of the

[1] *Rec., Geol. Surv., Ind.*, Vol. XXI (1888), p. 163. See also description of the mica-traps occurring in the Damuda rocks of Darjeeling district. *Ibid.*, Vol. XXIII (1890), p. 241.

[2] For example, Jherria (Hughes), Jainti (Hughes), and Raniganj (Blanford).

[3] The numbers in parenthesis refer to the specimens in the Geological Museum, Calcutta, which illustrate the features described or figured in this paper.

[4] *Loc. cit.*, pp. 146 and 147.

[5] *Loc. cit.*, pp. 148 and 149.

[6] *Rec., Geol. Surv., Ind.*, Vol. XXI (1888), p. 164. (Specimen No. 8·283).

Damudas, therefore, must be fixed as older than this intrusion. In a paper by Dr. Saise and myself which is in course of preparation, it will be shown that the mica-peridotite is, as Dr. Blanford suggested from more indirect evidence, older than the associated basaltic rocks, and if we take these (as all later workers have agreed with Dr. Blanford) as contemporaneous with the Rajmahal lava flows, the age of the mica-peridotite can be fixed between the narrow limits of Damuda on the one side, and Rajmahal on the other, that is to say, not far from the Trias of Europe and the Panchet of India.

Contact effects.

15. Wherever the peridotite has invaded the coal-measures the *coal* has lost its lustre, is heavier, hardened, coked and often made beautifully columnar in zones of variable width along both sides of the dykes.

In an equally striking manner *sandstones* have been baked and even partially fused, with the production, in the more felspathic kinds, at structures which sometimes recall the corroded quartz-crystals and crypto-crystalline fluidal matrix of a rhyolite. These contact-effects will be described in detail in the joint paper already referred to.[1]

IV.—PETROLOGICAL CHARACTERS.

Macroscopic characters.

16. The most coarsely-grained varieties have been obtained in the Darjīling district. In specimens of these the glistening scales of brown mica measuring about 2 mm. across form the most prominent feature (8·723, 9·707). The freshest specimens have been obtained from Giridih, and appear as tough and almost black rocks with spangles of biotite, glassy-looking phenocrysts of olivine, and large numbers of acicular crystals of apatite (9·876). Specimens from the narrower dykes and veins are generally dark green in colour, finer in grain, and are always more decomposed, masses of serpentine representing the original phenocrysts of olivine (9·104). In small veins and on the selvages of larger intrusions the rock is compact, of a greenish tinge, weathering to a buff-coloured earth (9·1044, 9·1045). Sometimes the selvages present a variolitic appearance, but the structures which represent the original varioles are now made up of secondary minerals. A similar variolitic appearance has been recorded by Diller at points where in the peridotite of Elliott County, Kentucky, the rock comes in contact with the strata and includes fragments of shale.[2] (See also para. 35.)

17. Where in breaking through the coal the rock has met a nest of iron-pyrites there has been produced a slaggy mass with very distinct fluidal structure and

[1] The late J. B. Jukes, referring in the memoir on the South Staffordshire coal-field to the distances to which the narrow veins of igneous rocks run in the coal-measures of that area, concludes that "at the time of the injection it had a temperature not merely just sufficient to melt it, but a much higher one, sufficient to allow of the loss of a considerable quantity of heat, and yet for the matter to remain still molten in its passage to very considerable distances from the volcanic focus" (2nd edition, (1859), p. 123). I have referred above (para. 10) to the fine ramifications and the long, yet narrow, dykes of mica-peridotite in the Bengal coal-fields, and the conclusion that such a condition is indicative of high temperature is confirmed by the intensity of the widely-extended results of contact metamorphism noticed by Dr. Blanford.

[2] *Bull., U. S. Geol. Surv.*, No. 38 (1887), p. 23.

black colour, like the artificial slags darkened by sulphides described by Percy (9·877).[1]

18. In some cases, where the biotite occurs in excessive proportions, the result of pressure at the margins of the dykes has given rise to a rock as fissile as mica-schist (9·1047).

19. At the surface the dykes weather to a soft buff-coloured earth in which the partially bleached and hydrated mica frequently appears, as noticed by Dr. Blanford, wrapped around small spheroidal masses, which are often hollow in the centres and remind one again of varioles (9·874). In these weathered specimens bands of cavities strongly resembling those of a scoriaceous lava frequently occur; they are presumably only hollows from which serpentine and other minerals have been removed in solution (9·872).

Specific gravity.

20. As all specimens have suffered to some extent from hydration the specific gravity of the rock has been lowered to varying degrees. The following table shows the average specific gravity of the principal types :—

	Rock.	Sp. Gr.
9·876.	The freshest specimen with porphyritic olivine, from the centre of the large mass in No. 7 Jogitand shaft, Giridih. Depth, 286 ft.	2·99
8·723.	Coarse-grained variety from the eastern branch of the Cherang Khola, Darjíling district	2·90
9·105.	Fine-grained rock with olivines completely decomposed. Dyke in No. 7 Jogitand shaft, Giridih	2·80
9·104.	More decomposed and finer in grain. Same locality . .	2·71
9·199.	Buff-coloured and soft decomposed variety from the dyke at the surface	2·684

Fusibility.

21. Specimens, like 9·105, in which the olivines have been hydrated into serpentine, fuse easily before the blowpipe to a black, non-magnetic, and slightly vesicular glass (degree 3 of von Kobell's scale). The fresher varieties containing clear olivine are more refractory—a difference evidently due to the contained water whose influence on the fusibility of substances is well-known from the results of the late Prof. Guthrie,[2] whilst Prof. Judd, with these researches in mind, has pointed out that rock-masses heated to within a small range of their fusion points when dry may become molten on the introduction of water.[3]

22. Fragments of a partly decomposed variety fused for five minutes in a crucible gave on cooling a streaky bronze-coloured glass, which was easily decomposable by hydrochloric acid, and had a specific gravity of 2·895, being thus heavier than the original rock (2·80).

23. The glass kept at a cherry-red heat for 12 hours, lost its vitreous lustre and darkened in colour, resembling tachylyte. The fracture at the same time became "uneven," and the specific gravity rose to 2·99, whilst the product was far less easily decomposed by acid than the original glass.

[1] Metallurgy (Fuel), 1875, p. 58.
[2] *Phil. Mag.* vol. XVIII (1884), p. 117.
[3] *Geol. Mag.*, dec. III, vol. V (1888), p. 10.

24. Under the microscope the glassy form has a yellowish brown colour with feathery skeleton-crystals generally developed around nuclei of magnetite. The partly devitrified form, however, is so crowded with such feathery skeleton-crystals that they interfere with one another during growth. These microlites are colourless in their centres, possess a high index of refraction, high double refraction, and in shape resemble those of olivine.[1] (Plate I, fig. 5.)

Chemical composition.

25. All but the freshest specimens effervesce with mineral acids, and the microscope confirms the presence of rhombohedral carbonates (paragraph 36). It seems natural to expect that slow oxidation of the coal by oxygen dissolved in the circulating under-ground waters would result in the production of considerable quantities of carbonic acid and consequent formation of carbonates from the decomposing silicates of iron, lime and magnesia. A similar phase of alteration seems to have been noticed in most cases of igneous rocks which have intruded into coal measures.[2]

Of specimen No. 9·876 as much as 58·23 per cent. was *soluble* in hydrochloric acid.

26. A remarkable feature of the rock is the large quantity of *phosphoric acid*, which the microscope shows to be in the form of apatite (Plate I, figs. 1, 2 and 3). Specimen No. 9·876 yielded 5·234 per cent. P_2O_5 (equivalent to 11·426 per cent. $Ca_3 P_2 O_8$), whilst the analysis of a more hydrated form (9·105) from the same shaft, gave phosphoric acid equivalent to 10·66 per cent. of lime phosphate. The decomposition of large quantities of this rock at the surface must contribute sensibly to the fertility of the neighbouring soil; but though the quantity of lime phosphate would be considered large enough to warrant remark from the petrologist, it would not be sufficient to justify raising for economic purposes. Even the richest form would be poor compared with the basic Bessemer slags, and the use of these has been attended with indifferent success.[3]

27. The proportion of *silica* rises not only by the removal in solution of the soluble bases, but in this case, where the rock invades masses of sandstones, fragments of quartz are caught up and infiltrations of silica would naturally be expected. The following results have been obtained:—

Nature of the rock.	Sp. Gr.	Silica per cent.
9·876. Olivines partly decomposed	2·99	40·25
9·105. Olivines completely hydrated	2·80	41·32
8·284. Rock much decomposed, with secondary quartz	2·77	48·48[4]
8·284. Ditto ditto	2·45	51·68[4]
8·282. Vesicular rock containing much secondary silica	...	57·88[4]

[1] *Cf.* Rosenbusch, Micro. Phys. (Iddings) 1888, p. 213.

[2] *Cf.* Delesse, *Ann. des Mines.*, 5th ser. vol. XII (1857), p. 144 *et seq.* J. B. Jukes, *op. cit.*, p. 118. I. L. Bell, *Proc. Roy. Soc.*, vol. XXIII (1875), p. 547. J. S. Diller, *Bull. U. S. Geol Surv.*, No. 38 (1887), p. 19. E. Stecher, *Tschermak's Min. Mitt.*, vol. IX (1888), pp. 190, 195. also *Proc. Roy. Soc. Ed.*, vol. XV (1888), p. 172.

[3] Wedding, Basic Bessemer Process, Eng. Ed. (1891), p. 172.

[4] Analysed by Mr. T. R. Blyth; Bose, *Rec., Geol. Surv., Ind.*, vol. XXI., pp. 164 and 165.

Microscopic characters.

28. The numerous specimens which have been collected from different parts of the coal-fields exhibit a wide variation in structure and, within small limits, a variation in mineral composition. There is no difficulty in recognising the fact that the selvages of the dykes are finer in grain than the portions nearer the centres, and that the middle portions of the larger masses are more perfectly crystalline than the smaller veins which branch from them. But, as the face of a dyke is generally a plane of water circulation, the selvages and—for the same reasons—the smaller veins have been in all cases much decomposed, with the destruction of the glass which was very probably amongst the original constituents. (See para. 35.) With the exact knowledge, however, obtainable from the undecomposed types there is little chance of error in identifying the shapes of minerals whose places have, since consolidation, been filled with such secondary products as quartz and rhombohedral carbonates.

Minerals.—The minerals which enter into the composition of these rocks are as follows:—

Primary (approximately in order of crystallization).—

- Apatite.
- Olivine.
- Spinelloid iron-ores (Magnetite, Chromite) and Ilmenite.
- Biotite.
- Anthophyllite.
- Augite.
- Doubtful matrix in small quantities.

Secondary—

- Serpentine.
- Magnetite.
- Perofskite.
- Rhombohedral carbonates, chiefly dolomite.
- Hydrated oxides of iron and clay.
- Pyrites.

Primary minerals.

29. *Apatite* (Plate I, figs. 1, 2, and 3) occurs in slender prisms sometimes 3 mm. long and seldom measuring more than 0·15 mm. across. Basal sections are hexagonal in shape with sharp angles, exhibiting undoubted isotropism. The centres are often darkened by numerous cavities disposed parallel to the vertical axis and sometimes arranged in zones (9·105). Occasionally, however, the apatites are free of such inclusions (9·876, 8·723). Longitudinal sections are jointed transversely, and show low double refraction polarising in characteristic greys, with unmistakeable straight extinction. The quartz-wedge plainly shows the negative character of the double refraction.

Treated with hydrochloric acid the crystals are dissolved, leaving empty spaces on the slide; the solution readily gives a yellow precipitate with ammonic molybdate.

Apatite occurs only in comparatively small quantities in the Darjíling specimens (8·723) and is most conspicuously developed in those from Giridih (9·104, 9·105, 9·876), amounting to over 11 per cent. of the rock. It withstands decomposition longer than any of the constituents of the rock except biotite, and is found in scattered needles in specimens in which the olivines have been completely replaced by carbonates (9·877).

Apatite as usual is included by all other constituents, but most rarely by the olivines. The excessive quantity of this mineral in view of previous descriptions of igneous rocks, and especially of peridotites, certainly seems surprising; but chemical analysis so completely confirms the microscopic characters that there is no question of its identity,[1] I have considered it necessary to give these details because this mineral has, apparently, been taken for plagioclase. Mr. Bose, whilst omitting to mention the presence of apatite in specimen No. 8·283, has referred to "lath-shaped, badly-developed crystals of plagioclase occurring as individuals and exhibiting no twinning."[2] On examination of the original slide I should not hesitate to identify these crystals with apatite, whilst there is no evidence now of the presence of plagioclase (slide No. 563).

30. *Olivine* (Plate I, figs. 1—4) occurs as large clear phenocrysts measuring sometimes as much as 10 mm. across (9·876), and as smaller crystals, which are almost always serpentinised. The crystals are well-shaped, and sometimes have sharp edges preserved. Serpentinous hydration has developed along the characteristically irregular cracks with separation of magnetite dust. A common occurrence is a more or less circular crack cutting off an exterior zone, which is cracked radially and into small fragments, from a central mass which is cracked more irregularly (fig. 4). The high refractive index and strong positive double refraction are those of olivine. Cleavage is sometimes developed parallel to the brachy-pinacoid as shown by the position of the interference figure in macro-pinacoidal sections. Pieces taken from the clear porphyritic crystals sank in a liquid of specific gravity 3·30. In a few types olivine still remains fresh (8·723, 9·707, 9·876), but most specimens show either complete conversion into serpentine (9·105) or final replacement by rhombohedral carbonates (8·283), sometimes with secondary quartz (9·877).

31. *Iron-Ores* (*Magnetite, Chromite*) *and Ilmenite* (figs. 1—3).—These are very variable in development. In the Darjíling specimens they are either absent or rare as primary constituents (8·723 and 9·707). In some Girídíh specimens they occur in numerous well-shaped crystals included in the biotite, but not in the olivine or apatite. Some of these granules transmit light of a brown-yellow colour, possess a high refractive index, and are isotropic. As this rock gives decided reactions for chromium, it is more than likely that these grains are chromite, which is so characteristic of ultra-basic rocks.

[1] Mr. Harker in describing recently the gabbros of Carrock Fell has made the interesting observation that whilst apatite is scarcely to be found in most specimens of the more acid varieties of the gabbros it becomes locally abundant in the highly basic marginal rocks. (*Quart. Journ. Geol. Soc.*, vol. L (1894), p. 324, and plate XVII, fig. 4).

A concretionary substance infilling joints and cracks in a compact peridotite from St. Paul (Atlantic) contained considerable quantities of phosphate of lime, but Renard concluded that it was formed after the manner of common mineral incrustations and is, therefore, not comparable to the large quantities of apatite which exists as a rock-forming mineral in the Bengal peridotites under consideration ("Challenger" Reports. Narrative, Vol. II, Report on the Petrology of the rocks of St. Paul (1879), pp. 16 and 21).

[2] *Rec., Geol. Surv., Ind.*, vol. XXI (1888), p. 165.

32. *Biotite* (figs. 1 and 2) is preserved in all but the most decomposed varieties. The pleochroism is very striking, changing from deep red-brown to bright yellow. Numerous inclusions of apatite and olivine sometimes give the crystals an ophitic aspect (9·105), but occasionally clear crystal-outlines are noticeable (9·707). The small optic axial angle is noticeable in basal scales.

33. *Anthophyllite* (fig. 2).—In the Darjíling specimens, and to a less extent in some from Girídíh (9·104, 9·105), there occur platey or divergent bundles of a mineral exhibiting most striking pleochroism. Cross-sections of these show prismatic cleavages like those of amphibole, and I am indebted to Professor Judd for calling my attention to the way in which these features can be paralleled amongst the anthophyllites. Between crossed Nicols sections show colours always of a lower order than the neighbouring olivines, whilst longitudinal sections show straight extinction. Partial interference figures are obtained in the longitudinal sections which show pleochroism from deep claret-red to gamboge-yellow. From these the double refraction appears to be negative. Other longitudinal sections showing pleochroism from straw-yellow to gamboge-yellow never give an interference figure in convergent polarised light. The crystallographic relations of these features can be made out from the cross-sections, which show the characteristic amphibole cleavage: in these the pleochroism is claret-red (rays vibrating parallel to the macro-diagonal) and straw-yellow, (rays vibrating parallel to the brachy-diagonal). We see, therefore, that the rays vibrating parallel to the vertical axis, as shown in the longitudinal sections, are gamboge-yellow, and as the interference figure is obtained only in the sections which show the claret-red to gamboge-yellow pleochroism the optic axial plane must be parallel to the brachy-pinacoid, and, the double refraction being negative, we have the following optical scheme:—

$a = \mathfrak{a}$, straw-yellow.
$b = \mathfrak{b}$, claret-red. *Absorption*, $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$.
$c = \mathfrak{c}$, gamboge-yellow.

The crystals are frequently marked by bands of fine cavities which can only be individualised under 1-8th inch objective. Along the edges and into cracks there is generally a bluish green fringe which seems to be a change to chlorite, polarising with very much lower colours. The grains were too small and too well intergrown with other minerals to permit isolation of pure material for chemical analysis; but from the properties which can be tested it seems safe to refer this mineral, as Professor Judd has suggested, to the group of rhombic amphiboles. Anthophyllite is, according to Rosenbusch, often found in serpentines.

34. *Augite* (fig. 2) occurs in colourless or pale green crystals often developed around biotite. It occurs in the Darjíling rocks in very small quantities, and its intimate association with the amphibole suggests an origin for the latter. In the Girídíh specimens its distribution is variable. It occurs with the anthophyllite sometimes in considerable quantities (9·105), and sometimes is absent in specimens obtained from the same shaft; in this case it is noteworthy that the amphibole is at the same time wanting (9·876). Unless represented by the microlites of the groundmass it is absent also from the more compact varieties (9·109).

35. *Matrix* (fig. 2).—In addition to the minerals described above, there occurs in the Girídíh specimens a dirty matrix polarising with very low tints, either in small irregular patches like a partly devitrified glass, or as a microcrystalline mosaic. In

ne places it suggests felspar, but there are no signs of twinning or definite crys- structures and its quantity is very small. It appears like a residuary matrix 876, 9·105). Classing this substance as an altered glassy matrix seems to be : more justified from the occurrence in the American mica-peridotites of a glass esenting similar characters. In a mica-peridotite occurring as a dyke of late boniferous age in Central New York C. H. Smyth, Jr., has recognised a glassy atrix which is not always devitrified.[1] A brownish-grey clouded material with nilar relations has been noticed by Diller in a mica-peridotite dyke in Kentucky,[2] d similar material has been found in other peridotites, for example, in kimberlite m South Africa (H. Carvill Lewis) and in the Elliott county peridotite in Ken- cky (J. S. Diller).

Secondary minerals.

36. In all specimens the processes of hydration and the production of carbo- tes have commenced. *Serpentine*, as usual, results from the hydration of the vine, the change being attended with the separation of dusty *magnetite*. In one ecimen in which decomposition has well advanced small crystals imbedded the serpentine exhibit the characters of *perofskite*. They occur as yellow, ouded grains generally diamond or spindle-shaped, measuring up to 0·1 mm. long d 0·05 mm. wide. The grains when sufficiently clear to examine with polarised ht show occasionally very strong double refraction which seems to be due to rbonates filling the yellow shells. When quite brown, however, they are isotropic. emoved from the serpentine with a sharp needle and fused with sodium-carbonate ey gave a distinct reaction for titanium on being boiled with hydrochloric id and tin. Diller has described as anatase similar grains in the serpentine eudomorphous after olivine in the peridotite of Elliott County, Kentucky. . H. Williams identified perofskite in the serpentine of Syracuse, New York in 387,[3] and at his suggestion Diller on re-examining the Elliott Country peridotite und that similar grains which had been doubtfully referred to anatase were ally perofskite.[4] Similar grains in peridotites have been referred to perofskite by . H. Smyth (Central New York),[5] by Diller (Kentucky)[6] and by Branner and rackett (Arkansas).[7] The *carbonates*, which are so common in these rocks, give e chemical reactions for dolomite.[8] These are found, sometimes with clear *condary quartz*, infilling cavities from which decomposable minerals have been emoved. As a final stage in the processes of decomposition, the magnetic oxides

[1] *Amer. Journ. Sci.*, 3rd Ser., Vol. XLIII (1892), p. 324.

[2] *Ibid*, 3rd Ser., Vol. XLIV (1892), pp. 287 and 288.

[3] *Ibid*, 3rd Ser., Vol. XXXIV (1887), p. 140.

[4] *Ibid.*, 3rd Ser., Vol. XXXVII (1889), p. 219.

[5] *Ibid.*, Vol. XLIII (1892), p. 324.

[6] *Ibid.*, Vol. XLIV (1892), p. 287.

[7] *Ibid.*, Vol. XXXVIII (1889), p. 57.

[8] Previous records of the occurrence of carbonates among the secondary products of gneous rocks which have intruded into carbonaceous strata have already been referred to *ante*, p. 135). In the case of the Elliott Co. peridotite similarly situated, the carbonate was found lso to contain magnesia (Diller, *loc. cit.*, p. 19). For further development of dolomite from eridotite, see Wadsworth, Lithological studies, *Mem. Mus. Comp. Zool. Cambr. Mass.*, Vol. XI (1884), p. 139, and R. D. Irving, Fifth Ann. Rep., U. S. Geol. Surv., 1883-84, . 217.

become oxidised and hydrated, the carbonates removed in solution, and the aluminous minerals reduced to a soft yellow, buff-coloured or red clay at the outcrop.

Varieties due to differences of mineral composition.

37. All the rocks originally contained olivine in large quantities, but variations occur especially in the proportions of the augite and amphibole, and to a smaller extent, of the apatite. These ultra-basic rocks differ only slightly from the mica-olivine dolerites, which in the same way break through the coal-measures of the Barakar area, but which I have not found in the Giridih coal-field.[1]

The following are the principal types of ultra-basic rocks represented, with the primary minerals given in approximate order of quantity, the most abundant first:—

(1) Olivine-mica-apatite rock, with magnetite and chromite (9·876).
(2) Olivine-apatite-mica-augite-anthophyllite rock, with small quantities of spinellids (9·105).
(3) Olivine-mica-apatite-anthophyllite-augite rock, with spinellids (9·104).
(4) Olivine-mica-anthophyllite-augite rock, with apatite (9·707).
(5) Mica-olivine-anthophyllite-augite rock, with apatite (8·723).

Varieties due to differences of structure.

38. The rocks vary from a fine-grained variety with a matrix probably originally glassy to varieties composed of crystals measuring 2 or 3 mm. across with porphyritic crystals of olivine quite 10 mm. in diameter. In the former type phenocrysts of olivine occur in a pilotaxitic matrix; but biotite, which is so prominent in other types, occurs in rare and small crystals; being one of the latest minerals formed, this is only what might be expected. The olivines are generally replaced by rhombohedral carbonates with smaller quantities of a yellowish brown limonitic product, evidently a further stage in the decomposition of the ferro-magnesian silicates. The apatite crystals are still preserved, and by their arrangement in directions approximately parallel to the junction with the sandstone, show the direction of pressure to which the rock was subjected before final consolidation (9·109, fig. 3). Rocks of this structure would be included under those referred to by Professor Cole as *compact peridotites*[2], and are equivalent to the *picrite-porphyrites* of Rosenbusch and the *kimberlite* of Carvill Lewis.

The holocrystalline types are granitic in structure and require no further notice under this head.

V.—SUMMARY.

39. The so-called "mica-traps" intrusive into the coal-measures, sandstones, and shales of Lower Gondwana age in Bengal, prove to be basic and highly phosphatic ultra-basic rocks (paras. 26, 27, 37).

"Mica-traps."

[1] The rock which for the present I have referred to as a mica-olivine-dolerite, is distinguished from the ultra-basic rocks by containing considerable quantities of felspar with a very small proportion of apatite; its magnetite also occurs in long laths instead of in granules. On account of these peculiarities, I have provisionally separated certain compact and partly decomposed specimens from the ultra-basic group until by fresher specimens their characters can be traced out more fully. Specimens so separated occur so far only in the Barakar-Ránigani coal-field.

[2] Aids in Pract. Geol. (1891), p. 220.

Mineral composition.

40. Members of the latter group invariably contain large quantities of *olivine* and *biotite* with *apatite*, which is always abundant and sometimes forms as much as 11 per cent. of the rock. Amongst the other primary minerals, *augite* and pleochroic *anthophyllite* take a prominent place, whilst *ilmenite*, *magnetite*, and *chromite* are variable. Amongst the secondary minerals *serpentine* and *magnetite* are the earliest products of alteration. These are followed by *perofskite* and *rhombohedral carbonates* which always contain magnesia. The final result of weathering is a ferruginous, yellow, buff-coloured or red *clay* (paras. 28—36).

Structure.

41. In structure the rocks vary from the coarse holocrystalline varieties which form the central portions of the large masses, to compact peridotite forming the selvages of dykes and the smaller veins. In the latter the phenocrysts of olivine, apatite, and magnetite occur in a pilotaxitic matrix which probably originally contained some glass (paras. 16, 28, 38).

Occurrence.

42. The rock occurs as narrow dykes and intrusive sheets in the coal-fields of Dárjíling, Ránígani, Barfkar, Jherria, Deoghur, Girídíh and probably Rámgarh, thus occurring in places more than 250 miles distant from one another (paras. 10—13).

Geological age.

43. As these dykes are younger than the Ránígani series and older than the Rajmahál traps we have a petrographical province of about Pánchet age (para. 14).

Analogies with South African peridotites.

44. As far as can be judged from descriptions, there is an interesting analogy between these rocks and those intruding into the Kimberley shales of South Africa, where, in carbonaceous beds of about the same age as the Damudas, a diamond-bearing peridotite is also associated with basaltic dykes, which are the underground representatives of the sub-aërial lava-flows capping the Stormberg beds, thus occupying a position corresponding to the Rajmahál traps of Bengal (para. 1).

VI.—EXPLANATION OF PLATE I.

Fig. 1. Olivine-biotite-apatite rock with magnetite and chromite. Central portion of a large mass in No. 7 Jogitand shaft, Giridih coal-field (9·876).

Fig. 2. Olivine-biotite-apatite-augite-anthophyllite rock with iron-ores and a decomposed grey groundmass. The olivines in this rock are almost completely serpentinised (9·105). From another dyke in the same shaft.

Fig. 3. Compact peridotite showing fluidal structure by pressure at the selvage of a dyke intruding into sandstone. Apatite crystals occur as numerous rods; olivines mostly replaced by carbonates and limonite; magnetite scattered through the pilotaxitic groundmass. Sibpore Colliery, Assensole (9·109) (see p. 140).

Fig. 4. Crystal of olivine showing two series of cracks (9,876) (see p. 137).

Fig. 5. Microlites developed by maintaining the artificially-produced glass of No. 9·105 at a bright red heat for 12 hours (see p. 134). Sp. gr. 2·99.

All magnified ×45/2.

On a Mica-Hypersthene-Hornblende-Peridotite *in Bengal*—By THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Deputy Superintendent, Geological Survey of India.*

I.—INTRODUCTION.

Taking the essential and primary constituents in their approximate order of proportion, the peridotite from Mánbhúm described in this paper may be classed as an olivine-hornblende-biotite-hypersthene-augite rock with accessory pyrrhotite and pyrites.

A certain amount of interest attaches to a rock of this composition—

(1) On account of the very small number of peridotites known in which biotite is a primary and an essential constituent.

(2) On account of the still smaller number of mica-hornblende-peridotites known.

(3) On account of the presence also of hypersthene which, with primary olivine, biotite and hornblende, forms a combination of minerals it seems hitherto undescribed.

(4) On account of the proximity of this rock to the Bengal coal-fields in which mica-peridotites of a very peculiar character pierce the sedimentary rocks in all directions.[1]

(1) *Previously described Mica-Peridotites.*

An *olivine-biotite rock* with blue-green spinel, titaniferous iron, augite and plagioclase as accessories associated with the gabbro mass of the Harz, was described in 1889 by Max Koch[2]. This seems to have been the first mica-peridotite described.

In 1892 C. H. Smyth described a *mica-peridotite* occurring as a dyke of late carboniferous age in Central New York.[3] The structure of this rock in being distinctly hemi-crystalline like kimberlite, agrees strikingly with that of some of the varieties of mica-apatite-peridotites occurring as intrusions in the Bengal coal-fields.

Later in the same year J. S. Diller published an account of a *mica-peridotite* from Kentucky describing it as a dyke-rock composed essentially of biotite, serpentine and perofskite, with smaller proportions of apatite, muscovite, magnetite, chlorite, calcite and some other secondary products. In this rock also there are considerable quantities of a brownish grey clouded material without crystallographic outline or such physical features as definitely indicate its origin.[4] From the description it resembles the substance which in the mica-apatite-peridotites I have referred to decomposed and devitrified residuary matrix.

[1] The locality in which the rock was found is on the southern border of the Jherria coal-field and is only 36 miles west of Raniganj. The peridotites referred to are described in a separate note (*Rec., Geol. Surv., Ind.*, vol. XXVII (1894), p. 129).

[2] *Zeitschr. d. Deutsch. geol. Ges.*, vol. XLI (1889), p. 163.

[3] *Amer. Journ. Sci.*, 3rd ser., vol. XLIII (1892), p. 322.

[4] *Amer. Journ. Sci.*, 3rd ser., vol. XLIV (1892), p. 286.

(2) *Previously-described Mica-Hornblende-Peridotites.*

The well-known *Schillerfels* of Schriesheim in Baden described by Cohen is a hornblende-peridotite (hudsonite, cortlandtite) with mica, which apparently is less prominent than in the Mánbhúm peridotite.[1]

The nearest ally to the Mánbhúm specimens seems to be the rock described as *scyelite* (mica-hornblende-picrite) from Caithness by Professor Judd. In this rock, however, the pyroxenes which once existed have been completely changed to amphibole.[2]

Amongst the peridotites of the Cortlandt series near Peekskill, New York, the late Prof. G. H. Williams described as hornblende-peridotite (*cortlandtite*) a type in which, besides the essential constituents hornblende and olivine, there occur hypersthene, augite, biotite, felspar, spinellids and pyrrhotite in subordinate quantities.[3] This rock, therefore, very nearly approaches the Mánbhúm peridotite, but the biotite again appears to be far less prominent.

In 1892 Messrs. Dakyns and Teall described an *enstatite-diallage-hornblende-biotite-olivine rock* from amongst the plutonic intrusions near the head of Loch Lomond in Scotland.[4] In this rock the small quantity of both biotite and olivine remove it from the Mánbhúm type.

The rock described in 1880 by Sir Archibald Geikie as a *picrite* from the Island of Inchcolm, Firth of Forth, contains olivine and its serpentinous products, augite, biotite, plagioclase and its secondary products, and iron-ores with, according to Mr. Teall, hornblende and apatite. The hornblende, however, is variable and sometimes absent, whilst the biotite occurs only as occasional long scales and according to Mr. Teall is possibly of secondary origin.[5]

Other described peridotites contain subordinate quantities of brown mica, for example, Pen-y-Carnisiog Anglesey (Bonney),[6] Gipp's Land (Bonney),[7] Pike county, Arkansas (Branner and Brackett)[8], Elliott county, Kentucky (Diller)[9] Taberg, Sweden (Törnebohm),[10] but in these cases there is an absence of the pyroxene, or hornblende, or both. I know of no case, therefore, similar to that of the Mánbhúm peridotite.

II.—MODE OF OCCURRENCE.

Specimens of this rock, labelled "hornblende rock" (No. 3·22), were collected by the late Mr. Fedden in the season 1865-66 near the Ijri river, west of Bhurro (Lat. 23° 37′N., Long. 86° 30′ E.) in the Mánbhúm district. It is associated with the other crystalline rocks near Chypabad and Palkuree, and according to Mr. Fedden

[1] *Neues Jahrb. für Min.*, 1885, vol. 1, p. 242.
[2] *Quart. Journ. Geol. Soc.*, vol. XLI (1885), p. 401, plate XIII, fig. 8.
[3] *Amer. Journ. Sci.*. 3rd ser., vol. XXXI (1886), p. 29.
[4] *Quart. Journ. Geol. Soc.*, vol. XLVIII (1892), p. 112.
[5] Geikie, *Trans. Roy. Soc. Ed.*, vol. XXIX (1880), pp. 506—508. Teall, Brit. Petrography, 1888, pp. 94—96, and plate IV, fig. 2.
[6] *Quart. Journ. Geol. Soc.*, vol. XXXVII (1881), p. 138.
[7] *Min. Mag.*, vol. VI (1884), p. 54.
[8] *Amer. Journ. Sci.*, 3rd ser., vol. XXXVIII (1889), p. 50.
[9] *Ibid.*, 3rd ser., vol. XXXII, (1886), p. 121, and *Bull. U. S. Geol. Surv.*, No. 38, 1887.
[10] *Neues Jahrb. Min.* (1882), vol. II, p. 66.

can be traced westward through Futtoodee to Bagoolah, where it forms a large mass. Between Hotoopathar and Partand, 6 miles west-north-west, it is exposed in a mass running north-west and cropping out at right angles to the mica-schists and gneisses.[1]

III.—PETROLOGICAL CHARACTERS.

The specimens exhibit in a striking manner the lustre-mottling which is so characteristic of hornblende peridotites; and in this case the structure is due to the bright cleavage-faces of the hornblendes and the ophitically disposed scales of biotite, which often determine the fracture of the rock. The specific gravity is 3·234.

Under the microscope the following minerals are distinguished:—

Apatite.
Olivine.
Pyroxene (Hypersthene and Augite).
Biotite.
Hornblende.
Magnetite.
Pyrite and Pyrrhotite.
Felspar.

Apatite occurs in sparsely distributed crystals measuring up to 0·25 mm. in diameter. Rod-shaped cavities are arranged parallel to the vertical axis.

Olivine, colourless and without crystalline form, is included by all the other minerals. A striking feature in this mineral is the separation of magnetite in stellar and dendritic markings reaching sometimes 0·1 mm. long, like those described by Professor Judd in the olivines of a picrite from Halival, Isle of Rum.[2] In the olivines of this rock also the branches of the dendrites frequently exhibit rectilinear limits as if bounded by the edges of negative crystals in the olivines, and these straight lines are always parallel to a direction of extinction; they are parallel, therefore, to one of the crystallographic axes. In sections cut at right angles to these inclusions they appear as lines and rows of dots: on examining these sections with a quartz wedge there is an appearance of thinning when the axis of the wedge is placed parallel to the inclusions; the inclusions therefore cannot lie in the brachypinacoid.[3] As only one set of inclusions is present they are presumably not parallel to the prism faces; they are, therefore, either parallel to the macropinacoid or the basal plane. Several sections approximately parallel to the inclusions have been made, and these invariably give at least a partial interference figure; as the optic axial plane is parallel to the basal plane in olivines, it may be concluded that the sections parallel to the inclusions are macropinacoidal.[4] Irregular cracks traverse the olivines in all directions and sometimes cross the

[1] Fedden, MS. report on parts of Mánbhúm and Hazaribágh, 1865-66.

[2] *Quart. Journ. Geol. Soc.*, vol. XLI (1885), p. 381, and plate XII, figs. 2-7.

[3] In olivine with positive double refraction (as shown by this mineral)—$\mathfrak{a} = b$, $\mathfrak{b} = c$ and $\mathfrak{c} = a$.

[4] No crystallographic faces or trustworthy cleavage cracks being exhibited, this statement has to be made without the confirmation desirable. Tabular inclusions parallel to the macropinacoid are curiously like the shapes of fayalite crystals.

dendritic plates. These cracks are also filled with black material which is often arranged in a dendritic fashion; but these lie in irregular positions, and the dendritic growths are analogous to those of the well-known manganese-oxide infiltrations in the joint-planes of rocks. There are other cavities irregular in shape and often joined to one another by tortuous canals; these are generally partially filled with black stones.

The olivines in this rock show scarcely a trace of serpentinisation, and in this respect present a striking contrast to those of the mica-peridotites in the adjacent coal-fields. It is noteworthy also that in the latter rocks the dendritic products of schillerization are quite wanting.

Pyroxenes.—When free of inclusions the *hypersthene* shows a distinct pleochroism in thin sections (pale pink to almost colourless). The majority of the crystals are schillerised, the plates lying, as in that from St. Paul, parallel to a direction of extinction. The colours between crossed Nicols are low. Polarisation-effects of a distinctly higher order are exhibited by a colourless mineral occurring in granular aggregates and less often as isolated crystals. In these crystals the rod-like inclusions crossing one another nearly at right angles are so numerous that a satisfactory determination of the optical properties of the mineral could not be made. All extinctions from the directions of the inclusions, as well as from the cracks occasionally presented, are oblique, and as the mineral is unaffected by hydrochloric acid, it has been taken for *colourless augite,* which would not be remarkable in this association. The crystals, too, are patched all over with green hornblende which has apparently developed by paramorphism.

Hornblende occurs in two forms—a brown variety in crystals 40 mm. or more in length and including all the other minerals in the rock except biotite, and a green variety of later development, being the result of the paramorphism of augite and occurring in isolated patches with the granular aggregates of this latter mineral, as well as on the margins of, and in optical continuity with, the larger brown hornblendes. The extinction-angle of the large crystals is noticeably wide, the maximum measurement being 22°. The quartz-wedge placed along the direction of extinction in clinopinacoidal sections gives (with crossed Nicols arranged at 45° to the quartz-wedge) an appearance of thickening. Taking this direction as the axis of optical elasticity $\mathfrak{c}$ we have the pleochroism :—

$\mathfrak{c}$ = deep brown.

$\mathfrak{a}$ = very pale brown with a tinge of green;

and from cross-sections showing the characteristic prismatic cleavage,

$\mathfrak{b}$ = deep greenish brown.

Sections, therefore, parallel to $\mathfrak{b}$ and $\mathfrak{a}$ are not strikingly pleochroic. Minute rod-like inclusions arranged parallel to the cleavage-cracks appear sparsely distributed through the longitudinal sections. The green hornblende calls for no special remark.

Biotite, by its cleavage, often determines the direction of fracture in the rock. It is intergrown with hornblende, and apparently is of later development than any of the other primary constituents. Basal plates show a very narrow optic-axial angle, and in the same sections numbers of brown and black plates, sometimes hexagonal in shape, are arranged parallel to the cleavage-plates. I have not been able to discover that these have any definite crystallographic disposal of their edges with reference to the percussion-figure. Associated with the plates are fine hairs which are often arranged at angles of 60° to one another. These are generally referred to sagenitic rutile, but a careful chemical examination of a number of flakes gave no reactions for titanium. Whether a portion or the whole of these inclusions are primary or secondary cannot be decided by this specimen alone, but the fact that distinct schillerization with definite crystallographic disposal of the secondary products is exhibited by the other minerals in the rock, points to a similar origin for the blemishes in the biotite.

Iron-ores.—The *magnetite* is almost wholly secondary, the olivines being sometimes almost opaque from the separation of this mineral. Granules of *pyrrhotite* and *pyrite* measuring up to 5 mm. in diameter are sparsely scattered through the rock. A test for metallic iron gave negative results.

Plagioclase occurs in very small quantity apparently infilling cavities as if of secondary origin. The crystals are clear, unschillerized and generally twinned. Simultaneous extinction occurs in patches separated by distances of 2 mm. or more. The extinction-angles agree with those of labradorite.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 21.—Ending 31st October 1894.

Director's Office, Calcutta, 31st October 1894.

The programme for the next field season (1894-95) has been arranged as follows:—

SCIENTIFIC.

Central India.—Mr. R. D. Oldham, Superintendent.

Mr. P. N. Datta, Assistant Superintendent, and an Assistant Superintendent about to be appointed by the Secretary of State.

Central Provinces.—Mr. P. N. Bose, Superintendent.

Madras.—Mr. C. S. Middlemiss, Deputy Superintendent.

Burma.—Dr. Fritz Noetling, Palæontologist.

Baluchistan.—Mr. F. H. Smith, Assistant Superintendent.

ECONOMIC.

Sukkur Experimental Boring, and Economic Geology of Baluchistan:—

Mr. T. D. La Touche, Superintendent.
Lala Hira Lal.

Madras and Burma.—Dr. H. Warth.

Chota Nagpore.—A specialist about to be appointed by the Secretary of State.

The Director and Mr. Holland will be at Headquarters during the coming season.

Mr. Hughes, Superintendent, is still on sick leave; Mr. Oldham re-joined his appointment on the 17th instant from furlough, during which he had occasion to visit the Galician oilfields with permission of the Secretary of State. Lala Kishen Singh is on furlough and Lala Hira Lal on privilege leave, which he re-joined on the 16th instant.

During the last three months most of the officers have been in recess-quarters for the purpose of working up their maps and notes, and all have sent in their progress reports for the last field-season.

Important work has been done and is still in progress in the Laboratory under Mr. Holland, who is ably assisted by Mr. Blyth, the Museum Assistant. The re-arrangement and cataloguing of the mineral and rock collection is a work of paramount importance, and it is hoped will be completed during the coming cold weather.

Dr. Noetling was engaged for several months past in working out and describing some important collections of fossils. The tertiary fossils of the Yenangyoung oil-tract have been described and figured and will shortly appear as part 1 of Vol. XXVI of the Memoirs. A still more important suite of fossils, namely those collected by the survey in Baluchistan, has been subjected to critical examination, and the first instalment of a new "series" of the Palæontologia Indica will be published as soon as the plates belonging to it are lithographed in the office. It will contain the jurassic fossils of Baluchistan.

The overflow of the Gohna Lake.—It will be remembered that a landslip occurred early in September 1893 and dammed up the Birahi Ganga which drained 90 square miles above Gohna. The locality was examined by Mr. Holland early in March 1894, when the lake was nearly 3 miles long with a maximum width of 1 mile. Mr. Holland's report described (1) the geographical and geological features of the Birahi Ganga valley, (2) a description of the landslip and lake, and (3) a discussion of the causes which led to the landslip.

With regard to the second point he predicted:—

(1) That the lake would be full and would overflow the barrier about the middle of August.

(2) That the dam was strong enough to resist the pressure of the water before overflow.

(3) That after overflow the lake would be reduced to one about 3¼ miles long, and that this would remain permanent for some time.

(4) That landslips would occur into the lake.

The lake overflowed the dam early on the morning of August 25th, the stream flowing down the steep slope to the bed below Gohna. The erosion thus continued until late at night when a channel having been cut back to the lip of the lake a rapid recession of levels followed until the erosion was checked by reduction of the slope and exposure of large blocks of dolomite, by removal of the fine detritus forming the upper part of the dam. The lake left is about 3 miles long and over 300 feet deep, with, according to the latest accounts, every chance of being historically permanent, although its gradual destruction by silting up of the basin and gradual erosion of the dam will, geologically considered, happen at no distant time. The landslips which have occurred into the lake have with the silt raised the bottom nearly 100 feet. The dam is now quite firm and the outlet through the gorge cut in its upper part is over a rocky bed with a slope of about 1 in 15.

In this gorge, cut through a portion of the first of the two main falls, there are exposed, according to Lieutenant Crookshank, R.E., great bundles of strata dipping towards the south at an angle of about 50°, which he regards as a striking confirmation of Mr. Holland's conclusion with regard to the peculiar character of the first slip in which Mr. Holland considered that the hill must have pitched forward and not have slipped down in stream fashion after the manner of smaller and more common landslips. (Records, vol. XXVII, page 59.)

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1894.

Substance.	For whom.	Result.
1 Specimen of quartz, with iron pyrites, from Dongreea hill, Bhandara Dist., C. P., for Gold.	P. N. DATTA, Geological Survey of India.	Contains no Gold.
3 Specimens of manganese ore (*Braunite* with *psilomelane*), from the Central Provinces.	P. N. DATTA, Geological Survey of India.	9/1008. 1 mile N. of Seetasaongee, S. by W. of Chicklah. *Quantity received* 3¼ oz. 61·08 9/1002. ¾ mile N. by E. of Koodmoora village *Quantity received* ¾ lbs. 35·97

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1894—continued.

Substance.	For whom.	Result.
		$\frac{9}{998}$ Dhola hill, S. of Beemasoor Peak, Chicklah. *Quantity received* $1\frac{3}{4}$ oz. Percentage o manganese (Mn.) . . . . 43·97
1 specimen from near Goona, Gwalior, for examination.	Col. D. G. Pitcher, Director of Land Records, Gwalior State.	Fibrous Calcite.
Rocks from the Sone Valley, Rewah State.	P. N. Bose, Geological Survey of India.	$\frac{9}{1050}$ Slide 1299. From the Sone, Rampurwa, Ramnagar Tahsil. BIOTITE-GNEISS WITH LEPTYNITE VEINS—The hand-specimen shows black-mica gneiss with bands of leptynite arranged parallel to the direction of foliation. Under the microscope the structure is granulitic to granitic. The minerals are :—*Quartz* in bands of granules with liquid-bearing cavities in rows. *Felspar*, sometimes showing lamellar twinning. The central portions of the crystals are grey or brown by the abundance of kaolinized products. The margins are clear and appear sometimes to be of secondary growth. *Biotite* in irregular highly pleochroic bundles α = greenish-yellow; β and γ = dark-green with almost complete absorption. Seldom fringed with chlorite. *Colourless mica* occurs in very small quantity. *Apatite* in sparse stumpy crystals. *Iron-ores* occur very rarely. *Epidote* is developed in large quantities. $\frac{9}{1051}$, Slide 1300. From the Sone at Rampurwa, Ramnagar Tashil.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1894—continued.

Substance.	For whom.	Result.
		APHANITE— Occurs in contact with gneissose granite. The section under the microscope appears like a net-work of finely, granular green *hornblende* enclosing almost colourless *augite*, *plagioclase felspar* and possibly *quartz*. Granular *iron-ores* appear to be a product of the change of the augite. $\frac{8}{1082}$, Slide 1301. Sukha river, north of Sidi, Sahaol Tahsil. APHANITE— Occurs penetrating granite. The rock is composed almost entirely of actinolitic *hornblende* and decomposed *felspar*, with mesh-like patches of *iron-ores*. By parallel arrangement of the fibres the actinolite sometimes shows simultaneous extinction over considerable areas. Originally the rock was probably an augite-plagioclase rock. $\frac{8}{1083}$, Slide 1302. Marka, Sahaol Tahsil. QUARTZ-APHANITE, intrusive in the transitions. Differs from the last only in the introduction of *quartz* and in the numerous needles of *apatite*. $\frac{8}{1084}$, Slide 1303. Deora, Sahaol Tahsil. Decomposed amygdaloidal ANDESITE, interbedded in the Bijawars. The cavities arranged in parallel bands have been infilled with *calcite* and *chlorite*. Under the microscope, there is a ground-mass of felted microlites of two minerals, which, from their different double refractions, appear to be *hornblende* and *felspar*. Opaque white patches scattered through the ground-mass could not be determined. Well-shaped and sometimes twinned crystals of *epidote* form the most striking feature in the sections. $\frac{10}{78}$, Slide 1306. BIOTITE-GNEISS WITH LEPTYNITE VEINS like No, $\frac{8}{1080}$, slide 1299, from the Sone, Rampurwa, Rewah State. $\frac{10}{79}$, Slide 1305. AMPHIBOLITE— Satnara, south-east of Sidi, Sahaol Tahsil. Dark-green tough rock with bright phenocrysts of *hornblende* measuring up to 5 mm. long. Ragged masses of magnetite in fair quantity are made out under the microscope, but the larger crystals of hornblende make up the principal mass

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1894—concluded.

Substance.	For whom.	Result.
		of the rock. These are imbedded in a fine-grained matrix of green hornblende and microcrystalline aggregate of *quartz* and *felspar* in small quantities. 18, Slide 1307. MICA-SYENITE. Harbora, Sahaol Tahsil. Pink *felspar* and small quantities of *quartz* with dark-green *hornblende* and *chlorite* are easily seen with the naked eye. Under the microscope the following minerals are distinguished:— *Apatite*, dark-green *hornblende*, *biotite* almost completely changed to *chlorite*, *felspar* principally orthoclase, sometimes plagioclase always kaolinised, and *quartz* in small quantities showing a feeble attempt at micrographic intergrowth with the felspar. 19, Slide 1304. EURITE (devitrified rhyolite approaching syenite-felsite). Ponri, east of Kua, Ramnagar Tahsil. The hand specimen is compact, has a conchoidal fracture and grey colour like many eurites. Phenocrysts of *felspar* are more common than those of *quartz* which occur in small granules. Some of the felspar is plagioclase. The matrix is microcrystalline and shows fluidal structure.

Notifications issued by the Geological Survey of India during the months of August, September, and October 1894, published in the "Gazette of India," Part II.—Leave.

Department.	No. of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	REMARKS.
Geological Survey Department.	2047, dated 21st September 1894.	Dr. H. Warth, Deputy Superintendent, Geological Survey of India.	Privilege.	23rd September 1894.	...	...

Annual increments to graded officers sanctioned by the Government of India during August, September, and October 1894.

Name of officer.	From	To	With effect from	No. and date of sanction.	REMARKS.
F. H. Smith, Assistant Superintendent, Geological Survey of India.	R 410	R 440	1st August 1894.	Revenue and Agricultural Department No. $\frac{2484}{180}$, Surveys, dated 30th August 1894.	
T. H. D. LaTouche, Superintendent, Geological Survey of India.	800	850	1st April 1893.	Do. No. $\frac{2877}{157}$, Surveys, dated 4th October 1894.	
Ditto	850	900	1st April 1894.	Ditto	
P. N. Bose, Officiating Superintendent, Geological Survey of India.	950	1,000	Do	Do. No. $\frac{2879}{156}$, Surveys, dated 4th October 1894.	

Notifications issued by the Government of India during the months of August, September, and October 1894, published in the "Gazette of India," *Part I.—Appointment, Confirmation, Promotion, Reversion and Retirement.*

Department.	No. of order and date.	Name of officer.	From	To	Nature of appointment, etc.	With effect from	REMARKS.
Revenue and Agricultural Department.	$\frac{2401}{14}$, Surveys, dated 21st August 1894.	T. H. D. La Touche.	Officiating Superintendent, Geological Survey of India.	Superintendent, Geological Survey of India.	Substantive, permanent.	17th July 1894.	...
Ditto .	Do. .	T. H. Holland.	Assistant Superintendent, Geological Survey of India.	Deputy Superintendent, Geological Survey of India.	Ditto .	Ditto .	...
Ditto .	$\frac{2950}{14}$, Surveys, dated 11th October 1894.	P. N. Bose.	Deputy Superintendent, Geological Survey of India.	Superintendent, Geological Survey of India.	Officiating.	Ditto .	...
Ditto .	Do. .	C. S. Middlemiss.	Ditto .	Ditto .	Ditto .	Ditto .	...
Ditto .	Do. .	P. N. Datta.	Assistant Superintendent, Geological Survey of India.	Deputy Superintendent, Geological Survey of India.	Ditto .	Ditto .	...

Postal and Telegraphic addresses of Officers.

Name of Officer.	Postal address.	Nearest Telegraph Office.
T. W. H. HUGHES	On furlough	...
R. D. OLDHAM	Rewa	Rewa.
T. H. D. LATOUCHE	Sukkur	Sukkur.
P. N. BOSE	Raipur	Raipur.
C. S. MIDDLEMISS	Ootacamund	Ootacamund.
H. WARTH	On privilege leave	...
T. H. HOLLAND	Calcutta	Calcutta.
P. N. DATTA	Rewa	Rewa.
W. B. D. EDWARDS	On furlough	...
F. H. SMITH	Quetta	Quetta.
F. NOETLING	Calcutta	Calcutta.
HIRA LAL	Sukkur	Sukkur.
KISHEN SINGH	On furlough	...

DONATIONS TO THE MUSEUM.

FROM 1ST AUGUST TO 31ST OCTOBER 1894.

A core of Barakar sandstone from Giridih (Karharbari) coal-field, 300 feet below surface of ground, and 600 feet above lower coal seam.

PRESENTED BY DR. W. SAISE, A.R.S.M., F.G.S., *Manager, E. I. Ry. Collieries.*

Specimens of the crystalline rocks in the neighbourhood of the Giridih coal-field.

PRESENTED BY DR. W. SAISE, A.R.S.M., F.G.S., *Manager, E. I. Ry. Collieries.*

Specimens of mica-peridotites and dolerites from dykes in the neighbourhood of Asansol.

PRESENTED BY DR. W. SAISE, A.R.S.M., F.G.S., *Manager, E. I. Ry. Collieries.*

Specimens of mica-peridotite and dolerite from Dhadka, Asansol.

PRESENTED BY S. HESLOP, F.G.S.

Specimens of coal altered by intrusions of peridotite, Cheranpore, Asansol.

PRESENTED BY F. J. AGABEG.

ADDITIONS TO THE LIBRARY.

FROM 1ST JULY TO 30TH SEPTEMBER 1894.

Titles of Books. *Donors.*

BECK, *Dr. Ludwig.*—Die Geschichte des Eisens. Abth. II, lief. 2—5. 8° Braunschweig, 1893.

BEHRENS, *Prof. H.*—A manual of micro-chemical analysis. 8° London, 1894.

BRONN, *Dr. G. H.*—Klassen und ordnungen des Thier-Reichs. Band III, lief. 2-3, and 10—14. 8°. Leipzig, 1894.

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