RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA

VOLUME XXVII.

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RECORDS

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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 outcrops 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 1877-79, 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 on nearly all important points the work harmonizes with that of Dr. Waagen and

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 Burmà.

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 ract 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 requent 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 ascertaine d 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 structural 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.

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:—

Quetta Coal.

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."

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.

Salt Range 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 o 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

Tenasserim Coal.

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 Malacclogical 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] Memoirs, G. S. I., Vol. XIV.

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 which 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.

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.

Nummulitic limestone.

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.

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.

Coal-bearing beds.

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 the place of the coal is irregularly carbonaceous.

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

Gahi ravine.

In the Gahi ravine also a small closed area of the rocks beneath the limestone is exposed, but with the same disappointing results, as regards indications of coal, as in the Rai ravine. At only 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 Rai 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 extent 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,

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

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—

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

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.

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

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—

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

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.	Proximate 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.* $\frac{8}{181}$ *26-1-86. Slide 1195.* Epidiorite, approaching hornblende schist. Actinolitic hornblende, quartz-felspar, mosaic and magnetite. S. G. 2·97.
		Kudatami, Bellary. $\frac{8}{187}$ *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. $\frac{8}{788}$ *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 Uravakonda Guti Taluq, Anantapur. [illegible] *29-1-85.*
		Fine-grained diorite approaching aphanite. S. G. 3·07.
		Mudkalpenta, South-East Valley, Sandur, Bellary. [illegible] *20-3-86. Slide 1219.*
		Aphanite. S. G. 3·05.
		South-West of Uravakonda, Guti Taluq, Anantapur. [illegible] *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. [illegible] *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. [illegible] *23-4-85. Slide 1216.*
		Aphanite, with highly kaolinized, porphyritic crystals of felspar. S. G. 3·19.
		Devadura spur, Sandur Hills, Bellary. [illegible] *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. [illegible] *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. [illegible] *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, Geolog cal Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		West of Halakandi, Bellary. $\frac{8}{617}$. *27-1-86. Slide 1207.* Hornblende schist.
		West by South of Yettan Budihal, Bellary. $\frac{8}{183}$. *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. $\frac{8}{488}$. *21-1-87. Slide 1212.* Hornblende-granitite with sphene and pleochroic mica. S. G. 2·66.
		Verupur Hill, Bellary Taluq, $\frac{8}{788}$. *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 Permadavanholli Bungalow and Joladarathi, Bellary Taluq. $\frac{8}{478}$ and $\frac{8}{474}$. *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 $\frac{8}{478}$ = 3·02; S. G. of $\frac{8}{474}$ = 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, a=yellowish-green, b = grass green 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," Gwajsha defile. A brecciated and crushed micrognanitic 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," Gwajsha 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 Gwajsha 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," Gwajsha defile.* Finely laminated and decomposed rock, possibly orginally similar to L. *M.—From margin of "Trap-belt," Gwajsha 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 Spintisha.
		(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 Governmeut 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. $\frac{2537}{220}$, 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.

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	
Between 150° C. and 175° C.	8·0 „ „	Specific gravity ranging from 0·765 to 0·850.
„ 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 I. 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 $\frac{2}{3}$ 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 ⅘ 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. °/₀	Specific gravity ranging from 0·755 to 0·865.
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 Kodoung, the only difference exists with regard to the smell. Fractions above 300° are solid at ordinary 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 part, about of the total, and can be used for the manufacture of lubricating oil and paraffin wax.

Crude oil of this kind yielded—

Light oil (flashing point below 150° C.) .	5·5 vol. °/₀	of 0·755 specific gravity.
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 done without any danger, the percentage of the latter can be raised to about 40 vol. °/₀: the oil must, however, be burnt in specially constructed lamps, owing to its high specific gravity.

IV.—Petroleum from Minbu.

Colour: In thin films, dirty brown; reddish brown without fluorescence by reflected light.

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 could not be determined. It is, however, liquid at the ordinary temperature. Below 300° only water distills; it only begins to boil at 300°, and therefore contains no constituents from which illuminating oil could be manufactured.

Fractional distillation.

Below 300° C.	2 vol. °/₀ (water).	
Between 300° C. and 325° C.	8·3 „	„ of 0·920 specific gravity.
„ 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 of the

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. °/o	49·4 vol. °/o	30·8 vol. °/o	2 vol. °/o
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. °/o 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°/₀ for wasteage, 36,000,000 tons left to be gotten.

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

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* Najibabád.	Miles.	
Najibabád	0	D. B.
Kotdwara	18	D. B.
Daramundi	12	D. B.
Banghát	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	—
Bayasghát	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 dolomites, 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 $11\frac{1}{2}°$ 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 $2\frac{1}{2}°$ 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 $2\frac{3}{4}$ 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:— $\frac{1,000}{2} \times (2 \times 1000 \times \textit{cotan.}\ 11^\circ) =$ 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.

Missing 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.

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

Missing 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 1894

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*, 1¾lbs. 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
1 Specimen of quartz, with iron pyrites, from Pardiah, Chota Nagpur.	A. Mervyn-Smith, Oriental Prospecting Syndicate, Ld., Calcutta.	Assayed for gold.
1 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. Extinctions 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. C. 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 (FeS_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	Ootacamund.
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.

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 1) 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 2½ 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 subdivisions 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 subdivisions 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 3½ 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.

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 lb 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.

In thin seams.

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-dela*, as natives say), the work is stopped on the next row of pillars until the roof is safely in.

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 thick seams.

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.

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 thunderstorm 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. *Hinduised 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).

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 siliceous 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 1½ 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, Dese. 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 I.

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, Khargusani 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 lb. „ 2. „ . 22 lb. „ 3. „ . 19 lb. „ 4. „ . 9 lb. 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.	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.	1952/139 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	...

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.*
„ „	*2*	„	*7.*
„ „	*3*	„	*8.*
„ „	*4*	„	*9.*
„ „	*5*	„	*10.*
„ „	*6*	„	*11.*
„ „	*7*	„	*12.*
„ „	*8*	„	*13.*
„ „	*9*	„	*14.*
„ „	*10*	„	*15.*
„ „	*11*	„	*16.*
„ „	*12*	„	*17.*
„ „	*13*	„	*18.*
„ „	*14*	„	*19.*
„ „	*15*	„	*20.*

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1894. [November.

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 bills 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 } Nam of stream unknown, but close to the above.
Zibinmaw
Nayaungbinmaw

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 side 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 Chotiali, 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 *Ammonoidea* 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*,

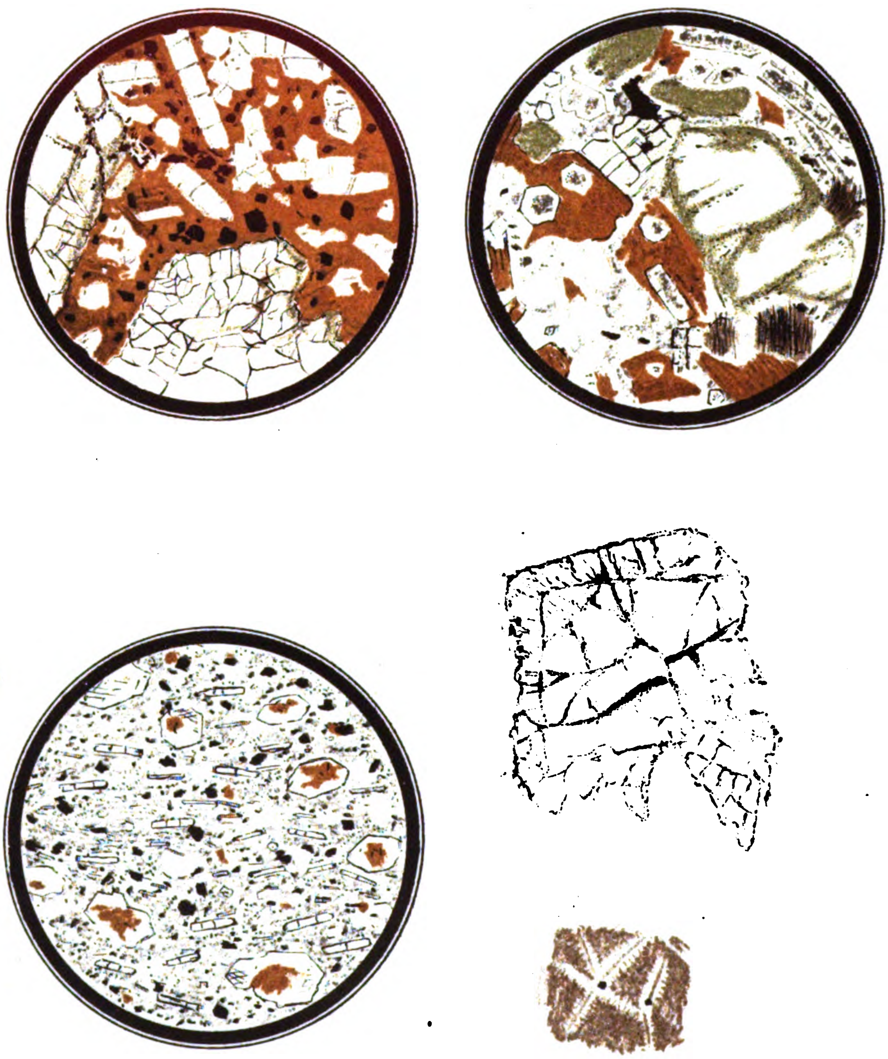
and probably also a sixth, the genus *Hemipneustes*; but the presence of the latter in Southern India is somewhat doubtful, because I base it on the supposition only that the ill-preserved *Cardiaster orientalis*, Stol., does not belong to that genus, but to *Hemipneustes*, as its poriferous zones indicate. 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 Ràniganj 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 Ránigan j 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 Ránigan j 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 Darjíling 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, Darjiling 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]
8·283. 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 nó 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 Darjīling 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 Darjīling 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

some places it suggests felspar, but there are no signs of twinning or definite crystal structures and its quantity is very small. It appears like a residuary matrix (9·876, 9·105). Classing this substance as an altered glassy matrix seems to be the more justified from the occurrence in the American mica-peridotites of a glass presenting similar characters. In a mica-peridotite occurring as a dyke of late carboniferous age in Central New York C. H. Smyth, Jr., has recognised a glassy matrix which is not always devitrified.[1] A brownish-grey clouded material with similar relations has been noticed by Diller in a mica-peridotite dyke in Kentucky,[2] and similar material has been found in other peridotites, for example, in kimberlite from South Africa (H. Carvill Lewis) and in the Elliott county peridotite in Kentucky (J. S. Diller).

Secondary minerals.

36. In all specimens the processes of hydration and the production of carbonates have commenced. *Serpentine,* as usual, results from the hydration of the olivine, the change being attended with the separation of dusty *magnetite.* In one specimen in which decomposition has well advanced small crystals imbedded in the serpentine exhibit the characters of *perofskite.* They occur as yellow, clouded grains generally diamond or spindle-shaped, measuring up to 0·1 mm. long and 0·05 mm. wide. The grains when sufficiently clear to examine with polarised light show occasionally very strong double refraction which seems to be due to carbonates filling the yellow shells. When quite brown, however, they are isotropic. Removed from the serpentine with a sharp needle and fused with sodium-carbonate they gave a distinct reaction for titanium on being boiled with hydrochloric acid and tin. Diller has described as anatase similar grains in the serpentine pseudomorphous after olivine in the peridotite of Elliott County, Kentucky. G. H. Williams identified perofskite in the serpentine of Syracuse, New York in 1887,[3] and at his suggestion Diller on re-examining the Elliott Country peridotite found that similar grains which had been doubtfully referred to anatase were really perofskite.[4] Similar grains in peridotites have been referred to perofskite by C. H. Smyth (Central New York),[5] by Diller (Kentucky)[6] and by Branner and Brackett (Arkansas).[7] The *carbonates,* which are so common in these rocks, give the chemical reactions for dolomite.[8] These are found, sometimes with clear *secondary quartz,* infilling cavities from which decomposable minerals have been removed. 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 igneous 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 also to contain magnesia (Diller, *loc. cit.*, p. 19). For further development of dolomite from peridotite, 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.

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).

Mineral composition.

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).

Structure.

42. The rock occurs as narrow dykes and intrusive sheets in the coal-fields of Dárjíling, Ránígan j, Barfkar, Jherria, Deoghur, Girídíh and probably Rámgarh, thus occurring in places more than 250 miles distant from one another (paras. 10—13).

Occurrence.

43. As these dykes are younger than the Ránígan j series and older than the Rajmahál traps we have a petrographical province of about Pánchet age (para. 14).

Geological age.

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).

Analogies with South African peridotites.

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]

(*i*) *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. I, p. 242.
[2] *Quart. Journ. Geol. Soc.*, vol. XLI (1885), p. 401, plate XIII, fig. 8.
[3] *Amer. Journ. Sci.*. 3rd ser., vol. XXXI (1885), 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 3½ 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.	$\frac{9}{1008}$ 1 mile N. of Sretassongee, S. by W. of Chicklah. *Quantity received* 2½ oz. 61·08 $\frac{9}{1002}$ ¾ mile N. by E. of Koodmoora village *Quantity received* ½ 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.
		$\frac{9}{908}$ Dhola hill, S. of Beemasoor Peak, Chicklah. *Quantity received* 1¼ 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. $\frac{8}{18}$, Slide 1306. BIOTITE-GNEISS WITH LEPTYNITE VEINS like No, $\frac{8}{1080}$, slide 1299, from the Sone, Rampurwa, Rewah State. $\frac{8}{18}$, 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 large 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 *quarts* and *felspar* in small quantities. 18, Slide 1307. MICA-SYENITE. Harbora, Sahaol Tahsil. Pink *felspar* and small quantities of *quarts* 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 *quarts* in small quantities showing a feeble attempt at micrographic intergrowth with the felspar. 18, 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 *quarts* 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.*

Lepartment.	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.
	R	R			
F. H. Smith, Assistant Superintendent, Geological Survey of India.	410	440	1st August 1894.	Revenue and Agricultural Department No. $\frac{2484}{158}$, Surveys, dated 30th August 1894.	
T. H. D. LaTouche, Superintendent, Geological Survey of India.	800	850	1st April 1893.	Do. No. $\frac{2817}{157}$, 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 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.

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

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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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„ Jahresbericht der Königlich Ungar. Geologischen Anstalt fur 1890. 8° Budapest, 1892. HUNGARIAN GEOLOGICAL INSTITUTE.

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„ Geological Survey of Canada. Catalogue of Section one of the Museum of Geological Survey. 8° Ottawa, 1893. THE SURVEY.

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„ Sitzungsberichte der Kais. Akademie der Wissenschaften.

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„	„	IIa,	„	8—10.
„	„	IIb,	„	8—10.
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„ CI,	„	I,	„	1—6.
„ „	„	IIa,	„	1—5.
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" Monographs of the U. S. Geological Survey. Vols. XVII, XVIII, and XX. 4° Washington, 1892. U. S. GEOLOGICAL SURVEY.

" Proceedings of the U. S. National Museum. Vol. XIV. 8° Washington, 1892. THE MUSEUM.

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PARIS.—Carte Géologique detaillée de France. Sheet, No. 13. Map. Paris, 1893. GEOLOGICAL SURVEY OF FRANCE.

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G. I. C. P. O.—o. 31 D. G. Survey.—12-3-94.—

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.

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G. I. C. P. O. - No. 1 D. G. Survey.- 12.6-94.- 620.

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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.

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MAP.

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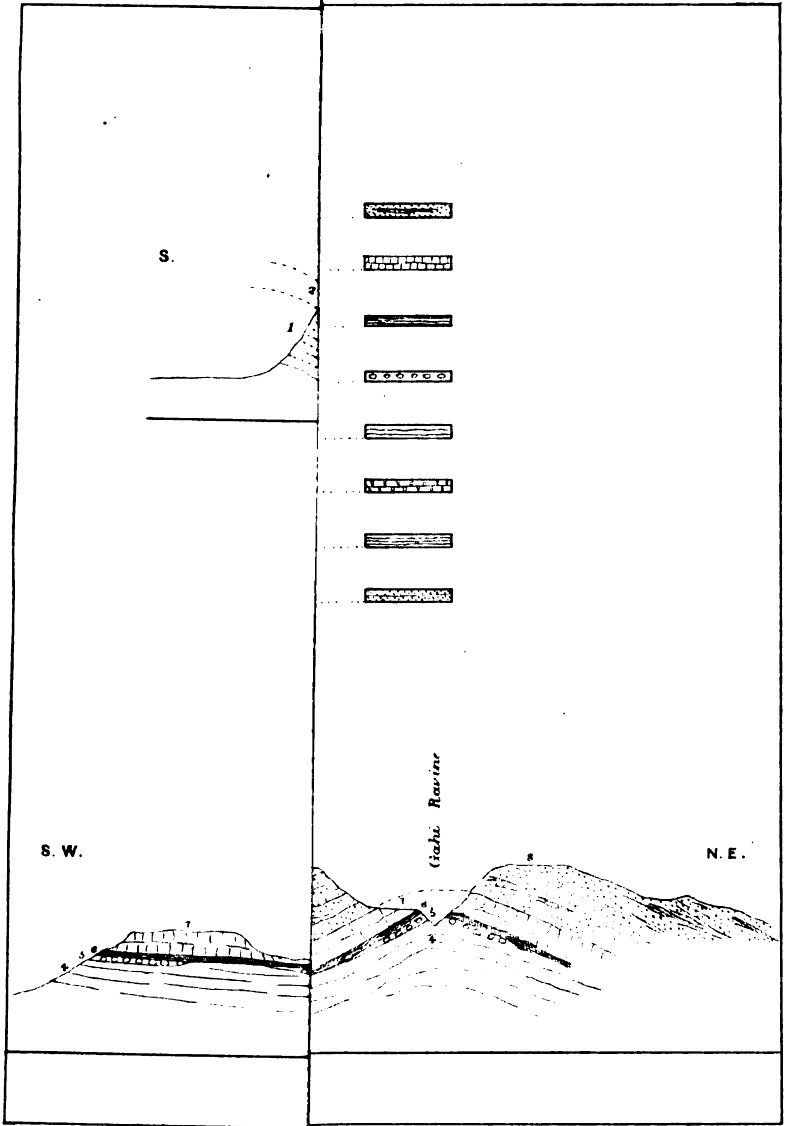
Pl. 1



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pl. 3

Dr Saise

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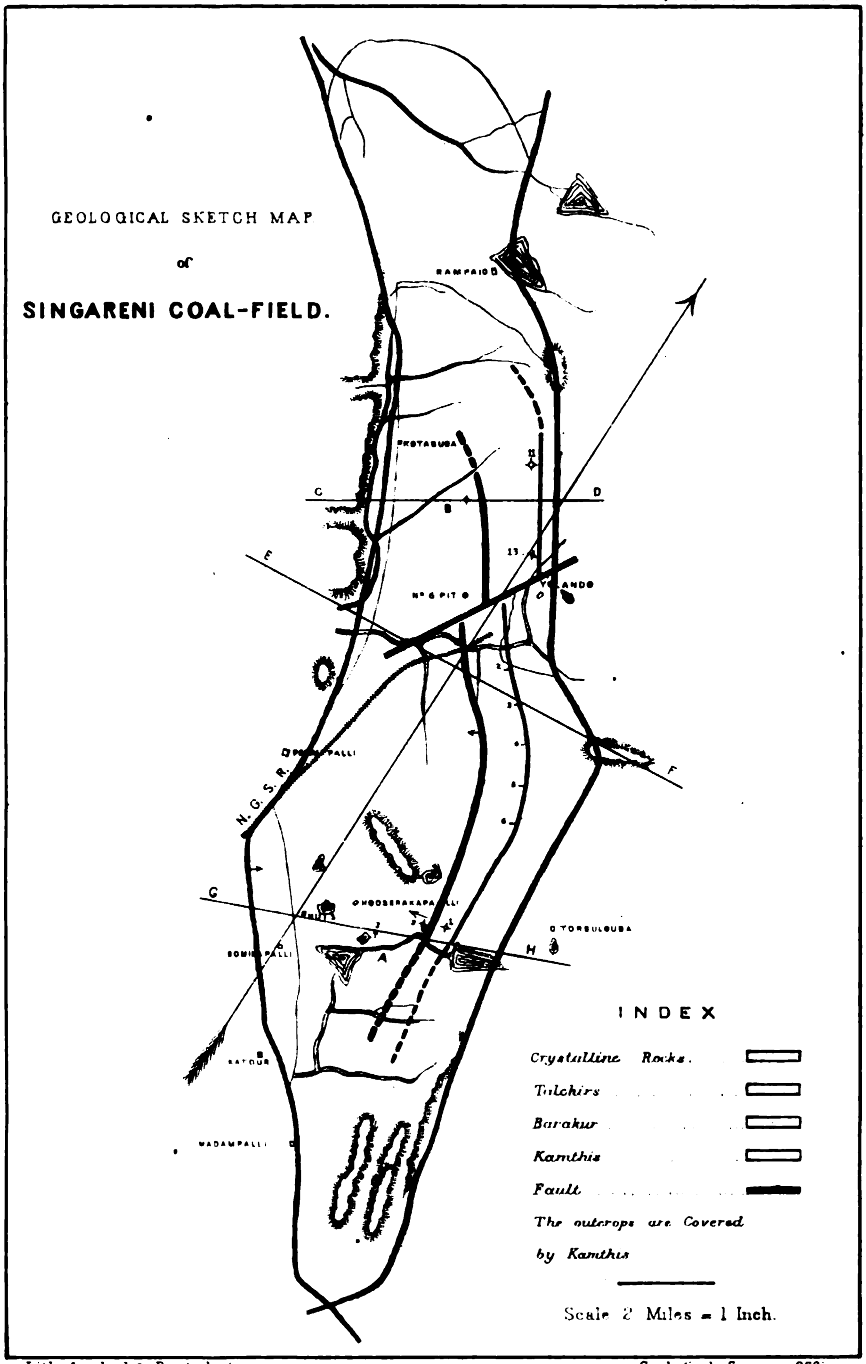

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Pl. 3

Pl. 4

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

SINGARENI COAL-FIELD

SECTION OF THE SEAMS

That go to make up the

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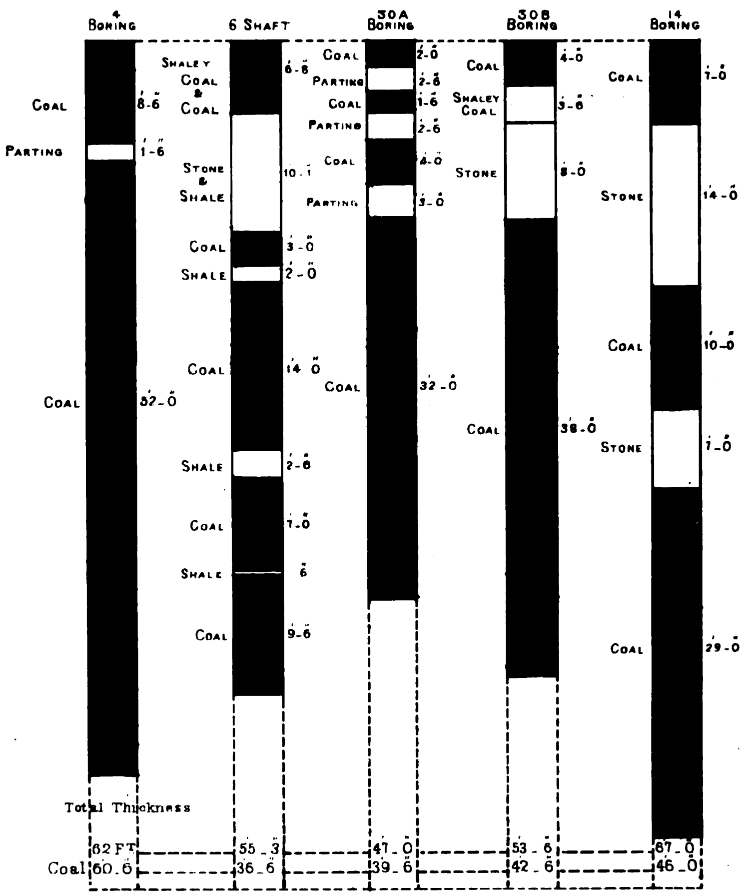

Average Thickness of Seam 56 ft. 10 In.

" " Coal in Seam } 45 Feet

Scale 16 Feet – 1 Inch.

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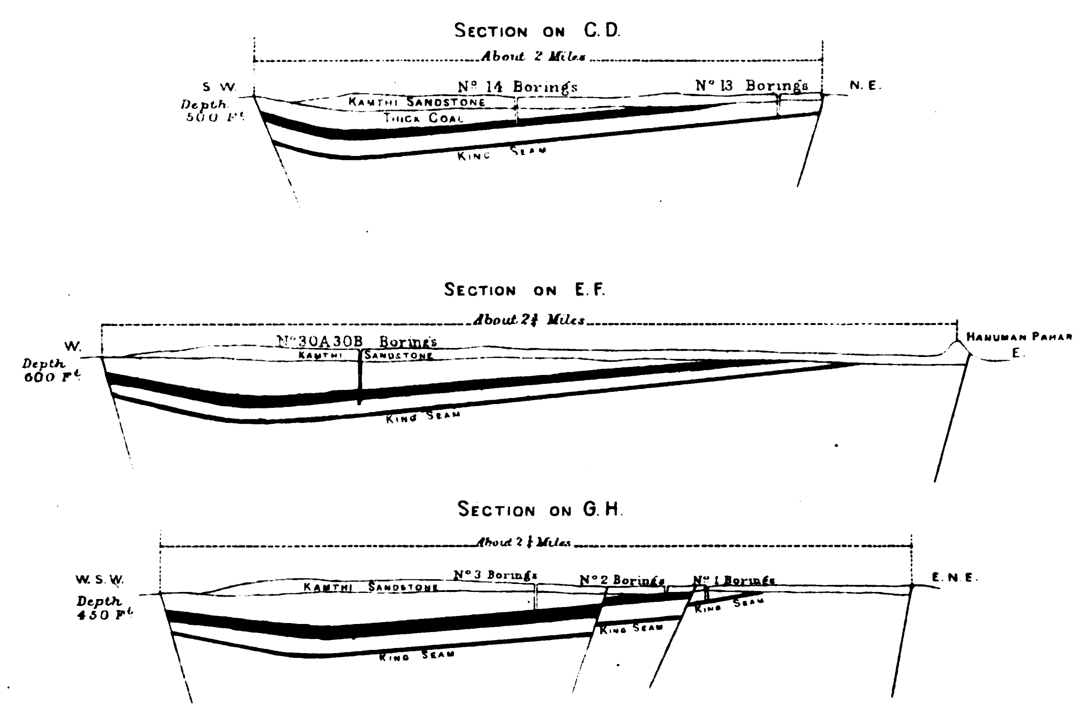
Pl. 4

Pl. 5

Pl. 6



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SINGARENI COALFIELD DIAGRAMMATIC SECTIONS ILLUSTRATING GENERAL STRUCTURE OF THE FIELD.

Pt. 6

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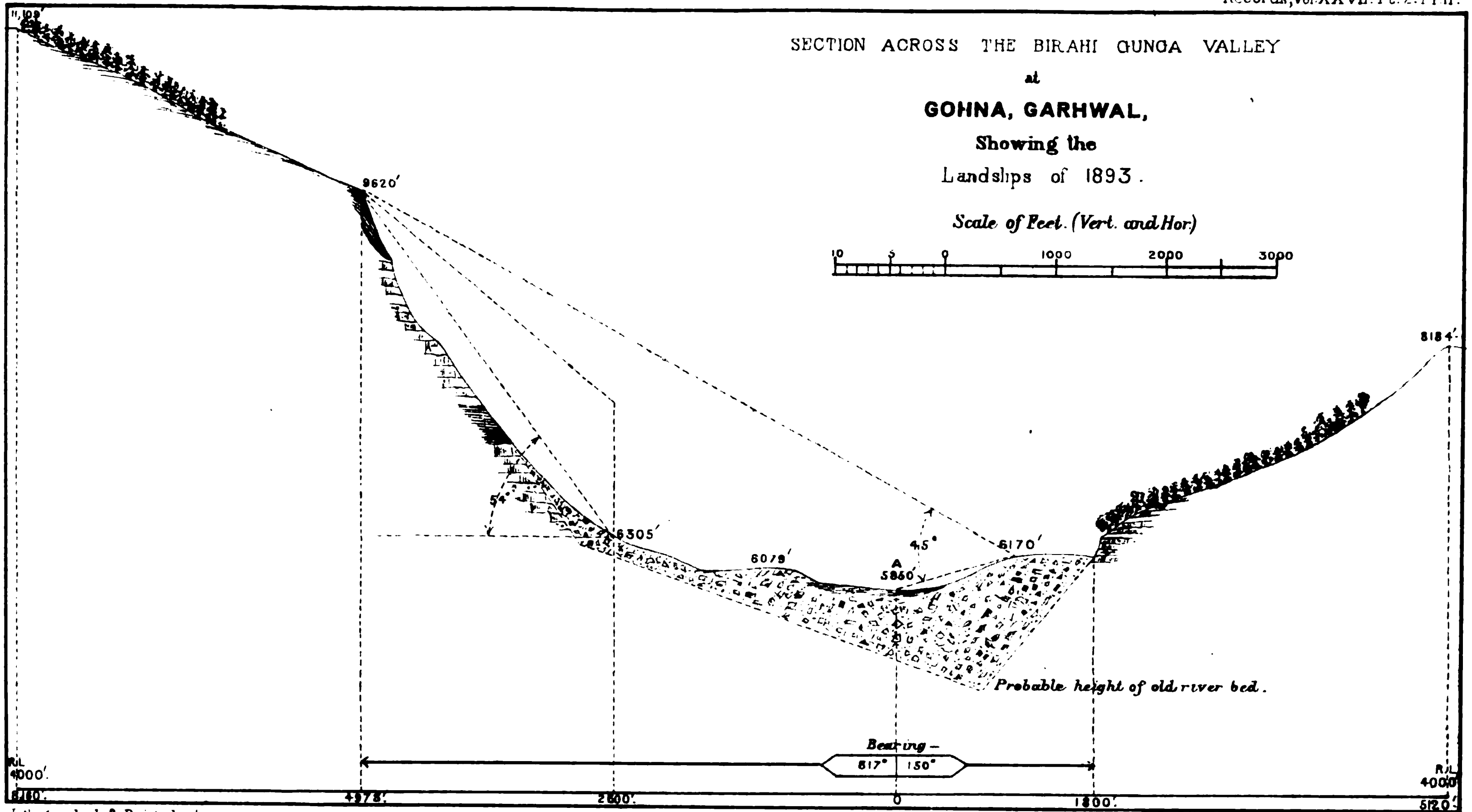

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Pl. 8

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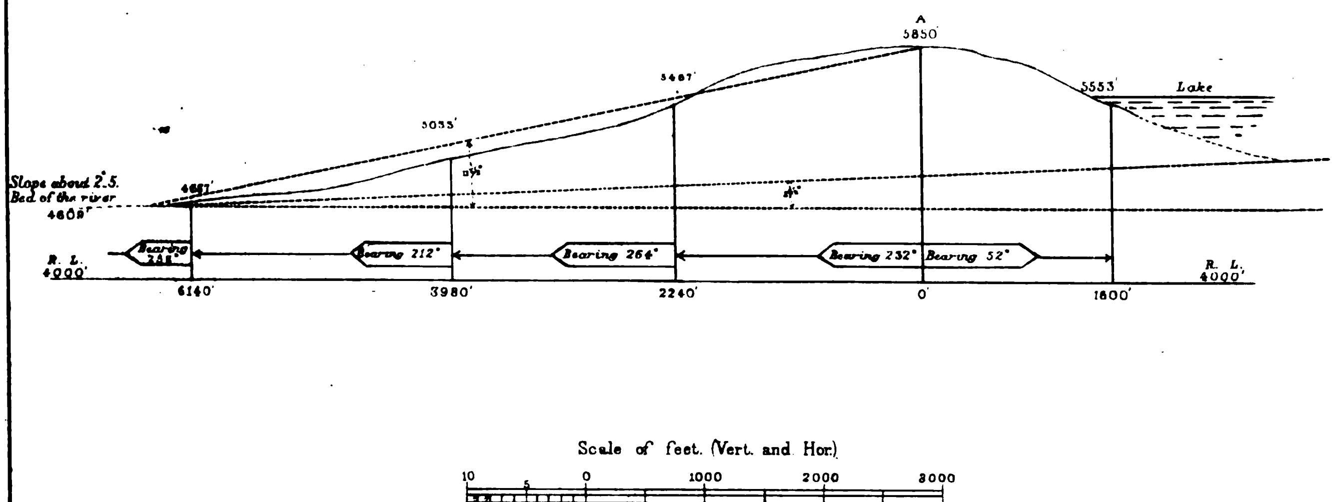
SECTION ALONG THE BIRAHI GUNGA VALLEY

at

GOHNA, BRITISH GARHWAL.



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VIEW OF GOHNA TAL, FROM EDGE OF THE DAM.

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Photo-etching.

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VIEW OF GOHNA TAL, FROM NEAR DURMI.

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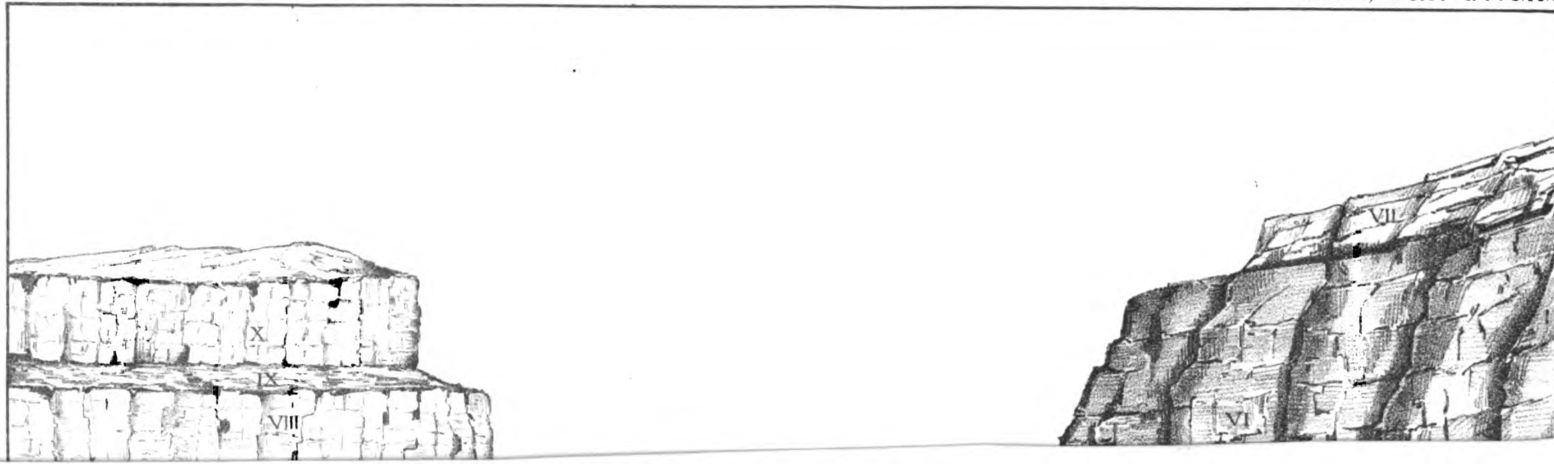

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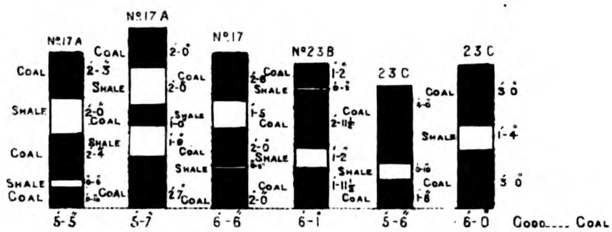
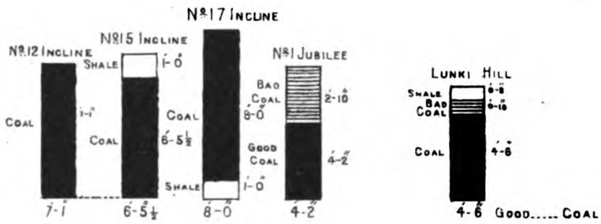
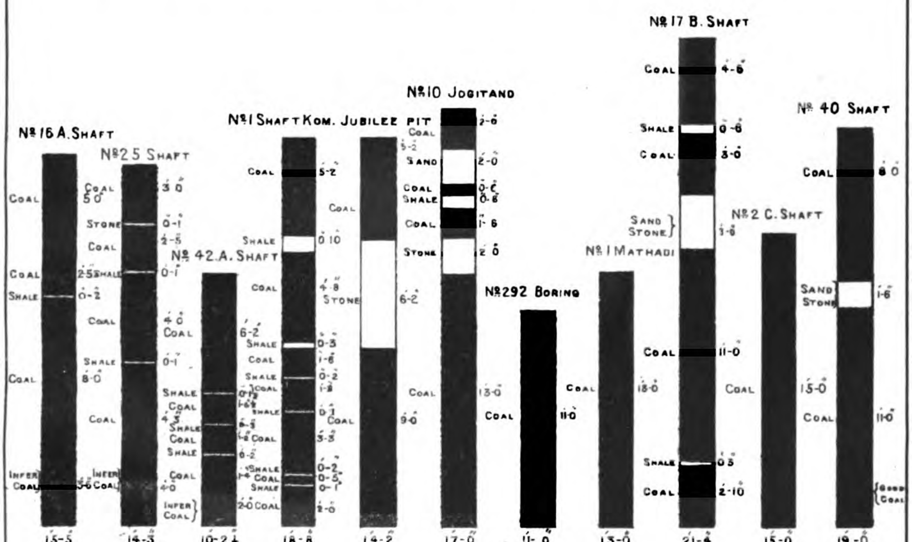
SECTIONS OF KURHURBAREE UPPER SEAMS.



SECTIONS OF BHADDOAH MAIN SEAMS



SECTIONS OF KURHURBAREE LOWER SEAMS AT VARIOUS PLACES



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Pl. 17

Dr. Saise

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fig. 1.

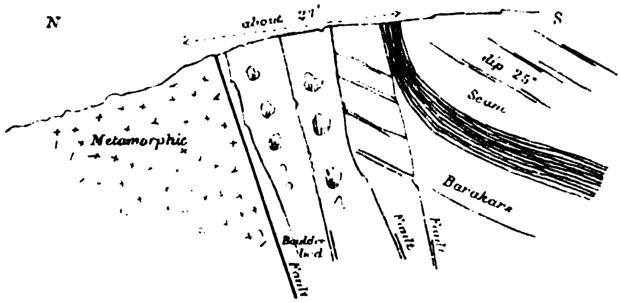


fig. 2.

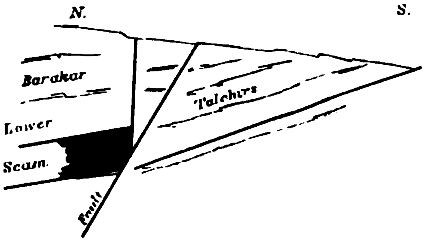


fig. 3.

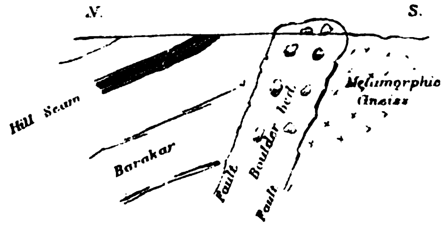
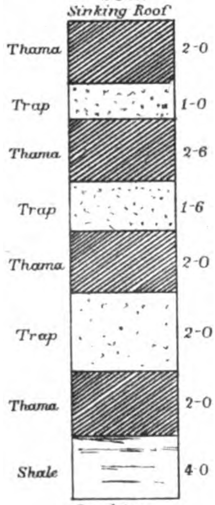
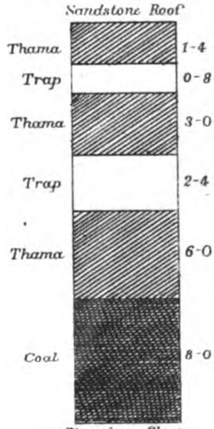


fig. 4.
23 E.
Sinking Roof



Sandstone

fig. 5.
23 D.
Sandstone Roof



Fire clay floor

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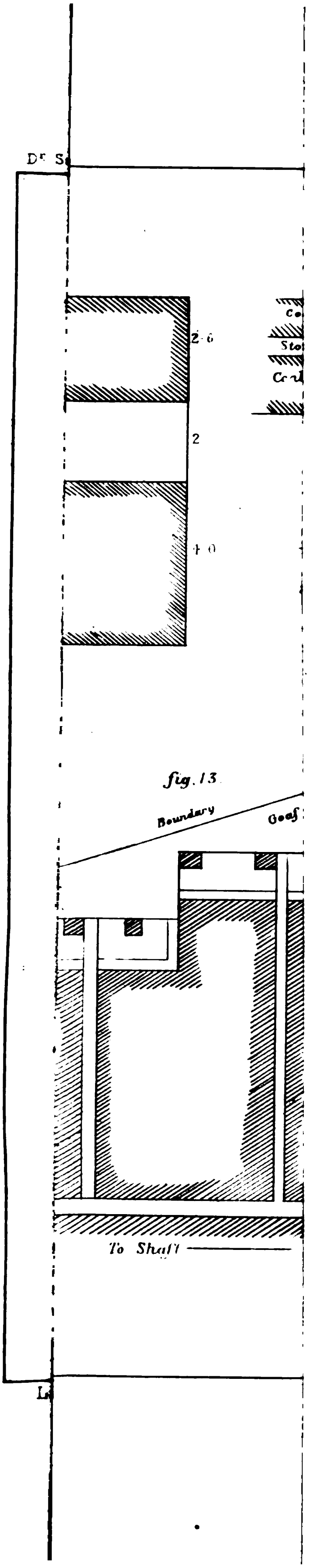

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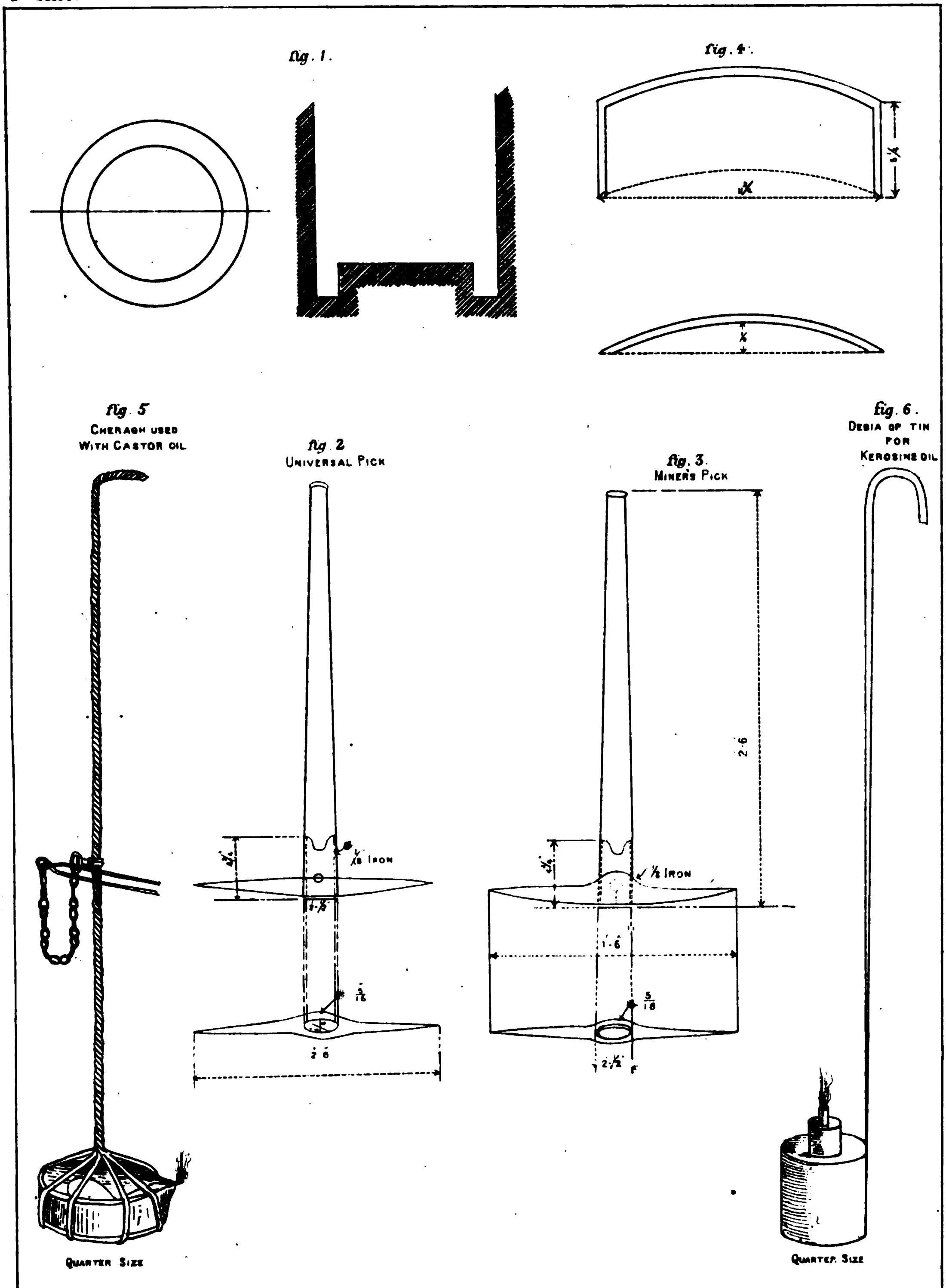

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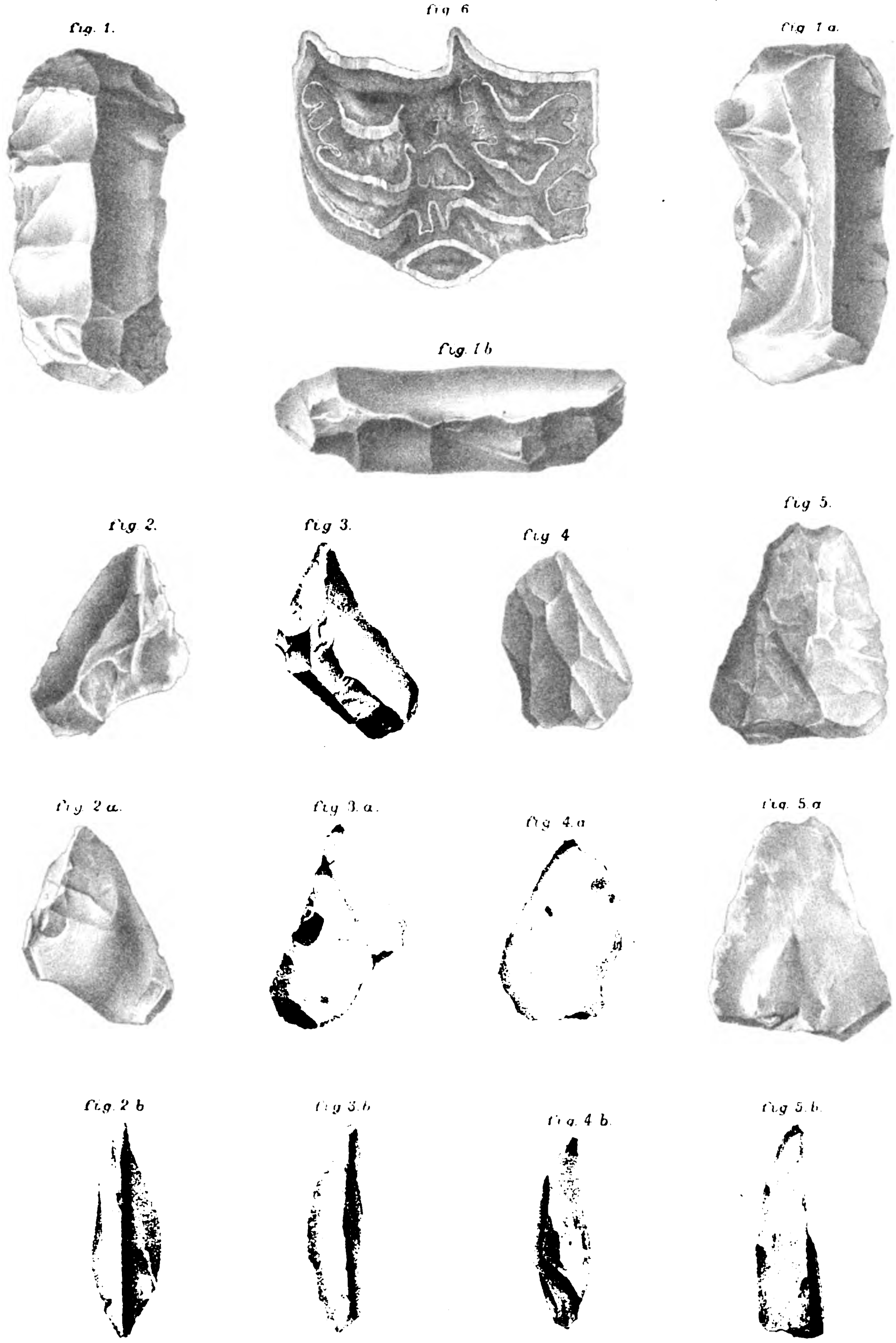

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fig. 1 b.

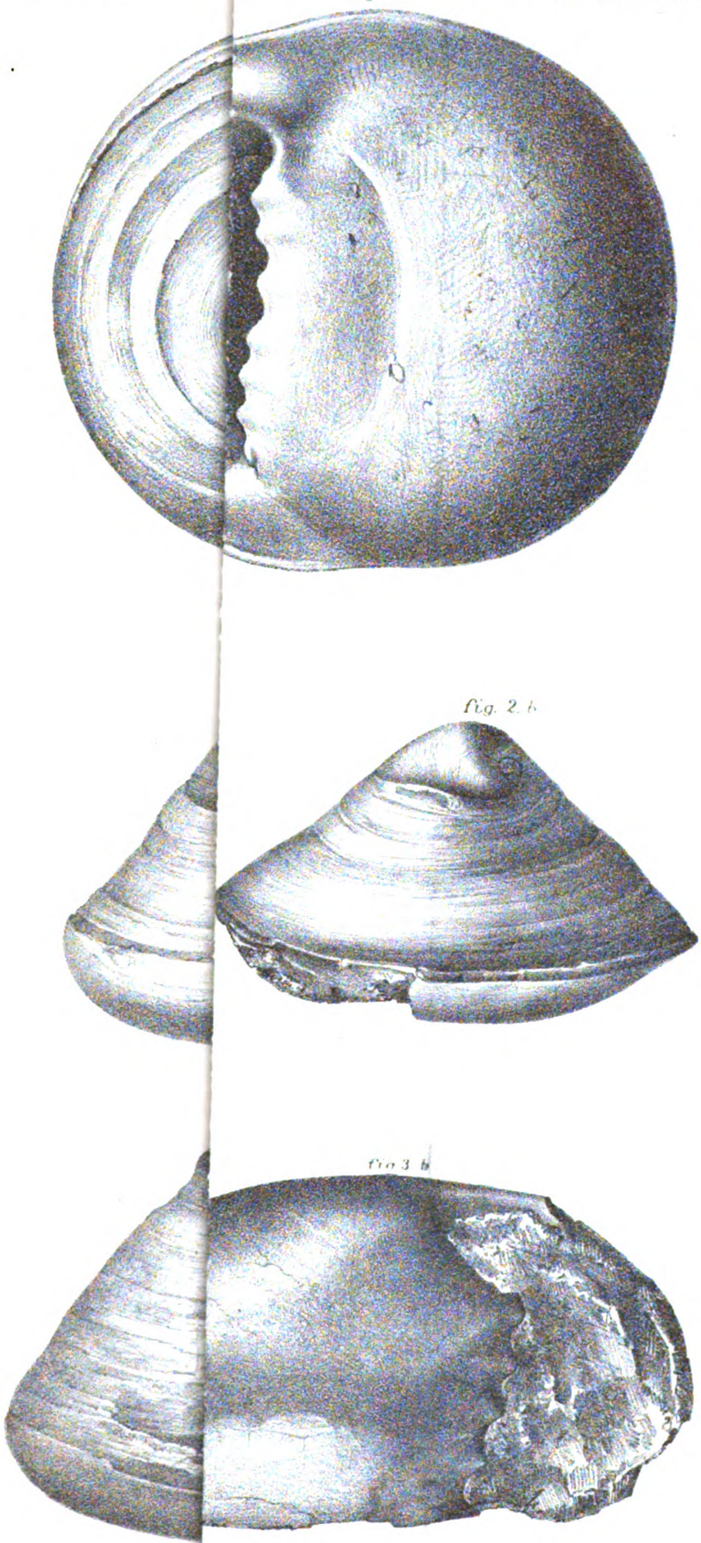

fig. 2. b.

fig. 3. b.

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OF

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXVIII.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1895. **[February.**

Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1894.

Staff of the Survey.

Dr. William King retired from the Directorship on the 16th July last, after a total length of service of 37 years, seven of which were passed as Director. His services are briefly noticed in the Records, Vol. XXVII, page. 109.

Mr. T. W. H. Hughes was compelled to retire from the 17th October, owing to an unfortunate accident, which has deprived him of his eyesight.

Mr. W. B. D. Edwards, having obtained an appointment as Inspector of Schools in England, has resigned his appointment from the 4th November 1894.

The vacancies thus created will be filled in due course by men selected by Her Majesty's Secretary of State.

Mr. William Anderson was appointed by the Secretary of State to be Mining Specialist on the Survey, and joined the Department on the 15th November 1894.

At the beginning of the year 1894, the officers of the department not on leave were disposed as follows :—

Myself with Mr. F. H. Smith and Lala Kishen Singh in Baluchistán; Mr. T. H. D. La Touche in charge of boring at Sukkur; Mr. P. N. Bose, Rewah; Mr. C. S. Middlemiss, Madras; Dr. H. Warth, Madras; Mr. P. N. Datta, Central Provinces; Mr. T. H. Holland and Dr. F. Noetling at Head-Quarters.

At the beginning of the present field-season the officers of the department were distributed as follows :—

Mr. R. D. Oldham and ,, Datta	Rewah.
Mr. LaTouche and Lala Hira Lal	Sukkur.
Mr. P. N. Bose .	. Central Provinces.
,, Middlemiss .	. Madras.
,, Holland .	. Head-Quarters.
,, Smith .	. Baluchistán.
Dr. Noetling .	. Upper Burma.
Mr. Anderson .	. Chota Nagpore.

Summary of work accomplished.

In the following notes will be found an outline of the work done during 1894.

Rewah.
P. N. Bose.
R. D. Oldham.
P. N. Datta.

During the season of 1893 to 1894 Mr. Bose surveyed a rather extensive area in Rewah and the ground east of it, in all more than 2,000 square miles, of which, however, some parts had already been reported on by Mr. Smith and Kishen Singh, who were attached to the party under Mr. Hughes in 1893. Mr. Bose distinguishes the following formations in descending order:—

4. Gondwanas.
3. Vindhyans.
2. Transitions.
1. Metamorphics.

and amongst the intrusive rocks: granite and diorite.

He separates a schistose formation from the transitions proper, *i. e.* the representatives of the Bijáwar system, and includes a belt of gneissose rocks amongst the former, being probably the result of local metamorphism of the schistose series by the intrusive granites. The lower vindhyans rest unconformably on the transitions.

Mr. Oldham has taken over charge of the Rewah survey this field-season, with Mr. Datta to assist him; he has since had an opportunity of inspecting Mr. Bose's work, and has come to the conclusion that the so called "gneiss" of Mr. Bose is in reality an intrusive granite. Mr. Oldham has not yet been able to confirm the separation of the schistose beds from the transitions. If the "gneiss" is only intrusive granite, it seems very probable that the difference in lithological character between the schistose and transition series is due to contact metamorphism. Mr. Bose describes the two series of rocks as conformable and renders their position in this manner in his section.

I myself crossed this belt of transition rocks further eastwards some years ago and was struck at that time with the general resemblance of the series with the great thickness of beds which underlie the lower silurian of the Himálayas, which I had comprised under the name of the haimantas and of which the upper portion may possibly he correlated with the cambrians. I still believe that this series of transitions underlying the lower vindhyans will turn out to be an equivalent of the haimanta group of the Himálayas.

Mr. Datta is working at the lower vindhyans north of the Sone and has been able to examine some sections in greater detail, but so far Mr. Oldham suspects that the lower vindhyans (so-called) belong to a different and unconformable series to the vindhyans proper in which opinion he differs from Mr. Mallet. (See Vol. VII of the Memoirs.)

Central Provinces.
P. N. Datta, 1893-94.
P. N. Bose, 1894.

Mr. Datta had been posted to the Bhandara District during the previous field-season, and he was engaged at the beginning of 1894 on the geological survey of part of a still unknown ground in the Central Provinces. He managed to go over two separate areas, namely, part of the valley of the Kanhun river in Nagpur and Chindwara, and secondly, parts of the Bhandara district. In the first-named district he came across a crystalline and schistose series with intrusions and spreads of igneous rock, which is unconformably overlaid by lameta beds; the latter proved unfossiliferous.

In the second or Bhandara area Mr. Datta observed crystalline rocks with transition beds, the series forming the western extension of the Chattisgarh basin. A number of sections were examined in detail, but until the rock-specimens can be examined microscopically, not many new facts can be made out regarding the structure of that part of India. Mr. Datta has brought back a fine collection of hand-specimens for the museum.

At the beginning of last field-season Mr. Bose was posted to the same ground, and he started work in continuation of the surveys of Dr. King in the Chattisgarh division. He believes to have met with confirmatory evidence in favour of the unconformable superposition of certain beds over the Chilpi Ghât series, which may possibly represent lower vindhyans in this area. It is a point, however, which will require much clearer evidence before this view can be finally adopted. It is directly opposed to both Mr. Medlicott's and Dr. King's views (for the latter see Records, Vol. XVIII, p. 190).

Madras.
Mr. C. S. Middlemiss.
Dr. H. Warth.

During December 1893, Mr. Middlemiss was transferred to the Madras Presidency, where he began a detailed investigation of the mineral resources and petrology of the Salem district, with special reference to the occurrence of corundum.

During the first few months of 1894, a cursory examination of the ground was only made, but nevertheless some very valuable observations were the result; he came to the conclusion that the corundum is not an original mineral constituent of the gneissose rocks in which it occurs, but is the result of a mineral change or metamorphism of the matrix rock. He infers this from the patchy way in which it occurs, from the zone, or shell of carbonate of lime and of quartz (at Sithampundi), and from the similar shell of pink felspar enclosing the corundum crystals in the Paparapatti rock. The general aspect is, as if it had segregated out in certain places, leaving an enclosing lenticular patch of altered gneiss and an envelope of another mineral behind. This field-season Mr. Middlemiss is provided with the necessary outfit for a microscopic examination of the rocks, and we may expect a large addition to a more exact knowledge of the petrology of Madras, which, it is to be hoped, will eventually form a useful and more or less complete guide to the crystalline rocks of India. He divides the Salem rocks provisionally as follows :—

Crystalline gneissic rocks—

(1) White and grey quartzo-felspathic rocks.
(2) Purple and grey biotite gneissic do.
(3) Hornblende gneissic do.
(4) Hypersthene gneissic do.

The above, though mutually interbanded in places, also predominate individually over certain areas. Hence they may be separated when traversing from East to West :—

(*a*) The Morappur	band of	hornblende	gneissic	rocks.
(*b*) The Mukhunur	,,	hypersthene	,,	,,
(*c*) The Dharmapuri	,,	quartzo-felspathic	,,	,,
(*d*) The Paparapatti	,,	biotite with corundum.	,,	,,

Foliation of the above varieties seems to be genuine, consisting of (1) layers of different width, often contorted, composed of different minerals, and combinations of minerals, (2) layers of different degrees of coarseness of grain. The rocks are not as a rule fissile to any extent along the foliation.

Intrusive rocks—

(A). Purple granites are non-foliated massive rocks, occurring sparsely and are intruded along foliation of gneissic rocks. They often include large pieces of hornblendic rocks.

(B). Dark traps, doleritic, composition augite and plagioclase, non-foliated, tough, massive dyke rocks, crossing the foliation of the gneissic rocks at right angles; fairly numerous, but difficult to trace far, except locally.

The cretaceous rocks of Pondicherry; Dr. H. Warth.

It was desirable to study the cretaceous beds of Pondicherry in greater detail, and collect therefrom good material for description; Dr. Warth was deputed to do so, and he devoted the field-season of 1893-94 to this task.

The fossils which were collected by Dr. Warth are somewhat dissappointing, both as regards numbers and preservation, but they have been sent to Dr. Kossmat of the Vienna University, who is also engaged on the determination of the collection of cretaceous fossils from Trichinopoly belonging to the Madras Museum. From a preliminary note which this gentleman has sent it appears that the entire series of Pondicherry beds belongs to the Ariyalur group of Southern India.

Himālayas. Mr. T. H. Holland.

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 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.)

Punjáb.
Dr. F. Noetling.

The alarming increase of accidents in the Dandote coal-mines made an immediate inspection of the Dandote (Punjáb) and Warora (Central Provinces) collieries desirable; the Inspector of Mines in India had not been appointed then (October 1893), and Dr. Noetling was therefore deputed on this duty. In addition to this inspection, Dr. Noetling was able to add to our knowledge of the older palæozoic strata of the Salt-Range. He has since published his observations in a paper in the Records, Vol. XXVII, pages 71 to 86, which clears up many discrepancies in the Salt-Range geology.

Mr. Wynne, who described the geology of that range in greater detail, was the first observer who insisted on the age of certain beds as older than carboniferous and to be quite distinct from the latter. On the strength of Dr. Waagen's determination of the few fossils which had then been found, these beds were considered to be of silurian age. Later on Dr. Waagen combated this view and claimed a lower carboniferous age for these beds, but modified this opinion as cambrian trilobites were found, whilst his work, Vol. IV of Ser. XIII of the Palæontologia Indica, was in progress.

Dr. Noetling, who had studied the Khusak section carefully (already well described by Mr. Middlemiss, Records XXXIV, page 24) now divides the cambrian system of the Salt-Range as follows, 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.

Each of which divisions he further sub-divides.

The fossils which he has found, have been forwarded to Dr. Waagen for determination.

Sukkur boring.
Mr. T. D. La Touche.
Lala Hira Lal.

The boring for petroleum which has been put down at Sukkur on the Indus has steadily progressed, and it has been sunk to a depth of 957 feet. Considerable difficulty is occasionally experienced, but not more than might have been anticipated. The practical result is so far *nil*, although signs of escape of gas have been observed at depths below 800 feet, which afford some slight hope of obtaining oil further down. But the boring is not without some geological interest, as it proves that the thickness of the strata is much in accordance with the estimate which I have given, which was practically taken from the Sharigh section. The lithological character of the beds passed through is very similar to that of the Sharigh section, and in some respects, particularly in the upper portion, very like the section near Khattan. As near Sharigh, so also at Sukkur, a great thickness of clays, alternating with thin limestone bands, and traversed by numerous gypsum veins and nests, occurs below the light coloured upper nummulitic limestone of Sukkur.

The boring ought to reach the carbonaceous horizon within the next 200 to 250 feet, if the section corresponds as closely with the Sharigh section, as seems likely.

Mr. La Touche reported in December 1894 that he had examined a spot about 8 miles south of Rohri, where the freshly broken soil emits a strong smell of petroleum, which may indicate the escape of oil below the thickness of alluvium. There is no rock *in situ* within miles of the spot, but the question is being investigated now.

Baluchistán.
C. L. Griesbach.
W. B. D. Edwards.
F. H. Smith.
Lala Kishen Sing.

Considerable progress has been made in the geological survey of Baluchistán, which is, perhaps, one of the most interesting countries in the world, from a structural point of view.

Mr. Edwards joined my party in the early part of the year and was told off to examine the so-called Quetta coal-area. Before he could quite finish the task, he became seriously ill, which led eventually to his retirement this year.

Mr. Smith joined my party in the autumn of 1893, and after continuing the work which Mr. Edwards had begun, brought it to a close during this year.

He accompanied me afterwards (Spring 1894) on a tour to the Mari country, which I undertook to study certain sections which Mr. Oldham had reported on previously (Records, Vol. XXV, pages 18 to 29). Mr. Smith was instructed to take up work in continuation eastwards of Mr. Oldham's surveys, and he has since geologically mapped some 2,000 square miles of very interesting country east and south-east of the sections which are reported on in the paper quoted.

Mr. Smith has shown considerable acquaintance with field-work, and has prepared a number of working sections, drawn to scale. These, with the map, will be published later on, when the survey of that country has been completed.

During November and December 1894, Mr. Smith continued his former work in the high hills east and south-east of Quetta, which have now all been examined, with the result of confirming in most cases my first conjectures, which I expressed in Memoir, Vol. XVIII, part 1. When I visited that country in 1880 a close study of the sections was impossible, owing to the disturbed state the frontier was in at that time, but I concluded from the general structure of the country, that the Takatu hill mass represented a section comprising both cretaceous and lower eocene strata; Dr. W. T. Blanford in his Memoir, Vol. XX, part 2, combated this view, having had better opportunities of studying this particular section. My view, however, has now been amply upheld by Mr. Smith's subsequent work, and not only have upper cretaceous rocks (with belemnites) been found to constitute the main mass of the Takatu hills, but also evidence has been produced of the presence of older (neocomian and jurassic) limestones with fossils. The uppermost portion of the hill-mass is lower nummulitic as represented in my memoir. A fault separates this section from younger eocene beds east and south-eastwards; this fault may be observed for some distance and forms one of the great structural features of Baluchistán.

Lala Kishen Singh was engaged in systematically collecting fossils from certain beds described by Mr. Oldham in the paper quoted above; in the end a very valuable collection of fossils has been brought together, which have since been examined and described by Dr. Noetling. The description will be published in the Palæontologia Indica as soon as the numerous plates can be lithographed; the manuscript is ready for the press.

The general result fully justified my original opinion that there is quite a sharp division between the cretaceous and eocene strata. The examination of the fossils proved also the existence of a distinct neocomian and below it, of a jurassic horizon. A local unconformity occurs above the neocomian.

The section at Mazár Drik, which is merely a type of numerous similar sections, is as follows in descending order :—

Middle Eocene	6 Shales and sandstones.
Lower Eocene	5 Grey limestone beds with *nummulites*.
Upper Cretaceous . .	4 Calcareous grit, shales and limestone with an abundant fauna of *cephalopods*, *echinoids*, *corals*, *foraminifera*, etc.
	3 *Belemnite* bearing series of shales and limestone beds.
	Local unconformity.
Neocomian . . .	2 White and grey limestone with *belemnites*.
Upper Jurassic . .	1 Hard grey, thick-bedded limestone with a rich ammonite fauna.

In the spring of 1894, I instructed Kishen Singh to survey the area south and south-east of the Zarghún and south of the Harnai and Khóst hills on sheet 21-$\frac{SE}{4}$ of the Baluchistán survey, which he did satisfactorily,—in all 590 square miles.

I myself continued the work, which I had begun during the previous field-season ; the ranges which divide the Quetta valley from the Pishin and the Kójak range were examined, and several traverses were completed, to settle the question of structure of these ranges. But there is still much to be done and it will require at least one more season's work to fill in the gaps on our geological map of the country west and north-west of Quetta. The first 4½ months of 1894 I devoted to the study and survey of the ranges which inclose the western Zhób valley, and especially the mass of hill-ranges between Loralai and Khanazai. This was a continuation of my previous field-season's work and the result is a fairly accurate geological survey of about 3,400 square miles, completed during the greater part of two seasons. In this part of Baluchistán, I could distinguish the following divisions of strata in descending order :—

Recent	(11) Alluvium ; wide-spread deposits of sandy clays, conglomerates, and also in places, blown sands, which generally pass up imperceptibly from the next older formation.
Seistán formation Pleistocene .	(10) Red and white sandy clays with sandstone and conglomerate beds, with much gypsum in layers and strings.
Miocene and pliocene . .	(9) Sandstone, shales, and conglomerate of the ordinary Siwalik type ; fossil bones and casts of large *gastropods*.
Younger Eocene and Miocene .	(8) Great thickness of sandstone beds, very like the Siwaliks in character, but with occasional limestone partings, which contain marine fossils.

Eocene.	Great development of basic igneous rocks. Intrusions of later date.	(7) Concretionary limestone and shales with fos (6) Sandstones, shales, and clay. (5) Thick limestone with *nummulites.*
Upper Cretaceous.	Interbedded basic rocks; gabbro, tufa.	(4) Limestone with *Sphenodiscus, Cardium Beaumonti,* etc., etc. (3) Shales and limestone with *belemnites.*
Neocomian	. . . .	(2) Thick limestone with neocomian fossils.
Jurassic	. . . . .	(1) Massive limestone with jurassic fossils.

Along a great line of dislocation which runs along the Chinjan and Yusuf Kats valleys, I have met with what I must consider genuine "blocs exotiques,"—of carboniferous and triassic rocks, bearing fossils. The dislocation is characterized by intrusions of basic rocks which obscure the position of these "blocs." It is hoped that more evidence of the same will be forthcoming during the next field-seasons.

One of the most remarkable features of Baluchistán geology is the association or igneous rocks with the upper cretaceous and the lower and middle part of the eocene deposits. The first outburstl of basic rocks, as far as can at present be ascertained, occurred in later cretaceous times; at least evidence of *intrusions* only have been met with in the jurassic beds, and even the lower part (limestones) of the upper cretacious seems free from interbedded igneous rock, but on the other hand these beds show locally great alteration near intrusions of the latter examples; Kach near Quetta, Gwál and other localities in the Zhób valley. The earliest evidences of contemporaneous igneous action occur in the upper cretaceous belemnite beds. This is seen clearest in the upper Zhób valley, especially near Gwál. Certain large areas of Baluchistán (south of Hindu Bágh and Kójak range) are entirely made up of great outbursts and spreads of basic igneous rocks, with gabbro and serpentine, associated with a few sedimentary beds, which are much altered in places and quite schistose in some. It is hardly possible to divide this complex of rocks, as precisely similar conditions seem to have continued right into middle eocene deposits. The higher portion of this facies, which may be compared to the Flysch formation of Europe, especially as developed in the Island of Elba,—contains a few beds of limestone which yielded *nummulites*, thus limiting the duration of igneous action to the period between the deposition of upper cretaceous and middle eocene beds. Quite unaltered limestone with upper eocene (Spintangi) fossils overlies the igneous facies of the northern Zhób and of the Kójak range. All trace of igneous action seems to have died out during that epoch.

The Kójak formation of shales, limestones and tuffaceous rocks,—in places quite schistose—I considered to be tertiary in 1880 (Memoirs, Vol. XVIII) and later in 1884 (Records, Vol. XVIII, page 59), as possibly cretaceous; probably both views are correct to some extent, and they may represent the igneous facies ranging from the upper cretaceous belemnite shales to middle eocene, and the formation may be a continuation westwards of the upper Zhób rocks. They are also associated with some irregular beds of limestone which contain large *nummulites.*

Connected with this great volcanic outburst are acid rocks, chiefly of the granitic family, which form part of the Khwája Amrán, and these may have been amongst the earliest eruptions which took place there.

Burma.
Baluchistán.
Dr. Fritz Noetling.

There are still a few questions of structural importance involved in the Yenangyoung oil-bearing tract and to clear up the same, Dr. Noetling was sent to Burma during this field-season. An exhaustive report on the oil-region will be brought out by him shortly.

During the hot weather and rains of last year Dr. Noetling examined and described the fine collection of cretaceous and jurassic fossils from Baluchistán which will be published as series XVI of the Palæontologia Indica.

Economic Geology.

During 1894, several officers were employed in practical investigations only, but in all cases where useful minerals were come across by the other parties engaged in field work, such occurrences have also been reported on.

Mr. LaTouche was during the past year, and is still, engaged in the trial boring for petroleum at Sukkur. Mr. Middlemiss has been engaged in the examination of the corundum and magnesite deposits of Madras.

Mr. Holland was employed in reporting on the Gohna landslip and has since been engaged in making numerous assays of minerals and rocks.

Mr. Smith surveyed the so-called "Quetta" coal-area, and has prepared a report which will be published. Dr. Fritz Noetling was deputed to report on the working of the Dandote and Warora coal-mines and has issued his reports on the same. He is now at Yenangyoung in Burma in order to finish his investigations of the oil-fields.

Mr. Grundy, the Inspector of Mines in India, has issued his first report for the year ending 1st July 1894, which has been printed and published. He has since inspected the mines in Mysore, Central Provinces and Rewah, and will proceed to Hyderabad (Dekkan), the Punjáb and Baluchistán.

Mr. William Anderson has been posted to Chota Nagpur to report on the supposed metalliferous belt of rocks.

Amongst the notes on useful minerals made by officers engaged in scientific surveys only, may be noticed reports by Mr. Bose on iron-ores, pockets of manganese, traces of copper and veins of argentiferous galena (61·60 per cent. lead and over 7 oz. of silver to the ton) in the Rewah State.

Mr. Datta reports on considerable quantities of an iron-ore in the Sone Valley, which is used locally for iron-manufacture.

Publications.

Considerable advance has been made in the publication of the Palæontologia Indica. Dr. Waagen has at last completed Vol. IV of series XIII, which deals with the ammonites of the ceratite beds of the salt-range. It is illustrated by 40 quarto plates and will appear shortly.

Series XV of the Palæontologia Indica has been commenced, and will illustrate the large and most important collection of fossils from the Himálayas, embracing not only the specimens preserved in the Geological Museum in Calcutta, but also every known specimen found in the Himálayas and preserved in the various European museums. Part 2 of Vol. II of this series is completed, and will appear shortly, illustrated by 31 quarto plates, descriptive of the Muschelkalk fauna of the Himálayas. Several other parts are in preparation.

Memoirs, Vol. XXV, on the geology of the Bellary district by R. B. Foote, is nearly ready for publication, and the final sheets are being passed for the press.

Vol. XXVI on the geology of Hazára by C. S. Middlemiss is in the press, and will appear shortly.

Vol. XXVII, Part 1 on the miocene fossils of Yenangyoung by Dr. Noetling, is in type and will shortly appear; Part 2 on the oil-fields of Yenangyoung is in manuscript, but will be ready for publication shortly after Dr. Noetling returns from Burma.

Museum and Laboratory.

Mr. Holland has re-arranged and labelled the collection of minerals to correspond with the more modern classification adopted in the new edition of Mr. Mallet's guide which has been re-written by Mr. Holland for the use of students. He also described a large number of rock specimens as contributions towards the work of classifying and arranging this portion of the collection. Where the description of the specimens has given promise of results of more than local petrographical interest, Mr. Holland has taken the opportunity of college vacations to work out their characters more fully in the field. In this way we have obtained a fairly comprehensive account of the distribution, and contact effects in the Bengal coal-fields of varieties of some new types of the remarkable group of peridotites. Amongst these the mica-peridotites which frequently contain anthophyllite and chromite are, from the excessive amount of apatite which they contain, most exceptional types amongst the known igneous rocks of the globe. The occurrence of these peridotites, which have now been found breaking through the lower Gondwana series in all the Bengal coal-fields, forms an interesting comparison with the peridotites which are similarly intrusive in the carbonaceous rocks of about the same age in South Africa. The large number of specimens of the peridotites and the altered and associated sedimentary rocks form a most instructive series in the Museum. In making this collection and in tracing out the field relations of the rocks, Mr. Holland has received most valuable help from Dr. Saise, Manager of the East India Railway Company's collieries at Giridih. (A detailed description of these rocks appears in Part 4 of Vol. XXVII of the Records).

Mr. Holland has described another new type of peridotite from the district of Manbhum which differs from previously known ones in containing hypersthene associated with olivine, augite, biotite and hornblende. (Records, Vol. XXVII, part 4.)

The mode of occurrence of the rare mineral columbite has been examined at Pananoa near Nawadih, East Indian Railway. Mr. Holland has found it in lumps imbedded in the quartz of a very coarse grained pegmatite dyke, intruded into a mica schist, which is crowded with tourmaline crystals.

The list of assays and determinations made in the laboratory has been published in the previous volume of the Records.

The work in the Museum was naturally interrupted during the early part of the year by Mr. Holland's absence at Gohna and Naini Tal, but he attributes the satisfactory progress which has been made largely to the valuable work done by the Museum Assistant, Mr. T. R. Blyth.

Whilst so much progress has been made in the mineral gallery of the Department, it is much to be regretted that the palæontological collection is in a most unsatisfactory state, both as regards arrangement of specimens and condition of the labels and cases. But this is entirely owing to the long absences of the Palæon-

tologist of the Survey, who for some years past has been engaged on entirely different work, such as reporting on the mineral resources of Burma and the inspection of collieries in India. But it is hoped that he will be able to devote himself to more scientific work in future. A good beginning has been made by him in describing the miocene fossils of Burma and the cretaceous collections from Baluchistán, and we may reasonably hope to get the Palæontological Museum into order during the next two years.
There is much need of an efficient Assistant in that branch of the Department.

Library.

The additions to the library amounted to 1,756 volumes, of which 777 were acquired by presentation, and 979 by purchase.

C. L. GRIESBACH,
Director, Geological Survey of India.

CALCUTTA,
The 31st January 1895.

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 1894.

ADELAIDE.—Royal Society of South Australia.
ALBANY.—New York State Museum.
BALLARAT.—School of Mines.
BALTIMORE.—John Hopkins University.
BASEL.—Naturforschende Gesellschaft.
BATAVIA.—Bataviaasch Geonootschap van Kunsten en Wetenschappen.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—Deutsche Geologische Gesellschaft.
„ K. Preuss. Acad. der Wissenschaften.
„ K. Preuss: Geologische Landesanstalt.
BOLOGNA.—Reale Accademia delle Scienze dell' Istituto.
BOMBAY.—Meteorological Department, Government of Bombay.
„ Natural History Society.
„ Royal Asiatic Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
„ Society of Natural History.
BRESLAU.—Schlesische Gesellschaft fur Vaterländische Cultur.
BRISBANE.—Royal Geographical Society of Australia.
„ Royal Society of Queensland.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Acad. Roy. des Sciences.
„ Société Belge de Geographie.
„ „ Roy. Malacologique de Belgique.
BUDAPEST.—Kön. Ungarische Geol. Anstalt.
BUENOS AIRES.—Acad. Nacional de Ciencias en Cordoba (Republica Argentina).
CAEN.—Société Linnéenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of India.
„ Asiatic Society of Bengal.
„ Editor, Indian Engineering.
„ „ The Indian Engineer.
„ Indian Museum.
„ Meteorological Department, Government of India.
„ Royal Botanic Garden.
„ Survey of India.
CAMBRIDGE.—Philosophical Society.
„ University of Cambridge.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CASSEL.—Verein für Naturkunde.
CHRISTIANIA.—Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Kong. Danske Videnskaberns Selskab.
DEHRA DUN.—Great Trigonometrical Survey.

DES MOINES.—Iowa Geological Survey.
DRESDEN.—Naturwissenschaftliche Gesells. Isis.
DUBLIN.—Royal Irish Academy.
„ „ Dublin Society.
EDINBURGH.—Geological Society.
„ Royal Scottish Geographical Society.
„ „ Scottish Society of Arts.
„ „ Society.
FLORENCE.—R. Biblioteca Nazionale Centrale di Firenze.
GLASGOW.—Glasgow University.
„ Philosophical Society.
GOTHA.—Editor, Petermann's Geographische Mittheilungen.
GÖTTINGEN.—K. Gesells. der Wissenschaften.
HALLE.—Academia Cæsarea Leop.-Carol. Naturæ Curiosorum.
HAVRE.—Société Géologique de Normandie.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Société Vaudoise des Sciences Naturelles.
LEIDE.—École Polytechnique de Delft.
LEIPZIG.—Verein für Erdkunde.
LIÈGE.—Société Géol. de Belgique.
LILLE.—Société Géologique du Nord.
LISBON.—Section des Travaux Géol. du Portugal.
LIVERPOOL.—Geological Society.
LONDON.—British Museum.
„ Geological Society.
„ Iron and Steel Institute.
„ Linnean Society of London.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoölogical Society.
MADRID.—Sociedad Geografica de Madrid.
MANCHESTER.—Geological Society.
„ Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
„ Royal Society of Victoria.
MILAN.—Societá Italiana di Scienzé Naturali.
MOSCOW.—Société Imp. des Natur.
MUNICH.—Kon. Bayerische Acad. der Wissensch.
NAPLES.—Reale Accademia delle Scienze Fisíche e Matematiche.
NEWCASTLE UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Editor, "American Journal of Science."
NEW YORK.—Academy of Sciences.
OXFORD.—University Museum.
OTTAWA.—Geological and Natural History Survey of Canada.
PARIS.—Editor, Annuaire Géologique Universel.
„ Commission des Mines.

PARIS.—Ministere des Travaux Publics de la Carte Géologique de la France.
„ Socíété de Geographie.
„ „ Géologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
PISA.—Societa Toscana di Scienze Naturali.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Scienze.
„ „ Comitato Geol. d'Italia.
SACRAMENTO.—California State Mining Bureau.
SAINT PETERSBURG.—Comité Géologique.
„ Russische Mineralogische Gesellschaft.
SALEM.—Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch of the Royal Asiatic Society.
SPRINGFIELD.—Illinois State Museum of Natural History.
STOCKHOLM.—L'Institut Royal Geol. de la Súede.
„ Kongliga Svenska Vetenskaps Akademie.
SYDNEY.—Australian Museum.
„ Department of Mines and Agriculture, New South Wales.
„ Geological Survey of New South Wales.
„ Linnean Society of New South Wales.
„ Royal Society of New South Wales.
TOKIO.—Deutsche Gesellschaft für Natur und Volkerkunde.
TORONTO.—Canadian Institute.
TURIN.—Reale Accad. delle Scienze di Torino.
„ Regia Universita di Torino.
VENICE.—Reale Istituto Veneto di Scienze.
VIENNA.—K. Akad. der Wissenschaften.
„ K. K. Geographische Gesellschaft.
„ K. K. Geologische Reichsanstalt.
„ K. K. Naturhistorisches Hof-Museum.
WASHINGTON.—National Academy of Sciences.
„ Smithsonian Institution.
„ United States Geological Survey.
„ „ „ Mint.
„ „ „ National Museum.
WELLINGTON.—New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ Seismological Society of Japan.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Naturforschende Gesellschaft.

The Governments of Bengal, Bombay, India, Madras, and the Panjáb.
The Chief Commissioners of Assam, Burma, and the Central Provinces.
The Residents, Hyderabad and Mysore.

The Cretaceous Formation of Pondicherry by H. WARTH, D. SC., (Tübingen), *Deputy Superintendent, Geological Survey of India.*

The area which I was deputed to examine during January and February 1894, had last been visited by the late Mr. H. F. Blanford in 1860, and was described by him in Vol. IV, p. 156 of the Memoirs. It is situated between the Red Hills of Pondicherry on the south-east and between what Mr. Blanford called the Tirvukarai ridge on the north-west, and is bounded on the south-west by the alluvium of the Ariankupam river. The total length is about 8, and the width 4 miles. A large surface of this ground is occupied by numerous tanks or artificial reservoirs for rainwater, used for irrigation. Most of the area consists of level and cultivated fields, amidst which are a few isolated exposures of rock *in situ*. It is not nearly as favourable for study as are the cretaceous sections near Trichinopoly; there the exposures of strata on eroded patches measure square miles, whereas in the Pondicherry area they amount to acres or even square yards only. This great paucity of exposures has been repeatedly pointed out by Mr. H. F. Blanford, and if, notwithstanding this, the first explorers, Messrs. Kaye and Cunliffe obtained such large numbers of valuable fossils in 1840, it will be shown further on how this may be accounted for.

Mr. H. F. Blanford showed that the cretaceous strata may be separated into two distinct divisions: the lower he named the Valudayur group, which hitherto has been considered to be equivalent to the Utatur group of Trichinopoly, whilst the upper series he found to be identical with the Ariyalur group of Trichinopoly.

Considerable confusion has taken place in the collections made in Pondicherry, and the object of my visit to that area was not only to obtain a large number of fossils, but to establish them in the various horizons. I have succeeded not only in separating the fossils according to the two main divisions, but I have been able to distinguish three successive horizons in each of these divisions. We have, therefore, altogether 6 horizons from which fossils have been obtained, the three lower of which constitute Mr. H. F. Blanford's Valudayur group, whilst the three upper ones are what he accepted as Ariyalur group. As will be shown later on, the whole of the strata must now be considered as Ariyalur group.

The bedding of these horizons is either horizontal or a gently dipping towards south east. The general lithological character of all the beds is that of sand or sandy clay with calcareous nodules or concretions which are scattered throughout the whole formation. Only the uppermost horizon contains a continuous thin layer of limestone in addition to concretions.

Horizon A.

Horizon A is the lowest sub-division and appears on the surface as a strip 2 miles wide. It is separated from the Tirvukarai ridge by a band of alluvium 1½ miles wide which conceals all outcrops. Going from north-west to south-east, the first indication of the horizon consists of white sands with nodules of one foot thickness. These nodules or concretions contain traces of annelid channels only. They are also stained with dendritic manganese. The localities examined are well-exacavations, ¼ mile east-south-east of Lingaredipaliam and 1 mile north-east of Katarampokam.

Next in ascending order we observe yellow sands with gravel, 1 mile east-north-east of Katerikupam in the bed of the canal, and in the ravine 1 mile north-east of Vanur. The latter place is referred to by Mr. H. F. Blanford on page 157 of his Memoir.

Lastly, we have sandy clays with large concretions, which contain; annelid casts, they have a diameter of ¼ inch, and some were up to 6 inches in length. They are usually curved. The concretions consist of crystalline calcite with a distinctly botryoidal surface. They are usually somewhat lenticular, 2 feet thick, and of 3 feet diameter. I have searched for them in vain in the neighbourhood of the Ariankupam between Valudayur and Muterampatu, but the concretions are well exposed at the following three localities which are on the same strike, from south-west to north-east :—The first is near Katerikupam, where the concretions show along a length of over ¼ mile of the canal excavation. The blocks had about 2 feet diameter and the surfaces were decidedly botryoidal, proving their concretionary origin. The second locality is about ¾ miles south-west of Vanur; the concretions are shown very clearly in several square wells. They form layers which have a slight inclination towards the south-east. Many of the lenticular concretions had about 1½ feet thickness and 3 feet diameter with botryoidal surfaces. In one well were so many concretions and so close together that they presented the appearance of a continuous bed of limestone, 2 feet thick. The concretions contain numerous annelid burrows. I broke up one of the blocks entirely without finding a trace of any fossil. In the neighbouring fields were also scattered blocks of the same kind. Near the village of Wattai close by, is a large square tank which is lined with the same blocks said to have been derived from the excavated tank bed. Many blocks of the concretions from horizon A are also seen in the lining of other tanks in the neighbourhood, for instance at Vanur. But in the latter many stones had been used, which must have been brought from near Saidarampet in French territory, and belong possibly to horizon E, and are usually fossiliferous. It is not easy to distinguish always the different blocks from each other. But those from horizon A have no fossil shells and are botryoidal, whilst certain fossils show others at once to have been derived from horizon E. The third place is the best of all the exposures. It is immediately south of the village of Andipaliam, where many concretions are exposed on the surface. One of them was 2 feet by 4 feet by 6 feet. The concretions formed layers with a moderate dip to the south-south-east, many of them were also washed out of the matrix, but most probably are very near their original site. Some of the concretions contained quartz pebbles about 2 inches in length arranged in layers.

I observed also some concretions about half a mile south-east of Olundiapati, in which I have not found any fossil, but which I am inclined to include in horizon A.

Horizon B.

The next higher horizon B contains fossiliferous concretions and has also yielded some fossils from the sandy matrix. I include herein the exposure of yellow sands in a tank-bed, 1 mile south-east of Vanur. At that place I found many minute bivalves and a few distinct *Baculites vagina*. On the Vanur Pondicherry road, 1 mile north of Saidarampet, small bivalves occur in a white sand, which I include in B, although it is in contact with scattered blocks of horizon E. I also include with B large, slightly fossiliferous concretions and nodules, 1 mile south-south-east of Pulichapaliam. In the road ditch and in some wells east of the road, I found fossiliferous concretions of large size, of which one has yielded a small *ammonite*.

Horizon C.

Horizon C is the most important of all, as it seems most probable that from it were derived the cephalopods which Messrs. Kaye and Cunliffe obtained about the year 1840. The spot from which most of these fossils appear to have come is north-north-east of Valudayur and north of Tutipet. It is from this place that I obtained the best fossils of horizon C, but some I found further north-east close to the village of Rautankuppam. I found in this horizon four small *ammonites*, several species of *Hamites*, *Baculites vagina* in numerous well preserved specimens, many *lamellibranchiata*, *gastropoda*, etc. The list at the end of this paper refers to preliminary identifications by Dr. Kossmat.

The fossils occur in blocks which are not *in situ*, but washed out of the alluvia ground, and are largely used for building purposes, so that the supply is really limited. I have now used up all the loose blocks which I could see, and I doubt whether more will be found for a considerable time to come. Mr. H. F. Blanford considered the place already exhausted, as will be apparent from his remarks on pages 154, 155, 156, 158, 163, Memoirs, Vol. IV, and page 2 of his account of Cretaceous Cephalopoda in the *Palaeontologia Indica*.

Mr. Blanford referred at some length to the ridge east of Valudayur on which he traced the boundary between his Valudayur group and the overlying Ariyalur group. This ridge is not a very prominent object in the landscape, and some of the exposures on it, which Mr. H. F. Blanford described, must since have disappeared. If the Topographical Survey map had been provided with contour lines, this ridge as well as the Tirvukarai and Red hills ridges would be clearly shown, but although this is not the case, the ridge in question is marked by the space which it occupies between two rows of irrigation tanks, and a line drawn on the map from Tutipet to Akasampatti travels along the centre of the ridge. It rises about 115 feet above the sea and thus about 45 feet above the cretaceous area to the north-west of it and 89 feet above the level of the great Usteri tank lake to the south-east. Near Tutipet and Valudayur, the north-west base and part of the slope of the ridge comprises horizon C. Towards north-east the ridge merges more or less into the more elevated country, and the exposure of horizon C near Rautankupam is on nearly level ground. As will be seen hereafter, the south-east slope of the ridge about Tutipet, Karasur and Saidarampet coincides with the harder beds of the horizon F, and it is very probable that these limestone banks have been the cause of the preservation of the ridge.

Horizon D.

The horizon D is characterized by a continuous bed of sandy shale, several feet thick, which is full of casts of shells, most of them those of *lamellibranchiata*, *Trigonoarca Galdrina*, *Macrodon Japeticum*, *Alectryonia ungulata*, etc. Others will be found on the list at the end. I also found a few *ammonites* and *Baculites vagina* and some specimens of *nautilus* two feet in diameter. A few specimens of *terebratula* were also found in this horizon, also some *corals* and *echinoidea*. Small fish teeth were numerous.

A fact of importance is the wholesale conversion of shells into phosphate, or rather the production of interior casts of shells consisting of rich black phosphate.

Some of the casts show also the impression of honey-combed cells one-fiftieth of an inch in diameter, most likely due to bryozoa. In this same stratum are also numerous concretions of light brown colour, which are likewise strongly phosphatic; they are of irregular shapes, resembling some organic structure.

I found three very clear exposures of this horizon. The first in a well, a quarter of a mile west-south-west of Tutipet, the second is *in situ* on the surface of the road a quarter of a mile north of Karasur, the third is in a well a quarter of a mile west of Rautankupam on the west side of the Tindivanam Pondicherry road. A small exposure was also noted in a well, a quarter of a mile north-west of Royapudupakam. In the Rautankupam well the sandy bed, which contains the casts of shells, is also partly replaced by concretions of one foot thickness, in which fossils occur.

Phosphatized shells are not found in any of the other horizons, with the exception of the lowest portions of horizon E. There are some phosphatic cores of light color in the centre of gastropods, in nodules of the upper part of horizon F. But these cores are of quite different appearance to the phosphatic matter in D, and in much smaller quantity. The black phosphatized shells are a sure indication of horizon D and the overlying portions of horizon E. They are seen in several places scattered over the fields mixed with other fossils, where no distinct exposures of the strata are otherwise seen.

Horizon E.

This horizon is important on account of the large number of nodules of shell limestone it contains. A very great number of the nodules have been utilized for tank revetments and buildings in the neighbourhood. Many were also used for walls, buildings and pavements in Pondicherry. The pavement shows all the various fossils of the horizon in sections. One fossil is especially very prominent and characteristic. It is a coral, *Cyclolites filamentosa*, which is seen in semicircular sections. *Exogyra ostracina* is also common. Owing to the systematic removal of blocks from the surface of the outcrop, it is generally difficult to trace the area of horizon E, but at a place near Karasur I still saw the blocks being quarried, and one very large deposit of blocks is exposed *in situ*. There is also an outlier of this deposit consisting of some 40 blocks, at a point 1 mile north of Saidarampet. The worn surfaces of the blocks show sections of numerous fossils, which contrast strongly against the brown matrix. Besides *gastropoda* and *lamellibranchiata* in great numbers, the sections also show the semicircular or crescent shaped outlines of *Cyclolites filamentosa*, which coral is most characteristic of horizon E.

The wall of a tank near the village of Royapudupakam yielded numerous fossils as has already been pointed out by Mr. Blanford. Amongst them I collected *Exogyra ostracina*, *Alectryonia ungulata*, *Euptycha larvata*, *nautilus*, *etc*. Some of the fossils are also found in horizon D and with them were also some black phosphatic nodules.

Horizon F.

The uppermost horizon is characterized by fucoid casts, which are cylindrical and about three quarter of an inch thick and generally in broken pieces of about five inches length; some of these casts are bifurcated. They are much used for lime burning, along with calcareous nodules found in the same bed. The latter are about two inches diameter and contain spiral *foraminifera* of minute size; they are dug up from the soil which overlies some of the fucoid limestone.

The same yellow, crystalline, somewhat sandy limestone was found exposed at the Usteri canal, one mile south-south-east of Valudayur and half a mile along that canal towards south-east; at four places on the way thence to Kadaperikupam; at the kilns half a mile south-west of Kadaperikupam; at Kadaperikupam; at Saidarampet; at the kilns quarter of a mile east-north-east of Saidarampet; half a mile west of Akasampati; quarter of a mile east-south-east of Akasampati; quarter of a mile south of Wattampalliam (French part of village called Sanjiverampet), and lastly in the bed of a large open tank near Royapudapakam.

The limestone is the only continuous bed of hard rock in the Pondicherry cretaceous. At the Usteri canal I estimated the total thickness to be five feet of limestone, with partings of sand. At Saidarampet a solid bed of limestone showed two feet thickness with a dip of four degrees south-east.

Most of the fossils are obtained from the overlying sands. Amongst them are some very characteristic corals (*Coryophylla arcotensis, Cyclolites conoidea*), *Teredo* tubes in abundance and very large gastropods (cones of one foot length), *Nautilus serpentinus* and one nautilus with a very sharp keel, apparently a new species.

The limestone dips generally towards south-east, the surface of the country coinciding with the dip slope. Above the limestone, clays and sands with nodules continue. One clay bed with layers of nodules has already been mentioned as containing some shells with light coloured phosphatic cores. In this bed remains of a turtle were found. Still higher up in the series large concretions of two feet diameter are seen in an excavation one mile north of Tirusitambalam (at the road fork). Near Tirusitambalam I noticed yellow clays with minute bivalves, and similar clays continue up the side of the Red hills ridge. These were no doubt the upper-most cretaceous deposits mentioned by Mr. H. F. Blanford, page 160, Vol. IV.

These six horizons represent the whole sequence of the cretaceous strata.

A line of section.

With the exception of horizon F the exposures of the strata are very few and it would be difficult to find a continuous sequence. But there is, however, a line of section, in which four horizons are well represented and the other two at least indirectly. This is along the Tindivanam Pondicherry road. Starting at a place 12 miles from Pondicherry, we obtain a fair section along a straight road of about 4½ miles length, along which exposures of most of the horizons are seen.

Dip of strata.

The general dip of the sequence of beds was given by Mr. H. F. Blanford as two degrees, which accords with my own observations.

Thickness.

The total thickness of the cretaceous rocks of Pondicherry may be about 900 feet.

Preliminary table of fossils.

The fossils obtained were sent to Vienna for determination and they have since been examined by Dr. F. Kossmat of the University of that city. He will describe the collection in detail, but has given the annexed preliminary list of fossils.

Preliminary List of Fossils.	Horizons.				
Caryophyllia arcotensis Forb.	...	...	...	...	F
Cyclolites conoidea Stol.	...	...	...	...	F
Hemiaster, n. sp.	...	...	D	...	...
Stigmatopygus elatus	...	C	...	...	...
Terebratula arabilis, Forb.	...	...	D	...	...
Alectryonia ungulata, Schl.	...	C	D	E	...
Exogyra ostracina, Lam.	...	...	...	E	...
Gryphaea vesicularis	...	...	...	...	F
Plicatula	...	...	D	...	...
Spondylus, n. sp.	...	...	...	...	F
Spondylus calcaratus, F.	...	...	D	...	...
Pinna cf. laticostata, Stol.	...	C	...	...	...
Modiola flagellifera, Forb.	...	C	...	...	...
Modiola polygona, Forb.	...	C	...	...	...
Macrodon Japeticum, Forb.	...	...	D	...	...
Trigonoarca sp.	...	C	...	...	...
Trigonoarca Galdrina, F.	...	C	D	E	...
Cyprina cristata, Stol.	...	...	D	...	...
Protocardium bisectum, Forb.	...	C	...	...	...
Panopaea orientalis, Forb.	B	C	...	...	...
Pholadomya caudata	B	C	D	...	...
Corimya pertusa, Stol.	...	C	...	...	...
Pharella obscura, Forb.	B	C	...	...	...
Teredo aff. glomerans	...	...	...	...	F
Phasianella cf. conulata, Stol.	...	C	...	...	...
Euspira sp.	...	...	...	E	...
Euptycha larvata, Stol.	...	...	...	E	...
Nerita sp.	...	C	...	...	...
Nerita divaricata, Orb.	...	C	D	E	...
Turitella sp.	...	...	D	E	...
Cerithium, n. sp.	...	...	D	...	F

Preliminary List of Fossils.	Horizons.				
Nerinea, n. sp.	...	...	...	...	F
Cypraea Newboldi, F.	...	...	D	...	...
Cypraea sp.	...	...	D	E	...
Cypraea Kayei, Forb.	...	...	...	E	...
Rostellaria palliata, Forb.	...	C	...	...	...
Athleta purpuriformis, Forb.	...	C	...	...	...
Nautilus sp.	...	...	D	E	F
Nautilus aff. Bouchardianus	...	...	...	E	...
Nautilus cf. serpentinus, Blanf.	...	...	...	...	F
Nautilus sphaericus, Forb.	...	...	...	...	F
Lytoceras sp.	B	...	...	...	...
Hamites subcompressus, Forb.	...	C	...	...	...
Hamites indicus, Forb.	...	C	...	...	...
Hamites tenuisulcatus Forb.	...	C	...	...	...
Ptychoceras sypho Forb.	...	C	...	...	...
Baculites, sp.	...	C	...	...	...
Baculites vagina, Forb.	...	C	D	E	...
Desmoceras sp.	...	C	...	...	...
Pachydiscus ganesa, Forb.	...	C	...	...	...
Pachydiscus species	...	C	D	...	...

The fauna.

Dr. Kossmat intends giving a fuller description of the fossils later on, but I am authorized to state that he considers the Pondicherry cretaceous series to belong to the Ariyalur division. I may also remark here that these fossils have confirmed this conclusion, which Dr. Kossmat had already arrived at from other evidence; he had compared the original type specimens of the cepalopods of the Utatur and of the so-called Valudayur groups and had also discovered new points of agreement between the fauna of the Ariyalur group of the Trichinopoly area and the Valudayur group, and also with the cretaceous fauna of Natal. The Valudayur group will cease to be so distinguished and the horizons A, B, C, will have to be considered to be lower Ariyalur only

Some early allusions *to* Barren Island; *with a few remarks thereon, by* F. R. MALLET, F. G. S., *late Superintendent, Geological Survey of India.*

When writing the description of Barren Island that appeared in the twenty-first volume of the Survey Memoirs, I was unable to refer to any accounts of the Volcano earlier than that by Lieutenant Colebrooke, who saw it from a distance in 1787, and that by Captain Blair, who landed during a violent eruption in 1789[1]. The name 'Barren Island,' however, was not originally given by either of those observers: it had been applied before their time to the Volcano which, by some, had also been called 'Monday' and 'High' Island. It was clear, therefore, that the island was more or less known before Blair's visit, and it seemed possible that some one or more accounts of it, by navigators who had seen, or even landed on it, might be in existence, and that perchance some allusions to its volcanic condition earlier than those mentioned above, might be on record. I have recently taken advantage of residence near London to try whether any such accounts could be found, and with this object in view, have made a somewhat laborious search at the libraries of the India Office, the British Museum, and the Public Record Office. The examination of a very large number of printed works and manuscripts has, I am sorry to say, not led to the acquisition of a corresponding amount of new information, and there can be little doubt that there still exist accounts which remain to be discovered. But the following records, however meagre, at least add something to our knowledge of the volcano.

Van Linschoten, 1595.

The earliest indication of the island being known, that I am aware of, is to be found in the original Dutch edition of Van Linschoten's[2] voyages[3]: this work contains two maps engraved in 1595, one of India and some adjoining countries, the other of the Malay Peninsula and archipelago[4]. The 'Andemaon' and adjacent islands are included in both, the configuration in one being identical with that in the other. 'Nacondaon' is placed in lat. 14° 20'. No longitudes are given, but the position is 90 miles[5] E. or E. ½ N., from the northern end of the Andamans. About 45 miles S. by E. from "Nacondaon" (Narcondam), in Lat. 13° 35', there is a nameless island which is much nearer the true latitude of Narcondam (13° 26') than that to which the name is attached, and it is probably a duplication of that island, through a discrepant, and more accurate, determination of its position.[6]

[1] Asiatic Researches, Vol. IV, p. 397.

[2] Erroneously printed "Linschten" in Memoirs, G. S. I., Vol. XXI, foot-notes to pages 264 and 285.

[3] "Itinerario Voyage ofte Schipvaert, Van Jan Huygen Van Linschoten naer oost ofte Portugaels Indien," etc., Amstelredam, 1596.

[4] Facsimiles of these maps (but with the Dutch titles, etc., rendered into English) are included in "John Huighen Van Linschoten, his Discours of Voyages into ye Easte and West Indies," London, 1598, a translation of the original work.

[5] Here, and elsewhere, the miles given are nautical ones.

[6] On a "Chart of the Bay of Bengal," contained in the "East India Pilot, or Oriental Navigator," and dated 1778, or nearly two centuries later than Linschoten's maps, "Narcondam of the Portuguese"| is marked in Lat. 13° 47' and "High. I. or Narcondam of the

A second small and nameless island is marked about 45 miles east of the Andamans, in Lat. 12° 25′. This is some 10 or 12 miles N. W. from the true position of Barren Island, for which, I think, there can be no reasonable doubt that it is meant, as there is no other land for which it can possibly be intended.

Linschoten makes no mention of having himself visited the Andaman Islands. In the titles of the above named maps it is stated that they were "perfectly drawne and examined with the most expert cardes of the Portingales Pilots," which suggests that the island just mentioned were inserted on Portuguese authority as the explorer who charted them thought Narcondam worthy of a name on the map. Perhaps if Barren Island had been in eruption, and thus specially attracted his attention, he would have attached one to it also.

Gough, 1708.

On many charts of much later date than Linschoten's, no land near the position of Barren Island is indicated. Hence it was a new discovery to Captain H. Gough, when he sighted it in 1708. The log of his ship, the Stretham, is preserved at the India Office. On the 17th December of the year just mentioned, the following entry was made:—"Now at sunrise we see Land[1] from W. b. N. to N. W. b. N., at 7 o'clock ye squall being over we had an Island appearing thus" (small sketch given); "then ye other land bore from W. to N. W. by W. distance, I judge, 10 or 12 leagues. Now we have no drafts[2] that anything answer these bearings; therefore I commenced one From ye Lat. 11° which will include ye shoall,[3] to Lat. 14°, which will carry me to ye Cocos Islands; see the other side." The last sentence refers to Gough's M. S. chart,[4] on which the island, without any name, is marked in Lat. 11° 53′, and 58 miles E. S.E. from the Andaman coast. It is about 23 miles south of the true position of Barren Island, an error which is probably due to the fact that while Gough obtained his latitude on the 16th by observation, that on the 17th was by "account." There is, however, a discrepancy between the log and the chart. In the former his latitude on the 17th is given as 12° 30′, while on the chart his position at noon is marked in Lat. 12° 18′. If this difference were applied to the island, it would bring its latitude within 11 minutes of the correct one.

The island when seen was at a distance of 8 or 10 leagues to the E. S. E., and

French" 45 miles to the S. E. by E. in Lat. 13° 20′. On "a general map of the East-Indies" (1781), contained in the same Atlas, "Narcondam according to the Portuguese" is marked in Lat. 13° 45′, and "Narcondam or High Island according to the French," 60 miles to the S. by E. in Lat. 12° 50′. The French Island is certainly not intended for Barren Island, although the latter, as previously remarked, has also been known under the name of High Island. (See remarks, further on, about the "Flat Islands," and *cf.* Memoirs G. S. In Vol. XXI, foot-notes to pages 264 and 285). I have not succeeded in finding any original accounts of the Portuguese or French observations.

[1] The Andaman Coast.

[2] The obsolete term for chart.

[3] The "Flat Rock, awash" of the Admiralty chart (lat. 11° 8′). Capt. Gough puts it in 11° 10′, and on the 14th December writes :—Now as we rose from dinner we see Breakers N. N. E. of us nothing appearing above water. I suppose them 7 or 8 miles of as they broke high. We tacked. This shoall we find in our Drafts as to Latitude, but its laid not above 7 leagues off ye little Andemons and we see them not."

[4] Scale 3¼ inches to 1° of latitude. A copy, on a reduced scale, is included in Dalrymple's Plans and Charts.

measures on the chart about 4 miles × 2, with the length perpendicular to the line of sight; but this was evidently a mere eye-estimate.

There is a rough free-hand sketch of the island in the log, from the point of view just mentioned, which represents it as a very high one,[1] with the culmination near the S. S. W. extremity, a nearly flat top inclining gently towards the N. N. E., and steep slopes at the ends exactly the appearance which Barren Island, at the present time, would have, if viewed from the same position,[2] except that the height, in proportion to the breadth, in the sketch,[3] is a good deal more than in nature. This is so obviously due to exaggeration, which might, perhaps, be almost expected in a rough outline evidently dashed off *currente calamo*, that it would be waste of space to raise the question whether the valcano really was much higher in 1708. Had such been the case indeed, the truncation of the ancient cone must necessarily have been far less than is implied by the sketch, and the latter would entirely fail to represent the facts.[4] There is no indication, in the sketch, of smoke[5] rising from the volcano.

Various observers.

Reference to the observations of several navigators may be found in a "Memoir of a chart of the Indian Ocean," 1787 (contained in the first volume of Darlymple's Nautical Memoirs), where at page 36 we read:—

"The Island, called *Barren Island* by Capt. Taylor and Capt. Justice, *Monday Island* by Cheyne, from old Draughts; and *Alto* by Capt. Baker and C. Alves[6] is in

Lat.	12°·20′ N. by	C. Mills, 1758.
	12·22	Alves, 1760.
	12·20	Justice, 1771.
	12·20	Taylor, 1780.

Long. by Capt. Taylor's observations of Sun and Moon 93° 10′E. from Greenwich."

Cheyne, 1748.

The log of Capt. Cheyne's ship[7] (the Lapwing) shows that Cheyne passed "Monday" (Barren) Island, at the close of October 1748, and saw it from various points of the compass, but he made no nearer approach than 8 or 9 leagues. His observed latitudes on the 28th and 29th, combined with the bearings and estimated distances of the island, respectively made it in lat. 12° 6′ and 12° 16′. He remarks that "this by some is called Monday Island, but we have no account of it in the draught."

[1] The greatest elevation, as measured by Capt. Hobday in 1884, is 1,158 feet: therefore allowing for curvature and refr action, the island at a distance of 8 leagues would rise more than 700 feet above the horizon, while at 10 leagues it would still rise nearly 500.

[2] *cf.* Capt Hobday's sketch, in the corner of his map (Memoirs, Vol. XXI), taken from nearly the same bearing, but much nearer the volcano.

[3] One to five, which, under the circumstances of distance mentioned, would indicate a height of more than 2,000 feet if the sketch had been drawn accurately to scale.

[4] *cf.* Remarks, in the succeeding paper, as to the probable antiquity of the truncation.

[5] A convenient term, and quite as accurate as cinder and ash, in connection with volcanoes.

[6] "Barren Island, still smaller than Narcondam, is called likewise *Monday Island*; and by the Portuguese *Ilha Alta* (High Island)." 'The Oriental Navigator,' by J. Purdy, London, 1826, page 350. The information in this work about the Andamans is of somewhat old date and "extracted chiefly from Capt. Richie's account."

[7] India Office Records.

In the year 1758, Captain Mills, of the Drake, noticed "Land even with the water" in Lat. 11° 12', and "he says the land and (Alto, which he calls) *Arracondam*, bears of each other N. b. E. ½ E. and S. b. W. ½ W. distant 21 leagues,"[1] which makes the latitude of Alto (Barren Island) 12° 12', or within 4 minutes of the now accepted value. This quotation is of interest from the name Arracondam (presumably a corruption of Narcondam) being applied to *Barren Island*. Although I do not think Captain Mills' application of the name can be taken as proving anything, as he probably so used it through imperfect imformation, still the point is worthy of notice in connection with the origin of the term Narcondam alluded to in my memoir on the volcanoes.[2]

Mills, 1758.

I have not met with any record by Captain Alves or Baker. The discovery of a dangerous rock was reported by Captain Justice in 1771, which he describes in some detail[3] and at the conclusion says "Imagining I was to the westward of the Little Andaman I stood to the N. N. E.—ward in order to get its true place, but on the 2nd November, at 6 o'clock in the morning, I was surprised to see *Barren Island*; it lays by my account, not allowing the current, to be 20 miles to the westward of Barren Island[4] in the latitude of 11·07 or 11·12."[5]

Justice 1771.

The following remarks by Captain Taylor[6] of the Ship 'Ceres' are perhaps worth reproduction in full, as illustrative of the inaccuracy and uncertainty that prevailed about Barren Island until late in the last century:—

Taylor 1780.

× × × × ×

"January 12" (1780), "per medium of 13 good sights of the longitude found ourselves in 93° 36' longitude from Greenwich, which is 1° 33' W. since last sights and by the charts is nearly the longitude of the Islands, laid down in 12° and 11° 30' N. Lat. by the name of *Barren Island*. Kept a very good look out in the night and sounded as per log; next morning at daylight saw a pretty large Island bearing N.E. ½ E., 10 leagues, the ext. of the *Andamans* (just in sight) from W.N.W. to S.W. by S., 9 or 10 leagues. Till noon, that we had a good observation, could not determine whether the Island in sight was the northernmost *Barren Island* or *Narcondam*; we observed in 11° 59' N., the lat. of the northernmost *Barren Island* as laid down in the charts; the Island bearing N.E. by N. between 8

[1] Memoir of a Chart of the Indian Ocean, 1787, p. 37, in Dalrymple's Nautical Memoirs, Vol. I.

[2] Page 284.

[3] He was not, however, the original discoverer of the danger, which was seen by Gough in 1708, and alluded to by him as previously known.

[4] *i.e.* the rock is 20 miles west of the meridian of Barren Island.

[5] M. S. Bengal Public Consultations, India Office Records; and Memoir of a Chart of the Indian Ocean, 1787, (*op. cit.*), p. 36. I may mention here, incidentally, that the earliest illustration of Narcondam I have met with, is to be found on a "Chart from Negrais to the Island Carnicobar, by John Richie, 1771" (Dalrymple's Plans and Charts), as might be anticipated in respect to an extinct volcano; this sketch ("Narcondam, bearing E. by S. distant 7 miles"), shows no perceptible variation from the present outline. On this Chart Barren Island is not indicated.

[6] Dalrymple's Nautical Memoirs, Vol. II.

and 9 leagues distant which makes it come nearest the lat. of Barren Island. A day or two afterwards by a very good observation within 2 or 3 miles from the northern end of it, find its latitude to be 12° 20′ northern (21 miles to the northward of its situation upon the Charts)[1] and its longitude, by several very good observations of the Sun and Moon, to be 93° 10′ E. from Greenwich.

The nearest of the *Andaman* Islands we could see bearing S. W. by W. from it 18 or 20 leagues. As for the southernmost *Barren Island* we concluded that it did not exist, or if it did, that it must be very erroneously placed in the charts, for the day after we saw *Barren Island* we were set to the southward in endeavouring to pass to the eastward of it, and at noon had the Island bearing from N.b.W. to N.N.W., 12 leagues and observed in 11° 48′ N., which is nearly the southernmost *Barren Island* (as laid down) notwithstanding which, saw no such Island although the weather was very clear; since which time I was informed by the Captain of a Portuguese schooner that he had seen both the Islands, the southernmost being situated much further to the westward than laid down.

"I likewise have it from good authority that Captain Sharrington of the Bahar country ship saw the rocks under its ship's bottom and sounded in 4 fathoms *Barren Island* being N.N.W. 5 or 6 leagues. In the charts there is some dangers laid down[2] to the southward of the southernmost *Barren Island*, I imagine it is meant to be placed to the southward of the northernmost, as I think it seems doubtful whether there are but one or two Islands. The Island of *Narcondam* bears N. by E. ½ E. 23 leagues distant, from *Barren Island* in lat 13° 26′ N. and Long. 93° 30′ E. from Greenwich, both ascertained from very good observations. The Island *Narcondam* and *Barren Island* appear very different when seen at some distance; so that, independant of their latitudes, with a simple sketch of each Island a man could be at no loss readily to know the one Island from the other. *Narcondam* makes like a sugar loaf, quite flat at the top, and may be seen at least 18 leagues from the mast head, for we saw it 13 or 14 leagues from the poop pretty high out of water, the weather rather hazy; this distance may be depended upon as its calculated from the bearings and differences of latitude.

"*Barren Island* appears much longer, but not quite so high; the watermost ext, is the highest, and makes with a peak, descending to a low point to the eastward, although when you come near it, it seems of an equal height, with a peak at each end; it may be seen at least 15 or 16 leagues, for it was high out of the water when we saw it bearing N. by W. 12 or 13 leagues distant per calculation."

One Island, or two?

In explanation of Captain Taylor's surmise, whether one Barren Island, or two, existed, I may say that in various atlases of the eighteenth century[3] two small islands are marked, one nearly due north of the other, on a meridian some 50 miles east of (what appears to represent)

[1] *Cf.* Gough's observations, F. R. M.

[2] That reported by Gough and Justice? F. R. M.

[3] *e. g.* "Le Neptune Oriental on Routier général des Côtes des Indes Orientales," Paris, 1745 (*Isles Rases*). "Carte de L' Inde par le Sr. D'Anville, dated 1752, contained in the same author's "Géographie Ancienne Abrégée," 1769 (*Isles Rases*). "A New Directory for the East Indies" (based on Le Neptune), 6th edition, London, 1767 (Barren Islands). "The East India Pilot or Oriental Navigator," 2 charts dated respectively 1778 (Flat Islands and Barren Islands—both names given) and 1781, Flat Islands.

the South Andaman. The latitude of one varies from 11° 21′ to 11° 30′; that of the other from 11° 59′ to 12° 8′. In the French Atlases these are called the '*Iles Rases*,' while in some of the English they are called the 'Barren Islands' and in others the 'Flat Island.' However, one or two of these names came into use (possibly through some mistranslation from one language into another), the northern *Isle Rase*, as charted, agrees very fairly in position with Barren Island, and cannot be intended for anything else. What the southern *Isle Rase* was intended for I do not know. It was not meant for the rock east of Duncan's passage,[1] for in some Atlases, (*e.g.*, Le Neptune Oriental), the latter is marked *in addition to* the *Isles Rases*, in latitude 10° 55′ or 11° 0′.

Perhaps the most likely solution is that (like Narcondam, as previonsly mentioned) Barren Island was duplicated on the charts, through discrepant determinations of its position. But it is at least a possibility that, like Graham's Island, in the Mediterranean, the southern Isle may have been an ephemeral one, due to a volcanic eruption, chiefly of fragmentary ejecta. It is conceivable that, after it had been washed away by the sea, the last visible remnants were the rocks reported by Captain Sharrington, 5 or 6 leagues S. S. E. of Barren Island, and that even these subsequently disappeared, thus explaining Horsburgh's remark that Sharrington's account "is rendered doubtful, for no signs of a shoal-bank in the situation described have been discoverd for many years."[2]

Another possibility is that the temporary Island, and Sharrington's rocks, were S. S. W. of Barren Island (the S. S. E bearing given by Taylor being due to a not uncommon kind of clerical error). This would place them in the line joining Flat Rock, Barren Island, and Narcondam, and on the suppositional submarine ridge of Dr. Prain,[3] and would account, in another way to that suggested above, for the rocks not being re-discovered to the S. S. E., as well as for the statement of the Portuguese Captain. It would be useless, however, to pursue this speculation reared on such a slender basis.

Blair, 1789.

I have made unsuccessful attempts, at the libraries mentioned, to discover the original of Captain Blair's report on the Andamans, part of which, relating to Barren Island, is quoted by Lieutenant Colebrooke in the Asiatic Researches. The following letter,[4] however, dated 19th April 1789, serves to supplement the above: "To the Right Hon'ble Charles Earl Cornwallis, K. G., Governor General, etc., in Council:—

My Lord * * * * After examining Diligent Strait and the archipelago, I proceeded to Barren Island and found the volcano in a violent state of eruption, throwing out showers of red hot stones and immense volumes of smoke. There were two or three eruptions while I was close to the foot of the cone; several of the stones rolled down and bounded a good way past the foot of it. After a diligent search I could find nothing of sulphur or anything that answered the description of lava. * * * I have, &c. "Archibald Blair."

[1] The 'Flat Rock awash' of the Admiralty chart; that reported by Captain Justice.

[2] India Directory, 3rd edition, 1827, Vol. II, p. 37.

[3] See abstract of his memoir in the following bibliography.

[4] Bengal Political and Secret Consultations. Dated Fort William, the 21st August, 1789. India Office Records. The portions of the letter omitted relate to the Andaman Islands.

The preceding account is, in most respects, very similar to that in the report alluded to, and the chief interest lies in the final sentence. I have argued, on other grounds,[1] that the lava streams which now extend from the central cone westward towards the sea were emitted after Blair's visit; but his own statement, that after diligent search he could find nothing resembling lava, puts the question beyond discussion. It is scarcely conceivable that any one, however inexperienced in volcanic geology, could fail to recognize the true character of such typical streams at the first glance.[2] There are, however, still further proofs that the lava was emitted after Blair's time. From the points of issue the streams flowed down the slope of the cone, and their heads now constitute a portion of its surface, so that there have been no accretions to the cone since the occurrence in question. But it is shown, in the succeeding paragraphs, that the cone has greatly increased in bulk since 1789, and any lava emitted then, or previously, and solidified on its flanks, would now be deeply buried beneath the later products of eruption. I have previously stated,[3] that no fragmentary ejecta (scoriæ, &c.) have ever fallen, direct from the crater, on to the surface of the lava, which must, therefore, have been emitted after the last eruption of such material. In other words, the lava must be the latest volcanic product, and cannot, apparently, have been emitted earlier than 1804, the date of the last outburst of which we have any record. We have no reason to suppose that the different streams were emitted at considerable intervals, and the existence of the hot spring in 1832 shows that the southern stream, at least, had been poured forth before that date.[4] That Blair found no sulphur is very natural. The superficial deposits are entirely confined to the newer cone,[5] which was inaccessible to him, owing to the eruption. Even if he could have ascended it, he would have found none. The present deposits have been formed since the last eruption of scoriae, and therefore long after his visit, while the outburst he witnessed must have destroyed, or buried, any previously visible.

Captain Blair's landing on the island still remains the first, of which we have any record.

It is worthy of mention in connection with Blair's visit, that Test's "view of the volcano on Barren Island, bearing east, about one mile off"[6] taken the day before Blair landed, gives the means of arriving at an approximation to the height of the newer cone at that time. The sketch represents the summit of the cone as rising very slightly above the sky line of the old crater rim behind it, and a careful comparison of corresponding points in the sketch, and in Hobday's map of 1884, shows that the artist, the summit of the cone, and the eminence on the old crater rim which Hobday marked as 1060 feet, in height, were in a line; and likewise shows that the eminence in question was concealed, and only just concealed, by the summit of the

[1] Mem. G. S. I., Vol. XXI, p. 271.

[2] There was of course lava in abundance visible to Capt. Blair, at a distance, where it outcrops, interbedded with scoriae, on the scarped walls of the ancient crater. But its petrological character in such position would be far from self-evident to a non-geologist.

[3] Mem. G. S. I., Vol. XXI, p. 271.

[4] *Ibid* p. 274.

[5] There may possibly exist buried deposits amongst the rocks of both the ancient and the newer cone.

[6] A water colour sketch measuring 16½ inches × 6: British Museum library, Press mark K. 116, 31, *Vide* Mem. G. S. I. Vol. XXI, p. 262, the illustration accompanying this paper is a photographic reproduction on the scale of one-half.

cone[1]: in other words, the eminence and the cone subtended almost exactly the same angle, their respective distances from the point of view, and the height of the eminence,[2] being obtained from the map, give the height of the cone as exactly 800 feet, assuming the two angles involved to be identical, and that Test estimated his distance from the shore correctly. I do not think any probable difference in the angles would make a difference of more than 20 or 30 feet in the height, while an error of a quarter of a mile in the estimated distance, one way or the other, would make a difference of about 30ft. The errors due to these two sources if they exist, may partially, or entirely, neutralize each other; but even if they are both of the same sign, the total error is probably well under 100 ft., and is almost certainly not over this amount. While, therefore, it may be taken as almost beyond question, that the height of the cone was between 700 and 900 ft., it is much more likely that it was between 750 and 850 than outside these limits, and the most probable altitude is about 800[3].

Lieutenant Wales' sketch, as reproduced in the Asiatic Researches (Vol. IV) is on a smaller scale than Test's, and shows marks of less careful elaboration; but the height calculated from it agrees very fairly with the above, giving the most probable elevation as between 800 and 830 ft., the lower figures being the more likely.

Corroborative evidence of a considerable increase in the size of the cone is afforded by a large protuberance, represented in Test's sketch on the lower part of the north-western slope. This was quite obliterated in 1884, owing, doubtless, to its having been buried beneath the ejecta that have been emitted since Test used his brush.

Supposing the true height to have been 800 ft., the cone, which is now 1015 must have just doubled in bulk between the time of Blair's visit and 1857, since which date we know that there has not been any eruption, a suggestive conclusion in regard to the period of time during which the entire pile may have been heaped up.[4]

Test, like others,[5] over-estimated the slope of the newer cone, where, as is mostly the case, the sides are composed of fragmentary ejecta, the declivity is almost perfectly uniform, at an angle of about 32 degrees, except near the base, where the inclination gradually diminishes in a graceful curve.[6]

[1] That is to say if the cone were away, the sky-line of the crater rim would be seen to rise towards, and culminate in the eminence. As the sky line at each side is but slightly lower than the summit of the cone (in the sketch), the eminence must be, as nearly as possible, equally high.

[2] Test's sketch gives no reason to suppose that the height of the eminence is different now to what it was in 1789, although it is perhaps a few feet more, owing to accumulations of scoriae due to the eruptions since then. Any alteration due to movement of the crater walls (had such occurred) would probably be in the direction of subsidence, and would tend to reduce the calculated height of the newer cone.

[3] According to Blair's account, as quoted by Colebrooke, the elevation was "1,800 feet nearly"; a manifest clerical error. Were the figures he actually gave 800?

[4] *Cf.* Mem. G. S. I., Vol. XXI, p. 265.

[5] As pointed out by Dr. Ball (Records, G. S. I., Vol. VI, p. 82).

[6] See illustration in Mem. G. S. I., Vol. XXI, p. 251.

The following extract from the log of the Ship 'Worcester,'[1] commanded by Captain Hall, adds one more to the recorded eruptions towards the close of the last century:—

Hall, 1795.

"Sunday, 20th December, 1795. At 10 A.M. the Commodore made the signal for seeing the land. Saw a long Island higher at the westward end sloping gently to the eastward N. W. ½ W. 14 or 15 leagues off deck. At noon it bore from N. W. to N. W. ½ W. take it for Barren or Monday Island. In the centre a smoke arises and has the appearance of a volcano. Its Lat. by the bearings is 12° 22′ N. and Long. by my chron. No. 1, 93° 54′ E. Greenwich × × × ×.

"Monday, 21st × × × ×. At 6 A.M. it bore S. ½ W. about 10 leagues and Narcondam (both from the deck) N. N. E. ¾ E. about 12 leagues. It was astonishing the repeated columns of black smoke which were sent up. There appeared no hill (as the whole Island is nearly a plain surface gently sloping to the eastward as mentioned in yesterday's log) but the smoke was from the other side of the ridge or on the eastern side."

Any one unacquainted with the true topography of the Island, and viewing it from a distance of several leagues, might easily suppose it to have a nearly plain surface, or to form a ridge. Captain Hall's remark that the Island is "higher at the westward end sloping gently to the eastward" agrees with Captain Taylor's that "the westernmost extremity is the highest, and makes with a peak descending to a low point to the eastward." But this appearance is evidently a deceptive one, as Captain Hobday's map shows that the volcano is highest towards the south-east, and we have evidence, in Test's sketch of the Island in 1789,[2] that, as far as the ancient cone is concerned, the outlines then were practically identical with the present ones.

The volcano was again in eruption at the end of January 1804, when H. M. S. "Caroline" passed the Island. The log[3] contains the following entry on the 31st—"Several eruptions of fire from the volcano on Barren Island during the night." This outburst (as pointed out by Dr. V. Ball[4]) is also mentioned, by one of the officers, in an "account of a voyage to India and China, etc., in H. M. S. "Caroline."[5] His remarks are given in the following table.

Cason, 1804.

Not one of the observers before Colebrooke (1787) record any appearance of smoke rising from the Island, or make any remark indicative of their being aware of its volcanic nature, from which it may not unreasonably be assumed that, when they saw the volcano, it was quiescent or at most giving off a little steam.[6] It seems difficult to imagine that while the bearings, etc., of the Island were duly recorded in the log, an eruption, if witnessed, should be absolutely ignored, and we may, perhaps, further surmise that the volcano was in the same condition when seen by the unknown

Probable condition of volcano in 18th century.

[1] India Office Records.

[2] *Vide* accompanying reproduction and Mem. G. S. I., Vol. XXI, p. 262.

[3] Public Record Office.

[4] Geological Magazine, 1888, p. 404.

[5] Phillip's Voyages and Travels, Vol. V.

[6] Colebrooke saw smoke when he was 7 leagues off the Island, and Hall (1795) when 10 leagues, or more. Such indeed would be easily visible when the Island itself was below the horizon.

observers who first applied the names 'Monday' and 'Barren' Island; at dates we are unacquainted with, but which seem not improbably to lie between 1708, when Stretham charted the Island as an anonymous one, and 1748, before which time both names appear to have been in use.[1] Had the volcano been in eruption when the observers in question saw it, it does not seem unlikely that they would have given names suggested by the remarkable phenomenon of which they were spectators.[2]

Assuming, however, that the volcano was quiescent at the dates previously given, it would still be unsafe to argue very confidently as to its general condition in the eighteenth century, as, during the intervals of which nothing is known, many eruptions may have occurred for ought we can assert to the contrary. But, at the same time, the fact that on every one of the six dates included in the following records, between 1787 and 1804, the volcano was very active, and mostly in eruption, while on each of the (three or) four dates between 1748 and 1780 it appears to have been quiescent, can hardly be attributed entirely to chance. Hence it can scarcely be doubted that several outbursts during the two decades following 1785, have passed unnoticed, while we shall, perhaps, not greatly err if we regard the preceding four decades as a period of at least comparative, and possibly total, tranquillity. There is also, as we have seen, some very slight ground for surmising that this tranquillity may have extended back to the early part of the century. Of antecedent ages we know nothing from direct observation unless the suggestion thrown out in connection with Linschoten's map may be taken as one very faint hint.

Tabular abstract.

In conclusion, it may be convenient to add a revised edition of the tabular abstracts given in my memoir on the volcano,[3] incorporating the preceding records, and also the observations that have been made since 1884.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
1595	The Island appears to have been known at this time, but there is no indication of its volcanic nature having been recognised.	......	Maps in Van Linschoten's itinerario.
7th Dec. 1708.	Dormant	......	Captain Gough; log of ship "Stretham."
28th & 29th Oct. 1748	Dormant	......	Captain Cheyne; log of ship "Lapwing."
1758	Dormant?	......	Captain Mills, of ship "Drake." "Memoir of a chart of the Indian Ocean, 1787, p. 37, in Dalrymple's Nautical Memoirs, Vol. I.

[1] *Cf.* Notice of Cheyne's observations, and foot-note mentioning "Le Neptune Oriental" etc.

[2] *Cf.*, however, foot-note in the next paper, on the possible origin of the name 'Barren.'

[3] Mem. G. S. I., Vol. XXI, p. 272 and 275.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
2nd Nov. 1771 .	Dormant	......	Captain Justice, of ship 'Union' M. S. Bengal Public consultations, and Memoir of a chart of the Indian Ocean (op. cit.), p. 36.
13th & 15th Jan. 1780 .	Dormant	......	Captain Taylor, of ship "Ceres," Dalrymple's Nautical Memoirs, Vol. II.
12th May 1787 .	"Column of smoke ascending from the summit" was seen from a distance of 7 leagues. No nearer approach to the Island was made.	......	Lieutenant Colebroke, Asiatic Researches, Vol. IV. p. 397.
24th March, 1789.	"The volcano was in a violent state of eruption, bursting out immense volumes of smoke, and frequently showers of red hot stones. Some were of a size to weigh three or four tons, and had been thrown some hundred yards past the foot of the cone. There were two or three eruptions, while we were close to it; several of the red hot stones rolled down the sides of the cone, and bounded a considerable way beyond us." The newer cone was probably about 800ft. high.	No mention of the spring. Blair was the first who landed on the island, as far as is known.	Capt. Blair, quoted by Colebrooke; *loc. cit.* Letter from Capt. Blair, dated 19th April, 1789. Test's sketch of 23rd March, 1789.
1791 .	"A quantity of very white smoke close to the crater."	......	India Directory, by J. Horsburgh, 3rd edit. (1827), Vol. II, p. 37.
20th and 21st Dec., 1795.	On 20th smoke observed: on 21st, "It was astonishing the repeated columns of black smoke which were sent up."	......	Capt. Hall; log of ship "Worcester."
November, 1803.	"Exploded regularly every 10 minutes, projecting each time a column of black smoke perpendicularly to a great height; and in the night, a fire of considerable size continued to burn on the east side of the crater."	......	Horsburgh; *loc. cit.*
29th—31st Jan., 1804.	29th. Volcano "was burning very fiercely, the eruptions taking place every eight or ten minutes, with a hollow rumbling noise. * * * We passed within a mile of it, and as the winds were trifling we observed the eruptions for three days and nights successively." 31st. Several eruptions of fire during the night. The recent lava streams appear to have been emitted not earlier than this date.	......	Officer of H. M. S. "Caroline"; Phillip's Voyages and Travels, Vol. V. Log of the "Caroline."

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
March, 1832 .	"Large volumes of thin white smoke kept continually issuing" from the summit. The southern lava stream was emitted before this date, as evidenced by the existence of the hot spring. Probably the other recent streams had also been poured forth.	"On approaching to within a hundred yards of the shore, we were suddenly assailed by hot puffs of wind, and on dipping our fingers into the water, were surprised to find it as hot almost as if it had been boiling. The stones on shore, and the rocks exposed by the ebbing of the tide, were smoking and hissing, and the water was bubbling all round them."	Commander of a ship; Journal, Asiatic Society of Bengal. Vol. I, p. 129.
April, 1843 .	From the summit of the cone "a clear and full stream of transparent vapour issued, so transparent that it was not perceptible from the sea."	......	Captain Miller; Calcutta Journal of Natural History, Vol. III, p. 423.
1852 .	Very active. . . .	......	"Bombay Times," July, 1852.
18th Dec., 1857 .	"Some smoke was seen occasionally to issue from the slope of the cone" a little way below the summit. The date of the last eruption is unknown, but the unchanged condition of the crater shows that there was none between December 1857 and April 1891.	Temperature "too high to be borne by the hand, the mercury in the only thermometer in our possession rising immediately to 140°—its limit."	Dr Playfair; Selec. Rec. Govt. of India (Home Department), No. XXV, p. 123. Mem. G. S. I, Vol. XXI, p. 268. Dr. Prain; see below.
Ibid. .	......	"A natural boiling spring."	Dr. Mouat; Researches amongst the Andaman Islanders.
19th March, 1858	"Clouds of hot watery vapour," with a sulphurous smell, issued from cracks near the summit, on the northern and southern edges of the crater. The recent lava streams were (superficially) "cold."	"The water, where escaping from the rock, must have been nearly at the boiling point."	Dr. Liebig; Zeitschrift der Deutsch Geol. Gesellschaft, Vol. X, p. 299. Selec. Rec. Govt. of India, No. XXV. p. 126. Also in Jour. As. Soc. Bengal, Vol. XXIX, p. 1; and in Mouat's Researches.
1862 .	Sulphurous vapours issuing along the edge of the crater.	"Scalding hot" . .	Rev. C. Parish; Proceedings, Roy. Geog. Soc., Vol. VI, p. 217.
19th April 1866	A whitish vapour was evolved from several deep fissures near the summit.	158° to 163° F. . . .	Andaman Committee; Proceedings, As. Soc. Bengal, Oct. 1866, p. 215.
March 1873 .	From the highest point on the northern edge of the crater a thin column of white vapour, and sulphurous fumes were slowly poured forth.	130	Prof. V. Ball; Records G. S. I., Vol. VI, p. 88.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
Feb. 1884 .	Superheated steam, with sulphurous vapour issued rather copiously from the solfatara on the north side of the crater, the column, as it rose into the air, being visible from the landing-place, or even some distance out at sea. Steam, in smaller quantity, issued from some other spots also.	106° to 116° . . .	F. R. Mallet; Mem. G. S. I., Vol. XXI, p. 273, 274.
25th April 1886 .	"From the ship the thin column of steam (from the central cone) could be barely seen at 3 miles distance."	110°	Capt. Carpenter, R. N., H. M. I. M.S. 'Investigator'; Records, G. S. I., Vol. XX, p. 48 Mr. Daley, of Investigator; Ex. Cit.
April 1891 .	Some steam issued from the crater but considerably less than in 1886; it was not visible from the sea, or even from the landing-place. New crusts of sulphur, from ½ to 2½ inches thick, had been formed at the solfataras since February 1884.	102° to 106°. . . .	Dr. Prain; Proceedings, As. Soc., Bengal, May, 1891, p. 84.
1894 .	" The Volcano is apparently entering on a period of renewed activity." This somewhat vague statement does not seem to have been corroborated.	......	Port Blair correspondent of the Allahabad 'Pioneer'; quoted in 'Nature', 7th June 1894, p. 131.

Bibliography *of* Barren Island *and* Narcondam, *from* 1884 *to* 1894; *with some remarks by* F. R. MALLET, F.G.S., *late Superintendent, Geological Survey of India.*

The Bibliography of the Islands up to 1884 may be gathered from Dr. V. Ball's paper in an earlier volume of the records,[1] from my report of 1884, and from the preceding pages. The following papers have appeared during the last ten years, but I am not prepared to say that the list is complete, as there may be other references to the Islands which have escaped my notice.

1. "Volcano of Barren Island in the Bay of Bengal": American Journal of Science, Vol. XXXI (1886), p. 394. A critical notice of my Memoir, by Professor J. D. Dana.[2]

[1] Vol. VI (1873), p. 81. Republished in the Geological Magazine 1879, p. 16.
[2] It is, perhaps, worth mentioning here, that the statement, alluded to by Prof. Dana,

The writer discusses the way in which the upper part of the cone of a volcano is destroyed, and a great crater, like the ancient one of Barren Island, produced. He holds that, during a paroxysmal eruption, the portion of the cone in question is not blown away peacemeal, but that the walls of the crater are undermined by the melted lava, and sink down in consequence into the abyss beneath. "Finally in the catastrophic eruption when the force from the rising vapours and from other conditions becomes greater than the mountain can withstand—a point often abruptly reached—the sides break and one or more fissures let out the liquid lavas. However explosive the action, the solid rock of the summit of the cone, while it may be more or less removed by the forces engaged, instead of being projected over the outer slopes, sinks down into the abyss so made. Thus a volcanic cone under the most formidable of explosive eruptions may lose its head, but if so, it is by swallowing it, or simply by a collapse. The same is the process in quiet Kilauea, the solid lavas of the borders of the fiery region sink because the discharge of the liquid rock makes a void beneath them."

A subsidence of the lava in Kilauea, and concomitant collapse of the crater walls into the fiery lake, which took place last July, was observed by Mr. L. A. Thurston, apparently the first actual eye-witness of such an occurrence. His graphic account[1] is in complete accordance with Professor Dana's view. But Kilauea is a volcano of an unusual type, and widely different from Vesuvius or Barren Island. However large a share engulphment may have in producing great craters in volcanoes of the latter type, that it is the sole agent and that ejection of the material of the crater wall, in a more or less communicated state (produced mechanically, or by fusion), never plays a prominent part in the affair, is an opinion widely at variance with that held by most volcanologists.

2. "On soundings recently taken off Barren Island and Narcondam by Commander A. Carpenter, R.N., H.M.I.M.S., 'Investigator,' the officer in charge of the Marine Survey of India." By F. R. Mallet. Records, Geological Survey of India, Vol. XX of 1887, p. 46.

The results of soundings, taken in May 1886, are given with some remarks thereon. The depths measured within four miles of Barren Island range up to 855 fathoms, aud those within a league of Narcondam up to 652. Sections of the islands are appended, based on Captain Carpenter's soundings and Captain Hobday's maps.

3. "The volcanoes of Barren Island and Narcondam in the Bay of Bengal." By V. Ball, M.A., F.R.S., F.G.S, Geological Magazine, 1888, p. 404.

Mainly a notice of the chief results of the survey by Captain Hobday and myself in 1884, with some remarks thereon. Refers to the eruption of January 1804, seen by an officer of H. M. S. 'Caroline' (*vide* preceding paper.)

4. "The Andamans and Andamanese." By Colonel T. Cadell, V. C., Scottish Geographical Magazine, February 1889, p. 56.

Includes a brief account of Barren Island, written partly from personal observation, partly from previous descriptions.

that the cone "has been entirely built up during the last 1800 years," is not merely in connection with Barren Island, but a quotation from Professor Judds' 'Volcanoes,' in reference to Vesuvius.

[1] American Journal of Science, Vol. XLVIII (1894), p. 338.

5. "On the present condition of Barren Island." By D. Prain, M B., Proceedings, Asiatic Society of Bengal, May, 1891, p. 84.

Gives some of the geological results of a visit in April 1891—An abstract of these is included in the preceding table.

6. "Remarks on the Fauna of Narcondam and Barren Island." By D. Prain, M. B., Proceedings, Asiatic Society of Bengal, April, 1892, p. 109.

The paper is almost entirely geological, but, at the end, contains some remarks on the relation between the geology and biology. The author recognises that the islands are, and always have been, oceanic. "The present physical conditions in Narcondam appear, moreover, to be very ancient; there is no trace of a crater at the top of its peak which rises 2,330 feet above the level of the Andaman Sea, and the whole island is clad with a dense jungle much richer in species than the forest on Barren Island is. But though the present biological features of Barren Island are of a much more modern aspect, it is not necessary to consider that island as really less ancient than Narcondam. The topography of its outer cone, combined with the historical fact of recent activity on the part of the volcano, points to the possibility of some catastrophe similar to that which devastated Krakatau, having once happened in Barren Island, and if this has been the case it would follow that the island must have required, even if previously covered with vegetation, to be stocked *de novo* with vegetable and animal life. Still, granting that the present fauna and flora of Barren Island are of more recent introduction than those of Narcondam, the fact remains that we must look upon every species present, even in the island with the older biological features, as an immigrant one."

The only catastrophic outburst of which evidence still remains, and that, I presume, referred to by Dr. Prain is the one which probably effected the truncation of the ancient cone, and originated the crater now over a mile in diameter. From a biological point of view, as well as from a geological one, therefore, the period at which this change took place is of some interest. It is impossible to form any definite estimate of the time involved, but there is reason to believe that the event occurred at a very remote epoch. The deep gorges which score the external slopes of the volcano, point to long-continued denudation, which shows no apparent signs of having been interfered with by lava flows from the ancient cone. But still more suggestive is the gorge which debouches into the crater S. S. E. from the hot spring, unless, as is conceivable, this ravine, drained into a great east and west "barranco," which may possibly have existed prior to the origination of the present amphitheatre, the ravine must, apparently, have been excavated since the amphitheatre was formed. That is to say, since the event in question, some hundreds of feet of alternating scoriæ and lava beds have been cut through near the mouth of the gorge, where it is deepest. The stream, too, which has done the work, owing to its small size, and the porous nature of the rocks, is under the disadvantage of flowing only in the rainy season, and perhaps not constantly even then.[1]

The time indicated above is so immense, compared to that during which the

[1] The water, for some distance seaward from the breach, appears to have been somewhat reduced in depth, owing, doubtless, to the material swept into the sea from the gorge just mentioned, and from the amphitheatre generally, combined with the submarine portion of the recent lava (cf. sections in Vol. XX, p. 48.)

materials of the present cone may have been piled up,[1] as to suggest that the paroxysmal eruption, supposed to have truncated the ancient cone, was perhaps followed by a long interval of quiescence, before the building up of a newer cone was begun, and several such may have arisen, and been destroyed, before the present one was reared. In comparison with the antiquity of the older cone, the existence of the present one may date from almost yesterday. Or, to put it differently, while the duration of the one must be measured by geological time, it is possible for the other to have originated during an even historically recent period.[2]

Granting that life was extinguished by the catastrophe just alluded to, as suggested by Dr. Prain, the question may be raised whether the present fauna and flora date from that epoch, or from a still later destruction due to some overwhelming shower of ejecta. I am not competent to express any opinion as to the time required to re-stock the island : but looking simply to the probable intensity of the eruptions in comparatively recent times, *i.e.*, since the present cone was commenced. I see no cogent ground for regarding a total destruction of the island life as very probable. There is no reason for assuming that the earlier outbursts from the present cone were on an essentially grander scale than the later ones; and I have shown in the preceding paper that a large fraction, perhaps half the bulk, of the cone[3] has been added by the eruptions that have occurred since 1789. But Test's sketch shows that the exterior slopes of the island were well-wooded at that date, and that the arboreal vegetation was not subsequently destroyed may be inferred from Capt. Miller's describing the outer slopes as well-wooded in 1843, and from the fact that no remains of lifeless forest have ever been noticed.[4] At the same time it can scarcely be doubted that considerable damage has been done to the vegetation, perhaps on many occasions. But such damage would be much more severe in the amphitheatre than on the external declivities.[5]

7. "Note on the occurrence of quartz in an Indian basic volcanic rock." By T. H. Holland, A. R. C. S., Bulletin of the Microscopical Society of Calcutta, Vol. II, No. 6 (1893), p. 3.

The rock in question is from Narcondam, and described by the author as a basaltic andesite, the quartz being regarded as of volcanic, not extraneous origin.

[1] Cf. remarks in preceding paper in connection with Blain's visit, and Mem. G. S. I., Vol. XXI, p. 265.

[2] If we may regard the relative bulks of the two cones as giving some sort of rude illustration of the orders of magnitude of the two periods involved, we find that while the newer cone is about 1,000 ft. in altitude, the ancient one was probably once 8,000 or 10,000 from the sea floor (Vol. XX, p. 46), requiring, perhaps, 500 or 1,000 times as much material.

[3] That is to say, the cone above sea-level, and not including the mass of material which was doubtless required to fill up the ancient crater to that level.

[4] *Cf.* Memoirs, G. S. I.. Vol. XXI, p. 262.

[5] If the view expressed in the above paragraph be correct, the island can scarcely have acquired its name from any striking barrenness of the now well-wooded outer slopes. Although I believe the name was most probably given on account of the barrenness of the newer cone, and parts of the amphitheatre, it has occurred to me, as a possibility, that, as the word Narcondam is of eastern origin, so 'Barren' may be an English corruption of some name applied by the Asiatic sailors of the region in question. The Hindustani *barna*, to burn, *barat*, burning, and *barhm jon*, a volcano, for instance, are somewhat suggestive. Some reference to the island may yet be discovered which will elucidate the origin of the name.

8. "On the Volcanoes and Hot Springs of India, and the Folklore connected therewith." By V. Ball, C.B., LL.D., F.R.S. Proceedings of the Royal Irish Academy, 1893, p. 151.

Refers, *inter alia*, to Barren Island and Narcondam.

9. "The Volcanoes of Barren Island and Narcondam in the Bay of Bengal." By V. Ball, C.B., LL.D., F.R.S., Geological Magazine, 1893, p. 289.

Descriptive of a model of Barren Island, constructed under the author's superintendence, and based chiefly on the data supplied by Capt. Hobday's map. A bird's eye photographic view of the model is given, in which the sea surrounding the island is also represented. The paper concludes with some notes on the fauna of the islands.

10. "On the flora of Narcondam and Barren Island." By D. Prain, M.B. Journal of the Asiatic Society of Bengal, Vol. LXII (1893), Part II, p. 39.

A memoir divided into three sections. The first, or 'Introductory sketch,' commences with some remarks on the hydrography of the Bay of Bengal (in its wider sense), for the portion of which, enclosed by the Andaman and Nicobar Islands, Alcock's name of 'Andaman Sea' is adopted. Carpenter's soundings round the two volcanoes[1] are reproduced, with some additions: the configuration of each island is described, and a summary account of its vegetation given,[2] the soundings round flat rock[3] are added, which the author very plausibly suggests is probably of Volcanic origin. The bathymetry of the Andaman Sea is reviewed, and the question of the northern prolongation of the line of volcanoes through the Sunda Islands, Java, Sumatra, Barren Island, and Narcondam is discussed. This the author, following Dr. W. T. Blanford, considers, is to be found in the extinct volcano of Puppa, in Upper Burma, and that near Momein, in Yunnan, which, as he remarks, lie in common with the volcanoes of the Andaman Sea, to the eastward of, and rudely parallel to, the line of elevation represented by the Andaman Islands and the Arrakan Yoma. Evidence is likewise adduced to show that Flat Rock, Barren Island, and Narcondam are not isolated peaks rising from the sea-floor, but are situated along a submarine ridge.

The second portion of the Memoir is an annotated list of the plants found on the islands, and the third discusses the "Nature and origin of the Flora." 174 species were discovered, of which 138 occur on Narcondam and 88 on Barren Island, only 52 being common to both volcanoes. In conclusion the probable mode of introduction—by the sea, by winds, by birds, or by man—is taken into consideration. Appended are two bathymetric charts of the area surrounding the Andaman Islands.

An abstract of the Memoir was given in the Geographical Journal for March 1894, p 234.

[1] Records, G S. I., Vol XX, p. 46.

[2] With reference to the foot-notes in Dr. Prain's Memoir, at pages 45, 49, 56, and 77, in connection with the occurrence of cocoanut trees on the islands, I may say that Mr. Wight, 2nd Officer of the I. M. S. 'Celerity,' and I, landed at Coco Bay in Narcondam, and saw the trees in question there. We found a large log of teak, with hewn ends, on the beach, which may be presumed to have drifted from the mouth of some Burman river; a suggestive fact with reference to the origin of the cocoanuts from which the trees have sprung, and of other species of plants also. We, and several other members of the expedition, also landed at Anchorage Bay, in Barren Island, the surf at the time being comparatively slight.

[3] The rock east of Duncan's passage, alluded to more than once in the preceding paper.

ERRATA.

RECORDS, GEOLOGICAL SURVEY OF INDIA, Vol. XXVIII, part 1, pages 22—38.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA,

Part 2.] 1895. May

On the importance of the Cretaceous Rocks *of* Southern India *in estimating the geographical conditions during* later cretaceous times[1]; by FRANZ KOSSMAT.

OUR knowledge of the extra-European cretaceous rocks, more especially those of the Indo-Pacific area, has, in the course of the last few years, made enormous strides, and we shall soon be in a position to form a clear conception of the zoological and geographical conditions of that period. The cretaceous rocks of Southern India, which formerly, in spite of their great wealth of fossils, were accorded little more than the importance of a mere local development, are now coming more and more to the front, since the elements of their fauna have been discovered in a great series of cretaceous beds, while Neumayr[2] in his "Erdgeschichte" selects them as the type of the Pacific cretaceous area.

Nevertheless, since the completion of Stoliczka's[3] great monograph on the cretaceous Fauna of Southern India, neither our palæontological nor yet our stratigraphical knowledge of this important area has been appreciably extended, although of late years, the urgent necessity of revision—more especially as regards the cephalopods—has repeatedly asserted itself. Opportunity for such research is now offered by the new collection made in the Trichinopoly district during the winter of 1892-93, and part of the summer of 1893, by Dr. H. Warth, of the Geological Survey of India, and sent by him to Prof. Waagen, at Vienna, who has entrusted this interesting and important task to me. Our material for this research is now practically complete, owing to the addition to it of a large number of Stoliczka's original specimens, which have been sent to us for re-examination by Dr. King, the late Director of the Geological Survey of India.

The results, as regards palæontology, will shortly be published in the "Beiträge zur Palæontologie und Geologie" (edited by Professor W. Waagen), to which I hope to add a detailed account of those relating to the stratigraphical and zoological conditions. I will, therefore, at present restrict myself to a few general conclusions.

Owing to their peculiarly favourable position between the chalk of the Altantic and that of the Pacific area, the cretaceous rocks of Southern India are eminently adapted to serve as a starting-point for observations on the zoo-geographica condi-

1 Translation of paper published in the Jahrb k.k. Geol. Reichsanst 1894, Vol. 44, pt. 3.
2 M. Neumayr: Erdgeschichte, Vol. II. p. 390.
3 F. Stoliczka: Cretaceous Fauna of Southern India (Palæontologia Indic 4 Vol. Calcutta, 1865-1873.

tions of later cretaceous times. Their fauna combines in itself the elements both of the eastern and of the western hemisphere, and thus serves as a connecting link between the two.

On the subject of the rich endemic fauna of the Indian cretaceous rocks, and the interesting survivors from older beds, which play such an important part in them, it would not be advisable to speak here.

The cretaceous rocks of Southern India fall into two main divisions: *viz.*, the larger Trichinopoly district, and the smaller and more northerly Pondicherry area—both south of Madras, and part of the so-called Coromandel coast, on the eastern side of the Indian peninsula.

During the geological survey of the Trichinopoly district,[1] it was found that a large number of the fossils collected bore a striking resemblance to forms occurring in Central Europe, and Stoliczka, in his work on the fauna, was thereby induced to unite no small proportion of the species — among the cephalopods no less than 25 per cent. — directly with European forms. Although on re-examination several of these identifications have proved erroneous, the affinities to the European fauna are still remarkable, more especially if we have regard not only to identical, but also to closely allied, forms. Extremely important also, and of great service in estimating the age of the beds of this system, is the fact that the succession of individual forms is to a great extent identical with that seen in Europe—a fact not fully appreciated by earlier observers.[2]

At the base of the Utatur group, just as in Europe at the base of the cenomanian, occur *Schlœnbachia inflata* Sow. and several allied species, *Hamites armatus* Sow, *Turrilites bergeri* Brongn., etc. In higher beds we meet with an extraordinarily rich *Acanthoceras* fauna, of the type of *Ac. rhotomagense* Brong., while a large number of other well-marked forms, such as *Turrilites costatus* Brong., and *Alectryonia carinata* Lam. identify this horizon as the equivalent of the middle and upper cenomanian. The uppermost beds of the *Utatur group* I consider to be of lower turonian age, the typical *Acanthoceras* element having disappeared, and being replaced by Ammonites related to the European *Mammites nodosoides* (*Amm. conciliatus* Stol.) and to the well-marked *Inoceramus labiatus* Schloth. of the turonian.

The Trichinopoly group abounds in excellent specimens of Gastropods and Bivalves, which are, however, of little assistance in the determination of the horizons. Ammonites of central-European character are somewhat scarce, some very well-marked forms, however, being present. In the lower Trichinopoly group, *Am. serrato-carinatus* Stol. (allied to *Am. bravaisianus* Orb.) represents the turonian form *Prionocyclus*, while with it are associated typical forms of the important group of *Pachydiscus peramplus* Mant. The higher beds of the Trichinopoly group are marked as lower senonian by their gastropods and bivalves, but more especially by a *Schlœnbachia* of the *tricarinata* type and a *Placenticeras* extending from the group of *P. placenta* Mort.

In the Ariyalur group, the most important cephalopods are the upper senonian

[1] H. F. Blanford: On the cretaceous and other Rocks of the South Arcot and Trichinopoly Districts; Madras (Mem. Geol. Surv. India. Vol. IV, pt. I.) Calcutta 1865.

[2] F. Stoliczka merely remarks that the Utatur group (the oldest of the three lower divisions) may be broadly compared to the cenomanian, the Trichinopoly group to the turonian and the Ariyalur to the senonian. (loc. cit. vol. IV, p. II.)

Pachydiscus and *Baculites*. In the highest division at Ninnyur, which ought preferably to be separated from the rest of the group,[1] the ammonites have disappeared while *Nautilus danicus* Schloth., and numerous gastropods and bivalves of more recent type, mark these beds as the boundary between the cretaceous and tertiary rocks.

To the Ariyalur group also I refer the great fauna of Pondicherry, which was considered by E. Forbes[2] to be of lower-cretaceous age. Stoliczka, following Blanford,[3] endeavoured to distinguish, by their fauna, two horizons, the older of which, the Valudayur group, he characterised as cenomanian (Utatur group), while the other he considered to be of the same age as the Ariyalur group. In the course of time, however, it became evident that many of the fossils of the Valudayur group occurred in the Ariyalur beds of the Trichinopoly district, and Stoliczka was consequently much puzzled as to the true age of the Valudayur group, nor did he ever arrive at a solution of the difficulty.

During the past summer, I had the opportunity of studying Forbes' original specimens of the Pondicherry fauna, and came to the conclusion that all his specimens of ammonites from that district were derived from the hard brownish or bluish "Lumachelle" (fire-marble) and plainly from one single horizon. This may be proved by the similarity in the association of the forms and the mutual resemblance of the specimens. This horizon is Blanford's Valudayur group. In the abundant ammonite fauna of this series, we find not a single representative of the typical cenomanian fauna, so familiar in the Utatur group; we find no *Schlœnbachia*, no *Acanthoceras*, no *Turrilites* while on the other hand we have the typical senonian *Pachydiscus*, a true *Sphenodiscus* (*A. siva* Forb.) very closely allied to the senonian *S. lenticularis*, as well as innumerable *Baculites vagina* and other ammonites. That the Valudayur group is in reality a development of the Ariyalur group, differing from it somewhat in lithological characters, may be proved by the following facts: (1) many of its most important fossils, such as *Pachydiscus egertonianus*, *Am.* (*n.g.*) *brahma*, *Baculites vagina*, etc., occur also in the Ariyalur group, whereas (2) the small number of species, which it contains in common with the Utatur group, has, on re-examination, been reduced to a few doubtful cases; and lastly, the gastropods and bivalves associated with the ammonites have considerable affinities to those of the Ariyalur, but none to those of the Utatur group.[4] Even in the Trichinopoly district the Ariyalur group overlaps the older cretaceous beds, which, further north, disappear beneath it, both in the S. Arcot district and also, as has now been proved, in the Pondicherry area. During the winter of 1893-1894, Dr. H. Warth undertook a revision of the survey of the Pondicherry district, and the fossils collected by him are now in course of transmission to Vienna, and will, it is hoped, throw much light on the question of the age of these rocks.

Lithologically, the upper beds exposed in Pondicherry (white sands and conglomerates) which were included by Blanford and Stoliczka in the Ariyalur group, differ from the Valudayur beds; nor could I find a single ammonite in

[1] This suggestion is also made by H. Leveillé in his small work: Geologie de l' Inde Francaise (Bull. Soc. Geol. France, 1890. t. XVIII) p. 144 ff.

[2] E. Forbes: Cretaceous fossils of Southern India (Transaction of the Geol. Soc. of London, II Ser., Vol. VII, London 1845-1856, Art. V. p. 165).

[3] H. F. Blanford. l. c., p. 151 ff.

[4] A. d'Orbigny considers the Pondicherry beds to be of senonian age. (Prodrôme de Paleontologie II., Paris, 1850, pp. 213, 215, 216, etc.)

Forbes' collection, while, on the other hand, Blanford discovered a *Nautilus danicus*, of the species occurring in the Ninnyur beds of the Trichinopoly district.

The question as to the connection between the cretaceous sea of southern India and that of Europe has already been repeatedly discussed. The careful examination of the Narbada cretaceous fauna, in which, after a cursory determination, Bose [1] believed that he had discovered Trichinopoly species, has proved its entire dissimilarity to that of the Trichinopoly-Pondicherry districts, while its echinodermata [2] have been shown to bear a striking resemblance to those of the cretaceous beds of Syria, North Africa, and Southern France, the typical members of the Mediterranean province. The theory of the former existence of land between the South of India and the North of Africa has thus gained additional evidence in its support. The upper cretaceous rocks of the northern and western mountain ranges of India have no connexion whatsoever with the Trichinopoly-Pondicherry series, while the Hippurite-limestone of Persia, Afghanistan and Baluchistan, [3] and the Glauconia-beds of Namcho Lake [4] in Tibet belong to the Mediterranean province. We must therefore seek elsewhere for a connection between the cretaceous seas of Central Europe and of Southern India.

The only remaining means of communication is therefore southwards through Africa,[5] and here we find the famous cretaceous beds of Natal, of which detailed accounts have been published, first by Baily [6] and subsequently by Griesbach.[7] The latter believed that he recognised in Natal all the three lower divisions of the cretaceous rocks of southern India, and he distinguished in the rocks of that country five separate horizons, lying unconformably on the Karoo beds:—

(*f.*) Limestone with *Amm. gardeni* Baily *Sp.*—Ariyalur group. (Senonian.)	
(*e.*) Soft sandstone with numerous bivalves and gastropods. (*Fasciolaria rigida* Baily, *Chemnitsia undosa* Forbes, *Protocardium hillanum* Sow., *etc.*)	—Trichinopoly group (Turonian.)
(*d.*) Sandstone with *Amm. umbolazi* Baily, *soutoni* Baily, *stangeri* Baily, *rembda* Forbes, *kayei* Forb., *Anisoceras rugatum* Forb. (*c.*) Soft brown sandstone (resembling *e*) with *Trigonia shepstonei* Griesbach. (*b.*) Calcareous sandstone with *Teredo*.	—Utatur group. (Cenomanian.)
(Base of the exposure.)	

During the past year, I examined Baily's original specimens in the collection of the Geological Society in London, and had also, through the courtesy of Mr.

[1] P. N. Bose, Mem. Geol. Surv., India, XXI, p. 43.

[2] P. M. Duncan. On the Echinoidea of the cretaceous strata of the Lower Narbada Region. (Quart. Journ. Geol. Soc., London, 1887, XLIII, p. 154.)

[3] *See* Mem. Geol. Surv. of India, Vol. XVIII, p. 34, Vol. XX, p. 140, 143 (Afghanistan), Vol. V., p. 116 (N.-W. Himalaya), etc.

[4] O. Feistmantel: On the occurrence of the cretaceous genus Omphalia, near Namcho Lake, Tibet (Records Geol. Surv., India, 1877, X, p. 21. ff).

[5] In Madagascar also, Newton discovered upper cretaceous species, among which were Ostreæ (O. vesicularis, O. pectinata, O. ungulata), all equally characteristic of the European senonian and of the Ariyalur group. (Quart. Jour. Geol. Soc., London, 1889, XLV, p. 333.)

[6] W. H. Baily: Description of some cretaceous fossils from Southern Africa (Quart. Jour. Geol. Soc., London, 1855, XI, p. 454 ff.)

[7] C. L. Griesbach: Geology of Natal. (Quart. Jour. Geol. Soc., London, 1871, XXVII, p. 60 ff.

G. C. Crick, the opportunity of seeing, at the Natural History Museum, a new collection of Natal fossils, far surpassing all collections hitherto made. From these it was evident that certain modifications of the views hitherto held were necessary. It was clear to me from Baily's specimens, that *Schlœnbachia stangeri* and *soutoni* do not belong to the lower cenomanian group of *Schlœnbachia inflata* Sow., as was originally supposed, but to the newer, lower senonian series of *Schlœnbachia tricarinata* Orb. In young forms *Schlœnbachia stangeri* Baily has three keels and only two sets of tubercles, one umbilical, the other external. Those of the latter series show on the ridge a faint linear extension (as in *Schl. tricarinata* type) which becomes more marked as the shell increases in age, and finally develops into a tubercle. Simultaneously, the earlier external series of tubercles extend down the side, while between them and the umbilical series yet another (a fourth) series appears. Finally, the two outer keels break up into a series of elongated tubercles, and even the median keel becomes somewhat varicose; the species then bears a strong resemblance to *Schlœnbachia texana* Rom. from the lower senonian of North America and Central Europe, while *Schlœnbachia soutoni* is a further development of the same type. Both these forms indicate a later age than that hitherto assumed for the beds in which they occur. That this view is correct, appears to me to be distinctly evident from the fact that in the new collection of Natal fossils, a beautiful and well preserved cast of a large fragment of *Schlœnb. stangeri* is associated in the same hand-specimen with *Puzosia gardeni* Baily: both of these species must therefore come from the same horizon. The forms *Puzosia rembda* Forbes, *Lytoceras kayei* Forb., *Anisoceras rugatum* Forb. are derived from the Valudayur group (senonian) of the Pondicherry district, while *Amm. umbolazi* Baily belongs to the somewhat involute *Schlœnbachia* (*Prionocyclus*) group of the lower senonian. (Next to these we have *Am. paon* Redtenbacher and *Am. haberfellneri* Hauer.)[1]

Baculites sulcatus Baily, which evidently did not come under Griesbach's observation, is also a senonian form allied to *Baculites teres* Forb. (*Baculites teres* Stol. from the Utatur group is entirely different.)

I attribute very great importance to the fact that, among the new material already mentioned is a very large specimen of *Amm.* (*n. g.*) *indra*, a characteristic and common form in the Valudayur group. I may also state here that the same species occurs in Vancouver, where it is associated with *Pachydiscus otacodensis* Stol. (an Ariyalur form). A complete account of the interesting facts connected with the investigation of the cretaceous fauna of South Africa will shortly be published by Mr. G. C. Crick.

The above observations are sufficient to justify the assertion that among the cephalopod fauna of Natal, so far as it is at present known, not a single species occurs indicative of a horizon earlier than lower senonian.

The horizon (*e*) has already been correctly identified by Griesbach as the palæontological equivalent of the Trichinopoli group. Almost all species common to both countries occur in India in the Upper Trichinopoli group. Since, therefore, of the known cephalopods of Natal, a large proportion belong to Ariyalur (Valudayur) species (*Puzosia gardeni, rembda, Lytoc. kayei* Forb., *Anisoceras rugatum*

[1] A. Redtenbacher: Die Cephalopodenfauna der Gosauschichten in den nordöstlichen Alpen. (Abhandl. der k. k. Geol. Reichsanst. Wien 1873. Bd. V., p. 131, 133.)

Forb., *Am. indra* Forb.), if the same connection also holds good in the Upper Trichinopoli group—as for example, that of *Schlœnbachia stangeri* and *soutoni* with *Schl. tricarinata* Stol. (non Orb.) of the *uppermost* Trichinopoli beds—then it appears that these latter forms extend beyond zone (*e*) and must be sought for in (*f*) with *Puzosia gardeni*.

There being no fossils on which to base an opinion, none can be offered as to Griesbach's horizons *b* and *c*.[1]

As in India, so also in Natal, which is so closely connected with that country, the cretaceous rocks bear a striking resemblance to those of the Atlantic area, both in their *Schlœnbachia*, which are allied to *Schlœnb, tricarinata* and *texana*, in their *Puzosia gardeni* (connected with *P. pseudo-gardeni* Schlüter), and also in several bivalves (*Protocardium hillanum* Sow., *Janira quinquecostata* Sow.) etc. It is, however, a remarkable fact that just as in the Trichinopoli and Ariyalur groups, so also in the fauna of Natal, the number of central European (or rather Atlantic) species is relatively much smaller than in the Utatur group.

A connecting link between the cenomanian of India and that of Europe is found in the well-known cretaceous rocks on the west coast of Africa, *viz*., Angola[2] and the Elobi Islands.[3]

The small *Schlœnbachia* fauna of the latter comprises, in addition to *Schl. inflata* (type), another specially Indian variety of this series, and in the same horizon in Angola occurs a *Stoliczkaia dispar* d'Orb., which corresponds exactly with an Indian form distinguished by Neumayr[4] as *Stol. clavigera*. At this stage the bivalve and gastropod fauna of the upper cretaceous beds of Angola begin to show signs of the influence of the Mediterranean province.

Here, however, the connection ceases between the cretaceous rocks of Southern India and those of Europe. Further north, in Morocco and Algiers, we find ourselves in the Mediterranean cretaceous area, the eastern extension of which we found in Narbada, Baluchistan, etc. In the western portion of this area may be seen unmistakeable signs of the connection between the cretaceous faunas of India and of Central Europe (*e.g.*, the fauna of the cretaceous rocks of the south of France, of Algeria, and also the Gosau beds); these, however, become less numerous as we approach the centre of the Mediterranean area. Blanckenhorn[5] figures an *Acanthoceras harpax* Stol. from Syria; I have examined the original specimen, which is in the possession of the Geological Institute of the University of Vienna, and find that, although closely allied to the Utatur form, it is not identical. His

[1] The adoption of a separate lower cephalopod zone (*d*) by Griesbach, is probably due to the fact that the section examined was the face of a cliff undermined by water (Izinhluzabalungu caves) and consequently masses from the higher beds had rolled down, and might be mistaken for independent outcrops. Baily, however, distinctly states that his *Am. Soutoni* was derived from a hard bed "high up the cliff." *l. c.*, p. 455.

[2] P. Choffat and P. de Loriol: Matériaux pour l'étude Stratigraphique et paléontologique de la province d'Angola. Mém. Soc. de physique et d'histoire naturelle de Genéve, Vol. XXX, I Partie, No. 2 1888.

[3] L. Szainocha: Zur Kenntniss der mittelcretäcischen Cephalopodenfauna der Inseln Elobi. (Denkschriften d. Akad. d. Wiss. Wien., 1885.)

[4] M. Neumayr: Ueber Ammoniten der Kreide, etc. (Zeitschrift d. deutsch. Geol. Ges. Berlin, 1875, p. 933.

[5] M. Blanckenhorn: Beiträge zur Geologie Syriens, Cassel, 1890, pl. X, fig. 3., pl. XI.

Schlœnbachia cf. *blanfordiana* (Ariyalur type)[1] is too badly preserved to justify any expression of opinion. The fact that the species with which we are concerned disappear in the eastern portion of the Mediterranean area proves that they found their way from the Atlantic, and to a certain extent, from Central Europe, into an otherwise isolated basin.

The cretaceous area of Southern India was connected with that of Central Europe west of the Mediterranean area.

The eastern boundary of the present Atlantic Ocean was already open in later cretaceous times, and a free interchange of fauna between Europe and the south of India was possible by way of Natal and the west coast of Africa.

Nor are there wanting links in the fauna to connect the eastern with the western side of the Atlantic Ocean, as also with Central Europe on the one side and Southern India on the other. For this purpose, great importance attaches to the cretaceous rocks of the Brazilian coast, with which, owing to the efforts of Charles A. White we have for some years been familiar.[2]

White describes the fauna of two separate cretaceous areas in Brazil; that of Sergipe, and the more northerly area of Pernambuco. He comes to no definite conclusion as to the age of these beds, merely assigning them generally to upper cretaceous times, and stating that they are more or less contemporary. Unfortunately, there is at present no detailed account of the stratigraphical conditions, Branner's observations[3] merely indicating several salient features. The area of Lastro, near Maroim, is very rich in important fossils, more especially cephalopods. The ammonites belong mainly to the genus *Schlœnbachia;* in fact, they all appear to be varieties of *Schl. inflata*, while many show affinities to forms found at Angola and figured by P. Choffat. From the same locality, White also describes a *Pusosia*, of which he identifies one as *A. planulatus*. From his figure, it appears not improbable that it may in reality be identical with Sowerby's cenomanian species. In the overlying beds, *viz*., the sandstones of Arœira and the limestones of Garajau a *Pusosia* was found, which was identified by White as *Pusosia hopkinsi* Forb., and which is almost indistinguishable from *Pusosia welwitschi* Choffat, from the Schlœnbachia horizon of Angola. The occurrence of *Aucella brasiliensis* White in the cenomanian limestones of Garajau is also very interesting, and forcibly recalls the appearance in India of an *Aucella*, *viz*., *Aucella parva* Stol. in the beds of the same age. From another locality, connected with Lastro by an Echinoid (*Echinobrissus freitasi* White), a very interesting ammonite had already been described by Hyatt under the name of *Buchiceras Harttii*, and was subsequently figured by White. This figure leaves no doubt that we are dealing with an *Olcostephanus*, in fact one of the peculiarly Indian type of *Am. rudra* Stol. (Neumayr's Stoliczkaia), while the form *Am. pedroanus* White, which is associated with it in Brazil, bears a striking resemblance to *Acanthoceras footeanum* Stol. of the Utatur group. From a calcareous sandstone assigned by Branner to the Lastro horizon, but by White to the succeeding zone—which corresponds better with the palæontological relations—an *Am. folleatus* and an *Am. offarcinatus*

[1] M. Blanckenhorn: *l. c.* pl. xii, Fig. 1, p. 134.

[2] Ch. A. White: Contributions to the Palæontology of Brazil. (Archiv. do Museu Nacion, Janeiro. vol. vii, 1888.)

[3] M. Branner: The Cretaceous and Tertiary Geology of the Sergipe-Alagoas basin of Brazil. (Transact. of the Americ. Philos. Soc. Philadelphia, 1889, vol. xvi, p. 429 ff.)

were figured; both belong to the genus *Acanthoceras*, the first being a member of the group of *Ac. cenomanense*, while the second is a variety of *Ac. mantelli*. We thus see that the *Acanthoceras* horizon, which plays such an important part in India and Europe, is represented also in Brazil. From the above facts, we may conclude that the extensive fauna of the neighbourhood of Maroim is of cenomanian age, and consequently the overlap in Brazil corresponds to that in Southern India, West Africa and Europe. The limestone of Sapucahy, the most recent member of the Sergipe cretaceous beds, is almost entirely devoid of fossils.

Of a very different character are the cretaceous beds of Pernambuco, which White, on the strength of a few identical species, assigned to the same horizon as those of Sergipe. Ammonites, however, have entirely disappeared, and are replaced by a much more recent type of gastropod. A very important fact concerning these fossils is the occurrence of a form nearly allied to the large and beautiful species *Cerithium pedroanum* White of these beds, in my new specimens from the Ninnyur beds, where it is associated with *Nautilus danicus*. The disappearance of ammonites in the Pernambuco beds is therefore of considerable importance, and clearly tends to show that as in India, at Ninnyur, so also in this area, similar passage-beds exist between the cretaceous and tertiary beds.

There appears to be no connexion between the cretaceous fauna of India and that of the Antilles, to which I shall presently have occasion to refer.

The cretaceous beds of Texas have several points in common with those of India, many more, however, with those of Central Europe; and the same holds good for the other cretaceous areas of North America, so far as they belong to the Atlantic basin, as well as for the band of cretaceous rocks running along the east coast of the United States, and for the great arm of the sea, which at that period included the Mississippi area and the Rocky Mountains.

Since the publication of Rōmer's work on Texas[1] our views on the subject of the cretaceous rocks of that country have undergone considerable alterations, and his "Cretaceous beds of the highlands" which he assigned to the upper turonian Hippurite series, have now proved to be Rudistes beds of lower cretaceous age.[2] Marine representatives of cenomanian species have quite latterly been discovered in Texas (in the *Cross Timber beds*), but the fauna is very meagre. In the lowest, Colorado group, of Utah has been discovered *Am. swallowi*. Shum,[3] (Hyatt's *Buchiceras*) which is closely allied to *Acanthoceras vicinale* Stol. of the Indian beds. In other respects, the ammonite fauna of the *Colorado group* shows many affinities with that of the turonian of Europe, while the Atlantic section of the ammonite fauna of the turonian of

[1] F. Rōmer: Kreidebildungen von Texas, Bonn, 1852.

[2] See J. Marcou: American Geological classification and Nomenclature. R. Hill: The Texas secton of the American Cretaceous. (Amer. Journ. Science. 3. Ser. XXXIV. No. 202. 1887. p. 287 ff.) etc.

Great uncertainty prevails, however, as regards the geology of that neighbourhood, and several species, which are undoubtedly upper cretaceous, are cited as being derived from the lower cretaceous Comanche series. See R. Hill: The Cross Timbers in Northern Texas. (Am. Journ. Science. 1887, 3 Ser. vol. XXXIII., No. 196.), where on p. 299 we find *Am. Swallowi, Am texanus, Ananchytes ovatus, Ostrea carinata*, and other species from different horizons of the upper cretaceous beds, included in the Comanche Series. That the lower cretaceous system is well represented in Texas and Mexico, is absolutely certain.

[3] F. W. Stanton: The Colorado formation and its invertebrate Fauna (Bull. U. S. Geol. Surv. No. 106, Washington (1893, p. 168.)

India is too poorly represented to be worthy of special mention. On the other hand, we find among the gastropod fauna, more especially among that of the upper horizons of the Colorado group, many striking resemblances to the Trichinopoli group; thus *Cyrodes conradi* Meek and *Rostellites* (*Fulguraria*) *dalli* Stanton are almost indistinguishable from *Gyrodes pansus* Stol., and *Fulguraria elongata* Stol. (non d'*Orb.*) etc. Such resemblances, however, are not wanting in Europe also. *Placenticeras guadaloupae* Römer from the Austin limestone of Texas [1] and even in a greater degree *Placenticeras placenta* Mort., var. *intercalare* Meek[2] of the Montana group of the Missouri basin and the upper cretaceous of New Jersey, bear a remarkable resemblance to the Indian *Placenticeras tamulicum*, which was in fact identified by Stoliczka with the former of the above-named species. Equally closely allied are *Sphenodiscus lenticularis* Mort. and *Sph. siva* Forb.

On the whole, however, the links between the cretaceous beds of the Atlantic portion of North America and those of India are very few; the then-existing distribution of land and sea imposing considerable barriers in the way of any great dispersion of species. Nevertheless, a considerable interchange of forms took place between Brazil and North America on the one side, and Europe, West Africa and Southern India, on the other. Southern India, however, plays a more subordinate rôle, and is only important, in this connection, in so far as it communicated with Central Europe and consequently, indirectly, with these areas. Only in the Brazilian fauna does the special Indian element appear to be of more consequence.

There are certain well-marked types of ammonites which were of exceptional importance in the Atlantic Ocean in cretaceous times, and which are essentially characteristic of that area. They are chiefly represented, in the cenomanian, by *Schlœnbachia* of the group of *Schl. inflata* Sow., with species of *Acanthoceras* and *Turrilites*; in the turonian, by forms of *Prionocyclus* (*Schlœnbachia* in which the keel has become varicose), and frequently *Pachydiscus* of the type *P. peramplus* Mant. In the senonian, *Placenticeras* (of the group of *P. placenta* Mort.), *Baculites*, *Scaphites*, and *Pachydiscus* are very important, while in the lower horizons, the *Schlœnbachia* are largely represented both by the peculiar *tricarinata* group as well as by *Prionocyclus* forms. If therefore we take into consideration all the invertebrata, we can no longer speak generally of an "Atlantic" zoological area, but must picture to ourselves conditions similar to those existing at the present day, that is to say, extremely confined zoo-geographical areas, which, however, contained certain species of very wide horizontal distribution.

Although taking but a subordinate part in the Atlantic area, the cretaceous rocks of India are of very much greater importance in the second great marine province, *viz.*, the Pacific area. Here, owing to the abundance of species, their fauna is of great service, and on it practically depends the possibility of a more accurate description of the stratigraphical conditions of the cretaceous rocks of this area.

If we endeavour to trace the cretaceous fauna throughout this area, we find, in

[1] F. Römer: l. c. pl. II. fig. 1. a, c, p. 32.

[2] F. B. Meek: Report on the Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri cy. (Report U. S. Geol. Surv. of the Territories, IX. Washington 1876, p. 68 ff., pl. 23.)

See also R. P. Whitfield: Gastropoda and Cephalopoda of the Raritan clays and Greensand marls of New Jersey (Monogr. U. S. Geol. Surv. XVIII., Washington, 1892). pl. XL., fig. 255.

the plateau of Assam,[1] beds which are closely allied by their fauna to those of the Trichinopoli district, the fossils indicating, according to Stoliczka, the presence of strata representing both the Utatur and the Ariyalur groups.

The characteristic fossil of the cenomanian beds of Europe, West Africa, and Southern India, *viz.*, *Schlœnbachia inflata* Sow., was found in the flysch-like sandstones of the Sandoway district of the peninsula of Further India.[2]

In Borneo, upper cretaceous beds occur which are characterised by an abundance of Nerineæ, and yield several species of fossils found in Southern India, amongst which are characteristic Ariyalur forms, such as *Nautilus trithinopolitensis* Blanf. Martin assigned the cretaceous rocks of Borneo to his Eastern Asiatic Province, extending from Japan, through Southern India, to Natal.[3]

In Australia,[4] the cretaceous rocks are exposed over a large area, and have from time to time yielded a considerable number of cephalopoda, including several typical lower cretaceous forms, such as *Crioceras*, etc., and consequently the beds in which they occur, the so-called "Rolling Down Formation," have been assigned to that age. From other localities, however, fossils have been obtained (*e.g.*, a *Schlœnbachia* of the group of *Schl. inflata*, and several Puzosia) which recall the cenomanian forms of India, and it is quite possible that an Indian fauna may also be discovered in Australia. The supposed upper cretaceous beds of that country are very poor in fossils.

So far as the cretaceous fauna of Eastern Asia is known, as for example at Jesso[5] and Sachalin,[6] it is of a well-marked Indian type. A comprehensive work by Jimbo on the cretaceous rocks of Jesso[7] appeared a few months ago, and considerably adds to our list of Indian types of ammonites. An especially important part is played by *Lytoceras* of the *Lytoceras Sacya* group which is also represented in India by a great variety of forms; we may also mention *Phylloceras*, *Pachydiscus*, etc., while *Acanthoceras*, of the *rhotomagense* type, is no longer unknown in the Pacific area. A large number of allied, as well as several identical species connect the cretaceous rocks of Japan and Sachalin to the Utatur group; thus we find *Lytoceras sacya* Forb., *Phylloceras velledæ* Mich., and *Acanthoceras rhotomagense* var. *asiaticum* Jimbo, also in the Utatur group. We can also trace a connection with the Trichinopoli group, for a form allied to *Pachydiscus peramplus* has been found at Jesso, while large and numerous specimens of a similar form had already been discovered at Sachalin. Very large also is the number of Japanese species of *Pachydiscus* which are closely allied to, or rather identical with Ariyalur forms.

[1] H. B. Medlicott: Geological Sketch of the Shillong Plateau in N. E. Bengal. (Mem. Geol. Surv. India. VII. Calcutta. 1871. p. 181. ff.).

[2] W. Theobald. Records Geol. Sur., India, V, Calcutta, 1872, p. 82.

[3] K. Martin. Die Kreideformation von Martapoera (Borneo). Sammlungen des Geol. Reichsmuseums in Leiden. Ser. I, Vol. IV, 1889, Heft 5, 6, p. 142.

[4] R. L. Jack and A. Etheridge. The Geology and Palæontology of Queensland and New Guinea. London 1892, p. 390 ff.

[5] M. Jokoyama. Versteinerungen aus der Japanischen Kreide. (Palæontographica, XXXVI Cassel 1889-90, p. 159 ff.

[6] F. Schmidt. Die Petrefacten der Kreideformation von der Insel Sachalin (Mem. de l'Académie Impériale des sciences de St. Petersbourg, VII. Ser. Tome, XIX. Nr. 3, 1873.

[7] K. Jimbo. Beiträge zur Kenntniss der Fauna der Kreideformation von Hokkaido. (Palæontologische Abhandlungen. Bd. VI, Heft 3, Jena, 1894.)

So striking is this fact, that Harada, Jokoyama, and now also Jimbo have concluded that the fauna of Japan must be considered as the result of an intermingling of forms from every possible horizon of upper cretaceous age, and that no division of the rocks into distinct horizons with characteristic fauna, can be attempted. But until we have a detailed account of these areas, little importance must be attached to the above statement, for in cretaceous beds, widely separated from India, *viz.*, in the Pacific section of North America, the Indian species occur in a succession almost identical with that seen in the beds of that country.

An especial interest attaches to the coal-bearing cretaceous rocks of Queen Charlotte's Islands [1] in the North-Eastern Pacific. The most fossiliferous bed of the cretaceous rocks of that area is Richardson's division C., which strongly resembles the Volga Series of Russia, not only in the occurrence of *Aucella*, to which fact the greatest importance has hitherto been attached, but also in the presence of many ammonites. Thus, for example, *Am. skidegatensis* Whiteaves [2] differs but very slightly from *Olcostephanus pallasi* Kaiserling, while several other varieties of *Olcostephanus* occur, and I cannot accept Whiteaves' view that the bed C. is equivalent only to the Gault. In the highest zones of this division can be seen numerous unmistakeable signs of a connection with the Utatur group; we find the same *Lytoceras Sacya* as in Japan and India, as well as *Schlœnbachia inflata*, *Lytoceras timotheanum* May, etc.

The overlying conglomerate, which is apparently the equivalent of the Dakota group is almost entirely devoid of fossils, but the higher shale beds, the "Upper Shales," have yielded *Inoceramus problematicus* Schloth., a common form in the Colorado group of the Atlantic section of North America and in the turonian of Europe.

We have, therefore, in Queen Charlotte's Island, a conformable series, extending from the lowest to the upper cretaceous beds. The most recent investigations also reveal very similar conditions in Northern California.[3]

To the west of the Upper Sacramento Valley a continuous series of cretaceous rocks is exposed: first, the Knoxville beds with *Aucella*; above these, the Horsetown beds, and at the summit, the upper cretaceous Chico group. The Knoxville and lower Horsetown beds yield lower cretaceous fossils, while in their uppermost horizons, the latter beds contain *Schlœnbachia inflata* Sow. and *Lytoceras sacya* Forbes, exactly as in the upper horizon of division C. in Queen Charlotte's Island. The lower Chico beds of Mt. Diablo have for some time been known to contain an *Acanthoceras* of the *rhotomagense* type, *viz.*, *Acanthoceras turneri* White,[4] which species I also obtained from the Utatur group of India.[5] In the upper beds of the Chico group, in addition to baculites of undoubted senonian facies, is found *Pachydiscus newberryanus* Gabb (non Meek), which is very nearly allied to *P.*

1 J. F. Whiteaves. Mesozoic Fossils. (Geol. and Nat. Hist. Surv. Canada) Vol. I; pt. I and III Montreal, 1876 and 1884.

2 J. F. Whiteaves. l. c. Pt. I, pl. IX, fig. 1 p. 34.

3 J. S. Diller and T. W. Stanton. The Shasta-Chico Series, (Bulletin of the Geol. Soc. of America). Vol. V, pp. 435-464. Rochester, 1894.

4 Ch. A. White: On invertebrate fossils from the Pacific coast. (Bulletin U. S. Geo. Surv. No. 51 Washington 1889. pl. V. p. 26.)

5 The identity of the two forms was confirmed by Ch. A. White, to whom I sent a figure of the Indian specimen.

otacodensis Stol. It is a very interesting fact that the Chico group, the lowest beds of which consist entirely of conglomerate and sandstone, overlaps the older strata of the so-called Shasta-Chico Series and over extensive areas in Washington, Oregon and California, lies directly on the older metamorphic rocks. The occurrence of a cenomanian *Acanthoceras* in the lower Chico beds, and of the lower cenomanian forms, *Schlœnbachia inflata* and *Lytoceras sacya* immediately below them proves that this overlap was almost contemporary with that of India, West Africa and Europe, etc.[1] The Chico group is known to extend to latitude 29° 30' N. (Lower California.) Beds resembling those of the Chico group, occur also further north in the Island of Vancouver,[2] where they are characterised by the number and excellence of their fossils. In the British Museum, in an old collection made by Hector and mentioned by Whiteaves, but not hitherto examined, I observed not only an excellent specimen of *Am. indra* Forb., but also, from the same beds the typical *Pachydiscus otacodensis* of the Ariyalur group, not hitherto identified in North America, and several other *Pachydiscus* forms, some of which were new, as well as *Baculites occidentalis* Meek, which is closely allied to the Indian *Baculites vagina*, etc. Whiteaves mentions the occurrence of *Pusosia gardeni* Forb. in the Chico group of Vancouver, while his *Lytoceras jukesii* (?) Sharpe is apparently identical with *Lyt. kayei* Forb.: the number of Indian species is therefore very considerable. So far as the fauna of the Pacific area of North America has hitherto been identified, the succession of the horizons is very similar to that seen elsewhere. In the upper Horsetown beds occur *Schlœnbachia inflata* and *Lytoceras sacya*, and next above them, in the lower Chico group, *Acanthoceras* followed in the upper *Chico group* by *Pachydiscus* and baculites.

Our knowledge of the other cretaceous rocks on the Pacific side of America is very meagre. In Chili unmistakeable upper cretaceous beds occur. In the Natural History Museum in London, I saw the specimens of *Baculites vagina* Forb.,[3] from Conception Bay, which are mentioned in Darwin's work on South

[1] Since a single "Shasta-Chico Series" has been established, extending from the lowest to the upper beds of cretaceous age, the question as to the date of the folding of the Sierra Nevada and coast ranges has assumed a new aspect. If the altered *Aucella* (Mariposa) beds of the Sierra Nevada, which are unconformably overlapped by the Chico beds, are of the same age as the lower Knoxville beds of the Shasta-Chico series, then the folding of the Sierra Nevada and the coast ranges would certainly be intercretaceous, a view which formerly met with general acceptance. Folding then took place simultaneously with that in Mexico, while at the same time, uninterrupted sedimentation was proceeding in the Upper Sacramento Valley and further to the North. (Queen Charl. Isl., Rocky Mts. and British Columbia). After the completion of the folding, the sea again flowed over the newly-formed mountains, and upon them the Chico beds were laid down. According to another view, however, the Mariposa beds are of Jurassic age, and consequently older than the Knoxville beds, and the folding took place previous to the deposition of the latter. See H. W. Fairbanks: The pre-cretaceous age of the metamorphic rocks of the California Coast Range, (Americ. Geologist. March 1892. p. 153 ff.). At present our data are too scanty to enable us to arrive at a decision of any value. This one important fact, however, is certain, that in upper cretaceous times (Chico period) the Sierra Nevada formed the western coast of a continent, the Great Basin, which extended eastward from that range.

[2] J. F. Whiteaves l.c. Pt. II. On the fossils of the Cretaceous Rocks of Vancouver, etc. Montreal, 1879.

[3] Ch. Darwin: Geological observations on the volcanic islands and parts of Southern America, 2 edit., London, 1876, p. 397.

America. These differ in no particular from the Indian specimens. At the Geological Congress held recently in Zurich, Prof. Steinmann,[1] speaking on the cretaceous rocks of Chili, said that, on investigation, he had indentified *Phylloceras* and *Lytoceras* forms connecting the beds of that country with the Utatur group of India. There may therefore be in the upper cretaceous rocks of Chili both Utatur and Ariyalur forms.

In general type, the cretaceous rocks of the Pacific area can be readily distinguished from those of the Atlantic province. Time has proved indeed that almost all species occurring in the one are also represented in the other, but often in a much less degree. Thus, for instance, *Schlœnbachia* and *Acanthoceras*, although not unknown in the cenomanian of the Pacific area, occur but rarely, and are quite out-numbered by a profusion of *Phylloceras* and *Lytoceras* forms, (the latter more particularly of the *Lyt. sacya* type). On the other hand *Desmoceras* and *Puzosia*, which are of rare occurrence in the upper cretaceous rocks of the Atlantic area, are here comparatively common, while *Holcodiscus*, which is not known to occur in the upper cretaceous beds of the Atlantic area, is represented in India by an abundance of forms. *Pachydiscus* and *Baculites* are more or less equally distributed in both hemispheres, being represented, however, by different species. It is impossible, therefore, nor would it be advisable, to enunciate shortly a hard-and-fast distinction, which on further investigation might prove to be erroneous, for only quite recently has it been shown by Jimbo that the true Atlantic type of *Placenticeras* and *Acanthoceras* (of the *rotomagense* group) occurs also in Japan.

On the whole, however, the cephalopod fauna of the upper cretaceous rocks in the Pacific area is not so rich in new forms as is that of the Atlantic province, the majority being closely connected with lower cretaceous forms; and this "conservative tendency," noticed by Neumayr[2] in the cretaceous fauna of Southern India, is, so far as we are at present aware, to a great extent peculiar to the Pacific area. The commingling of both types, which in India was so intimate that they almost balanced, is quite unknown in the cretaceous rocks of the west coast of America, which are much more closely related to the Atlantic area than are those of India.

The great difference between the cretaceous rocks of California and those of the Rocky Mountains, which are of the Missouri type, has long been known, and American geologists completely separate these two areas,[3] not only on account of the constitution of their fauna, but also on account of their geological conditions. As we approach the Great Basin, the cretaceous beds of the Rocky Mountains and of the Colorado plateau increase in thickness, and we find intercalated, at widely separated horizons, seams of coal and beds containing brackish or fresh-water shells; thus indicating the proximity of the western coast of the ancient continent, the Great Basin, which was subjected to folding in post-jurassic times, and from which cretaceous beds are entirely absent; while on the other side of the Sierra Nevada, we meet with the completely different cretaceous rocks of California.

[1] G. Steinmann: Procès-Verbaux des Séances des Sections 30. 8. Congrès Géologique international VI. Session à Zurich, 1894 pp. 6, 10.

[2] M. Neumayr: Erdgeschichte, Bd 2, p. 390.

[3] See Ch. A. White (Bull. U. S. Geol. Surv., No. 15, p. 30.)

An interesting addition to these facts was contributed by Hill,[1] in his investigations of the cretaceous rocks of Mexico. He discovered that the lower cretaceous (Comanche series of Texas) of the Mexican Sierras almost extends from ocean to ocean. Before the deposition of the upper cretaceous beds, however, these rocks were subjected to folding, and the next series (upper cretaceous) was then laid down, which, as may be seen in the Missouri district in the east, lies unconformably upon them. During upper cretaceous times, the lofty mountain folds of the Great Basin region of North America formed dry land, extending as far as British Columbia.

In the north of British Columbia we encounter somewhat different conditions. It has already been stated that the Upper Shales of Queen Charlotte's Islands yield *Inoceramus problematicus* Schloth., which is also frequently met with in the cretaceous rocks of Missouri. On the mainland of British Columbia between the parallels of 49° and 51° 30', Dawson discovered a bed resting on the *Aucella*-bearing Kootanie Series, which latter is the littoral representative of the Shasta group, or more particularly of Div. C of Queen Charlotte's Islands. This bed is a conglomerate similar to that found in Queen Charlotte's Islands, and is overlain by the clay of the Colorado group and by upper cretaceous beds extending to the Laramie Series.

In the same locality, it was also possible to identify with certainty upper cretaceous beds of Atlantic type resting upon lower beds of Pacific type, and the occurrence of *Inoceramus problematicus* in Queen Charlotte's Islands is a proof that the same conditions prevail there also. Hence we see that a connection resulting in overlap existed between the Atlantic beds and those of the Pacific area, which during lower cretaceous times extended to the eastern spur of the Rocky Mountains.[2] The interchange of fauna, thereby rendered possible, seems however to have been quite insignificant, the admixture in the Chico group of forms from the Atlantic portion of North America being very trifling.

The conditions prevailing in the northern districts of South America and in the Antilles, are very interesting. In Jamaica, corals[3] have long been known to occur of which several are identical with those of the Gosau beds, while hippurites are associated with them, and an *Actæonella* also has been stated to occur; all the above being fossils which undoubtedly occur in the Mediterranean cretaceous area. In striking accord with the above facts is the discovery in Peru[4] of an *Actæonella* and

[1] R. Hill: The Cretaceous Formation of Mexico and their relation to North American Geographic Development. (Am. Journ. of Science, 3, Ser., XVI, No. 268, 1893, p. 307).

[2] J. F. Whiteaves, too, finds that the upper cretaceous rocks are more nearly related to those of the eastern area than are the rocks of the more southern Chico group of California (l. c. Vol. I, Pt. II, p. 187) which is further evidence in favour of the above connection.

On the whole, Whiteaves agrees with Gabb in supposing that communication was carried on through the southern area, and adduces as evidence in support of his view the fact that cretaceous rocks occur to the west of the Sierra Madre in Mexico. But in the Chico period the coast extended much further west, embracing Lower California, while the fauna also of that district is entirely different to that of Mexico and Texas.

See also Ch. A. White: Notes on the Mesozoic and Cenozoic Palæontology of California (Bull. U. S. Geol. Surv. No. 15, Washington 1885), p. 30, and R. Hill: Cret. Format. of Mexico etc., p. 319.

[3] S. M. Duncan and G. P. Wall; A notice on the Geology of Jamaica (Quart. Journ. Geol. Soc., London, XXI, 1865), p. 2, ff.

[4] W. M. Gabb; Description of a collection of fossils made by Dr. A. Raymondi in Peru (Journ. Acad. Nat. Science Philadelphia, 2, Ser. Vol. VIII, Part III, Art. X, 1877, see pl. 36, fig. 1, a, b, p. 264 etc.)

of typical Mediterranean ammonites, closely connected with "*Buchiceras*" *syriacum* Buch. Such a fauna cannot fail to have been derived from the Mediterranean, and the assumption is therefore inevitable that an arm of the sea stretched across America, most probably in the neighbourhood of the Antilles and the modern Cordillera region of the northern part of South America, thus rendering possible the migration into the Pacific area of exclusively Mediterranean types. It was formerly supposed that the form "*Buchiceras*" *harttii* Hyatt, found in Brazil was connected with those discovered in Peru, and consequently it was assumed that communication had originally been possible by means of the valley of the Amazon. We can now, however, recognise the former existence of two arms of the sea, which divided America as it existed at that period into two great insular portions, constituting the boundary between the Pacific and Atlantic Oceans.

The cretaceous rocks of Southern India are more or less closely connected with a very large number of rocks of that age occurring in other countries, and are consequently well adapted to serve as their type. The European beds on the other hand, being merely a typical sub-division of the Atlantic area, are of but little service in this respect, and frequently fail us if we endeavour to correlate them with the cretaceous rocks of the Pacific. The great importance of the cretaceous beds of Southern India was therefore speedily recognised, but their connection with those of the Atlantic area has been much under-estimated.

In reality, the fauna of Southern India comprises the most important types of both the great areas and thus serves as a connecting link between them.

The marked contrast between the cretaceous rocks of the Atlantic area, and those of the Pacific consists not only in the great difference of extension of the overlap, but also in the independence of their respective fauna. This is particularly striking in America, but disappears to the south of the ancient Indo-African continent.

I have now stated in general terms the most important facts bearing on the geographical conditions which prevailed in upper cretaceous times. No other system offers such a profusion of material for a detailed reproduction of those conditions, and it is my intention, as soon as possible, to embody these in the form of a chart.

In conclusion I should like to enter briefly into a few general questions.

Neumayr ascribes great importance to the influences of climate, more especially as regards the horizontal distribution of the Ammonoidea. This question has received a considerable amount of attention,[1] and it is now probable that the dispersion of the cephalopods was due less to the effects of climatic influence than to those of the distribution of land and sea, and the consequent facilities for migration. The ammonite fauna of Central Europe is at least as intimately connected with that of Southern India, as with that of the Mediterranean.[*] Now the climate of Central Europe cannot have differed widely from that of the Mediterranean, while on the other hand that of Southern India was tropical, and the similarity in fauna must be due to migration of species from one hemisphere to the other by way of Natal. Even disregarding any possible deductions from the present climate, we can still establish

[1] S. Nikitin. Einiges uber den Jura in Mexico und Centralasien. (Neues Jahrb., Vol. II, 1890, p. 273, ff.)

A. Tornquist. Fragmente einer Oxfordfauna von Mtaru (Deutsch Ostafrika). Jahrb. der Hamburger wissenschaftlichen Anstalten. X. 2. Hamburg, 1893, p. 24.

the tropical character of the cretaceous fauna of Southern India, both by means of the reef-building corals and also, though in a lesser degree, by the presence and luxuriance of the gastropod and bivalve fauna. The argument in favour of a tropical climate based by Neumayr on the occurrence of *Phylloceras* and *Lytoceras*, applies equally well to the whole Indo-Pacific region. In that area, these forms are found in districts which, according to Neumayr, during the preceding Jurassic and lower cretaceous periods were closely connected with the Volga beds, that is to say, with the Northern basin. The less extensive faunas, inhabiting smaller and more isolated seas, may possibly have been less independent of climatic influences; but it is very difficult to decide with any degree of certainty the amount of importance to be attached to this factor.

The wide distribution of the Ammonoidea, which so complicates the question of climatic influence, induced Professor J. Walther[1] to believe that on the death of the ammonites, their floating shells became filled with air, and were borne hither and thither by winds and currents. He consequently concludes that their wide distribution was due, not to migration during life-time, but to a subsequent transportation of the empty shells. He even considers himself justified in propounding the theory that " the Triassic, Jurassic and Cretaceous systems may, for the most part, each be distinguished by a single species of ammonite, and may thus be recognised with facility in any part of the globe" : and again," during a given geological period, some one species of ammonite was uniformly distributed over the whole sea-floor, and after a short existence, became everywhere simultaneously extinct and was everywhere simultaneously replaced by a new species." The above statements involve a gross exaggeration of the true state of the case, for if we study the fauna of any given period over the whole earth, we find that in reality the phenomena are highly complicated. In the majority of cases, those species by means of which we correlate widely separated areas, are not identical, but are merely closely allied forms: *i.e.*, geographic variation involves variation of species.

The more careful our observations, the more frequently do we find that in numerous cases, species originally supposed to be identical, are in reality only members of similar groups, which may be distinguished from one another by certain constant characteristics. Thus, for example, we find in India neither *Acanthoceras rhotomagense* Defr., *Mammites nodosoides* Schloth, *Pachydiscus peramplus* Mant., *Schlænbachia tricarinata* Orb., *Placenticeras syrtale* Mort, nor *Baculites anceps* Lam.; closely allied forms, however, do occur, and these are found in an exactly similar stratigraphical relationship, and are evidently their representatives. Very similar examples of this may be seen if we compare the cretaceous fauna of Brazil, Japan or North America with that of India.

It is, however, undeniable that there are species, several of which I have already had occasion to mention, which, by their constant characteristics, may be recognised in almost every part of the world. Thus *Lytoceras timotheanum* May has been found in Europe, India, Sachalin, and Queen Charlotte's Islands. In Europe, it is connected with contemporaneous and also with older forms, while its descendants are found in India in the Trichinopoli and Valudayur groups; nearly allied forms also occur at Jesso. If, however, its presence in any given area were due to

[1] J. Walther: Einleitung in die Geologie als historische Wissenschaft. II. Th. Jena., 1893-94. (Die Ammoniten als Leitfossilien, p. 508. ff.)

marine transportation, it would there be isolated and not found in association with allied forms. Many other examples of a similar nature are to be seen in *Desmoceras, Puzosia, Pachydiscus, Acanthoceras, Schlœnbachia, Hamites*, etc. Any further demonstration of the fact would, however, be valueless without palæontological details. Hence we see that there are certain widely dispersed species of ammonites, which are found to be distributed in such a manner that we are compelled to assume an independent migration.

Very similar conditions prevailed during Triassic and Jurassic times: and the above facts prove that in all such cases the animals lived in the localities in which their remains have been found. The possibility of the occasional transportation of the empty shells need not be contested. Walther's theory, however, has no special bearing on the question of the zoo-geographical conditions.

If we compare the horizontal distribution of the ammonites with that of other forms of animal life, we find that it is by no means so abnormal as to necessitate an explanation other than that of simple migration. Thus, for example, in Southern India, associated with European ammonites, we find also European brachiopods, bivalves and gastropods, though certainly in smaller numbers. If again, we compare the conditions prevailing at the present day, we find numerous striking examples of the wide distribution of many marine shells. Thus, for instance, species are now living which are common to Natal, Ceylon, the Philippines, Japan, and even the coast of Australia; [1] and Fischer draws special attention to a considerable number of gastropods which are found both in the Indian Ocean and at the Antilles.[2] Similar, if less striking examples might be added—there is even an unmistakable resemblance in the distribution of the modern fauna [3] which, however, is not to be wondered at, if we consider the great resemblance existing between the geographical conditions during later cretaceous times and those prevailing at the present day.

Report on the Experimental Boring for Petroleum at Sukkur, from October 1893 to March 1895, by T. H. D. LATOUCHE, B.A., *Superintendent, Geological Survey of India.*

The actual drilling of the Sukkur boring was commenced on the 19th December 1893, the previous two months having been spent in bringing down from Babar Kuch the boring plant, which had been in use at the Khattan oil-wells, in selecting and repairing such portions of it as were suitable for the Sukkur boring, and in erecting the drilling rig and derrick. The site had been provisionally selected by Dr. King, late Director, Geological Survey. The reason of this choice was not that there was a greater probability of obtaining oil at that spot than at any other in the neighbourhood of Sukkur or Rohri, for at that time no surface indications of

[1] P. Fischer: Manuel de conchyliologie. Paris, 1887, tome. I. p. 158.
[2] P. Fischer. l. c. p. 177.
[3] See Fischer's chart, p. 126.

the presence of oil had been found anywhere in Upper Sind; it was merely a matter of convenience, for, being close to the North Western Railway workshops, repairs to the machinery could be carried out with as little delay as possible, while it was also at a convenient distance within the area of outcrops of the upper nummulitic limestone, the base of which forms a well-defined horizon for comparative measurements in relation to sections or borings in other localities.

Progress of the boring.

In the first place a well or sump was excavated down to the level of the surface water, which was found at a depth of about 10 feet. A length of 8-inch casing was then put in and sunk through the alluvial sandy clay overlying the limestone until the eroded surface of the latter was struck at a depth of 38 feet 6 inches. Now that experience has been gained of the nature of the rocks beneath the limestone, it is evident that it would have been better to have started with a larger diameter of casing than 8 inches, as this would have greatly facilitated subsequent operations; but, at the time the boring was begun, it was not anticipated that the hole would have to be lined with casing to so great a depth.

After the limestone was struck on the 23rd December 1893, at which date work was stopped till the end of the year, the progress made may be summarised as follows:—

Month.	Progress made.		Total depth.		REMARKS.
	Ft.	Ins.	Ft.	Ins.	
January 1894 .	281	0	324	0	The base of the limestone was reached at 140 feet from surface. The boring then entered beds of shaly blue clays, with thin bands of limestone and nests and veins of gypsum.
February „ .	76	0	400	0	Drilling much retarded by clogging of tools. Six-inch casing was put in to a depth of 167 feet.
March „ .	17	7	417	7	Greater part of month spent in substituting 7-inch casing for the 6-inch and in putting down the latter to the bottom of the hole.
April „ .	75	5	493	0	A thick band of limestone was passed through at 409 feet, which prevented the casing from going down. The casing had to be drawn out and the obstruction cut away.
May „ .	*nil*		...		The whole month was spent in lining the hole with 6-inch casing. The tools became jammed in the hole on the 12th, and were not recovered till the 21st. The 6-inch casing was put down to 440 feet, but could be sunk no further, and a string of 4⅝-inch casing was therefore put in.
June „ .	47	0	540	0	Drilling proceeded till the 8th, when the 4⅝-inch casing refused to go further. The 6-inch casing was driven down to 464 feet.

Month.	Progress made.		Total depth.		Remarks.
	Ft.	Ins.	Ft.	Ins.	
July 1894	5	0	545	0	The whole month was spent in trying to get the 6-inch casing past the obstruction at 464 feet. On the 13th the sand pump was lost in the hole, and was not recovered till the 28th. Subsequently, the 6-inch casing was driven down to 525 feet.
August „	87	0	632	0	The 4⅝ inch casing was put in again. From the 6th to the 23rd repairs were being made to the engine and boiler.
September „	113	0	745	0	Progress was more rapid this month, as the casing followed the tool down and was not stopped by bands of hard rock.
October „	134	6	879	6	Indications of gas were observed at about 785 feet, and water was struck at about 865 feet.
November „	78	0	957	6	The 4⅝-inch casing, which had now reached a depth of 917 feet, would not go further, and it was therefore pulled out and the lining of the hole continued with 6-inch casing by the aid of an under-rimer.
December „	*nil*		...		Putting in the 6-inch casing. Repairs to the engine and boiler were done between the 6th and 15th.
January 1895	6	0	963	6	Putting down 6-inch casing. Struck a band of hard limestone at 958 feet.
February „	79	0	1,042	6	Drilling proceeding fairly steadily, though slowly. The band of limestone at 958 feet proved to be only 20 feet thick. The hole was lined with 6-inch casing to 1,023 feet.

Since the beginning of March progress has again been very slow, and up to the present about 40 feet have been drilled. Two more lengths of 6-inch casing have been put in, making a total of 1,056 feet now in the hole, but these last two lengths have been driven down with much difficulty, and it is hardly likely that much more casing of this size can be used. It is, however, more than we expected it would be possible to introduce, and of course it is a great advantage to have the hole perfectly clear to such a depth, for it will considerably facilitate the progress of the smaller casing, which will shortly have to be put in.

Character of the strata beneath the limestone.

The shales and clays beneath the limestone are of very uniform character throughout the whole distance—about 940 feet—passed through up to the present, the only exception being the occurrence of thin bands and nodules of hard grey limestone; and th re can be no doubt, as pointed out by Mr. Griesbach, that they are the same beds as those found in a similar position beneath the upper nummulitic limestone in Baluchistan, as, for instance, in Mudgorge on the Hurnai Railway. What their thickness may be at Sukkur it is impossible to say, for the different members of the tertiary system vary considerably in thickness in different localities, and no measurements made in the hills to the west of Sind can be relied on to furnish an estimate of the thickness at Sukkur. They may continue without much change for another thousand feet, or, again, the underlying rocks, which it is to be hoped are of more solid character, may be reached at any moment.

Future prospects of boring.

Under these circumstances it is difficult to offer any opinion as to the future prospects of the boring, that is to say, as to the depth to which it should be carried before hopes of a successful issue are abandoned. But a discovery has quite recently been made in the neighbourhood of Rohri, on the other side of the Indus, which seems to point to there being a certain depth at which oil, if it exists in any quantity, should be met with, and to this depth I think that the boring should certainly be carried; and now that so much of it has been lined with 6-inch casing, there should be no great difficulty in doing this. I have already reported on the discovery alluded to, but it may be well to call attention to the facts here, and the conclusions I have drawn from them so far as they affect the Sukkur boring.

Traces of oil at the surface near Kundra.

My attention was recently called by His Highness the Mir of Khairpur to the fact that some peculiar gas had been observed for many years to issue from the soil at a spot about three miles to the west of Kundra, a village eight miles south of Rohri. I visited the place soon afterwards and noticed that the gas appeared by its odour to be similar to that observed in the boring at Sukkur; and recently I had a well dug at the spot so as to reach water, which was found at about 20 feet from the surface. After reaching a depth of 16 feet or so the gas, which is apparently carbonic acid, as it does not support combustion, issued in such volumes as to prevent the men working in the well, and the sinking had to be carried on from above. On examining the water, after emptying it out and allowing it to flow in again several times, distinct traces of oil appeared on the surface in the shape of iridescent films, and, on dredging up the sand from the bottom, these films could be seen oozing out from it and spreading over the surface of the water. The place is well out on the alluvium of the Indus valley, no solid rock being seen anywhere between it and the ridge of limestone running south from Rohri, which lies at about six miles distance to the east. Now, if we knew the thickness of the alluvium and the dip of the beds, it would be easy to calculate from what horizon in the rocks beneath the limestone these traces of oil escape, supposing that they escape from the outcrop of the rocks beneath the alluvium and do not rise through some fissure. Consequently, we should know at what depth we might expect to meet with them in the Sukkur boring. Estimating the thickness of the alluvium at 300 feet, and the dip at 2° to the east, which is about the average dip seen in the hills, the thickness of beds between the base of the limestone and the horizon at which the oil escapes works out to about 1,500 feet; and, as the base of the limestone at the Sukkur boring is 140 feet from the surface, the total depth to be drilled in order to reach that horizon should be a little over 1,600 feet. Of course the alluvium may be of greater or less thickness than I have estimated. This can only be determined by a boring at the spot; but the difference, whatever it may be, should be added to or substracted from the estimate above given, in order to determine the depth to which the Sukkur boring should, in my opinion, be carried before being abandoned.

The Development and Sub-division of the Tertiary system in Burma, by DR. FRITZ NOETLING, F.G.S., *Palæontologist, Geological Survey of India.* (With a map).

HISTORICAL SUMMARY.

In the following summary of the former geological work done in Burma, I shall restrict myself to a review of those papers which deal with Lower and Upper Burma, that is to say with that part of Further India which is situated between the Shan hills in the east and the Arrakan Yoma in the west, and which represents, properly speaking, the country of Burma. I shall therefore disregard all papers dealing with the geology of Tenasserim and Arrakan.

Although, since the end of the last century, Burma has been visited by numerous travellers who have related their experiences in various publications, the outcome of these travels has been very poor, with regard to the geological knowledge of the country. This is the more remarkable in that Burma has been famous for its mineral wealth, and nearly every traveller had in view the enormous mineral resources of the country. The meagre results are doubtless due to the want of geological training of most of the travellers, and this in its turn might again account for the legend of the enormous mineral wealth of Burma.

Among the names of those who wrote on geological subjects connected with Burma, previous to the researches of Dr. Blanford, Mr. Fedden, and Mr. Theobald, two only deserve mention, but they shine with the greater brilliancy amongst the numerous amateur attempts to deal with the geology of Burma: these are the names of Dr. Buckland and Dr. Oldham.

As early as 1829, from specimens which had been collected by Mr. Crawford in Upper Burma, and brought by him to England, Dr. Buckland recognised the following formations :—[1]

1. Alluvium.
2. Diluvium.
3. Fresh-water marl.
4. London-clay and calcaire grossier.
5. Plastic clay with its sands and gravel.
6. Transition limestone.
7. Grauwacke.
8. Primitive rocks, marble, mica slate.

Considering the state of geological science at that period, it is astonishing how accurately Dr. Buckland has recognized the formations which occur in Burma. It is unnecessary here to deal with his groups 6 and 8, as, for the purposes of this paper, we are mainly interested in the younger formations; but, with regard to these, it must be said that Dr. Buckland has already recognized some of the most important sub-divisions of the Burma tertiaries. Had he not been led by a mistaken inference to suppose that the fossil bones were also found in diluvial beds in Burma, he would, in fact, already have fixed the great divisions into which the tertiary rocks of Burma can be divided. If we substitute "Upper Tertiary" for the word "Diluvium," or if we keep in mind the fact that his diluvium really represents tertiary strata, we shall see that Dr. Buckland has already sketched in

[1] Transact. Geolog. Soc., 2nd series, 1829, vol. ii, p. 377.

broad outlines the sub-division of a part of the tertiary system in Burma, which still holds good at the present day. His diluvium and fresh-water marl represent the two groups into which I have divided the Burma strata, *viz.*, the upper ossiferous Irrawaddi division and the Yenangyoung division; the "London clay" represents the Pegu division, as is unmistakeably proved by the list of fossils, and if we unite his group No. 5 with the London clay, the three upper divisions of the Burma tertiaries are at once recognized.

That the nummulitic formation was overlooked is easily explained, when we remember that its outcrops are only visible far away inland at places that Mr. Crawford could not visit.

Dr. Buckland however, was, mistaken in identifying a piece of rock from Mindoung near Yenangyoung with the "Grauwacke" formation of Europe, as, no such strata occur within the neighbourhood of Yenangyoung, particularly at the said hill, which is entirely built up of tertiary strata.

It is much to be regretted that no opportunity for the study of the geological formations of Burma was afforded to Dr. Oldham, beyond those casual visits ashore, when the necessary delays of a river journey in those days stopped the progress of the mission to Ava. Otherwise that acute and careful observer would have been able to give us a more detailed account of the geology of Burma, than that to be found in his notes on the "Geological features of the banks of the Irrawaddi, etc."[1] As it is, Dr. Oldham was obliged to give his observations in the form of a narrative, which, although full of lucid and detailed observations, renders it very difficult to follow the author's opinion as to the division of the groups he has noticed. Dr. Oldham expresses his opinion that the rocks of the area within which the oilfields of Yenangyoung are situated belong to the tertiary system, but probably owing to lack of time he does not go into the subject of the division or correlation of these tertiary beds.

It was not until after the researches of Dr. Blandford, Mr. Fedden and Mr. Theobald in Lower Burma, that anything like a sub-division of the tertiary system was attempted. Mr. Theobald, who has embodied the results of his own researches and those of his two colleagues in his interesting memoir on the Geology of Pegu,[2] proposes the following sub-division for the Tertiary rocks of Lower Burma :—

Younger Tertiary	{ Fossilwood group. Pegu group.
Older Tertiary .	Nummulitic group.

Of these the Nummulitic group is considered as correlative with the Eocene of Europe, while the Pegu group represents the Miocene; the "Fossil wood group" represents the Pliocene, but Mr. Theobald leaves it an open question as to whether strata of probably Post-Pliocene age are not perhaps also represented in the "Fossil wood group."

We shall presently see that Mr. Theobald has quite correctly recognized the principal divisions of the tertiary rocks in Burma, and although he may have failed in the accurate delimitation of these groups, it is well to state at once that these three sub-divisions are also recognizable in Upper Burma. Where Mr. Theobald's division is chiefly defective is with regard to the Lower Tertiary. Subsequent researches have proved that the "Axial group" (which Mr. Theobald has, on the

[1] Yule: Narrative of a mission to the Court of Ava in 1855. Appendix A, *p.* 307.

[2] Memoirs of the Geological Survey of India, Vol. X.

strength of a misinterpreted fossil, regarded as of Triassic age) must either be included in the tertiary system, of which it represents the lowest division; or might probably form the highest beds of the cretaceous system. Now, anyone acquainted with the country in which the "Axial" formation is chiefly developed, will readily understand the difficulty of accurate observation in such a jungly country as the Arrakan Yoma. In fact, the question of the age of the "Axial group" is not quite settled yet. All we know is that it does not belong to the Triassic system: this may be considered as certain, but whether it represents the lowest tertiary or the topmost cretaceous strata, is a question which still requires careful investigation. In the following pages I have provisionally accepted the view of the tertiary age of the "Axial group," but I wish to state at once that by no means do I consider this question as decided.

The same applies to Mr. Theobald's Negrais rocks, which are probably only metamorphosed Eocene beds. But not having seen these beds I am unable to express my views as to their appearance.

Mr. Theobald has sub-divided both the Pegu and the Fossil wood groups, the first into two, the second into three sub-divisions; but none of these can, to judge from our present experience, claim more than a local importance.

In the following division of the Tertiary rocks in Burma, I have attempted to combine Mr. Theobald's observations with my own in Upper Burma, and I trust that I may have at least succeeded in fixing the outlines of groups therein represented. But years and years of patient labour will elapse before we can arrive at anything like a definite idea of the finer details. If in the following pages the Upper Tertiary is more explicitly dealt with, this is not because it is of much more importance than the Lower Tertiary, but because my work brought me chiefly in touch with the Upper Tertiary.

DIVISION OF THE TERTIARY ROCKS OF UPPER BURMA.

Wherever a complete series of the tertiary beds is developed in Upper Burma, we can, with the greatest ease, recognize and distinguish two groups, which differ widely in the character of the fauna they contain.

The lower group is characterised by a *marine* fauna, which is entirely free from any terrestrial or fluviatile elements in the lower part, but locally shows a slight foreign element by the admixture of rolled fragments of terrestrial animals in its upper beds.

The upper group contains chiefly remains of *terrestrial* animals, mixed with such forms as, according to the habits of their present representatives, must have led an *aquatic* life.

Hand in hand with this wide difference in the palæontological characters goes a distinct change in the features of the sediments. Dark bluish and grey colours characterise those of the lower, and yellow, olive-green and red those of the upper group.

Notwithstanding this wide difference between the two groups, it seems as if the upper rests conformably on the lower, although there exist no passage beds between the two,—a fact which must not be overlooked. I therefore divide the Burma tertiaries into two sub-divisions, *viz*:—

2. Upper Tertiaries or Burma series.
1. Lower Tertiaries or Arrakan series.

For the lower division I suggest the name of *Arrakan series*, owing to its chief development in the Arrakan Yoma; the upper one may be called the *Burma series*, because it is chiefly developed in the broad depression between Arrakan Yoma in the west and Shan hills in the east, which forms the country of Burma proper.

I. ARRAKAN SERIES.

The Arrakan series can again be sub-divided into three groups, which palæontologically, as well as lithologically exhibit considerable differences.

The lowest of these groups is very little known; in fact, we may say we know nothing with regard to its palæontological features.

The middle group is characterised by the abundance of *Nummulites*; while the chief feature of the upper group is the total absence of this genus. Lithologically the two lower groups are characterised by shales and limestones, while, in the upper, sandstones predominate to the nearly total exclusion of other rocks. For the lowest group I suggest the name *Chin division*, while for the middle and upper one Mr. Theobald's names *Nummulitic division* and *Pegu division* may be retained.

1. THE CHIN DIVISION.

Only the bare outlines of the features of this group can be laid down up to the present, it being one of the least known members of the Burma tertiaries. I am nearly certain that subsequent discoveries will essentially modify the views here expressed. So far as I am able to say for the present, the following are the features of this group.

Lithologically, flysch-like shales, and hard limestones are the predominating rocks. It seems as if the shales almost exclusively occupied the lower part of the group, and were followed by the limestones.

Not even the approximate thickness of the shales can be given, but it may safely be supposed that it was considerable. So far as it is known, the central part of the Arrakan Yoma is chiefly built up of these shales, where they form, particularly in the Chin country, numerous parallel ridges rising to over 7,000 feet above sea level. No fossils have been discovered for the present in these shales, but this by no means proves that they are unfossiliferous.

Mr. Theobald's so-called "Axial group" of the southern part of the Arrakan Yoma, which he considered of Triassic age, represents in a broad sense these shales, and it is chiefly due to the observations of Mr. Griesbach, who examined a part of the Arrakan Yoma, where the Axial group was supposed to be present, that we know that it belongs to the tertiary system, and probably forms its lowest part. It requires, however, a long and careful examination before more can be said about the Chin-shales, an examination which will be extremely difficult in a country like the Arrakan Yoma, which is covered with almost impenetrable virgin forest.

2. THE NUMMULITIC DIVISION.

We know a little more about the middle part of the Arrakan series, although this knowledge is very scanty. According to Mr. Theobald, the total thickness of the *Nummulitic* or *Eocene group*, as he calls this subdivision, is 1,223 feet, but to judge from the table given on page 100 of his Memoir, it is quite certain that he has included at least 227 feet more, probably about 500 feet of shales, which probably should be included in the Chin shales. However, this is a matter which can only be decided by actual observation in the field.

According to Mr. Theobald, the lower part of the nummulitic division consists of shales and sandstones, occasionally fossiliferous, capped by a bed of highly fossiliferous nummulitic limestone, of only 10 feet in thickness.

Although I have no doubt as to the correctness of this observation, it is quite certain that in a northern direction the limestone increases in thickness and importance, at the expense of the arenaceous beds. However, this is a matter which must be left to the future to decide.

The fauna discovered in this group, for which we may for the present retain the name *Nummulitic* division, is a rich one, but we know absolutely nothing as to its relationship, because owing to more pressing work, none of my predecessors have undertaken the task of studying it. All that we know at present is that it contains numerous species of the genus *Nummulites*, and, in a bed which most probably belongs to the upper part of the series, the well-known Eocene species, *Velates schmideliana*, Chem. sp. As I have pointed out in the paper, in which I described the occurrence of this species, [1] we may infer from the limited vertical distribution of this species, not only in Europe, but also in Western India, that the stratum in which it was found in Burma belongs to the Eocene system, and must most probably be considered as correlative to the Khirthar group of Western India.

The occurrence of the genus *Nummulites* together with the typical Eocene species, *Velates schmideliana*, Chemn. sp., leaves, therefore, not the slightest doubt that this part of the Arrakan series must be considered as of Eocene age, having in the Khirthar group its correlative in Western India. The lower Tertiaries would therefore be subdivided as follows:—

1. Upper Eocene: *Nummulitic* division.
   Shales and limestones containing a rich fauna of typical eocene forms,
2. Lower Eocene (?): *Chin shales.*
   Shales predominate and have not yielded any fossils up to the present time.

As regards the distribution of the two sub-divisions of the Eocene rocks in Burma it is practically such that the Chin-shales cover a much wider area than the nummulitic division, which, so far as our present knowledge goes, forms only a comparatively narrow band along the outskirts of the Arrakan Yoma.

In conclusion, however, I wish particularly to point out that all that I have said above regarding the subdivision of the Lower Arrakan series must be considered as preliminary. I myself have only very rarely had occasion to observe it, and the above remarks are chiefly based on Mr. Theobald's observations, as they appear in the light of the later researches, particularly those by Mr. Griesbach and myself. I need hardly add that it will require years and years of careful labour in the field, as well as in the museum, before we arrive at anything like a clear conception of the development of the Eocene rocks in Burma.

3. The Pegu division.

The name "Pegu group" was proposed by Mr. Theobald "for a very important

[1] Records, Geological Survey of India, 1894, vol. xxvii, page 103.

series of beds intervening between the Eocene or nummulitic division on the one hand, and the fossil wood division on the other."

The above definition of the Pegu division would be a very clear and concise one, if Mr. Theobald had more accurately defined the lower boundary of his "fossil wood group." As it is, the boundaries of the "fossil wood group" are very uncertain and thus the upper limit of the Pegu division is very ill-defined.

I propose to apply the name of Pegu division to that series of beds, which are between the Eocene rocks—characterised by their peculiar marine fauna—and the Irrawaddi division—characterised by its peculiar terrestrial fauna.

In the above definition, the Pegu division constitutes a very well circumscribed series of beds, which are characterised as follows :—

The fauna is of a marine type throughout, but the genus Nummulites is entirely absent. Towards the upper limit rolled fragments of terrestrial animals are, in one place at least, mixed with a purely marine fauna; lithologically, sandstones of pepper and salt colour are predominant, while blue clays are more subordinate.

The above features are so well defined wherever the Pegu-division occurs in Upper Burma, that it is not easy to mistake it, although it varies locally a good deal, as may be expected in a series chiefly composed of sandstones and clays; so that it is frequently very difficult to correlate the local developments of the Pegu division at different localities in Burma. In fact the local developments differ so widely that even at places close to each other, such as Minbu, Yenangyoung, Yenangyat it is extremely difficult, if not impossible, to correlate the single strata composing the sections at the different localities. The difficulty increases of course with the distance, and years will lapse before the relations of this division in Lower and Upper Burma are sufficiently studied. We know, however, for the present enough of the development of this group to enable us to give some more details. The Pegu division may be conveniently separated into two sub-divisions, for the lower of which I propose the name of *Prome stage* owing to its chief development in the neighbourhood of that town, while for the upper one the name of *Yenang-young stage* is suggested.

A.—Prome Stage.

a. Thickness.

Mr. Theobald describes a section of this stage near Prome, measuring 1,950 feet in thickness; but he adds that this apparently does not represent the total thickness. Although, if I interpret his views correctly, he does not think that the total thickness is very much greater.

At Yenangyoung the drill has gone through rocks of the Prome stage up to a depth of 1,000 feet without apparently touching their base.

At Yenangyat it is known partly by surface outcrops, partly by borings, to have a thickness of not less than 1,100 feet.

On the right bank of the Chindwin between the Kale and Yu river, I estimated its thickness at about 5,100 feet. In this part of the country I must have been pretty close to the base, although the actual contact between the upper Eocene and the lower beds of the Prome stage was not observed, but numerous pebbles containing Eocene fossils indicated the proximity of the Eocene beds.

If therefore we estimate the total thickness of the Prome stage at something like 5,000 feet, I think we shall not be very far off the mark

b. Lithological characters.

The chief constituents of the Prome stage are sandstones and clays, the latter are however much subordinate to the former; still more subordinate are coal seams and ferruginous clays ; locally the sandstones contain petroleum, and, at isolated places, the fossil resin, burmite. The sandstone is very uniform in character, it is finely grained, of a greyish colour, which may best be styled "pepper and salt colour." Sometimes the sandstone is very soft, other beds are more siliceous, and therefore harder. When exposed, these beds disintegrate into rather regular lumps, which retain for a long time their original position, before they fall to pieces. Such beds which resemble the pavement, may frequently be seen between Thayetmyo and Prome, or on the Upper Chindwin.

The clay is also of very uniform character, being generally a very tough clunch of bluish colour.

Sandstone and clay alternate in beds of various thickness; frequently, as for instance near Yenangyoung, beds of clay as thin as paper may alternate with similar beds of sandstone, while at other places, as for instance in the Upper Chindwin district, the sandstone forms a continuous bed of several hundred feet in thickness. The clay beds may also attain a considerable thickness, but I never found that they equalled the sandstone in this respect.

The coal seams are generally of small thickness, the thickest known to me is a seam of 10 feet, cropping out in the ravine of the Nantahinchoung in the Upper Chindwin district; generally they are between 1 and 2 feet in thickness. It would exceed the limits of this paper were I to dwell in detail on the occurence of the coal in Upper and Lower Burma; those interested in its occurence will find ample information in the papers cited below.[1]

It seems, however, that in the Chindwin district the coal seams are restricted to the lower part of the Prome stage, but to judge from other localities such as Kabwet, Wuntho or Thayetmyo some seams of inferior quality also occur in the upper parts.

As the occurrence of the petroleum will be dealt with in a special memoir, which will shortly be published, it is needless to go into details. All that may be said is, that it appears that the petroleum chiefly occurs in the upper parts of the Prome

[1] Oldham: Memorandum on the coal found near Thayetmyo on the Irrawaddi river. Selections from the Records of the Government of India, Home Department No. X, page 99, 1856. Reprinted in papers on Burma, issued by the Geological Survey.

Oldham, in Yule's Narrative of a Mission to the Court of Ava, Appendix A., page 330.

Jones: Notes on Upper Burma: Records of the Geological Survey of India, Vol. XX, Part II, 1887, page 185.

Noetling: Memoir on the Upper Chindwin Coal-fields, 1889.

Noetling: Report on the coal-fields in the Northern Shan States: Records of the Geological Survey of India, 1891, Vol. XXIV, page 99.

Noetling: Note on the Geology of Wuntho in Upper Burma: Records, Geological Survey of India, Vol. XXVII, page 119.

stage, but that it is unquestionable that small quantities are also found in the lower parts.

The occurrence of the fossil resin, burmite, the famous amber of Burma, has been described by me in a special paper.[1] Dr. Helm [2] has devoted two papers to the chemical properties of this fossil resin, which, according to him, is distinctly different from the real amber or succinite.[3]

c. Palæontological characters.

Although the rich fauna which Messrs. Theobald and Fedden collected in the Pegu division of Lower Burma still waits to be described, the examination of the fauna discovered in the petroleum-bearing strata of Yenangyat has shed so much light on the age of the Prome stage that we can now classify it definitely in the sequence of the tertiary beds without being obliged to have recourse to an indirect method. The information recently obtained by the deep borings at Yenangyat, has proved that the fauna which I have described [4] from this place comes from the petroliferous sandstone at the top of the Prome stage. The following species have been observed:—

1. *Paracyathus caeruleus*, Duncan.
2. *Eupsammia regalis*, Alcock.
3. *Ostrea sp.*
4. *Pecten cf. favrei*, d'Arch. & Haime.
5. *Daphoderma cœlata*, Reeve.
6. *Nucula alcocki* Noetling.
7. *Astarte* (?) *dubia*, Noetling.
8. *Venus cf. scalaris*, Bronn.
9. *Tellina* (*Tellinella*) *hilli*, Noetling.
10. *Tellina kingi*, Noetling.
11. *Solen sp.*
12. *Corbula harpa*, d'Arch. & Haime.[5]

[1] On the occurrence of Burmite in Upper Burma : Records, Geological Survey of India, 1893, vol. xxvi, page 31.

[2] Note on a new fossil amber-like resin occurring in Burma : Records, Geological Survey of India, 1892, vol. xxv, page 180

Further Note on Burmite, a new amber-like fossil resin from Upper Burma, Records, Geological Survey of India, 1893, vol. xxvi, page 61.

[3] It may here not be quite out of place to correct a mistake with regard to the age of certain coal seams occurring in Tenasserim. Mr. Oldham in the Manual of India, 2nd edition, page 297, expresses his view, that as the coal contains small nodules of a resinous mineral like amber, these coal seams were of cretaceous age, because in the Assam hills the mineral resin is characteristic of the cretaceous coals. If any inference regarding the age were admissible from the association of fossil resin and coal, it could only be one, and that is that the coal seams are of miocene age, because everywhere in Upper Burma the fossil resin is found in strata belonging to the Prome stage, which is of distinctly miocene age.

[4] Memoirs, Geological Survey of India, vol. XVII, Part I.

[5] It may be remarked here that the species which I determined as *Corbula harpa* d'Archiac and Haime is really different from that species, although this could not be recognised at the time owing to the rather deficient figure of Messrs. d'Archiac and Haime. The recent examination of the *Corbula harpa* d'Arch. and Haime from Sind has proved that notwithstanding the great similarity of the right valve, it materially differs from the Burma species by the sculpture of the left valve ; *Corbula harpa* d'Arch. and Haime from Burma must therefore be cancelled, and a new name substituted for it. My remarks on page 4 of the abovenamed memoir, have therefore been fully borne out by the facts, and one anomaly of the otherwise truly miocene fauna has disappeared.

13. *Trochus buddha*, Noetling.
14. *Trochus blanfordi*, Noetling.
15. *Solarium affine* Sow.
16. *Discohelix minuta*, Noetling.
17. *Turritella affinis*, d'Arch. & Haime.
18. *Siliquaria sp.*
19. *Calyptraea rugosa*, Noetling.
20. *Natica obscura*, Sow.
21. *Natica callosa*, Sow.
22. *Sigaretus cf. bicostatus*, Sow.
23. *Aporrhais* sp.
24. *Cypræa granti*, d'Arch. & Haime.
25. *Trivia smithi*, K. Martin.
26. *Cassidaria dubia*, Noetling.
27. *Cassidaria minbuensis*, Noetling.
28. *Ficula theobaldi*, Noetling.
29. *Triton pardalis*, Noetling.
30. *Ranella tubercularis*, Lamark.
31. *Nassa cautleyi*, d'Arch & Haime.
32. *Clavella djocdjocartæ*, K. Martin.
33. *Fasciolaria nodoulsa*, Sowerby
34. *Fasciolaria feddeni*, Noetling.
35. *Murex* (*Muricidea*) sp.
36. *Murex tschihatscheffi*, d'Arch & Haime.
37. *Murex arrakanensis*, Noetling.
38. *Voluta dentata*, Sowerby.
39. *Oliva djocdjocartæ* K. Martin.
40. *Cancellaria cancellata*, Lam.
41. *Rapana* sp.
42. *Terebra fuscata*, Brocchi.
43. *Pleurotoma* (*Drillia*) *interrupta*, Lamark.
44. *Pleurotoma yenanensis*, Noetling.
45. *Conus* (*Rhizoconus*) *mallacanus*, Hwass.
46. *Conus* (*Leptoconus*) *marginatus*, Sowerby.
47. *Balanus sublaevis*, Sowerby.
48. *Callianassa* sp.
49. *Pagurus* sp.
50. *Lamna* sp.
51. *Galeocerdo* sp.
52. *Carcharias* (*Prionodon*) sp.

Out of a total of 52 species, 48 were specifically determined, but among these there are three species which could only be, with some doubt, referred to previously known species. There remain therefore 38 species, which are sufficiently well determined to allow of geological conclusions being drawn from them. Out of these 38 species, 15 have been recognized as new, while the balance of 23 species could be identified with species previously described, but as the species referred to *Corbula harpa*, from western India, cannot be considered as identical with this species, the figures therefore now stand as follows :—

New species . . .	16
Previously described species	22

The geological distribution of these 22 species is as follows :—

Recent, but not previously known in fossil state.

1. *Paracyathus cæruleus*, Duncan.
2. *Eupsammia regalis*, Alcock.

Nari group—

1. *Daphoderma cœlata*, Reeve (*Arca burnesi*, d'Arch, and Haime).
2. *Solarium affine*, Sowerby.
3. *Turritella affinis*, Sow.
4. *Cypræa granti*, d'Arch. & Haime.
5. *Voluta dentata*, Sowerby.

Gaj group—

1. *Daphoderma cœlata*, Reeve (*Arca burnesi*, d'Arch. & Haime).
2. *Natica obcsura*, Sow.
3. *Nassa cautleyi*, d'Arch. & Haime.
4. *Balanus sublævis*, Sow.

Older Tertiary—

1. *Daphoderma cœlata*, Reeve.
2. *Fasciolaria nodulosa* Sowerby.

Of uncertain horizon are—

1. *Natica callosa*, Sowerby.
2. *Murex tschihatscheffi*, d'Arch. & Haime.
3. *Conus* (*Leptoconus*) *marginatus*, Sow.

In the Miocene of Java have been found—

1. *Trivia smithi*, K. Martin.
2. *Clavella djocdjocartæ*, K. Martin.
3. *Oliva djocdjocartæ*, K. Martin.
4. *Cancellaria cancellata*, Lam.
5. *Pleurotoma interrupta*, Lam.
6. *Conus* (*Rhizoconus*) *mallacanus*, Hwass.

From the above list it is evident that the fauna cannot be older than of Miocene age : only two species could be identified, which occur in the older tertiary beds of India : one of these, however, also ascends into higher groups, in fact, it is still living in the Indian Ocean. The geological horizon of three species is unknown, and we may therefore disregard them for the moment. Out of the remaining species—

Two are recent and not previously known in a fossil state.
Five range from the Miocene to the present day.
Three have been found in the Miocene of Java.
Four have been found in the Nari group of Western India.
Three have been found in the Gaj group of Western India.

As out of a total of 17 species, 7, that is to say nearly 50% are still living, we are therefore justified in assuming a miocene age for the beds which have yielded this fauna. It only remains to be seen whether the fauna bears a greater resemblance to the Gaj or to the Nari group of Western India. The evidence in this regard is very meagre, in fact it would be rather rash to form a final conclusion, but from the fact that the species from Java have been found in beds which are considered as of the same age as the Gaj group, I feel inclined to consider the fauna of the Prome stage as correlative to the Gaj group of Western India.

d. Facial development of the Prome stage.

In studying the development of this stage, particularly in Upper Burma, it is at once obvious that, notwithstanding the purely marine character of the fauna, some beds, which must be considered as homotaxial to the former, were either deposited in estuaries or at no great distance from the coast.

For instance, at Yenangyoung, a well, which had reached a depth of 156 feet from the surface, and which had, in the light of the information recently obtained, passed through the 1st and 2nd petroliferous sands, a highly fossiliferous conglomerate of about 6 inches in thickness was discovered in which I collected the following species :—

1. *Corallium, gen. div*; one closely related to *Paracyathus cæruleus, Dunc.*
2. *Teredo* sp.
3. *Venus* sp.
4. *Cardium* sp.
5. *Arca* sp.
6. *Pecten* cf. *favrei*, d'Arch & Haime.
7. *Gastropoda, gen. div.*

The invertebrata are all very ill-preserved, in fact they are either only casts or moulds, the calcareous substance of the shell being entirely destroyed by sulphuric acid, which is represented by a large quantity of iron pyrites. The latter makes the preservation of these fossils almost impossible: notwithstanding repeated coatings of varnish, they have, in the damp climate of Calcutta, almost entirely crumbled to pieces with considerable efflorescence. The vertebrata have yielded the following list :—.

1. *Teleostei* gen. div.
2. *Myliobatis* sp.
3. *Odontaspis* sp.
4. *Carcharias* sp.
5. *Chelonian* bones.
6. *Crocodilis* sp.
7. *Antelope* sp. (?)
8. *Anthracotherium silistrense.*
9. *Rhinoceros* or *Hippopotamus* sp.

Besides the abovenamed forms which could be recognized with certainty, the conglomerate contained numerous fragments of bones, which have been too much rolled to be determined. The chief interest however rests with the fact, that fragments of terrestrial and estuarine forms are mixed with a purely marine fauna, and that such a strangely composed fauna has been found in strata between the 2nd and 3rd oil-sand at Yenangyoung.

On the other hand, the petroliferous sand of Yenangyat, which is perhaps a little higher in the series, has yielded the purely marine fauna above described.

In the Upper Chindwin district the coal-seams in the lower part of the Pegu division apparently indicate an estuarine, or at least a littoral deposit, while further south near Thayetmyo, a purely marine fauna is found in the lower portion of the Prome stage. It seems to me, therefore, that not only are beds, which are undoubtedly homotaxial, partly marine and partly of littoral or of estuarine character, but that also owing to local oscillations these changes take place in a vertical direction. On the whole it may, however, be said that the marine character is more pronounced in Lower Burma, while the littoral or estuarine formation prevails in Upper Burma. This view, however, by no means affects the opinion expressed above as to the wide difference between the fauna of the Prome stage and that of the Irrawaddi division, nor does it modify the conclusions based thereon with regard to the sub-division of the Burma tertiaries.

e. Sub-division of the Prome stage.

It is obvious that, under the circumstances above described, a general sub-division of the Prome stage is extremely difficult, and that those attempts, which have so far been made by Mr. Theobald in Lower Burma, and by myself in the Upper Chindwin district are of purely local value, hardly holding good for more than a few miles around the locality for which they were made.

Under these circumstances it would be superfluous to repeat them here. All that can be said is that, perhaps, after years of careful study, and after an exhaustive examination of the fauna, and a most careful determination of the fossiliferous horizons in the sequence of the series, it will, perhaps, be possible to arrive at a general sub-division of the Prome stage; for the present we must be satisfied with local sub-divisions, without making any attempt at correlating their individual members.

B.—The Yenangyoung stage.

A marked lithological difference distinguishes the overlying series of beds from the Prome stage. No sharper boundary can be imagined than the contrast between the bluish tinges of the Prome stage, and the brown or olive-coloured beds of the Yenangyoung stage at places where the contact between the two is well exposed, as for instance in the Oung-Ban ravine between Kodoung and Twingon. In fact, the results of the deep borings carried out at Twingon render it utterly impossible to assume an absolutely conformable superposition of the Yenangyoung stage on the Prome stage. The study of these sections leads to the assumption that a break must exist between the Upper Prome beds and the lower beds of the Yenangyoung stage, at least in the country near Yenangyoung. On the other hand it deserves to be mentioned that at Yenangyat the Yenangyoung beds rest (apparently with absolute conformity) on the Prome stage.

Although there exists, therefore, a sharp lithological difference between the Prome stage and the Yenangyoung stage—a difference from which one would rather feel inclined to consider the latter as the basal beds of the Irrawaddi division, so great is the lithological similarity between the two—still the palæontological evidence unquestionably proves that the Yenangyoung stage is widely different from the Irrawaddi division and closely related to the Prome stage. It must therefore be included in one series with it.

a. Thickness.

At Yenangyoung the beds composing the Yenangyoung stage form a series of about 1,100 feet in thickness.

At Singu the thickness is about 700 feet, but here the whole series is not completely exposed, and it is impossible to say to what depth it may still extend.

At Yenangyat the whole series is again well seen: its thickness at this place is about 1,200 feet.

It is therefore tolerably certain that, at least in Central Burma, the Yenangyoung stage is only of moderate thickness as compared with the other groups composing the Burma tertiaries.

b. Lithological characters.

The chief constituents of the Yenangyoung stage are soft clays, alternating with beds of sandstone, which may either form thin hard bands, or thicker soft beds. The clay is usually of olive colour, but in various instances, bluish tinges, particularly near Yenangyat, have been observed. One involuntarily imagines a struggle between the bluish colour of the older beds and the olive colour of the newer strata; there are frequent relapses, so to speak, to the original bluish colour, till eventually the olive colour gets the upper hand and bluish tinges have entirely disappeared in the Irrawaddi division. This struggle between the two colours is extremely well seen at Yenangyat, where, after having made a final effort, the bluish colour of the clay disappears with the highest bed of the Yenangyoung stage. The sandstone is usually very friable, and of a yellowish colour; bands of hard kidney-shaped or globular concretions occurring very frequently.

A most remarkable feature is the presence of gypsum, which occurs frequently in large crystals in the clayey beds. It is noticeable that no gypsum is found either in the lower Prome stage or in the Upper Irrawaddi division, and in this respect its occurrence forms an exceedingly useful feature for the recognition of the Yenangyoung stage. One may be almost certain to have beds of the Yenangyoung stage under observation when the gypsum is noticed.

c. Palæontological characters.

Fossils are rather scarce in the Yenangoung stage, that is to say, the localities in which they are found are not numerous; but when present the fauna is usually a rich one. So far I have discovered three places where fossils have been found, and every one of these localities unquestionably represents a different horizon.

The lowest horizon is probably represented by beds which contain a very rich fauna near Minbu. In a similar horizion, fossils also occur at Yenangyat, but I never found at this place a bed where they were recognizable, being in every case mostly fragments.

Next in the series follows the *Cypricardia* bed of Singu.

The last in the series is the *Batissa* or *Cyrena* bed containing countless numbers of the two species *Batissa* (*Cyrena*) *crawfurdi* and *petrolei*. It will be useful to discuss the palæontological characters of each of these beds separately, and eventually compare the whole of the fauna with that of the Prome stage.

1. MINBU-BED.

The fauna of this bed, which is well exposed at the hill, north of the mud-volcanoes, has been described by me in the memoir previously quoted. So far the following species have been found:—

1. *Paracyathus cæruleus*, Duncan.
2. *Ostrea*, sp. 1.

3. *Pecten* cf. *favrei*, d'Arch. & Haime.
4. *Nucula alcocki*, Noetling.
5. *Venus* sp.
6. *Tellina kingi*, Noetling.
7. *Corbula* spec. nov.[1]
8. *Trochus buddha*, Noetling.
9. *Trochus blanfordi*, Noetling.
10. *Solarium affine*, Sowerby.
11. *Solarium cyclostomum*, Menke.
12. *Scalaria birmanica*, Noetling.
13. *Scalaria irregularis*, Noetling.
14. *Scalaria subtenuilamella*, d'Arch. & Haime.
15. *Turritella affinis*, d'Arch. & Haime.
16. *Calyptræa rugosa*, Noetling.
17. *Natica obscura*, Sowerby.
18. *Natica callosa*, Sowerby.
19. *Cerithium* sp.
20. *Strombus nodosus*, Sowerby.
21. *Cypræa granti*, d' Arch. and Haime.
22. *Cassis d' archiaci*, Noetling.
23. *Cassidaria dubia*, Noetling.
24. *Cassidaria minbuensis*, Noetling.
25. *Triton* (*Simpulum*) *davidsoni*, d'Arch. & Haime.
26. *Triton pardalis*, Noetling.
27. *Ranella tubercularis*, Lamark.
28. *Nassa cautleyi*, d' Arch. & Haime.
29. *Clavella djocdjocartæ*, K. Martin.
30. *Fasciolaria noduloso*, Sowerby.
31. *Murex arrakanensis*, Noetling.
32. *Volvaria birmanica*, Noetling.
33. *Voluta dentata*, Sowerby.
34. *Oliva djocdjocartæ*, Martin.
35. *Terebra fuscata*, Brocchi.
36. *Pleurotoma voyesi*, d'Arch. & Haime.
37. *Pleurotoma* (*Drillia*) *interrupta*, Lamark.
38. *Pleurotoma yenanensis*, Noetling.
39. *Conus* (*Rhizoconus*) *mallucanus*, Hwass.
40. *Balanus sublaevis*, Sowerby.
41. *Callianassa* sp.
42. *Lamna* sp.
43. *Myliobates* sp.
44. *Carcharias* (*Prionodon*) sp

The above list shows that the Minbu bed contains nearly the same number of species as the Prome beds and that out of a total of 44 species it contains 29 species which are common to both faunas. So far the forms peculiar to the Minbu bed are the following :—

1. *Ostrea* sp. 1.
2. *Venus* sp.
3. *Solarium cylostomum*, Menke.
4. *Scalaria birmanica*, Noetling.
5. ,, *irregularis*, Noetling.
6. ,, *subtenuilamella*, d' Arch. & Haime.

[1] Described as *Corbula harpa*, d'Arch. & Haime.

7. *Cerithium* sp.
8. *Strombus nodosus*, Sowerby.
9. *Cassis d'archiaci*, Noetling.
10. *Triton (Simpulum) davidsoni*, d'Arch. & Haime.
11. *Triton pardalis*, Noetling.
12. *Volvaria birmanica*, Noetling.
13. *Terebra fuscata*, Brocchi.
14. *Pleurotoma voyesi*, d' Arch. & Haime.
15. *Myliobates*, sp.

Of these 15 species 4 have been only generally determined, 4 are new forms and the remainder of 5 species have been previously described. Of these the following three species are found in the Gaj group:—

Scalaria subtenuilamella, d'Arch. & Haime.
Strombus nodosus, Sowerby.
Triton (Simpulum) davidsoni, d'Arch. & Haime.

in the. Nari group occur—

Solarium cyclostomum, Menke.
Triton davidsoni, d' Arch. & Haime.

recent is—

Solarium affine, Menke.

of uncertain geological horizon is—

Pleurotoma voyesi, d'Arch. & Haime.

while the last one—

Terebra fuscata, Brocchi.

occurs in the Upper Miocene of Europe.

I do not think that the above meagre list is in itself sufficient to decide the question of the age of the Minbu bed; if any inference could be drawn, it would be that it shows almost a larger number of species found in the Gaj group of Western India than the Yenangyat fauna. It may, perhaps, be possible that its actual horizon is a little lower down in the series than I have here assumed, and that it ought to be included in the Prome stage, although this would not materially alter the views here promulgated regarding the position and age of the Yenangyoung stage. I have assumed from its position in the series above the petroliferous horizon, which, so far as we know for the present, seems to be a very excellent one, that it is younger than the Yénangyat fauna; but of course it is extremely difficult, owing to the monotonous development of the tertiary strata, absolutely to correlate certain beds of two localities, which are at some distance from each other.

That there exists a difference between the two faunas cannot be denied, if we look through the above list; this difference may only represent the local variation of one and the same fauna, or it may really represent a difference in the geological age of the two faunas. For the present this question must be left undecided, as our imperfect knowledge of the tertiary fauna in Burma does not allow such intricate questions as the above to be settled; but my opinion is, that the Minbu fauna holds a position at the base of the Yenangyoung stage, and I have therefore included it in the discussion of this group. Should it, however, eventually be found better to include the Minbu-bed in the Prome stage, it must not be disregarded, that it certainly occupies a higher horizon than the Yenangyat beds.

2. *Cypricardia*-BED.

The geological position of this bed is much more accurately fixed with regard to the Yenangyat bed, than that of the Minbu bed. The Yenangyoung stage has been traced from Yenangyat down to Singu, and it is quite certain that at Singu only the higher beds of the Yenangyoung stage are exposed.

The Cypricardia bed holds a position comparatively close to the upper boundary of the Yenangyoung stage, and it must therefore be decidedly younger than either the Minbu or Yenangyat fauna. It is an argillaceous sandstone containing numerous lumps of hard clay, which, strange to say, are almost in every case perfectly riddled by the borings of a *Lithodomus*. Its thickness is not more than 6 inches, but it forms a most constant horizon, which can be easily recognized at either side of the anticline. It is probably from this bed that the late Dr. Oldham obtained some fossils, when visiting Singu in 1855.[1] Unfortunately this fauna has not been carefully examined yet, because it was only during the field season 1894-95, that I discovered the *Cypricardia* bed, but still the knowledge of the species occuring in the Yenangyat and Minbu beds has enabled me to identify some of the species occurring in it, while other forms were recognised as being absent in the abovenamed beds. The entire character of the fauna of the *Cypricardia* bed is totally different from that of either the Yenangyat or Minbu beds. While in the former the *Gastropoda* predominate—out of a total of 69 species, 45 belonging to the *Gastropoda*—it is certain that in the Cypricardia bed the *Pelecypoda* predominate not only by number of species, but also by number of individuals. The commonest forms are an *Ostrea* sp., *Pecten cf. favrei* d'Arch. and Haime, and a *Cypricardia*, besides *Paracyathus cæruleus*, Duncan. It is, however, strange that, although the *Ostrea* sp. is the commonest form, not a single well-preserved specimen could be obtained. *Pecten cf. favrei*, d'Arch. and Haime, is always well-preserved like the other Pelecypoda, and I dare say that the question whether it really represents the Indian species can now be settled; next in frequency is a beautifully preserved *Cypricardia*, and an *Avicula*, and then comes the easily recognizable *Paracyathus cæruleus*, Duncan. The following is a provisional list of the fossils, which I have been able to recognize; but I wish at once to state that this list is by no means exhaustive.

1. *Paracyathus cæruleus*, Duncan, very common.
2. *Ostrea*, sp. apparently related to *Ostrea*, sp. 1, from Minbu; very common.
3. *Pecten cf. favrei*, d'Arch. and Haime, very common.
4. *Modiola*, sp. 1, rare.
5. *Modiola*, sp. 2, rare.
6. *Lithodomus* sp., very common.
7. *Avicula* sp., very common.
8. *Daphoderma caelata*, Reeve (*Arca burnesi*, d'Arch. and Haime; common).
9. *Venus*. sp. 1, the same as found at Minbu; very common.
10. *Venus*, sp. 2, rare.
11. *Tellina* (*Tellinella*) *hilli*, Noetling; rare.
12. *Tellina kingi*, Noetling; always beautifully preserved, but not common.
13. *Trochus sp.*, *cf. blanfordi*, Noetling; common.
14. *Solarium affine*, Sow.; rare.

[1] Yule, mission to the Court of Ava, p. 27, and Appendix A, page. 319.

15. *Conus (Rhizoconus) mallacanus*, Hwass; rare.
16. *Conus (Leptoconus) marginatus*, Sowerby; rare.
17. *Callianassa* sp. nov. The hands of a gigantic *Callianassa* sp. are not very rare.

To judge from this specimen it seems that the isolated fragment of a finger which I referred to *Pagurush* [1] really belongs to this gigantic *Callianassa.* As I have remarked above, this list is by no means an exhaustive one, and a careful examination of my collection will swell its number considerably; but it may be stated at once, that almost all the forms, which have been recognized hitherto, are identical with those described from the Yenangyat and Minbu beds. On the other hand some new forms, which had hitherto not been found in either of the abovenamed beds, have been discovered; the most conspicuous among these are—

Avicula sp.
Cypricardia sp.

besides various others.[2]

The geological horizon of the *Cypricardia* bed being decidedly higher up in the series than either of the fauna abovementioned, it is almost certain that the faunistic difference noted cannot be considered as only a local variation.

3. *Batissa-(Cyrena-)* BED.

The highest position in the Yenangyoung stage is occupied by a bed which is unfossiliferous almost throughout its whole extent, but containing at two places at least in the neighbourhood of Minlindoung, countless numbers of *Batissa crawfurdi* Noetling and *Batissa petrolei* Noetling. These two forms are also found in the next higher bed, which most decidedly belongs to the Irrawaddi division, and they form the connecting link with that series of strata which contain such an entirely different fauna from that of the older tertiaries.

If the *Cytherea promensis*, a species established by Mr. Theobald, but neither described nor figured, is, as I suppose, identical with either *Batissa crawfurdi* Noetling or *Batissa petrolei*, Noetling, we are bound to assume that this form occurs far down in the tertiary series of Lower Burma. The question is an interesting one, but it can only be decided after the examination of Mr. Theobald's collections. In Upper Burma the *Batissa* bed concludes the Yenangyoung stage, and if we assume that this horizon would be the same in Lower Burma, the logical consequence would be that the Yenangyoung stage is much thicker in Lower Burma and that on the top of the *Batissa* bed there exist several fossiliferous horizons, which are not represented in Upper Burma.

These are, however, views which can only be settled by actual observation in the field, as I do not think that the examination of Mr. Theobald's collections will shed much light on this question, as the positions of the horizons in which the fossils were collected are not always known with certainty with reference to each other.

I may conclude the description of the palæontological features of the Yenangyoung stage with the remark that, to my knowledge, no fossil wood either car-

[1] Memoir, Geological Survey of India, Vol. XXVII, part. I, page 44.

[2] I hope that I shall soon be able to give an exhaustive description of this fauna which, from its geological position, has a particular interest.

bonised or silicified has been discovered in it. The absence may be accidental, but it seems significant to me that hitherto no silicified wood has been found in either group.

c. *Distribution of the Yenangyoung stage.*

The Yenangyoung stage being established as the series of strata intermediate between the Prome stage and the fossil wood group (Irrawaddi division) in Upper Burma, nothing can be said with regard to its distribution in Lower Burma; but it is almost certain that it is also represented in that part, although it seems that it does not form such a well circumscribed series as in Upper Burma. In fact it seems that in Lower Burma it merges more or less into the Prome stage.

In Upper Burma it is well represented near Minbu, at Yenangyoung, Singu and Yenangyat, but it must be kept in mind that the localities where it is well exposed, are comparatively speaking of limited extent, as it appears near the surface only where the conditions have been favourable; and in almost the whole of Upper Burma it remains hidden beneath the overlying Irrawaddi division.

I am not quite certain whether the Yenangyoung stage is represented in the Chindwin hills; it is most probably represented, but it does not seem to form such a conspicuous member in the series. It is, perhaps, possible that part of the sandstone beds, which to a thickness of approximately 6,000 feet overlie the Prome stage, represent the Yenangyoung stage, but with regard to this we must await the result of further examination..

II.—The Irrawaddi division.

The Irrawaddi division comprises, broadly speaking, Mr. Theobald's fossil wood group, and I have therefore to explain why I changed the name and substituted a new term for Mr. Theobald's designation. The chief reason is, that "Fossil wood group" is by no means an appropriate term for this series. Not only are numerous beds, particularly in the lower part of the series utterly destitute of fossil wood, but what is much more important certain post-tertiary beds abound in fossil wood. In fact, one would rather feel inclined to apply the term "fossil wood group" to some diluvial gravel beds, so full are the latter sometimes of enormous pieces of fossil wood. For this reason these post-tertiary gravels have frequently been mistaken for tertiary strata, and, in order to avoid any confusion, I preferred a different name, and have therefore chosen the name Irrawaddi division from the enormous development attained by these beds in Upper Burma in the basin of the Irrawaddi.[1]

a. *Thickness.*

I include in the Irrawaddi division all the beds above the Yenangyoung stage which are characterised by the remains of terrestrial and fluviatile animals but below the unconformity which separates the post-tertiary beds from those of tertiary age.

The Irrawaddi division, as thus circumscribed, exhibits a measured thickness of 4,620 feet in the neighbourhood of Yenangyoung, but it is quite certain that this does not by any means represent the total thickness of the division.

[1] In previous papers I used the term Irrawaddi sandstone to designate this group on account of the preponderance of yellow sandstones, but I think that the term Irrawaddi division would be preferable.

The cross-cut of the Irrawaddi bed between Singu and Salemyo affords an exceedingly good section of the Irrawaddi division, from its base to most probably within a short distance of its uppermost beds. The calculated thickness of the Irrawaddi division in this section would be about 20,000 feet. This will probably nearly represent its greatest thickness in Upper Burma, at least in that part of the country which chiefly interests us for the present.

In Lower Burma the Irrawaddi division is apparently much less developed than in Upper Burma. Mr. Theobald gives no figures regarding the total thickness of his "Fossil wood group" but, to judge from his figures, it cannot be anything like that attained in Upper Burma.

b. Lithological characters.

The rocks which compose the Irrawaddi division form by their light colours a most marked contrast to the dark coloured beds of the older strata. Light yellow is the prevailing colour, but dull red, brown and olive-green tinges are by no means rare, although they take only a subordinate rank.

The predominant rock is a very soft sandstone, which might perhaps better be termed "sand-rock" of light yellow colour. It forms thick beds which frequently contain nodular or kidney-shaped concretions of extremely hard siliceous sandstone. These concretions which are sometimes of considerable size, are arranged in strings, parallel to the bedding, and stick out of the surrounding softer material forming a very conspicuous feature in the landscape. Alternating with the sandstone are beds of olive-coloured soft clay, which, however, never attain the thickness of the sandy beds.

Still more subordinate, but very important from a palæontological point of view are dull red bands of a ferruginous conglomerate. Sometimes all foreign matter is so rare that these bands form regular layers of cellular iron ore, which have in former times been used for the production of iron. Their thickness changes from a few inches up to about 15 feet, but it must be mentioned that they do not as a rule seem to form continuous layers, but more or less irregular strings, which although parallel to the bedding, may suddenly die out at one place and re-appear at another. The only exception seems to be the ferruginous conglomerate at the base of the group, which forms a very continuous layer of which I shall presently have more to say.

The composition of these ferruginous conglomerates proves that they must have been formed along a beach, for they exhibit all the flotsam and jetsam which is generally gathered in such places. There are small pieces of drift-wood now changed into hydroxide of iron, small pebbles of quartz and ferruginous clay, rolled fragments of bones, all mixed up, sometimes gathered in small heaps, sometimes spread out and forming only a thin, disconnected layer. A femur of probably *Rhinoceros sp.* which I found in one of these layers affords an exceedingly good illustration regarding the conditions under which they were formed. It rested with one side on a bed of sandstone and around it, and partly over it, were heaped ferruginous clay—pebbles, etc. etc.; now that side on which the bone rested was considerably rubbed, thus indicating the result of the friction on the underlying sand, produced by the gentle rocking of the bone by the waves, while lying on the beach.

The ferruginous conglomerates afford us therefore a material help, with regard to the conditions under which the Irrawaddi division was deposited, and from this point they deserve special attention.

c. Palæontological characters.

The Irrawaddi division is undoubtedly the most interesting in the whole series of the Burma tertiaries owing to the fact that it contains numerous remains of terrestrial and fluviatile animals. It is, however, an open question whether these remains are generally distributed throughout the group, or whether they are restricted to certain localities only. It seems to me that there is no reason why they should not be found anywhere, whenever the strata of this group are exposed, but so far as my experience goes they are much more frequent at certain localities than at others.

For instance, along the river shore from Nyounghla to a few hundred yards north of Sithabwé village fossil bones are extremely common; further north they become scarce, and north of Yenangyoung I have not yet found a single specimen, although the beds developed in this part are the same as those south of Yenangyoung village. Near Pagan I have searched for miles along the bank of the Irrawaddi, where the Irrawaddi division is well exposed, without finding a single specimen.

It is further very remarkable that not only were the first fossil bones which came from Burma, and which were described by Dr. Buckland as early as 1823,[1] collected near Yenangyoung. probably at the very locality which I mentioned above, but that also the chief collection of fossil bones which was made by the members of the Mission to Ava, was found near Yenangyoung.[2] To judge from a remark made by King Mindon Min in the most interesting conversation recorded on pages 112 and 113 of Yule's Mission to Ava, "Biloos" bones[3] are very common in the Yaw country, and it is quite possible that the list which Mr. Theobald gives[4] as coming from "Ava" refers to fossils collected in the Yaw country. They certainly cannot come from Ava, as nowhere in the neighbourhood of that town do beds of the Irrawaddi division occur.

Mr. Theobald expressly states that in Lower Burma the fossil wood group is only locally mammaliferous, and if we thus take all the evidence we must believe that the fossil bones are only of frequent occurrence at certain localities, of which three are known at the present time, *viz.* :—

1. Lema, near Thayetmyo in Lower Burma.
2. Bank of the Irrawaddi between Nyounghla and Yenangyoung.
3. Yaw-country.

Of these three localities, I know only the second from personal experience; as regards the first, we have the evidence of Mr. Theobald, and as regards the third, I must say that all the probabilities are in favour of the occurrence of fossil bones, because the very strata in which they have been found near Yenangyoung are largely developed in the broad valley of the Yaw. On the other hand, I must say that this is no absolute proof, for although the Irrawaddi division is largely developed in Northern Burma, as for instance, in the Pakôkku, Upper Chindwin, Ye-u and Shewbo Districts, yet I have not found a single specimen of a fossil bone, although I repeatedly and carefully searched for them. I may have overlooked them, a possibility which I fully admit, and future researches may discover them in

[1] Transactions of the Geol. Soc., Series II, Volume II, page 377.
[2] Narrative of the Mission to the Court of Ava, 1858, page 315.
[3] Biloo, a fabulous monster.
[4] Op jam. cit., p. 67.

parts where I have looked in vain, but for the present we must content ourselves with stating that the locality in Upper Burma where fossil bones have been found in largest numbers is the country around Yenangyoung.

The seemingly erratic manner of horizontal distribution of the fossil bones might perhaps be explained if we assume that they are restricted to a certain portion of the strata of the Irrawaddi division, and that they are therefore only found at places at which that particular portion is well exposed.

The question is a difficult one to decide, and would require further observations, but if one may be allowed to draw a conclusion from the occurrence of the fossil bones around Yenangyoung it seems that they are restricted to the lower and middle parts of the Irrawaddi division, while they are extremely rare, if not entirely wanting, in the upper part, being replaced by the frequently occurring fossil wood. This supposition would explain the curious mode of occurrence near Yenangyoung the youngest strata of the Irrawaddi division being chiefly exposed along the river bank south of Nyounghla and north of Yenangyoung.

The late Dr. Oldham[1] had already observed that the fossil bones are chiefly found in the ferruginous conglomerates and "breccia or conglomerate" which he has found at Minlindoung[2] and which is considered by me as the bottom-bed of the Irrawaddi division, and distinguished as a special bone-bed, of which more will be said later on. Besides this bed, I found fossil bones at several higher horizons, and I think that I am able to recognize certain well marked horizons characterised by their vertebrate fauna; this sub-division will be discussed presently.

As regards the fauna, which has left its remains deposited in the Irrawaddi beds, the following species and genera have been noticed by various authors. The first to determine the collection made by Mr. Crawford was Dr. Buckland, who recognised the following species:—

Mastodon latidens, Clift.
,, *elephantoides*, Clift.
Hippopotamus sp.
Rhinoceros sp.
Sus sp.
Tapirus sp.
Bos sp.
Cervus sp.
Antelope sp.
Crocodilis sp. *aff. vulgaris.*
Leptorhynchus sp. (*Garialis* sp.)
Trionyx sp.
Emys sp.

The specimens collected by Dr. Oldham, of which he has given a rough list at the end of his paper, have subsequently been more accurately determined, and I suppose that the list of fossils from Ava which Mr. Theobald gives[3] refers to them. The following species and genera are enumerated:—

Mastodon latidens, Clift.
Elephas cliftii, Cautl. and Falc.
Mastodon elephantoides, Clift.

[1] Mission to Ava, page 315.
[2] Dr. Oldham spells the word Menleng.
[3] Op. jam. cit., p. 67.

Rhinoceros sp.
Equus sp.
Hippopotamus (Hexaprotodon) irravadicus, Caut. and Falc.
Merycopotamus dissimilis Caut. and Falc.
Sus sp.
Tapirus sp.
Bos sp.
Cervus sp.
Antelope sp.
Crocodilis sp.
Leptorhynchus sp.
Emys sp.
Trionyx sp.
Colossochelys sp.

Most of these have been subsequently examined and described by Mr. Lydekker in the Palæontologia Indica and a few more species added to the above list, *viz.*, *Ursus sp.*, *Mastodon sivalensis*, *Rhinoceros sp.*, *Vishnutherium irravadicum*, *Bos sp.* The following species have been collected by me in the neighbourhood of Yenangyoung:—

1. *Mastodon latidens*, Clift.
2. *Stegodon cliftii* Caut. and Falc.
3. *Acerotherium perimense*, Lyd.
4. *Rhinoceros sivalensis*, Lyd.
5. *Hippopotamus irravadicus*, Caut. and Falc.
6. *Sus titan*, Lyd.
7. *Bubalus* sp.
8. *Boselaphus* sp.
9. *Hippotherium antelopinum.*
10. *Cervus* sp.
11. *Lutra* (?) sp.
12. *Crocodilis cf. biporcatus* (?).
13. *Gavialis sp. cf. gangeticus.*
14. *Emyda palaeindica.*
15. *Trionyx* sp.
16. *Colossochelys atlas.*
17. *Testudo* sp.
18. *Emys* sp.
19. *Carcharias* sp.

Besides the species above mentioned, there are still some teeth representing three or four more species, which are, however, too ill-preserved to be determined.

Now, if we compare these lists of fossils collected at three widely separated periods, their great similarity is rather striking. In fact, although I had the best opportunity of all, my collection only adds a few more species to those already known through Dr. Buckland and Mr. Lydekker; but even these do not in the least alter the character of the fauna. If we omit the rather doubtful *Equus* sp. and assume that Mr. Oldham's *Antelope* sp. is identical with *Boselaphus* sp., the fauna consists of 26 species altogether. The character of this fauna is decidedly expressed by its composition, it being almost exclusively composed of animals which led either an entirely aquatic life or dwelt in swampy marshes bordered by shady forests, and required besides large quantities of vegetable food and an abundance of water for their welfare. Out of the 26 species above mentioned, seven are of entirely aquatic habits, *viz.*—

Crocodilis cf. biporcatus (?).
Gavialis, sp. cf. gangeticus.
Emyda palaindica.
Trionyx sp.
Colossochelys atlas.
Emys sp.
Carcharias sp.

To these we may add two which lead a semi-aquatic life, *viz.*:—

Hippopotamus irravadicus.
Lutra sp.

Out of the remaining species we may safely suppose that—

Rhinoceros [*Acerotherium*] *perimense.*
Rhinoceros sivalensis.
Rhinoceros sp.
Bubalus sp.
Sus titan.
Tapyrus sp.
Vishnutherium irravadicum.

and most probably also—

Merycopotamus dissimilis.
Hippotherium antelopinum.

chiefly dwelt in marshy swamps, while the remainder, *viz.*:—

Mastodon latidens.
Mastodon sivalensis.
Stegodon cliftii.
Boselaphus sp.
Cervus sp.
Bos sp.
Ursus sp.
Testudo sp.

most probably lived in the shady forests bordering the marshes.

The only region, in which were all the conditions for the existence of a fauna constituted as the above, would be the low islands and estuaries of the delta of a large stream. The numerous brooks and creeks afforded ample room and nourishment for the members of the reptilian tribe as well as for the sharks, while the low islands, covered with a luxurious vegetation, were the places where the *Ungulata* and *Proboscidea* led a comfortable life.

If we now examine the homotaxial relations of this fauna, it is at once obvious that it bears the strongest resemblance to the Siwalik fauna of India. Out of 26 species, at least 11 are recognized with certainty as being identical with Siwalik forms; these are :—

1. *Mastodon latidens.*
2. *Mastodon sivalensis.*
3. *Stegodon cliftii.*
4. *Rhinoceros* (*Acerotherium*) *perimense.*
5. *Rhinoceros sivalensis.*
6. *Merycopotamus dissimilis.*

7. *Sus titan.*
8. *Hippotherium antelopinum.*
9. *Gavialis sp. cf. gangeticus.*
10. *Emyda palaindica.*
11. *Colossochelys atlas.*

That is to say, all such forms as have been specifically determined, except those of course which are indigenous to Burma. Out of the remaining 15 species, two, *viz.*—

1. *Hippopotamus irravadicus.*
2. *Vishnutherium irravadicum.*

are indigenous to Burma, while the remaining 13 species have for the present been only generally determined.

The proportion of species identified with Siwalik forms is therefore, if we disregard the two indigenous species, about 50 per cent. of the total or much larger than Mr. Oldham supposed it to be.[1] In fact, I have not the slightest doubt that the proportion will be still greater once the fauna has been carefully studied, there being certainly among the 13 species hitherto only generally determined some which will be found identical with Siwalik forms.

On the other hand it cannot be denied that as regards the general character of the fauna of the Irrawaddi division, it exhibits some features decidedly different from the Siwalik fauna. The *Ungulata*, although being in the majority, are represented by a much smaller number than in the Siwalik fauna, but the most striking feature is the remarkable scarcity of *Carnivora* of which only two species have so far been discovered in the Irrawaddi division, which contrasts strongly with the large number of species in the Siwaliks. I am, however, not prepared to state that these differences are absolute, my opinion is rather that once the Irrawaddi division is more explored, and we know its fauna to a larger extent, the discrepancy between the total number of species on one side, and the remarkable difference of the development of the *Carnivora* in both regions will disappear, or at least become smaller.

For the present we must content ourselves with having pointed out that notwithstanding its smaller number of species the fauna of the Irrawaddi division must be considered as correlative to that of the Upper Siwaliks.[2]

Luckily in Burma we are in a much better position for ascertaining the age of the Irrawaddi division than were the Indian geologists, when fixing the age of the Siwaliks; as previously pointed out, the Irrawaddi division rests conformably on beds of miocene age. The natural conclusion is therefore that the Irrawaddi division represents the Pliocene of Europe, a supposition which is fully in accordance with the views lately promulgated by Mr. Oldham in the second edition of the Manual of the Geology of India, according to which "it is impossible to deny that the balance of evidence is in favour of a Pliocene age." In fact we might rather say that the evidence of the fauna of the Irrawaddi division is a further strong proof of the Pliocene age of the Siwaliks, for it would be impossible to assume that the Irrawaddi division was of Upper Miocene and not of Pliocene age. Such an assumption would simply mean a perversion of all facts and a negation of the natural divisions of the Tertiary rocks in Burma.

[1] Manual of the Geology of India, 2nd edition, page 341.

[2] Mr. Lydekker, when describing the fauna of the Siwaliks, never seems to have doubted this, for the specimens collected in Burma are included among his list of the Siwalik species.

Besides its fauna the Irrawaddi division is distinguished by an abundance of fossilized wood. In fact the fossilized wood has attracted the attention of travellers in Burma more than anything else with the exception perhaps of the occurrence of rubies. There is hardly a book dealing with Burma in which reference is not made to the fossil wood, and the quaintest theories have been set forth to explain its presence in such abundance. It is, however, strange to say that although quantities of it must have been brought to England since the end of the last century no scientific examination of it has hitherto been made.

The fossil wood is distributed throughout the whole of the Irrawaddi division, but I am unable to say whether there is any rule as regards its vertical distribution. Frequently enormous logs may be seen imbedded in the strata. I noticed a specimen of about 60 feet in length, east of Yenangyoung, broken into several pieces by its mere weight, but still partly imbedded in the soft sandstone. Pieces of smaller size are of course extremely common, and cart loads might be picked up in a few hours.

There are two modes of petrification, the one in which the wood fibre has been replaced by silica, the other in which it has been replaced by hydroxide of iron. The former is the common one; the latter has been only observed in a few cases of drift-wood imbedded in the ferruginous conglomerates.

The question as to how this wood became fossilized has of course occupied the attention of more than one observer, but it cannot be said that a satisfactory explanation has hitherto been given.

Mr. Theobald having observed that the fossil wood when found *in situ* never exhibits any signs of being rolled or otherwise worn away, nor gives any other indications of transport, therefore assumes that the wood could not have been in a petrified state prior to being embedded in its present position. He therefore supposes that petrification took only place after the trees had found their present resting place, an assumption which he explains by the following quaint theory. He supposes that the trunks of trees floated about till water-logged in shallow lakes, in which, on sinking, they became mineralised through the agency of springs holding silica in solution.

The logical outcome of this theory is, that wherever a single specimen of a silicified log is found *in situ*, we are bound to suppose that just underneath that very log, a spring rose, in order to petrify it, and, having done its work, disappeared without leaving behind it any other traces of its activity. The absurdity of such a theory is too evident, and no more need be said about it, but in discarding one theory one ought to be able to replace it by a more satisfactory one. I must, however, confess that in matters of this kind, which are chiefly of a chemical nature, I am unable to give a satisfactory solution. I was therefore extremely glad to find that Dr. Irving has propounded a theory regarding the origin of the silicified wood in the Pliocene of the Libyan desert[1] which might be equally well applied to the silicified wood of Burma. I cannot therefore do better than give Dr. Irving's own words, which are as follows:—

"Remarking on the silicification of wood, he wished again to emphasize the difference in the action of carbonic acid in petrological changes, according as it

[1] Quart. Journ. of the Geol. Soc., 1894, volume L., page 547.

existed as a free acid or in combination with a base, as in sodium carbonate. The extent of the "natron" deposits pointed to the supply of alkaline waters over large areas in former times, holding the mineral in solution. The reaction of such waters upon the potash felspar of the sands furnished, by the disintegration of the crystalline rocks, would not lead to the deposition of free silica (as in the ordinary process of kaolinization), because, while the potassium was taken up as a carbonate and carried away, the silica was also removed in solution, through combination with the sodium, to form sodium silicate. This last-named salt in solution would be readily decomposed by the organic acids and the carbonic acid furnished by decaying vegetable tissue, the silica being then deposited as a colloid *in situ*, and thus retaining the structural forms of the original tissue."

I may at once state that there is ample proof that the strata of the Irrawaddi division still contain the salts which were required for the above process.

This may here also be a fitting opportunity to correct an error, which though insignificant enough has been the source of the erroneous idea regarding the origin of the Irrawaddi division put forth in the 2nd edition of the Manual of the Geology of India. Mr. Theobald's statement that the silicified wood is never bored by xylophagous mollusca, has been used as a strong argument against the estuarine origin of the "Fossil wood group." The statement that the silicified wood is never bored by xylophagous mollusca is absolutely erroneous, as I have repeatedly found large pieces which have been riddled by the borings of these mollusca. Such pieces are rather rare, but still they exist, and with their existence the whole argument based on their absence falls through, which is another proof of the fallacy of negative proofs.

To conclude the palæontological features of the Irrawaddi division, I may mention here the curious flint flakes which have been found by me in the ferruginous conglomerate at the base of the group and which I described in a separate paper.[1] I may mention here that in the meantime several experienced colleagues have expressed their opinion that these flakes are in reality of artificial origin. As this is not a fitting place for the discussion of this question I simply record the fact without going into details.

d. Subdivision of the Irrawaddi division.

It is quite clear that the same reasons which render a subdivision of the Pegu division, extremely difficult apply also to the Irrawaddi division, even perhaps in a greater degree. It seems an almost hopeless task to subdivide this series of sandstones, clays, etc., of which the lowest exactly resemble in appearance a bed at the top of the series. But even after succeeding in working out a subdivision of a special locality, it is extremely difficult, if not almost impossible, to correlate the subdivisions of two somewhat distant localities, without having the connecting links.

Mr. Theobald's subdivision of the Fossil wood group in Lower Burma, as well as my own for the country around Yenangyoung, cannot therefore have more than local value. It may perhaps be probable that my subdivision, based on palæontological evidence, will eventually prove to be applicable over a larger area, but for the present there is no further support in aid of this supposition.

Mr. Theobald divides the Fossil wood group in descending order as follows:[2]—

[1] Records of the Geolog. Survey of India, volume xx, page 101.

[2] Op. cit., page 62.

a. Fossil wood sands.—Sand, in parts gravelly and conglomeratic, characterised by the profusion of concretions of peroxide of iron, associated with it. Fossils: Trunks of silicified exogenous wood, and, locally, mammalian bones. In the subordinate beds of conglomerate, rolled fragments of wood as above, silicified (that is, mineralized subsequent to their entombment), mammalian and reptilian bones and teeth of cartilaginous fish (squalidæ).

b. Fine silty clay.—Fine silty clay with a few small pebbles, mixed with sand, in strings here and there; the whole very fine and homogeneous and devoid of fossils.

c. Mogoung sands.—A mixed assemblage of shales, sands and conglomerates, the last very subordinate, partaking much of the charactersof beds *a* and *b*; a little of the concretionary oxide of iron. Fossils: rolled wood silicified, mammalian and reptilian bones and cartilaginous fish teeth. Towards the base, the beds contain marine shells and pass into those of the next group.'[1]

For the country around Yenangyoung I divide the Irrawaddi strata into the following subdivisions in descending order:—

1. Yellow, soft and friable sandstones, alternating with beds of brown clay. Fossil wood not very common, no fossil bones.

2. Zone of *Mastodon latidens* and *Hippopotamus irravadicus.* Lithological characters as above; fossil wood very common.

3. Zone of *Hippotherium antelopinum* and *Acerotherium perimense.* Ferruginous conglomerate.

These three zones are of very unequal thickness, and although the boundary between zones 3 and 2 is a very sharp and natural one in a palæontological as well as in a lithological sense, yet that between the two upper zones (2 and 1) is more or less artificial, the division being simply based on the apparent absence of fossil bones in the upper beds of the series following immediately above zone 3. As a more detailed description of the development of the Tertiary system near Yenangyoung will be given in the memoirs of the Geological Survey of India, Vol. XXVII, it is unnecessary here to dwell any longer on this subject.

d. Distribution.

The Irrawaddi division caps the older Tertiary beds nearly everywhere in Upper Burma within the boundaries of the basin of the Irrawaddi. Of course it varies considerably in different parts of Upper Burma, but it can always be easily recognised. In Lower Burma it seems to cover a much smaller area, being apparently much eroded, so that only isolated patches remain, while in Upper Burma it forms a continuous cover, stretching from the foot of the Arrakan Yoma as far as the foot of the Shan hills.

The following table shows the manner in which I have subdivided the

[1] *Viz.*, Pegu group.

Burma Tertiaries, with the names given to each subdivision; these are arranged in such a way that at a glance it may be seen what principles have guided me:—

Character of fauna.	Name of Series.		Character of Deposits.	Character of sediments.	Name of division.	
Terrestrial and Fluviatile.	Burma series.		Deltaic.	Yellow sandstones, olive-coloured clays, ferruginous conglomerate; no gypsum.	Irrawaddi division.	
Marine	ARRAKAN SERIES.	UPPER.	Littoral and Estuarine.	Yellow sandstone, olive coloured and bluish clay; gypsum.	Yenangyoung stage.	Pegu division.
				Grey sandstone, bluish clay.	Prome stage.	
		LOWER.	Littoral	Limestone, grey sandstone, bluish clay.	Nummulitic division.	
			Deep sea	Shales	Chin shales.	

In concluding this sketch of the Burma Tertiaries, the following table will convey my views as to the correlation of the Tertiary strata in Burma, India and Europe. It would, of course, be useless to attempt anything beyond a general comparison, and, I think, we must be satisfied if we recognize with some certainty the large sub-divisions of the European Tertiaries in distant Burma.

The Tertiaries of India, of which those of Burma form only the eastern continuation, exhibit, by their remarkable division into two large groups differing widely in the character of their respective faunas, such peculiarities that any correlation with the Tertiary rocks of Europe, except one based on the broadest lines, is almost impossible, a fact which has already been noted by Dr. Blanford.

Europe.	Burma.				Western India.	Himalaya, North-West area.	Himalaya, Simla area.
Pliocene.	Burma Series.			Irawaddi division.	Manchhar group.	Upper Siwaliks.	Upper and middle Siwaliks.
Miocene	ARRAKAN SERIES.	UPPER.	Pegu division.	Yenangyoung stage.	Gaj group	Lower Siwaliks.	Nahan beds Lower Siwaliks.
				Prome stage.	Nari group	Murree beds	Kasauli group.
Eocene		LOWER.		Nummulitic division.	Kirthar group	Upper and Lower Nummulitic.	Dagshai and Subathu group.
				Chin shales	Ranikot group	?	?

Notes from the Geological Survey of India.

I. Rewah.—" Vindhyans."—Mr. Oldham and Mr. Datta have been at work in the Rewah State, north and south of the Sone river; their surveys have already resulted in most interesting and, in some degree, rather startling facts, some of which are briefly noticed in the Annual Report; but since the latter has been set up in type some new facts are reported by Mr. Oldham. He distinguishes the following rock groups in ascending order:

(*a*) A transition series, into which granitic rocks intrude, locally altering them into schists; Mr. Bose had separated the latter from the transitions as a separate system, but Mr. Oldham shows this to be unnecessary.

(*b*) The transitions are unconformably overlaid by a series of rocks, consisting of a basal sandstone and conglomerate, indistinguishable from similar beds at the base of the so-called lower Vindhyans, followed by a great but indeterminable thickness of red, and occasionally green, slaty rock.

(*c*) This series is again unconformably overlaid by the so-called lower Vindhyans; Mr. Oldham drops that name and returns to the older term of the Semri series first used by Mr. Medlicott for the rocks of the same age in Bundelkhund. He has obtained evidence that this series is distinct from the

(*d*) Kymore group or Vindhyans proper, which rest unconformably on the Semri series.

Gondwanas.—Mr. Oldham re-examined a small coal-field, which Mr. Smith had partly surveyed some years ago; the Barakar age of the rocks has now been established, as they contain Vertebraria, Glossopteris, Schizoneura, etc. Mr. Oldham met with two coal-seams, respectively of 6′ and 5′ 6″ thickness; the former is 1½ miles south-west by west of Ujeini, the latter 2 miles north of Amilia, both places near the eastern edge of sheet 476.

II. Madras.—Mr. Middlemiss was engaged during January in examining the magnesite area of Kanjamallai, regarding which he reports:

(*a*) The ultra-basic rocks of the north-west end of Kanjamallai and the derivative magnesite (first discovered by Mr. Holland) were found to be much the same as those of the Chalk Hills. Their extent is, however, insignificant. Olivine-bearing ultra-basic rocks were found to run in a broken band nearly east to west from near Ellampaddi to the point at which the ridge becomes steeper, towards the high western end of Kanjamallai ridge. Pure olivine-rocks, such as compose much of the fundamental rocks of the Chalk Hills, are wanting here. Chromite was found at the eastern end of the band with the magnesite, running as a vein, 4—5 inches wide, through the serpentinized olivine-bearing rock. The amount of this mineral exposed is small. Excavations alone could decide its worth. The magnesite is too unimportant for economical purposes.

(*b*) South of Kanjamallai, a ridge near Ariyanur is composed of altered ultra-basic olivine-rock very closely resembling the dunite of the Chalk Hills. The same rock "massif" becomes talcose, with beds of rather impure potstone, which is locally excavated for making into vessels. A few unimportant magnesite veins occur in this ridge. Incidentally sections were carried round and across the Kanjamallai ridge, and the valuable magnetite bands were located and mapped on the 1-inch maps as closely as possible. The conclusion arrived at was that only the lowest band need be considered from an economical standpoint, because it seems to be the only one which contains the richer and compacter form of the ore.

(*c*) Between Macdonald's Choultry and Konganapuram, several veins of coarse graphic granite with mica were traced; they seem to be connected with the Idapaddi veins and mica quarries. The great granitic area of granite veins (in a biotite gneiss), of which the Sankaridrug hill forms one summit was mapped.

Mr. Middlemiss afterwards examined the rocks of Valaiyapatti and reports:

(*a*) *Magnesite and ultra-basic rocks.*—The magnesite occurs in very small quantities. The rocks associated with it resemble entirely those at the north-west end of Kanjamallai, as far as their appearance in the field permits an opinion. The absence here as at the latter place of pure olivine rock or dunite is noteworthy. Forming a long low ridge running east and west from Valaiyapatti there are interesting examples of the above type in close association with a very acid rock, namely, a coarse graphic granite composed almost entirely of pink orthoclase and quartz. Both rocks are intrusive among the basal gneisses of that area in parallel lines. Some good instances of this are to be found west of Valaiyapatti. The graphic granite was probably intruded last.

(*b*) *Charnockite south of Salem.*—Between Muttu Kalipatti and Salem on the Namakal-Salem road occurs a great exposure of Charnockite. From its position, strike and general appearance it is a continuation of the Shevaroy hills massif.

(*c*) *Chalk hills.*—As a whole, the aspect of each magnesite area in the Chalk hills near Salem is that of a series of concentric ellipses (roughly speaking) of rocks of varying composition and basicity.

At the centre of each area occurs the chromite in veins among the dunite and serpentine. Surrounding this is a paler dunite zone (almost pure olivine, partly or wholly converted into magnesite). Surrounding this again is a small ring of rocks containing olivine and pyroxene with sometimes biotite. Surrounding this at certain points come rocks like the last, but with felspar and quartz in small quantities. Finally, surrounding the whole area, come great ridges of hornblende-garnet rocks set among and with the ordinary gneisses of the country.

III. Sind. (*a*) *Salt.*—Mr. LaTouche, while superintending the trial-boring for oil at Sukkur, had occasion to examine a very interesting occurrence of rock-salt in nummulitic limestone. The spot where this mineral is found is about half a mile south-east of the village of Aror, which lies at about 4 miles east of Rohri on the left bank of the Indus. Here the low ridge of nummulitic limestone, which extends from Sukkur and Rohri for about 50 miles southward, is intersected by a broad valley, through which the Indus is said to have flowed in former times. On the south side of this valley, in the precipitous scarp overlooking the alluvial plain of the Indus, a band of nummulitic limestone is found about 20 feet from the base of the scarp, and portions of this band contain chloride of sodium in the form of nests and strings, whilst the whole band possesses a slightly saline taste.

(*b*) *Oil.*—Near the village of Kundra, about 8 miles south of Rohri, the natives of that part of Sind knew of a spot where a strong smell of earth-oil could be perceived, and where they used to drive their cattle during the hot weather, as flies are said to avoid the place, which is in the midst of a sandy plain, the present alluvium of the Indus. Latterly Mr. LaTouche had a well dug to ascertain the cause of the exhalations; at a depth of about 16 feet from the surface, the volume of gas issuing from the soil became so large that the men employed could no longer work in the hole without danger of suffocation. Indeed, in two instances, they were so overcome for the time being that they had to be hauled up with ropes. It was therefore necessary to continue sinking the well by means of an improvised dredger worked from above, and after a good deal of labour water was reached at a depth of 20 feet from the surface. On continuing the sinking for two feet or so below the level of the water, films of oil began to appear on the water,and on dredging up some of the sand from the bottom these films could be seen oozing from it upon the water. The quantity is of course exceedingly small, but it is enough to show that there is probably an escape of oil from the rocks below the alluvium, sufficiently large to have impregnated the latter, which is possibly some hundreds of feet in thickness at that spot. The indications are sufficiently promising to justify the sinking of a boring here.

The gas which escapes from the well is apparently composed principally of carbonic acid, for a light is immediately extinguished by it. But from its smell it is probably mixed with some gaseous hydrocarbon. It is probably caused by the oxidation of hydrocarbons during their slow passage through the alluvium.

There is no outcrop of solid rock anywhere in the neighbourhood of the well, the nearest being the scarp of nummulitic limestone, which forms a low ridge running south from Rohri and about 6 miles east of the well. The intervening ground is covered by the alluvium of the Indus, and at the bottom of the well, fine dark grey alluvial sand was found.

IV. Gondwanas in Argentina.—Dr. Fritz Kurtz, Professor of Botany at the University of Cordoba Rep. Argentina, writes to Dr. F. Noetling that in 1887 he received some fossil plants from Bajo de Velis in the Sierra de San Luis, amongst which he determined a *Neuropteridium* sp., he considered the species as new and described it as *N. argentinum*, Kurtz. However, after having received Vol. III of Feistmantel's Gondwana flora, he recognized at once that his new species was identical with *N. validum*, Feistm, from the Kaharbari beds.

Since that discovery he received some more fossil plants from Cachente, Uspallata (east slope of the Cordillera) and others from the abovenamed locality: among the latter he recognized:

Gangamopteris cyclopteroides, Feistm.
Neuropteridium validum, Feistm.
Noeggerathiopsis hislopi, Feistm.
Equisetites sp. nov.
Sphenozamites sp. nov.
Walckia (?) sp.

To this discovery, which is of the utmost importance for the homotaxy of the Gondwanas, I may add that it forms an additional evidence for the general similarity of geological structure between the southern part of South America and South Africa; we have in both continents marine devonian strata which have yielded practically the same fauna.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

The 1st May 1895.

RECORDS

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On the Jadeite *and other rocks, from* Tammaw *in Upper Burma: by* PROFESSOR MAX BAUER, *Marburg University:* (*translated by* DR. F. NOETLING *and* H. H. HAYDEN).

In the following pages I propose to describe the rocks collected by Dr. Noetling at the jade mines near Tammaw in Upper Burma, and which are now in the collection of the Geological Survey of India. These specimens including the jadeite and the serpentine (the most important) bear all the characteristics of true rocks.

Jadeite.

Jadeite.—The jadeite forms a fine-grained mass, chiefly white, and bearing at first sight a certain resemblance to marble. The size of the grains is not uniform; they are at times so small as to be indistinguishable by the naked eye, while at times they are somewhat larger, in which case they are characterised by an elongated form and distinct cleavage. On account of the smallness of the grains no single individual could be separated, and further information could be obtained only by means of the microscope. I will, however, first describe the general appearance of the jadeite.

General characters.

The colour of all specimens under my observation is a clear snow-white on fresh fracture; this monotonous white is, however, relieved by beautiful emerald-green spots, which represent the really valuable part of the stone. They are of variable size, being sometimes as large as a lentil or a pea, sometimes attaining a diameter or several centimetres. The colour is in many cases very intense, but in others again quite pale, at times forming a faint film-like covering over larger or smaller portions of the surface. As it approaches the white mass of the rock, the colour changes abruptly, without, however, there being any well-defined boundary between the two. The green colour is due to the presence of a small quantity of chromium, for powder of an intensely green colour gives an unquestionable Cr. reaction before the blowpipe: this, however, is less distinct when paler powder is used, and is entirely absent in the white portions of the rock. In the inner portions, when fresh, the lustre is vitreous, but towards the surface becomes somewhat duller. The fracture is uneven and splintery, while the hardness exceeds that of felspar, but is not so high as that of quartz. The tenacity is not very high; at some places splinters can be easily removed. This character varies, however, in different specimens, and at times even in the same specimen. This I believe to be due to disintegration, and also in part to cataclysmic structure, which, as we shall presently see, is a characteristic feature of the jadeite from Tammaw.

Specific gravity.

Special care was exercised in the determination of the specific gravity owing to the fact that in samples of jadeite from Bhamo, which might perhaps be considered identical with specimens from Tammaw, it was found to be very low. The average specific gravity of the Tammaw jadeite is about 3·3, while Issel gives that of two specimens of green jadeite from Bhamo, as 3·10, which corresponds with the values obtained by Damour. Mallet states that the s.g. of the Tammaw jadeite is 3·24. Six specimens of different degrees of coarseness served for my observations. In all of them the s.g. is high, and averages about 3·3, being sometimes higher, sometimes lower. By means of the hydrostatic balance and the pyknometer the following figures were obtained:—3·338, 3·332, 3·330, 3·329, 3·327, 3·325. No connection could be traced between the specific gravity and the texture of the rock. This variation of the s.g. is probably due to small differences in the chemical composition. It is, however, difficult to explain the wide divergence of the results obtained by Issel, Damour and others, and only by the examination of the s.g., chemical composition and microscopic characters of further material can we hope to solve this difficulty. All this, however, should of course be done for one and the same piece.

Chemical composition.

Dr. Busz has made an analysis of one of the coarse-grained pieces (s.g.=3·332), using as fresh and pure a portion of the rock as could be obtained. The results of his analysis are given under I. He specially notes the absence of chromium and oxides of iron.

	I.	II.	III.	IV.	V.
$Si\,O_2$	58·46	59·27	57·63	58·99	59·45
$Al_2\,O_3$	25·75	25·33	24·10	24·77	24·32
$Fe_2\,O_3$	...	...	...	·32	·36
$Ca\,O$	·63	·62	·62	·14	·22
$Mg\,O$	·34	·48	·48	Traces.	
$Fe\,O$	...	·71	·71	...	...
$Na_2\,O$	13·93	13·82	13·82	14·51	14·42
Loss	1·00	...	...	1·14	1·15
	100·11	100·23	97·36	99·87	99·92

The figures obtained by my analysis (I) very nearly agree with those obtained by Damour from a jadeite from Asia (II). If we adopt the views expressed by E. Cohen (Neues Jahrb. für Min., etc., 1884, Vol. I, p. 47), the jadeite under examination as well as that analysed by Damour would have the following composition:—90·1 per cent. of $Na_2\,O, Al_2\,O_3, 4\,Si\,O_2$, 4·59 per cent. of $Mg\,O, Al_2\,O_3, 4\,Si\,O_2$, 1·28 per cent. of $Ca\,O, Si\,O_2$. On the other hand the silicate $Fe\,O, Si\,O_2$, which has been found in most other jadeites, is entirely absent, while in that from Asia 1·3 per cent. is present. Column III represents the average of I and II, while IV and V give the figures obtained by Oliver C. Farringdon[1] from an analysis of jadeite from Mogaung.

Microscopic characters.

The microscopic examination shows that the ground-mass is composed of a confused aggregate of irregular prisms, varying in size; their length and breadth being in some cases the same, and nearly equal to 1 mm., but as a rule the prisms are elongated, their length considerably exceeding their breadth. In no case, however, did I observe a breadth

[1] Proceedings of the U. S Nat. Museum, Washington, 1894, Vol. XVII, No. 981, pp. 29–31.

of less than 0·1 mm. The ground-mass of the jadeite is perfectly pure, and without a trace of any accessory mineral. The prisms are perfectly colourless, except at the boundary between two individuals or along small cracks, where a slight discolouration may be seen, probably due to subsequent infiltration. The green spots always retain their colour even in slices: it is, however, very pale, even in cases in which it was originally intense. In very pale sections no pleochroism is noticeable, but thicker slices are slightly dichroic, the colours ranging from a bluish to a yellowish green. The prisms are at times colourless in places. In the centre of the green spots they are coloured, but as they approach the surrounding white ground mass, they begin to lose their colour, and become partly green and partly white. Hence we see that the green patches in the white ground cannot be due to an aggregation of green mineral grains at certain spots, but we must imagine local inpregnations to have taken place by means of a colouring matter containing chromium in solution. This permeates each spot with such uniformity that it does not appear to have any well-defined form even under the highest powers of the microscope. The green prisms are exactly similar in every respect to the white ones, with the sole exception of their different colour. No pitting of the surface can be noticed, the crystals appearing perfectly smooth: hence their refractive index is not high. Very minute liquid enclosures are locally numerous, occurring at some spots in aggregates of several individuals: more often, however, they are entirely absent. The characteristic cleavage of augite is very frequently extremely well-marked. In cross-sections the two cleavages intersect almost at right angles. The angle, however, depends of course on the direction in which the section has been cut. In none of my observations could I discover any difference in the two prismatic cleavages, which appear to be everywhere equally perfect. Hence, the cleavage of jadeite certainly does not justify us in including it among the triclinic minerals. In addition to prismatic, pinacoidal cleavage also occurs, and still more frequently, a cleavage transverse to the prismatic zone similar to that of diopside and other pyroxenes. The angle between the cleavage in this direction and that parallel to the prism faces is about 90°. I obtained values up to 96°, but this angle depends of course on the direction in which the slice has been cut. These cleavages frequently subdivide the prisms into single segments, having a strong resemblance to cross-sections of the prisms. They differ, however, from the latter in being less regular.

In polarised light, the prisms show very vivid interference colours. On sections with oblique extinction, the angle of extinction is very high, rising to 40°. Numerous longitudinal sections, however, have straight extinction, one direction being parallel to the cleavage and the other normal to it. In convergent polarised light the perfectly transparent crystals give very fine and clear interference figures, while owing to the thinness of the slide the narrow rings, as well as the vivid polarisation colours in parallel light, indicate a strong double refraction. According to the direction in which the section has been cut, these figures show the well-known differences in shape. On longitudinal sections, however, with straight extinction, one or two axes always undergo dispersion, with a wide axial angle, and the plane of the optic axis is parallel to the cleavage and perpendicular to the direction in which the section has been cut. If we include jadeite in the monoclinic system, then these sections are parallel to the axis of symmetry and the axial plane becomes the plane of symmetry. The above optical property is intimately connected with the crystalline form, and corresponds to that of all other monoclinic pyroxenes, which, without exception, show inclined dispersion. This, however, cannot be observed in the case of jadeite, owing to its wide axial angle. If, on the other hand, we place jadeite in the triclinic system, these optical properties will be anomalous. It seems therefore impossible to suppose that the mineral belongs to that system. It is true that in cross-sections, the directions of extinction are frequently not symmetrical to both cleavages. This symmetry, however, is found in the monoclinic system only when the direction in which the slice has been cut is parallel to the axis of symmetry. Otherwise, the direction of extinction forms different angles with the two systems of cleavage, and the difference of the angles depends on the more or less symmetrical position of the cleavage prism with regard to the plane in which the section has been cut. The optical symmetry is therefore no proof of the triclinic character of the mineral; and in our special case has absolutely no weight, inasmuch as cross sections also occur showing optical symmetry. The above refers chiefly to the properties of a single individual of jadeite. These, however, are frequently intergrown, and at times occur as a number of long prisms, forming a divergently radiating group with interpenetration, and producing a perfectly uniform groundmass. The longitudinal axis of the prisms do not point in any one direction more than in another, hence the groundmass consists of an aggregate of completely directionless individuals. In none of the specimens, however, is the original structure entirely unchanged. Frequently it is locally very distinct, but equally frequently it is more or less disturbed, in which case the prisms are no longer straight, but become more or less curved, and not infrequently distorted and broken: the fragments are then pushed out of place and a differently oriented substance squeezed in. The distorted prisms frequently exhibit at their ends a sort of fringing, which like the distortion is the result of mechanical action. The result of this action, however, is not merely bending and distortion, or fracture and fringing at the ends, but it even extends to the total smashing of the entire groundmass, which then no longer consists of elongated prisms, but becomes an "aggregate-polarising" agglomerate of small grains, which are the remains of the crushed prisms. Some of the prisms still remain in the fine-grained aggregate, but they clearly exhibit bending, distortion or some form of deformation. Sometimes it is possible to trace a transition from the fine grains to the complete prisms. In fact, this is one of the finest instances of cataclysmic structure, which can only be explained by means of violent compression of the already formed rock. The structure is of course better developed in some specimens than in others; but wherever it is well-marked, two other phenomena may be observed in those jadeite prisms which have been preserved: these are evidently due to the same causes as the cataclysmic structure. One of these phenomena is an undulating extinction which is apparently attributable to a slight deformation of the jadeite prisms. The other is polysynthetic twinning, so similar to that of plagioclase, that at first glance the twinned jadeite crystals might easily be mistaken for that mineral. The jadeite twins, however, gradually pass into single prisms, and the general properties of the twinned crystals are so exactly similar to those of the single individuals that no doubt of their identity can be entertained. The twin lamellæ are not very broad: in fact, as a rule, they are narrow; they are always numerous, more particularly in the latter case. Twinned prisms are frequently bent throughout and fringed at the ends. It appears that the twins are most numerous in the portions that have suffered the greatest crushing, and are absent where the effects of pressure are not well marked. We must conclude, therefore, that under favourable conditions crushing and pressure would produce in the jadeite a re-arrangement of the molecules into twins, similar to that observed in calcite. This, however, must have happened only in rare cases, for it had not hitherto been observed. The twinning plane, which in this case must be looked upon as a fault-plane, is distinctly seen to be a transverse plane, corresponding to that otherwise observed as a twinning-plane in pyroxene.

2. *Serpentine.*—The groundmass of the serpentine is dense, appearing completely homogeneous, with a very dark, somewhat brownish-green colour, which spreads evenly over the whole surface. Fracture uneven and splintery. Hardness considerable, exceeding that of pure serpentine: apatite is distinctly scratched in some instances. Under the microscope the cause of this anomaly is at once evident; for the specimen is seen to be an altered olivine-rock, the alteration of which into serpentine is not quite complete, but the process of serpentinization is proceeding in the usual manner along cracks and fissures. In microscopic sections, the olivine is perfectly colourless and transparent: in thick slices, however, it shows a greenish-yellow tinge. It forms an aggregate of rather coarse grains, which in several instances have a diameter of more than 1 cm. They are always irregularly circular, no indication of crystal faces being traceable. Between the larger grains, which throughout the slide extinguish simultaneously, occur aggregates of very minute, confused and variously oriented grains, which appear to be derived from larger olivine grains. This phenomenon seems to be analogous to the cataclysmic structure of the jadeite, a view which is supported by the fact that the serpentine possesses other properties which are undoubtedly due to mechanical pressure. The olivine individuals and also the aggregates formed by the small grains are intersected in the usual manner by strings of serpentine of a greenish-yellow colour, which usually show a distinct and very fine fibrous structure, running in most cases parallel to the walls of the small fissures: in a few cases, however, they are perpendicular to the walls. The rock is therefore a fibrous serpentine, very similar to chrysotile, and closely resembles it in the vividness of its polarisation colours. In microscopic slices these rise to the blue of the 2nd order, but by a combination of several fibres lying one upon the other, fall at times to an iron-grey of the 1st order. In all fibres, the direction of extinction is parallel to the fibres, corresponding to the axis of least elasticity as in the case of chrysotile. The strings intersect each other very irregularly as a rule, but occasionally cross in straight lines at right angles to one another, in which case, when the olivine appears dark in polarised light, a regular mosaic-like structure is produced. With the exception of numerous small black grains, with metallic lustre, no other minerals but olivine and serpentine can be seen. These black grains having a diameter of 1 mm., are magnetic, and hence are probably magnetite. B. b. they give no titanium reaction. Some of the grains are not magnetic, and in the borax bead give a marked Cr. reaction: they must therefore be chromite or picotite, most probably the former, as they did not appear to be particularly hard. These grains are unquestionably the

Serpentine. General appearance.

Microscopic characters.

Olivine.

Serpentine.

Magnetite and other accessory constituents.

source of the Cr. which permeates portions of the jadeite, producing the green patches. In the specimens under observation, however, no mineral can be identified as chromite or picotite; if, however, a larger number of specimens were examined, I have no doubt that sections of both minerals would be found. Under the microscope, the grains of magnetite exhibit very regular octahedral outlines; they are sometimes single, but not infrequently form parallel aggregates of small individuals, which, however, are not true skeleton crystals. The whole of the magnetite is always found among the serpentine fibres, and not a trace can be discovered in the fresh unaltered olivine: it is therefore unquestionably a secondary product of the alteration of the olivine into serpentine. A specimen of the serpentine rock, which had been freed as much as possible from magnetite, gave a s. g. of 2·838. If we take the s. g. of pure serpentine as being that of the pikrolite from Amelose, *viz.*, 2·551, and further if we take the s. g. of pure unaltered olivine as being that of chrysolite from the East, *viz.*, 3·331, we deduce from the s. g. of the serpentine from Tammaw (2·838), the fact that it contains 43·19 per cent. by weight of olivine and 56·81 per cent. of serpentine. The percentage by volume being—

Specific gravity.

Composition.

Olivine	36·79 per cent.
Serpentine	63·21 ,, ,,

These figures are of course not absolutely correct, but give a very fair idea of the composition of the groundmass, and certainly prove that not more than one half of the original olivine has been altered into serpentine. The newer portions of pure serpentine, usually observed in connection with this form of alteration, are not absent in the present case. Strings of pikrolite, in particular, may be seen running through the rock. These veins are of lighter colour than the chief mass of the rock, and are, as a rule, very narrow. Some, however, attain a thickness of nearly 2 cm. Some specimens, the outer surface of which is composed of pikrolite, exhibit the characteristic course, straight, striated appearance, producing the effect of a slickenside; and one of these specimens gives unmistakable evidence of the tremendous crushing and pressure which I have already mentioned. Numerous fissures distorted and bent and sometimes very complicated pass right across the striations, occasionally dying out and being replaced by new ones. They are partly filled with finely fibrous serpentine, resembling chrysotile, the fibres of which are usually normal but sometimes oblique to the walls of the fissure. Occasionally they contain pikrolite, of varying microstructure, of which I shall speak presently. The striæ on the pikrolite are displaced by these fissures, producing step-like markings on the striated surface. Sometimes, in consequence of this displacement, single parts are forcibly bent, and the pikrolite more or less squeezed into the olivine and serpentine. Evidence of the same crushing may also be seen in other specimens of the serpentine. In one case the result is a number of thin lamellæ, while the whole mass is squeezed into an irregularly rounded lenticular form, the rock having a soapy feel. On fresh fracture, the pikrolite has faint fatty lustre, but on the natural surface this lustre is much more marked. The colour is light green, with a distinct greyish or yellowish tinge. Only very rarely is the colour uniform, darker patches usually occurring here and there. The surface of the specimens, and at times even the walls of the inner fissures, are covered with a thin layer of a

Pikrolite.

white substance of lustre varying from mother-of-pearl to fatty. Like the serpentine fibres which intersect the olivine, the pikrolite contains much magnetite in the form of irregular grains, some of which are as large as a pea or even a hazel-nut. I have found no non-magnetic metallic grains, nor could I obtain any Cr. reaction. To the naked eye the pikrolite is perfectly opaque.

In places, the newly formed mineral is coarsely fibrous, the fibres being bent and curved, and the mass having the appearance of metaxite. True chrysotile, recognisable by its peculiar silky appearance and metallic lustre, does not seem to occur in large quantities. The specimens under observation show indications of it, but not its typical development. Under the microscope, the pikrolite is light yellow, almost colourless, and not pleochroic. It can hardly be distinguished from the surrounding Canada balsam, and must therefore have the same refractive index. Brownish patches occur here and there in the colourless groundmass, these are due to infiltration of hydroxide of iron. Their structure is always radial to fibrous, but the fibres are not so fine as those of the pikrolite. Not infrequently, broader fibres occur, forming divergent clusters. Like the single rays and fibres these clusters cross one another confusedly at various angles. Larger grains of magnetite are fairly common, always quite fresh and intimately associated with the rays and fibres, at times completely surrounding them and producing the effect of fluidal structure. The polarisation colours are blues of the second order, and, more often, iron-greys of the first order.

The pikrolite which occurs in strings and fissures, differs from that just described. This variety is formed in the centre of small radiating fibrous clusters, which in polarized light very distinctly show the black cross: the more nearly they approach to the walls of the fissures, the smaller do these clusters become; and they decrease in size more and more, till at length they disappear, becoming so small that even under the highest power of the microscope (× 600) they cannot be individualised. In this case, the whole seemingly structureless mass exhibits in polarised light an iron-grey colour, in which may be seen here and there a black cross, due to some larger clusters embedded in the minute ones.

I have already mentioned a white mineral which covers the surface of the plates of pikrolite and fills up the fissures. To judge from its mother-of-pearl lustre and soapy feel one would be inclined to identify it as talc. Under the microscope, however, it is seen to be a confused mass of mineral fibres resembling pik rolite; but whether it is fibrous pikrolite or chrysotile can only be determined by chemical analysis, for which the material at my disposal is not sufficient. It is highly probable that, comparatively speaking, a large proportion of this mineral composes the intermediate layer between the serpentine and the jadeite. Unfortunately, however, I have no specimens of that layer.

Certain other substances accompany the serpentine in small quantities. Grown over the pikrolite are small blackish-brown grains, exactly resembling webskyite as first described by R. Brauns. This mineral was discovered in some serpentines derived from palæopikrite from Hessen, Amelose and Reichenstein in Silesia. In miscroscopic slides, these grains become of a light brown colour and transparent, being scarcely affected by polarised light. Unfortunately there is not sufficient material for a more exhaustive examination, but such characteristics as I have succeeded in observing, agree so well with webskyite that there can be no doubt as to their identity, and R. Brauns was therefore correct in assigning such a wide distribution to that mineral. In addition to the above mineral, there occur small rounded or string-like and very fine-grained portions of a mineral of yellowish colour, not affected by hydrochloric acid. This may possibly be a hornstone quartz, such as is frequently found in serpentine. Carbonates, which are not uncommon in serpentines, are entirely absent, for no trace of effervescence could be observed either with hot or cold HCl.

Albite-hornblende rock.

General appearance.

3. *Albite-hornblende rock.*—The only specimen under my observation is of about the size of the fist, and apparently formed part of a large boulder exhibiting both rolled surfaces and fresh fracture. The rolled surface is brown owing to impregnation by hydroxide of iron, the coloration extending for some distance within the rock, but gradually fading and eventually disappearing. At the first glance, one would be inclined to identify this rock as a saussuritic gabbro, owing to the appearance of the fractured surface. The fine white sugary groundmass contains grains of a brown mineral, which cleaves easily and has a metallic lustre on the cleavage faces. Examination proved, however, that these two component parts are neither saussurite nor diallage, and hence the rock is not a saussurite gabbro, but represents a new type. The beautiful, snow-white groundmass is almost indistinguishable from some saussurites, as, for example, from that of Hamberge near Frankinstein in Silesia. It has the hardness of felspar, and fuses with great difficulty before the blowpipe. The s.g. of two fragments were 2·599 and 2·576, which gave an average of 2·587.

Specific gravity.

Microscopic characters.

Albite.

Under the microscope, the groundmass is seen to be a homogeneous aggregate of very small irregularly rounded grains, varying in size from ·02^{mm} to a fourth or fifth of that size. These grains are almost perfectly pure; enclosures being entirely absent, with the exception, perhaps, of a few small liquid enclosures with moveable bubbles. The grains are perfectly transparent and colourless, and between them occur foreign particles, which, however, are never included in them. The white grains show no cleavage faces, but are crossed in one direction by a series of fine cracks, indicating a perfect cleavage. In some cases numerous fine twin lamellæ of plagioclase occur: these, however, are not very common. The polarisation-colours are very vivid, and the surface of the grains is perfectly smooth and without any pitted appearance. Some grains give the interference figures of biaxial crystals, with a wide axial angle, which, however, cannot be measured. According to the analysis of Mr. Busz, the white groundmass is composed of—

Chemical composition.

	I	II
SiO_2	64·60	68·62
Al_2O_3	19·92	19·56
CaO	} traces.	——
MgO		——
K_2O	1·02	——
Na_2O	14·01	11·82
	99·55	100·00

It is therefore unquestionable that this represents an aggregate of albite grains most of which are single individuals. This view is also borne out both by the chemical and physical properties of the mineral. The composition certainly appears to differ somewhat from that of pure albite given under No. II, but we must remember that the groundmass is not entirely composed of pure albite, but also contains the foreign particles, of which we shall presently speak. The groundmass is slightly affected by HCl., and although albite has been stated to remain unaffected by this acid, it is undoubtedly acted on to a certain extent.

Hornblende.

The brown mineral resembling diallage, scattered through the white groundmass, has been proved to be hornblende. It occurs in single crystals of various sizes, the largest being nearly 4 cm. by 2 cm. This, however, is less than the original size of the crystal which was on the surface of the specimen and has been considerably broken. As a rule, the crystals are smaller, but are always as large as a pea. They are not numerous, being scattered throughout the rock. Their outline is generally irregular, although at times rough crystal faces can be made out. The colour is that of brown hair, but sometimes grey, and the cleavage faces have a metallic lustre, resembling diallage or bronzite. Each crystal is bounded by a green margin, while the surrounding groundmass is also coloured green. In both cases, this coloration is due to numerous microscopic enclosures to which I shall presently refer. In all these hornblende crystals, one of the two very well marked cleavage faces is unusually large, and thus gives the crystal its resemblance to diallage or bronzite. The second cleavage is everywhere equally perfect, and these two meet at an angle of 124° 47′, the characteristic angle of hornblende. This value was obtained by measuring three separate splinters, and in every case the results only differed by a few minutes. On one of those splinters a broad plane was observed truncating the obtuse prism edges; this plane corresponds to the orthopinacoid (100, $\infty \bar{P} \infty$) The hornblende showed no signs of fibrous structure.

Owing to the small amount of material at my disposal, I was unable to make an analysis. The green margin, however, as well as those parts of the albite groundmass which surround the hornblende crystals, gave with borax an unmistakable Cr. reaction; but no Cr. could be detected either in the brown or greyish portions of the hornblende or in the white albite. The micro-chemical examination of the hornblende proved the presence of silica, magnesia, lime, iron, and a little alumina but no alkalies. The average s.g. of the brown splinters was obtained in methylene iodide, and proved to be 3·10, being the average of two separate operations. These figures, as well as the cleavage and the other properties of the mineral, enable us to identify it with hornblende. In the Bunsen flame small splinters are slightly discoloured but do not melt. They melt easily, however, before the blowpipe, fusing to a grey non-magnetic glass. Iron must therefore be present in small quantities. Extinction is straight, parallel to the very distinct cleavage-fissures. Thicker slices exhibit very distinct pleochroism, which, however, entirely disappears in thin sections. The vibrations parallel to the axis of symmetry, and therefore perpendicular to the cleavage cracks, are light brownish-red, while those parallel to the cleavage are light yellow, and those perpendicular to both are light bottle-green. These colours differ but slightly in intensity, while the colour changes from red to green or yellow according to the direction in which the hornblende crystals have been cut. Occasionally, especially at the margin of the crystal, the colour becomes a deep bottle-green or even emerald green: this is most probably due to infiltration of a foreign substance containing Cr. These greenish patches gradually pass, without well-defined margins, into the differently coloured parts. Cross sections having the characteristic hornblende cleavages intersecting at 124°, extinguish diagonally, while the pleochroism varies from brownish-red to green. On longitudinal sections, the angle of extinction is as much as 19°.

Augite.

In the boundary zone between the hornblende crystals and the albite, a large number of needles of a green mineral occur. These are most numerous along the boundary, and decrease in number on each side of it, thus producing intensely green bands round the hornblende crystals. In the albite aggregate, these needles lie in all directions between the albite grains, but are never enclosed by them. In the hornblende, they not infrequently lie parallel to the cleavage, but more often they are disposed quite at random obliquely to the cleavage fissures. They are always straight, and their length, as a rule, is three or four times their breadth in the broader needles, while in the narrower ones the length is much greater. Their sides generally consist of sharp straight lines; sometimes, however, both edges are slightly curved, thus producing spindle-shaped sections. If the ends are not pointed, they are, as a rule, rough and irregularly indented, but never fringed nor bifurcating. The oblique extinction is important, and rises to as much as 36°. Not infrequently square cross sections may be seen, at times extinguishing parallel to the edges. Cleavage is probably present, but it is not well-defined. Transverse fractures obliquely inclined to the longitudinal axis are common. The characteristics above enumerated enable us to identify this mineral with augite. The colour of the larger prisms is an intense bottle-green to emerald-green, and thus produces the green zone already mentioned as occurring round the hornblende crystals. The narrower needles are of lighter colour, while the narrowest are almost colourless. As a rule, the pleochroism is faint, the colours varying between closely related shades of green. The broadest needles, however, occasionally show a pleochroism ranging through bottle-green and dark greyish-blue to colourless. All are perfectly clear and transparent, and entirely free from inclusions. This mineral is most probably a pyroxene, closely related to diopside or sahlite, which derived its green colour from a small percentage of Cr., and is in fact a chrome diopside. Unfortunately the scarcity of the material precludes a more searching examination of this mineral.

Rhombic pyroxenes and other accessory minerals.

I have already mentioned that a small number of brown crystals may be seen between the albite grains. These show numerous cleavage cracks, parallel to which straight extinction occurs. They consist of oblong plates of about ½mm. in length, the cleavage running parallel to the longer axis. This is most probably a rhombic pyroxene, not very rich in iron, very possibly bronzite.

Lastly, under a moderately high power, a very fine-grained aggregate may be seen, scattered here and there among the grains of albite, and running in fine strings into the hornblende crystals. This is always associated with a large number of the green to colourless augite crystals already described, which are particularly numerous in this aggregate. In thin sections, under a high power, these aggregates are seen to be clusters of minute radial fibrous spherulites, which between crossed nicols show, more or less distinctly, the characteristic black cross. The substance is colourless and gives very vivid polarisation colours, but cannot be more accurately determined.

From the above description, it is evident that the specimen under consideration is an albite-hornblende rock, in which the albite grains form a dense groundmass, containing porphyritic hornblende crystals. The remaining minerals have no particular share in the composition of the rock, and are therefore merely accessory constituents.

Hornblende-glaucophane schist. General appearance.

4. *Hornblende-glaucophane schist.*—This specimen has a dark brown surface, in some places rough and in others smooth, but apparently not much rolled. It is a schistose rock of an intense emerald to grass-green colour, and bears a strong resemblance to smaragdite. A closer examination, however, at once reveals the fact that it represents an aggregate of greyish hornblende individuals, largely permeated by green enclosures, which impart to it its remarkable colour. The greyish portions pass in places into a deep green, but in other places again the green colouring matter is entirely absent. The hornblende individuals are most irregularly intermixed, and show no signs of definite arrangement. They attain a length of as much as 3, and breadth of as much as 2 cm. They have no definite crystalline outlines, but their cleavage is perfect, the angle between the two prismatic cleavages averaging 124½°. This angle could not, however, be accurately ascertained, owing to the frequent distortion of the prisms, which at times even causes a fringing of the ends. The orthopinacoid was observed on one of these prisms; it gives rather indistinct cleavage, and sharply and straightly truncates the obtuse prism edges. Thin splinters melt in the Bunsen flame; the thicker ones easily fuse before the blowpipe, forming a greenish-grey non-magnetic glass. It is not acted on by HCl., either before or after fusion. The s. g. of the *whole mass*—not that of the pure hornblende—was obtained from two pieces of the rock, the values being 3·113 and 3·126. I endeavoured to obtain the s. g. of the hornblende after removing the green parts, but it was not possible to separate the green colouring matter from the greyish hornblende.

Hornblende.

Chemical composition.

I could, therefore, only ascertain the chemical composition of the whole mass, and not that of the pure hornblende. As we have seen, however, that the whole rock consists chiefly of hornblende, containing only emerald-green crystals, the following figures will represent the chemical composition of the hornblende. Mr. R. Busz, who made analysis I, obtained the following results:—

	I.	II.
SiO_2	53·53	58·76
Al_2O_3, Cr_2O_3	9·10	12·99 (Al_2O_3).
FeO	4·02	5·84
CaO	6·94	2·10
MgO	15·94	4·01
Na_2O., K_2O.	7·96	6·45 (Na_2O).
Loss	2·95	2·54 (H_2O).
	100·44	102·69

In the above analysis the very high percentage of alkali is remarkable: it consists chiefly of Na., containing only a small percentage of K.; $Cr_2 O_3$ and $Al_2 O_3$ were not separated. It seems, however, that no small quantity of $Cr_2 O_3$ must be present, for vividly green splinters give an undoubted Cr. reaction in the blowpipe flame. On the other hand, the grey hornblende hardly gives any tinge to the borax. The iron has been calculated as Fe O. According to the above analysis, the mineral proves to be an amphibole, containing a considerable amount of soda, thus resembling glaucophane, which, however, is distinguished by its dark blue colour from the mineral under examination. There are, however, grey varieties of glaucophane. The glaucophane most nearly allied to this mineral is that of Zermatt, the analysis of which is given under II. In both, the percentage of alkali, magnesia and iron very nearly agrees, as also the loss due to ignition. The difference in the percentage of $Al_2 O_3$ is rather more marked, while the difference in the silica is the most pronounced. There are, however, other glaucophanes, which, in this respect, closely resemble the mineral from Burma, *e.g.*, that from New Caledonia contains, according to Liversidge, only 52·79 per cent., while that from Sanjaron in Andalusia contains, according to Barrois and Offret only 47·4 per cent. of $Si O_2$. In the last mentioned variety, also, a low percentage of alumina corresponding to our 8·42 has been observed. From the majority of glaucophanes our mineral differs chiefly in the percentage of lime, for they do not as a rule contain more than 2 or 3 per cent. of CaO. Some, however, are known to contain a larger percentage, *e.g.*, that of Shikoko in Japan, which has a percentage of 4·80, while the glaucophane from Andalusia contains 12·90 per cent.

Glaucophane.

We are therefore undoubtedly entitled to consider this mineral as a glaucophane, inasmuch as its s.g. exactly corresponds with that of most glaucophanes, of which the s.g. ranges from 3·103 to 3·113, the average being 3·12, corresponding to the variety from New Caledonia. The low fusibility is another distinguishing feature. It is a remarkable fact that together with jadeite, which is a pyroxene, there should occur an amphibole, which, owing to its large percentage of Na. closely resembles it in composition. The strong pleochroism peculiar to the dark blue glaucophane is of course less pronounced in the mineral from Burma. In moderately thick slices, however, considerable differences of colour may be seen on rotation of the polariser. The vibrations parallel to $\mathfrak{a}$ are bluish-green, those parallel to $\mathfrak{b}$ greenish-brown and those parallel to $\mathfrak{c}$ yellowish brown, the absorption being $\mathfrak{b} > \mathfrak{a} > \mathfrak{c}$. In thinner slices the same colours appear, being, however, much paler, the differences being therefore less noticeable, while in very thin slices, they almost entirely disappear. The large extinction angle of the Burmese variety contrasts strongly with that of true glaucophane, in which it amounts to only a few degrees, while in the mineral from Tammaw it rises to 28°, a value much higher than that of other rock-forming amphiboles. Under the microscope, cross-sections show the characteristic prismatic cleavage of amphibole. In longitudinal sections the cleavages are very close together, thus producing an appearance of fibrous structure; and, as in the case of the prisms, these fissures are considerably distorted, while the ends are more or less fringed. There can be no doubt that these phenomena are due to the pressure which all the rocks of Tammaw have undergone. In longitudinal sections, also, may be seen an ill-defined transverse cleavage, running obliquely to the ordinary cleavage fissures. This most probably, as in other amphiboles, represents a cleavage parallel to $\bar{P}\infty$ $(10\bar{1})$, which is a very characteristic feature of glaucophane. Thus we see that the Tammaw mineral differs from true glaucophane only in its abnormal extinction angle.

Augite.

As already mentioned, the hornblende contains numerous fine needles or narrow prisms, which are always elongated in one direction. These are composed of a beautiful emerald-green augite, and produce the fine green colour of the rock, whenever they occur in any quantity. This colour we have already stated to be due to a small percentage of Cr., the very green grains giving a distinct Cr. reaction, while the grey crystals show no such reaction. These enclosures are very similar to those noticed above as forming part of the albite-hornblende rock. The latter, however, do not exhibit such a vivid emerald green, being rather of a bluish-green colour. As in the former case, their lateral boundaries are regular, but their ends are not infrequently fringed or pointed, in which case they assume the spindle-shape already described. The small needles are sometimes arranged very irregularly, but, as a rule, they lie parallel to the vertical axis of the amphibole prisms. The larger non-prismatic crystals form radiating groups, the ends of which are slightly curved and which, owing to their green colour, form a striking contrast to the colourless amphibole. Single crystals become alternately bright and dark in polarised light. The clusters, however, never extinguish entirely, for differently oriented crystals overlap each other. Cross sections show the typical form of augite, but prismatic cleavage is not well marked, the cleavage fissures being somewhat irregular. Transverse fissures, probably representing a transverse cleavage, as in diopside and other pyroxenes, are sometimes seen.

The angle of extinction is fairly high, but it is difficult to obtain measurements of it. Since the larger prisms never extinguish completely, while the smaller crystals are bounded by curves, straight cleavage-fissures being almost entirely absent. In some cases, however, I obtained values up to 50°. The pleochroism is very marked. Cross sections of moderate thickness, however, exhibit only slight differences of colour, the bluish-green remaining almost unchanged during a complete rotation of the polariser. On longitudinal sections, the differences are much more marked, the vibrations in the direction of the axis of elasticity being greenish-yellow, with at times a shade of uranium glass, while those normal to this axis are bluish green as in the cross-sections. Hence during rotation the colour varies between the above tints. Even in very thin slices, this is still visible; the very thinnest needles, however, having no distinct colour, have no pleochroism. The green material occurs in a different manner to that enclosed in the hornblende. The hornblende is frequently intersected by green strings, entirely composed of crystals of augite, as in the previous case. These are, however, of much smaller dimensions, and are, in fact, almost microlites. In rare cases circular clusters of such augite microlites have been observed filling up the fissures and other small cavities in the hornblende, while the larger augites, already described, were unquestionably developed at much the same time as the amphibole, in which they are enclosed; and there is no indication whatever that they were produced by subsequent alteration of the amphiboie. It is a remarkable fact that all the Cr. has been taken up by the augite, while none is found in the amphibole.

Geological age.

From the above description of the rocks occurring in the jadeite mines at Tammaw, *viz.*, the jadeite, the olivine-serpentine, the albite-hornblende rock, and the amphibole-glaucophane-schist, we are enabled to form a clear conception of their nature. Noetling believes that the jadeite and the serpentine penetrate the surrounding tertiary sandstone, while with regard to the relations between the occurrence of the two other rocks and the jadeite, nothing is known. Noetling's view necessitates the assumption of an eruption of jadeite and another of olivine rock, following one another; but the petrological composition of these rocks is not favourable to such a view, which would include them among the tertiary eruptive rocks. Judging by the petrological characters, we must consider them as representing a system of crystalline schists.

Now there is no doubt that in former geological times olivine rocks were produced by volcanic eruptions. Nowhere, however, have rocks of this nature been found in beds of such modern date, being according to Noetling not older than of miocene age. Wherever tertiary masses of olivine are known to occur, as for example the enclosures in basalt, they are perfectly fresh, and show no signs of serpentinisation. I wish particularly to emphasize this fact, since the basalt which I shall presently describe, and which occurs in close proximity to the jadeite mines, has no geological connection with the jadeite, but is unquestionably an eruptive rock passing through tertiary strata. In this basalt the serpentinisation of the olivine has just begun, but has not progressed beyond the first stages, while such a complete alteration as that exhibited in the above specimens is characteristic of all ancient olivine rocks—such as palæopikrite—and, as I have already observed, of the crystalline schists.

To consider the jadeite as an eruptive rock would be entirely unjustifiable: for neither in the older nor yet in the more recent series of eruptive rocks has any rock of the nature of jadeite been found. In Turkistan, however, it has been proved to be imbedded with nephrite in the crystalline schists (gneiss and mica schist), and belongs to that series.

The two other rocks also offer material proof in favour of this view, for it is highly probable that the glaucophane-schist is one of the crystalline schists. Hitherto, glaucophane has been found only in gneissic rocks and mica schists, no instance having been recorded of its occurrence in eruptive rocks, much less of its entirely composing such rocks. The same holds good for the albite of the albite-hornblende rock. This mineral frequently occurs as a component part of the crystalline schists, but hardly of eruptive rocks. The peculiar aggregation of the albite grains is in perfect harmony with this view, for such a structure would be by no means remarkable in a crystalline schist. I am therefore of opinion that the jadeite and the other rocks must be looked upon as part of the series of crystalline schists, overlaid by tertiary beds and probably denuded by erosion. It is most probable that they were raised to their present level together with the surrounding tertiary rocks, when these latter were subjected to folding. I have repeatedly laid stress on the fact that these rocks must have been subjected to great pressure, which can only be accounted for by folding. I do not assert for a moment that the above arguments are absolutely convincing, but they certainly support the view which best accords with the petrological evidence, while the stratigraphical conditions observed by Noetling in the mines at Tammaw fully bear out this view. Further observations, however, with regard to the geological conditions of that country, will certainly decide the question. On the geological map of Burma, west of the Irrawaddi, even west of Mogaung, towards Tammaw, sub-metamorphic rocks are indicated; while crystalline limestones, probably of silurian age, extend to within about two miles of the eastern side of the jadeite mines.

Basalt.

In conclusion, I wish to mention a rock which, although not belonging to the series described from the jadeite mines, has been found on a hill four miles east of Sanka village. It is an excellent felspar-basalt, with blackish-grey fracture, and brown weathered surface. Under the microscope, the felspar—plagioclase—forms a crowd of minute lamellæ, in which only very few individuals are twinned, while a very small number of the crystals are somewhat larger. The felspar crystals form the groundmass in which all the larger constituents of the rock are porphyritically imbedded.

The augite is of a very light yellowish-green colour, without noticeable pleochroism, but with oblique extinction as is usual in basaltic augites. The crystals, which are regularly bounded by straight lines, are usually of considerable size. There are, however, smaller crystals which in their dimensions very nearly approach the lamellar felspars. These small augite crystals form part of the groundmass together with the felspars, but they are not nearly so numerous as the latter. They are much more sharply and regularly bounded than the larger crystals, and probably represent a later generation of augite. As a rule, they are single, but twins are occasionally seen parallel to the orthopinacoid, and not infrequently polysynthetic. Cruciform twins appear to occur, but I cannot state with absolute certainty that any regular intergrowth takes place. The augite, like the felspar, is perfectly fresh, and both are fairly free from foreign enclosures of all sorts. Magnetite, however, generally very regular in shape, is not infrequently included in the augite. Olivine usually forms the largest crystals; it is either perfectly fresh or intersected by a few cracks along which serpentinisation has just set in, only small progress, however, having been made in this direction. It also contains inclusions of magnetite grains. A few dark brown transparent grains of picotite occur, while liquid enclosures containing moveable bubbles are frequently seen, arranged in the well-known zones. Magnetite is fairly common, and usually forms well-defined crystals of considerable size. These crystals sometimes occur singly, and sometimes in larger and regularly-arranged groups. They are partly imbedded in the groundmass between the felspar and augite microlites, and partly occur as enclosures in the larger augites and olivines. As already stated, I consider some of the darker brown and transparent enclosures in the olivine to be picotite. A number of long, colourless needles with straight extinction, and sometimes grouped in clusters, are crystals of apatite. No other minerals have been observed, while glass, in particular, is entirely absent, not a trace of it having been discovered.

The basalt is therefore holo-crystalline and falls under class II of Zirkel's classification, the members of which group are distinguished by a fine-grained, microscopic groundmass, which is crystalline throughout or only contains a small quantity of magma in which larger crystals—in this case augite and olivine—occur. Or if we adopt Rosenbusch's classification, we must describe it as a holo-crystalline porphyritic basalt, in which, notwithstanding the enormous number of plagioclase lamellæ forming the groundmass, no larger plagioclase crystals appear, as is more usually the case. Warm HCl affects the rock but slightly, while cubes of NaCl are not formed after evaporation.

On the Geology of the Tóchi Valley, by F. H. SMITH, A.R.C.S, *Assistant Superintendent, Geological Survey of India* (with pl. 3).

Towards the end of February 1895 I received orders to join the delimitation party at work in the Tóchi valley. A geologist was specially required to ascertain, if possible, whether the reported occurrence of copper and iron in the hills south of the Tóchi river, and between it and the Khaisor, was of economic importance.

Unfortunately, when I received my orders, I was engaged in field-work amongst the southern spurs of the Sulaimán range in Baluchistán, and by the time I caught up the Tóchi column that part of the delimitation work situated in the Tóchi hills had been completed, and I never had an opportunity afterwards of seeing more than the northern or Tóchi flanks of the hills.

Copper and iron.

I may say at once that, as far as I could observe, the hills between the Tóchi and Khaisor rivers contained no minerals of any economic importance. I have not met with any trace of copper, or mineral containing copper during my march along the Tóchi and one or two tributary streams.

The Waziris are said to work and smelt iron ore to a considerable extent in the hills to the south of the Tóchi; and the number of native-made knives seen all over Waziristán shows that there must be a considerable iron industry. The majority of the knives are made of very soft iron, and their value, when sold to Europeans, seemed to be from 2 or 3 rupees each; smaller knives of mottled native steel are fairly common, the price of which seems to run up to anything under 25 or 30 rupees, according to the appearance of the intending purchaser.

The only place where I found any traces of iron ore was Mirán Sháh. There I found several concretions of very pure soft hæmatite, in middle or lower eocene sandstone beds. These beds have *roughly* a north and south strike in this neighbourhood; to the north the series forms the Laram hills, while to the south the hill-country between the Tóchi and the Khaisor, or Khasora, is mainly composed of these same rocks. It is very probable that the iron ore supply is derived from this pure concretionary hæmatite, which could easily be found in sufficient quantities for the manufacture of knives and other small implements, but which would probably run out at once if worked to any great extent. Even if pure hæmatite were found in greater abundance, as is constantly the case in other parts of India, the total absence of fuel would render it useless in this valley.

Although my march up the Tóchi was not very successful from an economic point of view, it was none the less interesting geologically, especially as I traversed new country.

Topography.

Marching from Bannu up the Tóchi valley, one enters the outer range of tertiary hills near Tóchi village, at a height of about 1,000 feet above sea-level. From here to Dotoi, the farthest point I reached, is about 60 miles in a straight line, and rather more along the river bed which runs almost due east and west. At Dotoi the height is about 5,000 feet, and the higher peaks around run up to 10,000 feet. To the west of the outer hills mentioned above, which run roughly north and south, the river bed traverses two wide plains, the Idar Khél and Idak valleys. Both plains are bounded north and south by hills, which close in to the west of Idak, above which the river-bed lies between irregular hills, forming a more or less narrow valley.

I was able also to march up a tributary of the Tóchi, the Kazha nala, which rises on the Luara plateau under Charkhiaghar to the north of Dotoi, and runs nearly parallel to the Tóchi till it joins it near Pakki Kôt.

Geology.

As the newer rocks present none of the difficulties which are met with in the older rocks which I saw, I will describe the section in descending order. Roughly speaking, the younger rocks are found in the eastern outer ranges, which rise from the Bannu plain, and older rocks appear in the interior to the westward.

The rocks in this outer range—the Shinkai hills—showed a most striking similarity in composition and arrangement to those of the Fort Munro range, south-west of Déra Gházi Khán. This latter range, rising from the Indus plain, presents a perfectly normal section of rocks which dip steeply eastwards under the Indus plain; from upper siwalik conglomerate in the outer ranges, through lower siwalik, upper, middle, and lower eocene rocks, with beds of probably cretaceous age at the base. Having just traversed the Fort Munro range, the similarity between it and the Shinkai range rising from the Bannu plain, some 200 miles to the north, appeared all the more striking to me. Evidently the same, or nearly the same, series of tertiary rocks have been disturbed and folded in the same manner, and for a distance of hundreds of miles along the frontier hills west of the Indus plain. Taking the normal section of the Shinkai range from west to east, nearly the same series of beds is met with.

Siwaliks.

The outermost range commences two or three miles to the west of Tóchi village, where the massive conglomerates and grits of the upper siwaliks dip gently to the east under the Bannu plain. The dip becomes steeper further west, and in the highest ridge of these hills the rocks dip very steeply, still eastwards, till along the bank of the Tóchi river it becomes vertical; this dip is maintained westwards throughout the lower siwaliks and upper nummulitics at least. The thickness of these conglomerates must be great, and is probably several thousand feet, but the lower siwalik beds are of even much greater thickness. In the Saidgi valley the rocks change from conglomerate (east) into an immense thickness of sandstones and shales (west). The conglomerate passes gradually and perfectly conformably into finer sandy strata, which at once become interbedded with beds of shale. The lower siwalik beds consist entirely of grey sandstones and red shales; the latter predominate in the upper beds, but give way lower down to soft sandstone beds, which contain no shale bands at the base. The dip is vertical throughout the whole section of these beds across the Saidgi valley and up to the highest ridge of the hills westward. The strata appear not to be crushed to any extent, but are exposed as a perfectly normal section, with an outcrop of fully 2 miles in breadth, which gives the lower siwalik beds the immense thickness of 10,000 feet. I could find no trace of fossils in either the shales or sandstones.

Upper nummulitic.

Along the ridge of the hills west of Saidgi there runs a bed of white hard limestone, under 200 feet in thickness. The dip is vertical, and at Shinkai in the river bed the exact thickness is 170 feet.

The limestone is full of fossils, the harder bands being almost made up of *nummulites* and *alveolinæ*, while some softer muddy bands are full of gastropods and bivalves, with which I found part of a well preserved crab.

The junction of this white limestone with the overlying grey siwalik sandstone is clearly seen in the river bed. In position they are perfectly conformable; the white limestone is very nodular, so that the upper surface is not quite smooth. The sandstone fills up the irregularities, and the bedding of both is perfectly parallel: the sandstone contains many limestone pebbles for about 2 feet from the junction, but the parallelism appears perfect. The junction of this upper nummulitic limestone with the lower beds is not so well seen, but the white limestone appears to rest conformably on the soft shale beds below. To the north of Sheranni, upper nummulitic rocks occupy a considerable area, forming a flat basin north of the Tóchi. The rocks consist of white limestones and interbedded light green shales; the limestone is identical with that at Shinkai. The thickness of the whole exceeds that of the rocks at Shinkai, but the base beds rest on rocks so much disturbed by igneous intrusions that I could make no very definite observations on the lower beds.

Lower nummulitic.

Below the white limestone comes a thickness of 400 to 500 feet of olive green shales, very like the 'ghazij' shales of the Quetta area, which are of middle nummulitic age; at the base of these I observed some red shale bands, below which come 200 to 300 feet of shales, interbedded with shaly limestone and limestone breccia. The breccia contains many fossil organisms, but I have not found any nummulites amongst them; a fossil fruit was found in the associated shales, but nothing could be seen in the shaly limestone.

These shaly beds down to this point may probably represent the middle nummulitics, but they pass so imperceptibly into lower rocks that no distinct division can be made. Below the limestone breccia band the shales become interbedded with sandstones and calcareous sandstones, and dip again steeply to the east. This series of rocks continues from Shinkai to the Idar Khél plain on the west, the dip lessening towards the east on nearing the plain.

The main mass of the rocks consists of soft shales, greenish brown to red in colour, with frequent partings of softish sandstone, buff to brown inside, but always weathering a shiny black on the surface. Some beds appear to have been altered into red coloured porcellanic, shaly limestone bands. Near Idar Khél the sandstone bands, nearly white in colour, increase in size and contain pure limestone bands, layers of sandstone and limestone alternating several times in the course of 2 or 3 feet.

In some places this series is considerably contorted, but on the whole there is a steady easterly dip throughout. There must be several thousand feet of these rocks visible in the section along the river bed. I may mention here that the black weathering of the sandstones and calcareous sandstones is very typical of middle and lower eocene rocks in eastern Baluchistán. In the calcareous sandstones there are traces of organisms, apparently *foraminifera*, but I found no fossils in any of the other sandstone or shale bands.

The Idar Khél plain is cut out of a flat anticlinal of these lower eocene rocks; in the hills east of Idak they dip again gently westwards, but here the predominance of sandstone bands is changed to one of calcareous and limestone bands, which are remarkable for the quantity of corals in them. These beds, hard grey limestones and shales with some sandstone bands, form the hills south of the Tóchi as far west as Mahomed Khél, and to the north of the Tóchi from Mahomed Khél across to the Laram hills, and from thence down to the hills surrounding the Idak plain.

Mesozoic.

The range of hills between Idak and Mirán Sháh is formed by an anticlinal ridge which approximately strikes north and south, and which is composed of these lower eocene beds. In the core of the anticlinal a considerable thickness of massive dark grey limestone is exposed, in which I could find no fossil remains; the age of this limestone is therefore doubtful, and there is no evi dence of any kind to show whether it belongs to the lowest tertiary or upper mesozoic age.

Dotoi beds.

The middle and lower eocene beds between Shinkai and Mahomed Khél are conspicuous by the general absence of undoubted nummulites: corals and the broken shells of bivalves are abundant, but *foraminifera* only occur rarely and then the traces are badly preserved. Round Dotoi, however, beds of apparently lower eocene age appear, yellow limestones with interbedded blue slaty shales, of which the limestone bands are full of fine nummulites of all sizes. These beds have no resemblance to the very white limestones and light green shales of the upper nummulitics, and very little more resemblance to the non-nummulitic rocks round Idak; in fact they show no resemblance to any of the rocks seen in the Shinkai hill section. This may be explained by the amount of igneous alteration which has taken place in the neighbourhood, and which has effaced all evidence of connection between the Dotoi rocks, the upper nummulitics north of Sheranni, and the lower nummulitics east of Mahomed Khél.

Igneous intrusion.

One is much struck on marching up the Tóchi river bed by the great quantity of pebbles and boulders of igneous rocks met with *en route.* The majority of the pebbles, even at Tóchi village, are of diorites, gabbros, and basic rocks. No indication of their being anywhere *in situ* is met with till one arrives within about 3 miles of Mahomed Khél. Here the lower eocene limestones and shales are seen to rest abruptly, but conformably on a series of beds, and are doubtless part of the latter, which are altered by igneous action, but with evidence of having been interbedded with igneous rocks, which in many cases form massive intrusions in the former. This facies of beds covers the country between Mahomed Khél and Dotoi, though it is overlaid by upper nummulitic beds north of Sheranni.

The igneous intrusions are invariably of the more basic rocks. I never found a trace of any acid rock, but diorites are very common, and they, as well as more basic forms, appear to pass gradually into the rocks which they penetrate partially. As generally happens, the beds are altered to such an extent near the junction, that no definite line can be drawn between the true shales on one hand and the true crystalline rock on the other. Throughout the whole area of igneous disturbance I never found anything but shaly beds associated with the igneous rocks.

Age of igneous series.

In some cases the shales have undergone very slight alteration only, but unfortunately I have not found any traces of fossils in beds connected with the igneous rocks, so the only clue to the age of these beds rests on their relative position to other beds. On the west the igneous series is overlaid by the lower nummulitic Dotoi beds, with the bedding more or less parallel. On the east the Idak series of lower eocene rocks rests conformably on altered shale beds with igneous intrusions. Upper, and perhaps middle, nummulitic beds directly overlay the igneous rocks between these two junctions; the disturbance in the basal beds makes it impossible to see from a distance what connection there is between the upper nummulitics and the igneous series. It is singular that nothing but shaly beds should be found within the area of igneous disturbance. The natural conclusion to be drawn seems to be the supposition that igneous action, in the form of intrusions and deposition of ash beds, began some time before the beginning of the tertiary period; and lasted, with occasional variations causing interbedding, up to the end of middle eocene times.

Series.

The intrusive masses vary a good deal in composition. I found various forms of diorite, but the greatest variety seemed to be in the gabbros, which pass gradually into hypersthene (and diallage) rocks. Some pebbles, of what appeared to be amygdaloidal basalt, occurred in the river bed, but I never found this rock *in situ*. From the diversity of these rocks, ranging from intermediate to basic, and probably ultrabasic forms, coupled with their interbedding with shales and possibly other rocks of eocene age, it seems very probable that this series may correspond to the widespread formation of shales and igneous rocks which form large areas in Baluchistán; the Kójak shales are typical for this lithological formation, which also ranges from the later cretaceous to middle eocene times.

Description of sections.

In the absence of an accurate map, the accompanying sections (pl. 3), which are drawn approximately from east to west across the general strike of the beds, may give some idea of the arrangement of the rocks. The three sections, which are drawn to natural scale of 1 inch = 1 mile, follow the Tóchi river, mostly through the hills directly to the north of it. They do not conform quite to a straight line from east to west, but yet so closely, that they may be taken to represent a continuous section from the Dotoi country to the Bannu plain.

Section I.—To the west the Dotoi beds, considerably disturbed and contorted, form the greater part of the country, and rest near Dotoi village on the igneous series. The junction beds show a good deal of disturbance, as is natural in the immediate neighbourhood of igneous intrusions, and it is doubtful what connection there is between the beds. To the east there appears a flat basin of upper nummulitic beds, quite unaltered, composed of white nummulitic limestone, interbedded with light green shale beds. The base beds of this series is seen here and there to be drawn into the sphere of igneous action, showing that the disturbance lasted up to middle eocene times at least.

Section II.—The Idak series of lower nummulitic beds rests on the igneous facies, just north of Mahomed Khél. Igneous disturbance seems to have ceased half way through lower eocene times, leaving the upper half to the east unaltered. The only break in these beds to the east, as far as Idak, occurs in the anticlinal ridge of older limestone between that place and Mirán Sháh.

Section III.—The Idak beds form a flat broad anticlinal, which is mostly hidden under the Shamalara plain, between Idak and Shinkai, where they are seen to dip conformably under the upper nummulitic band of limestone, and this is followed normally by the lower and upper siwalik beds, which disappear finally under the Bannu plain.

On the existence of Lower Gondwanas in Argentina, by DR F. KURTZ[1]; *translated by* JOHN GILLESPIE.

I. INTRODUCTION.

As long ago as 1875, Dr. Luis Brackebusch had described a fossiliferous formation which occurs at Bajo de Velis, and on which he has written several papers. He says[2]: "Having received from Mr. D. G. Avé Lallemant some interesting data on the existence of fossiliferous shales in the Cautana valley, I proceeded to that locality, and was not a little surprised to find some fossiliferous beds at Bajo de Velis (about a league from the entrance to the Cautana valley). This exceedingly interesting find detained me a couple of days, and I ascertained that these beds, which consist of conglomerates and argillaceous shales, had only a small vertical and horizontal extent and were unconnected with the high cliffs of the Cautana valley; they form old lake deposits in which a large quantity of plant remains have been inclosed . . . there are no animal remains found in this place." The fossils which Dr. Brackebusch sent to Dr. A. Stelzner are too badly preserved for determination, and consist solely of casts of wood.

Later on, a resident of the place, Sr. Lucio Fúnes, quarried slate for a church at Bajo de Velis, and Sr. Bonaparte, who superintended the work was the first who discovered well-preserved fossil plants, amongst them *Neuropteridium validum*, Feistm., and *Sphenozamites multinervis* non-spec. Señor Bonaparte presented the collection to Sr. D. Gualterio G. Davis, Director of the Meteorological office of Argentina, who handed them over to me for description. In 1883 Señor D. Francisco P. Moreno, Director of the Museo de la Plata, added to this collection from Bajo de Velis, which has enabled me to establish the age of the fossiliferous shales of that locality.

In describing these plants, I have followed the system adopted by W. Ph. Schimper and A. Schenk (in the 2nd part of the Handbuch der Palæontologie by K. A. von Zittel).

II. DESCRIPTIVE PART.

Dr. Kurtz describes 8 species, amongst which there are 3 new species or rather varieties of well-known Gondwana fossils.

III. SUMMARY.

The fossil flora of the argillaceous shales of Bajo de Velis, as far as known at present, consists of the following species:—

Neuropteridium validum, Feistm.
Gangamopteris cyclopteroides, Feistm.
Equisetites Morenianus, Kurtz.
Sphenozamites multinervis, Kurtz.
Noeggerathiopsis, Hislopi (Bunb.) Feistm.
N. Hislopi, Feistm. var. *subrhomboidalis*, Feistm.
N. Hislopi, Feist. var. *euryphylloides*, Kurtz.

[1] Published in the Revista del Museo de la Plata, Vol. VI, p. 117 ff.

[2] Boletin de la Academia Nacional de Ciencias (Córdoba), Vol. II, 1875, p. 188; quoted by Dr. A. Stelzner in Beiträge zur Geologie und Palæontologie der Argentinischen Republik, part I, 1885, pp. 75-76.

All these species are new to Argentina, and partly also to science in general. The small number of specimens collected does not enable us to form an idea as to the relative frequency of the various species, but nevertheless it is apparent that the commonest form met with is *Noeggerathiopsis*. A similar flora is found at the Cape of Good Hope (Ekka-Kimberley beds), in Peninsular India (Kaharbari beds), in Australia (Newcastle beds, Bacchus-marsh sandstone), and in Tasmania

Kaharbari beds (India).	Bajo de Velis (Province De San Luis, Argentina).	Ekka-Kimberley beds (Cape).
Neuropteridium validum, Feistm.	Neuropteridium validum, Feistm.	......
Glossopteris communis, Feistm.		
G. indica, Fstm. . . .		Glossopteris Browniana, Brongn.
G. damudica, Fstm. . .		
G. decipiens, Fstm.. . .		
Gangamopteris cyclopteroides, Fstm.	Gangamopteris cyclopteroides, Fstm.	
G. cylopt. var. attenuata, Fstm.		Gangamopteris cyclopteroides var. attenuata, Fstm.
G. cyclopt. var. areolata, Fstm.		
G. cyclopt. var. subauriculata, Fstm.		
G. buriadica, Fstm.		
G. major, Fstm.		
G. angustifolia, McCoy.		
Sagenopteris (?) Stoliczkana, Fstm.		
Schizoneura gondwanensis, Fstm.		
Sch. cf. Meriani Schimp .		
Vertebraria indica, Royl. .		
	Equisetites Morenianus, Kurtz.	
Glossozamites Stoliczkanus, Fstm.		
	Sphenozamites multinervis, Kurtz.	
Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.
N. Hislopi var. subrhomboidalis, Fstm.	N. Hislopi var. subrhomboidalis, Fstm.	
	N. Hislopi var. euryphylloides, Kurtz.	

(Mersey coalfield). Of all these floras, that of the Kaharbari beds of the lower Gondwanas in India is closest related to the specimens found at Bajo de Velis, as may be gathered from the accompanying table, which contains a comparison of the various floras mentioned above.

Newcastle beds (New South Wales).	Bacchus-Marsh Sandstone (Victoria).	Mersey Coalfield (Tasmania).
Sphenopteris lobifolia, Morr.		
S. alata Brongn. et var. exilis, Morr.		
S. germana, McCoy.		
S. hastata, McCoy.		
S. plumosa, McCoy.		
S. flexuosa, McCoy.		
Glossopteris communis, Fstm.		Glossopteris communis, Fstm.
G. Browniana, Brongn.		G. Browniana, Brongn.
G. parallela, Fstm.		
G. linearis, McCoy.		
G. gangamopteroides, Fstm.		
G. ampla, Dana.		G. ampla, Dana.
G. reticulum, Dana.		
G. elongata, Dana.		
G. cordata, Dana.		
G. spathulato-cordata, Fstm.		G spathulato-cordata, Fstm.
		Gangamopteris cyclopteroides, Fstm.
		G. cyclopt. var. attenuata, Fstm.
		G. cyclopt. var. subauriculata, Fstm.
	Gangamopteris angustifolia, McCoy.	Gangamopteris angustifolia, McCoy.
	G. obliqua, McCoy.	G. obliqua, McCoy.
	G. spathulata, McCoy.	G. spathulata, McCoy.
Gangamopteris Clarkeana, Fstm.		
Caulopteris (?) Adamsii, Fstm.		Tasmanites punctatus, Newt.
Phyllotheca australis, McCoy.		Phyllotheca australis, McCoy.
Vertebraria australis, McCoy.		
Podozamites elongatus (Morr.), Fstm.		
		Noeggerathiopsis Hislopi, Fstm.
Noeggerathiopsis media (Dana), Fstm.		

Kaharbari beds (India).	Bajo de Velis (Province De San Luis, Argentina).	Ekka-Kimberley beds (Cape).
Carpolithes Milleri, Fstm. Euryphyllum Whittianum, Fstm. Voltzia heterophylla, Brongn.		
Samaropsis sp.		

The following may be deduced from this table with regard to the fossil plants of Bajo de Velis :—

Neuropteridium validum, Fstm., is found in the Kaharbari beds of Bengal where it represents one of the most frequent and most characteristic types. It is noteworthy that this beautiful fern is confined to one horizon only (sandstone beds) of Bajo de Velis.

Gangamopteris cyclopteroides, Fstm., (5 varieties) and 4 other species are the commonest and predominating forms which occur in the Talchir-Kaharbari beds; in the next succeeding horizon, the Damuda division, only some small forms of this genus survive, but they disappear completely higher up. In Africa *Gangamopteris cyclopteroides* has been found only in the lower beds of the "Karoo" formation (the "Ekka-Kimberley" beds) and this is the only species of *Gangamopteris* known in Africa. In Tasmania *G. cyclopteroides* has been found with its varieties, *G. attenuata* and *G. subauriculata*, all in the Mersey coalfield. *Equisetites morenianus*, Kurtz, may be compared with the various remains of the families of the *Equistaceæ*, and of the Schizoneuræ found in the Talchir Kaharbari beds, and very probably belongs to the genus *Schizoneura*, which would clear up an important point connected with the Damuda-Panchet system; in Australia the genus *Phyllotheca* is represented in the group of the Schizoneuræ. *Sphenozamites multinervis*, Kurtz, stands isolated and cannot be compared with forms elsewhere.

Noeggerathiopsis, Hislopi, Fstm., occurs in the Talchir-Kaharbari beds and in the middle Gondwanas (frequently at Damuda and South Aurunga); in the upper Gondwana (Rajmahal series) no species of *Noeggerathiopsis* exist (although they occur at Tonkin). In Africa *N. Hislopi*, Fstm., is only seen in the Kimberley beds, and in Tasmania the species has been found in the Mersey coalfield.

Bajo de Velis.	Ekka-Kimberley beds.	Kaharbari bed.
Neuropteridium validum, Fstm.		Neuropteridium validum, Fstm.
Gangamopteris cyclopteroides, Fstm.	Gangamopteris cyclopteroides, Fstm. var.	Gangamopteris cyclopteroides, Fstm.
Equisetites Morenianus, Kurtz.		
Sphenozamites multinervis,		

Newcastle beds (New South Wales).	Bacchus-Marsh Sandstone (Victoria).	Mersey Coalfield (Tasmania).
Brachyphyllum australe, Fstm. (?); cf. Schimper-Schenk, Palæophytologie, pp. 331, 336).		

where it is associated with another species of the same genus, *N. media* (Dana), Fstm. This last and two more species have been likewise found in New South Wales.[1]

The better to compare the relations which exist between the fossil flora of Bajo de Velis and the plants of the other areas, which we have had under consideration, I have compiled a table of the data available.

From the data given in the following table it may be concluded that the fossil flora of Bajo de Velis belongs to the same geological horizon which holds the other 5 plants mentioned, and that its prototype is the flora of the Talchir-Kaharbari beds of the lower Gondwanas. The palæophytologist O. Feistmantel has already discussed at some length the relation which the lower gondwanas, and the strata in Africa and Australia, occupy to the recognized horizons, especially those of Europe, and has arrived at the conclusion that the formations in question belong to the Permian system, that is to say, that they represent the close of the palæozoic group, a conclusion which several Australian geologists have endorsed, and which in my opinion may be generally adopted with reference to the age of the beds in Argentina[2]:—

[1] The genus *Glossopteris*, so abundantly represented in the various strata of the Gondwana system in South Africa, India and Australia, where it appears for the first time in the upper carboniferous strata (Queensland) and rises to the upper Trias or the lower Jurassic ("Jubbulpore group") is completely wanting in America (as also in Europe); *Glossopteris* is chiefly distinguished from the genus Gangamopteris by the existence on its fronds of a median vein, which character is completely absent in *Gangamopteris*.

[2] It must be mentioned here that this view had practically been adopted by the members of the Geological Survey of India some time before Dr. Feistmantel would admit it himself. (Director Geological Survey of India.)

Newcastle beds.	Bacchus-Marsh Sandstone.	Mersey coalfield.
Gangamopteris (1 spec.).	Gangamopteris (3 spec.).	Gangamopteris cyclopteroides, Fstm., cum var. et. 3 spec. alt.

Bajo de Velis.	Ekka-Kimberley beds.	Kaharbari beds.
Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.
N. Hislopi var. subrhomboidalis, Fstm.		N. Hislopi var. subrhomboidalis, Fstm.
N Hislopi var. euryphylloides, Kurtz.		

Up to date we know of three rock-formations in Argentina which have yielded fossil plants. The first is that of Retamito in San Juan, which corresponds to the lower carboniferous (Culm) as Dr. L. Szajnocha [1] has already shown; then follows the flora of Bajo de Velis which has no species in common with the preceding formation nor with the following series. The latter occurs in the neighbourhood of Cacheuta, Challas and Uspallata in Mendoza, at Mareyes in San Juan, and in the Escalera de Famatina in La Rioja. The fossils found at the latter places belong to completely different flora, which Professor H. B. Geinitz has already determined as belonging to the rhætic,[2] a conclusion confirmed by Dr. A. Stelzner [3] and also by Dr. L. Szajnocha[4].

To the same epoch belong the fossil plants, which are found in the Stormberg beds (Upper Karoo) of South Africa; in the Tivoli-Ipswich beds of Queensland; in the Wianamatta-Hawkesbury beds of New South Wales; and in the Jerusalem beds of Tasmania: that is to say, that these fossil plants occur in horizons between the upper triassic and lower jurassic systems. In India the lower beds of the Rájmahál series (Upper Gondwanas) correspond more or less to the rhætic system.

In the following table I have arranged the plant-bearing beds of Argentina according to their geological horizons:—

Series of beds at Cacheuta, Challas, Uspallata, Marayes, Escalera de Famatina.	Rhætic.
?	Trias.
Bajo de Velis series.	Permian.
?	Upper carboniferous.
Retamito series.	Lower carboniferous (Culm).

[1] Revista, Vol. VI, p. 119; see also Stz. Ber. Kais. Akad. d. Wissensch. Wien, Vol. C, pt. 4, p. 203 (Dir., G. S. I.).

[2] Ueber rhætische Pflanzen und Thierreste in den Argentinischen Provinzen La Rioja San Juan und Mendoza: 1876 (Palæontographica Suppl. III.).

[3] Beiträge zur Geologie und Palæontologie der Argentinischen Republic, I: 1885, pp. 68-82.

[4] Ueber fossile Pflanzenreste aus Cacheuta in der Argentinischen Republic. Sitz. Ber. Kais. Akad. Wiss. Wien., Vol. XCVII, pt. 1, 1888, pp. 219-245.

Newcastle beds.	Bacchus-Marsh Sandstone.	Mersey coalfield.
Noeggerathiopsis (1 spec.).		Noeggerathiopsis Hislopi, Fstm.

Note by the Director, G. S. I.—The evidence afforded in the above paper has such a strong bearing on the age and relations of the most important of all our rock-formations of India, namely the coal-bearing Gondwanas, that it appeared advisable to have it translated from the Spanish original, which has been ably done by Mr. John Gillespie, to whom our acknowledgments are due.

One of the chief points of interest in connection with the discovery of Gondwana plants in Argentina lies in the fact that there we have an unquestionable lower carboniferous series (Retamito) in the neighbourhood of which (and probably unconformably to it) a series of beds is found, which contains well known lower Gondwana species of plants, thereby limiting the geological range of the lowest beds of it, at all events to upper carboniferous at most, which is a further confirmation, long ago and independently arrived at by the authors of the "Manual" (1st edition) and generally adopted by the Geological Survey of India,

Notes from the Geological Survey of India.

I. *Central India, Rewah.*—Mr. Oldham with Mr. Datta have continued their surveys in Rewah, and some of the results of their work have already been noticed in my annual report and in the "Notes," Records, part 2; with regard to the Vindhyans and underlying rocks no specially new facts have come to light; but, on the other hand, Mr. Oldham has latterly been engaged in the survey of a patch of Gondwanas, which contained several rather fair coal-seams, though few over three feet in thickness. The total extent of the surveyed area of the coal-measures is about 200 square miles, and it is situated east of the Mohan river, shown in sheet 476 of the Rewah survey.

Near their western limit they are covered by red ferruginous sandstones and shales, whose extent has not been determined. The Barakar age (already determined correctly by Mr. Smith) is clearly shown by the fossil contents, amongst which are *Vertebraria, Glossopteris, Schizoneura,* etc. Two coal-seams of 6 feet and 5 feet 6 inches thickness were found by Mr. Oldham; the former is 1½ miles south-west by west of Ujeini, the latter, 2 miles north of Amlia, both places near the eastern edge of the standard sheet 476.

II. Madras.—Mr. Middlemiss continued his researches in the Salem district and reports in February.

(1) *Magnesite and ultra-basic rock of Valaiyapaddi.*—The magnesite is present in very small quantities. The rocks associated with it entirely resemble those at the north-west end of Kanjamallai, so far as their appearance in the field goes. Forming a long low ridge, running east and west from Valaiyapaddi, there are interesting examples of the above type in close association with a very acid rock, namely, a coarse graphic granite composed almost entirely of pink orthoclase and quartz. Both rocks are intrusive among the basal gneisses of that area in parallel lines. Some good instances of this are to be found west of Valaiyapaddi. The graphic granite was probably intruded last.

(2) *Charnockite, south of Salem.*—Between Muttu Kalipatti and Salem on the Namakal-Salem road a great exposure of charnockite occurs. From its position, strike, and general appearance it is a continuation of the Shevaroy Hills massif.

(3) *Chalk Hills.*—The final few days spent at the Chalk Hills enabled me to secure some "camera" sketches and photographs. As a whole, the aspect of each magnesite area is that of a series of concentric ellipses (roughly speaking) of rocks of varying composition and basicity. At the centre of each area occurs the chromite in veins among the dunite and serpentine; surrounding this is a paler dunite zone (almost pure olivine, or partly or wholly converted into magnesite). Surrounding this again is a small ring of rocks containing olivine and pyroxene with sometimes biotite. Surrounding this at certain points come rocks like the last, but with felspar and quartz in small quantities. Finally, surrounding the whole area come great ridges of hornblende-garnet rocks set among and with the ordinary gneisses of the country.

(4) *Corundum localities, Coimbatore District.*—The corundum localities visited in Coimbatore embraced Selengapalaiyam near Kavanthapatti where the mineral is only sparingly found and picked up from the surface after heavy rain. It is similarly found at Gopichettipalaiyam in one small field. The locality of Siva Mallai is the best that I have yet seen. The mineral is regularly worked for and occurs as large hexagonal prisms scattered about in an extremely coarse biotite granite with pink felspar. The latter follows along the north-west side of a range of low gneiss hills, a continuation of the Siva Mallai. The corundum is chiefly found on the margins of the granite veins.

III. Baluchistán.—During February Mr. Smith examined the high range between the Lúni plain and the Zhób territory. This range is apparently formed of massive jurassic limestone, containing ammonites; its thickness is very great, and in the Wat pass, which leads through the centre of the range, it is quite 2,000 feet, all within sight, and the base is not exposed.

This grey, massive limestone is overlaid by the neocomian belemnite beds, consisting of yellowish to pink, light green and white shaly limestones and shales,—conformably apparently. The entire area near Mekhtar is formed of these beds, which yielded belemnites in abundance besides some ammonites.

This neocomian horizon is overlaid by a great series, which Mr. Smith was enable to divide further, but which seems to have varied a good deal lithologically; the middle of the series apparently contained nummulitic limestone beds, and the uppermost beds were capped by the white nummulitic limestone of the Spintangi beds. Some of the beds of this great series appear to be derived from volcanic material, and even basaltic rock was met with.

There can be little doubt but that this sequence of beds represents the great belt of strata, which extends from south of Hindu Bágh, north of the Loralai hills along the southern side of the Zhób valley, and which show such a well pronounced flysch character. The lowermost beds are upper cretaceous, whilst the whole lower and middle nummulitic division of the tertiary system is represented.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

CALCUTTA;
The 1st August 1895.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1895. November.

On the Igneous Rocks *of the* Giridih (Kurhurbaree) Coalfield *and their* Contact Effects. *By* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Deputy Superintendent, Geological Survey of India,* and WALTER SAISE, A.R.S.M., D.Sc., F.G.S., *Manager, East Indian Railway Company's Collieries, Giridih.* (With map, pl. 4, and two wood-cuts.)

CONTENTS.

I.—INTRODUCTION.

1. The dyke-rocks of the Giridih coalfield have been mentioned and mapped by Mr. T. W. H. Hughes, late Superintendent, Geological Survey of India, in a memoir published in 1868[1]. The 15 dykes described by that author were classified as (1) dioritic traps, (2) compact felspathic traps, and (3) micaceous traps. Mr. Hughes

[1] *Mem. Geol. Surv. Ind.*, Vol. VII, p. 209.

has also briefly referred to the crystalline rocks which fringe the whole coalfield and form also two faulted inliers amongst the Talchirs in the north-west corner.

2. Later investigations facilitated by widely-extended subsequent mining operations have enabled us to add many facts concerning the relations and field characters of these dykes, whilst microscopic and chemical examination in the laboratory of the large number of specimens collected has revealed many additional facts, which appear to be of both local and general interest. We gratefully acknowledge the help most generously given in many ways by Mr. T. H. Ward, F.G.S.

II.—GENERAL STRATIGRAPHICAL CHARACTERS OF THE COALFIELD.

3. The Giridih (Kurhurbaree) coalfield consists of a small patch of strata of Barakar and Talchir age, measuring 11 square miles, and preserved between three nearly parallel faults, which trend east and west. The Barakars appear at the surface for over 7 square miles and the Talchirs for over 3⅛ square miles, the remainder ⅞ square miles, being inliers of crystalline rocks.

Barakar Stage.

4. The Barakars, having a total thickness of nearly 1,000 feet, include at the top several great seams of inferior coal (the *hill seams*) with coarse sandstones, conglomerates and dark felspathic grits, lying on 500 feet of light-grey, coarse sandstones and conglomerates containing well-rounded boulders of quartzite, with dark grey grits, and a few bands of shale or impure coal. Underneath these beds occur 150 feet of grits in which the two main seams of Kurhurbaree coal occur (Kurhurbaree upper and lower seams).

Talchir Stage.

5. The Talchirs, lying below the Barakars, consist of friable, greenish and yellowish sandstones overlying yellow and blue shales, which weather in a very characteristic fashion into nodular masses and acicular fragments. Underneath these shales occurs the well-known boulder-bed. The total thickness of the Talchirs is about 150 feet.[2]

III.—THE IGNEOUS ROCKS.

6. According to their geological age, the igneous rocks may be grouped into—

(*a*) those which were intruded into the crystalline series before the deposition of the Talchir group, and

(*b*) those which have been intruded subsequent to that period, and, probably, subsequent to the formation of the youngest Damuda rocks in Bengal.

7. The time which elapsed, therefore, between these two sets of intrusions was at least as great as that required for the deposition of the Damuda series. We shall give below (paras. 17,18 and 30) the evidences which suggest that some of the former group of intrusive rocks (*Pre-Damuda*) were subjected to statical metamorphism

[2] Detailed descriptions of the stratigraphy of this area will be found in the memoirs by Mr. Hughes (*Mem. Geol. Surv. Ind.*, Vol. VII (1868), p. 209), and in a paper recently published by one of us (Saise, *Rec. Geol. Surv. Ind.*, Vol. XXVII (1894), p. 86). Reference to previous literature on the same subject will be found in these papers.

at the time of the intrusion of the oldest of the latter group (*Post-Damuda*), and subsequently suffered from the results of dynamical metamorphism, probably when the main faults of the field were developed.

(*a*) PRE-DAMUDA IGNEOUS ROCKS.

8. The crystalline rocks, which have already been mentioned, have been invaded by igneous rocks whose pre-Damuda age is assumed principally from negative evidence. They can be traced up to the boundary faults in several places, but are never found within the limits of the stratified area; they are assumed, therefore, to be older than the boundary faults, and, with less certainty, than the Damuda strata forming the coalfield. The dyke of eurite on the north of the field marks the boundary for a considerable distance, the plane of the dyke-face forming apparently a line of low resistance along which the fault has developed.

9. Neglecting the question of the origin of the ordinary crystalline gneisses and schists, the rocks which form well-defined dykes and are considered to be of immediate igneous origin are—

(1) Diorites.

(2) Granites and Eurites.

(1) DIORITES.

10. By their resistance to the weather, the diorites generally rise as small hills from amongst the crystalline series. Similar rocks, in which, in hand-specimen, hornblende is always a prominent constituent, occur as dykes in various places amongst the crystallines of Chota Nagpore, the Sonthal Pergunnahs and Raniganj, but never breaking through the sedimentary rocks.

Origin of the diorites.

11. The way in which these have developed from an original pyroxene-plagioclase rock is very easily demonstrated in almost every one of these masses; but the secondary changes which have been brought about by both statical and dynamical metamorphism show some interesting variations in the different localities. On the north and east of the coalfield, for instance, the development of hornblende from the original pyroxene, and of a granulitic structure from an original granitic one, is accompanied by the production of large quantities of scapolite. In these rocks a prominent constituent is apatite. On the south of the coalfield, on the other hand, the augitic rocks pass into hornblende-granulites and even hornblende-schists, which are entirely devoid of scapolite. It is very interesting to note that in these rocks, which do not give rise to scapolite, there is, unlike those of the northern margin, not a trace of apatite.

Werneritisation.

12. In the rock described in 1875 by Brögger and Reusch[3] as *gefleckter Gabbro*, and in which the apatite veins of Oedegaarden occur, Professor Judd has traced the changes by which plagioclase-felspar has been transformed into scapolite. Liquids under pressure and containing chlorine in some form or other produced

[3] *Zeitschr, d. d. geol. Ges.*, Vol. XXVII, p. 646.

cavities by solution along the twin-planes in the felspar, and these cavities became filled with supersaturated solutions of sodium-chloride. Following these changes, which form a part of the statical metamorphism[4] to which the rock has been subjected, crushing of the mass has produced a granulitic structure accompanied by the conversion of the mixture of plagioclase and sodic chloride into crystals of scapolite[5]. In the hornblendic rocks on the north-east boundary of the Giridih coalfield, in the neighbourhood of Paharidih and Mongrodih, we have a most striking illustration of the development of scapolite from plagioclase by the successive effects of statical and dynamical metamorphism similar to those which have been so beautifully traced in the celebrated *Apatitbringer* of Oedegaarden in Norway by Professor Judd.

Mineral composition of original rock.

13. The original rock contained both monoclinic and rhombic pyroxenes. The former appears under the microscope as colourless plates with a feeble attempt at an ophitic arrangement around the felspars. These are invariably changed at their margins into granules of hornblende. The rhombic pyroxene occurs in minute granular aggregates darkened by the products of schillerization and forming at the junctions with felspar reactionary fringes which are composed of radially arranged blebs of a colourless mineral and hornblende.

Statical metamorphism of the plagioclase.

14. The plagioclase felspars are invariably crowded with minute colourless liquid inclusions arranged along the twin-planes (see plate fig. 3). As the crushed rock gave, with nitric acid and silver nitrate, unmistakeable reactions for a chloride, we concluded that these inclusions, like those in the Oedegaarden rock, are solutions of sodic chloride.

Accessory constituents.

15. Amongst the accessory constituents, crystals of black iron ores, garnet which is of secondary origin, apatite, quartz and calcite are found in small quantities.

Dynamical metamorphism of the rock.

16. This compact rock with *granitic* structure, composed almost wholly of *pyroxene* and *plagioclase*, and in which the effects of statical metamorphism are so strikingly shown, passes within a short distance along the same dyke into a distinctly foliated *granulitic* rock, in which *hornblende* and *scapolite*, by far the most abundant constituents, are mixed with a granulitic aggregate of *clear* felspar and quartz. Not the least interesting features in the rock are the patches which have escaped the effects of the dynamo-metamorphism. In these the old granitic structure is preserved and the felspars still clouded with inclusions, whilst scapolite is absent.

Paragenesis of apatite and scapolite.

17. The frequent close association of apatite and scapolite in Norway, Canada and elsewhere, naturally reminds us of the remarkable apatite-bearing peridotite which breaks through the Damuda strata in the immediate neighbourhood of the scapolite-bearing rocks of this area. According to the analyses of Waage, quoted by Brögger and Reusch[6], the apatite of Oedegaarden contains from 3 to 5·8 per cent. of chlorine. In the Giridih area also the apatite of the peridotite is a chlor-apatite. We have

[4] On statical and dynamical metamorphism: *Geol. Mag.*, Dec. III, Vol. VI (1889), p. 243.
[5] *Min Mag.*, Vol. VIII (1889), p. 186.
[6] *Loc. cit.*, p. 674.

thus a suggestion for the origin of the chlorine, which has in both cases brought about the preliminary changes necessary for the formation of scapolite from plagioclase in a previously-formed pyroxene-felspar rock, such as that at Mongrodih and the *geflecter Gabbro* of Oedegaarden.

Geological age of the scapolite.

18. Accepting this explanation, the formation of the scapolite may have commenced at any time after the deposition of the Damuda rocks, which we shall show to be the oldest limit of the peridotite intrusion (see para. 29—32; also Holland, *Rec. Geol. Surv. Ind.*, vol. XXVII (1894), p. 132). For the subsequent movements of the rocks which gave rise to the granulitic and foliated structures, the Rajmahal eruptions which fissured the country in all directions must have been sufficient to account for the younger faults and the small amount of crushing which has produced a rough foliation approximately parallel to the main faults. We consider that the intrusion of the peridotite, the production of the leading faults, and the wernerítization of the pyroxene-felspar rocks occurred in close succession, at a period not far removed from the time of the deposition of the Panchet rocks.

Uralitisation.

19. The production of hornblende by paramorphism of the augite is the most conspicuous amongst the secondary changes which have been produced in the pre-Damuda pyroxene-plagioclase intrusions. There are two principal types of this change: (1) At Bonkhoonju, a small peak west of the Oosri nuddi and north of the coalfield, hornblende develops with crystallographic parallelism to the porphyritic augite from which it is derived, and the rocks have suffered comparatively little from crushing. (2) In Chepo hill and near Gujiadih, on the southern border of the coalfield, where the band of dioritic rocks runs east-north-east and west-south-west, parallel to the general strike of foliation in the crystalline series, the hornblende has formed in isolated crystals in the augite without definite crystallographic relations to the latter, whilst the rocks themselves are sometimes so crushed and foliated that they become fissile hornblende-schists.

Uralitization at Bonkhoonju.

20. (1) In the rocks from Bonkhoonju hill the large phenocrysts of augite are darkened with schillerization plates, and the change to hornblende takes place along the margins of the crystals, extending inwards to varying degrees. The hornblende selvages so formed show optical continuity over considerable areas, the vertical crystallographic axis of the mineral generally coinciding with that of the augite undergoing the paramorphic change.

Without scapolite.

There are again two types of these rocks. In one lot the large augites show a lustre-mottling in the hand-specimen, whilst the felspars retain their original long prismatic shapes, and are darkened by inclusions. In this type there are patches of biotite generally with a lump of black iron-ore in the centre of each patch, and a granular pleochroic rhombic pyroxene which occurs in conspicuous quantities. In the other type, the felspars show

With scapolite.

a granulitic structure, with either clear scapolite crystals or patches of a grey fibrous material which strongly resemble the decomposition-products of scapolite. Biotite occurs irregularly but always intimately associated with the hornblende from which it has possibly been derived. Sphene and apatite are scattered irregularly through all these rocks.

21. (2) The Chepo hill mass shows generally a more advanced stage in the uralitization to hornblende, the crystals springing up at irregular intervals in the augite crystals, and showing little regard for the optical orientation of their neighbours. Epidorites and even well-foliated hornblende-schists occur along the same band of rocks at Gujiadih. Sphene and colourless epidote are represented, but apatite (unlike the Bonkhoonju rocks) is noticeably absent; the acicular crystals scattered through the felspar shew a much higher double refraction than that of apatite.

Uralitization at Chepo and Gujiadih.

(2) EURITES.

22. Besides the masses of binary granite which occur at several places amongst the felspathic gneisses, there are two large dykes of eurite—one running close to the northern boundary fault, and for some distance along the fault (see para. 8), and the other running in a parallel direction on the southern boundary from a point a little to the south of the junction of the Komaljore and Suni nadis to a point where the latter crosses the fault.

23. The eurite is a dark-green compact rock exhibiting a fracture which is conchoidal, except where interrupted by the numerous inclusions of hornblende-granite. Quartz in small granules is scattered through the grey microcrystalline matrix, and sometimes occurs in larger fragments which show crystal outlines. The absence of ferro-magnesian silicates amongst the phenocrysts is a very noticeable feature. The patches of coarse-grained granitic material, giving a glomero-porphyritic structure to the rock, contain considerable proportions of plagioclase with small quantities of hornblende. The whole rock has been brecciated and the pieces re-cemented with granular quartz.

Structure of the eurites.

(*b*) POST-DAMUDA INTRUSIONS.

24. The dykes which break through the stratified rocks of Damuda age are of two very distinct types:—

(1) A group of mica-peridotites remarkable for the amount of apatite they contain, and,

(2) Large dykes of basalt, younger than the foregoing set and probably the underground representatives of the Rajmahal lava-flows.

Dykes of the former class can generally be identified with the compact felspathic and micaceous traps of Mr. Hughes, whilst the latter are referred to as dioritic traps by the same author.

(1) PERIDOTITES.

25. The rocks which have been generally known to previous wrtiers as "mica traps" occur in this and in most of the Bengal coalfields in the form of dykes and intrusive sheets with very marked characteristics. The dykes are generally narrow (3—5 feet)

Characters of Peridotite intrusions.

and at the surface are always decomposed to a soft buff-coloured crumbling earth, which is often vesicular and contains remnants of partially-decomposed bundles of mica. Traced below the surface in the colliery workings, these dykes are seen to send out ramifying apophyses into the surrounding coal and sandstones, and in some places they thicken out into boss-like masses, or even spread out in wide sheets along the bedding planes, coking the coal with the production of beautiful columnar structures, baking the shales, and partially fusing the felspathic sandstones into compact rocks, which sometimes show structures in section like those seen in rhyolites (para. 53).

26. As compared with other igneous intrusions of this area, the results of the widely-extended results of contact-metamorphism produced by the irruption of these "mica traps" everywhere appear to a very marked degree. Taking this fact into consideration with the length of such narrow dykes in the different coal-fields, it seems natural to suppose, as previously suggested by one of us,[7] that the igneous material was injected in a very mobile condition at an exceptionally high temperature.

Microscopic characters of the Peridotites.

27. The colliery workings, besides enabling us to trace the various ramifications of these intrusive rocks, have exposed at greater depths masses of the rock which have suffered very little from secondary decomposition. The microscopic characters, which have been described in detail by one of us,[8] prove it to be of a type quite unique amongst the remarkable group of peridotites. A character which seems to be constant throughout the coalfield is the most exceptional quantity of apatite amongst the constituents of this peridotite, amounting in the freshest specimens obtained to as much as 11·5 per cent. of the rock. In these specimens which were obtained from the boss-like expansion in No. 7 Jogitand shaft, the apatite is accompanied by biotite, olivine, magnetite, chromite and a grey base which is considered to be the vitreous residue of the rapidly cooled and imperfectly crystallized magma. In other places augite and anthophyllite are amongst the ferro-magnesian constituents. Whilst the corresponding rocks in the Darjeeling coal-measures, where, by the way, apatite is subordinate in quantity, are sometimes composed entirely of crystals, those of the Giridih coalfield are, so far as our researches show, always hemicrystalline like the kimberlites described by Carvill Lewis in the Gondwana rocks of South Africa. As might be expected, the central portions of the larger masses are always coarser in grain than the more rapidly cooled selvages.

Decomposition of the Peridotites.

28. Subterranean circulating waters, in which the proportions of carbonic and to a less extent sulphuric acids are increased by the slow oxidation of the pyritous coal, bring about secondary changes in the rock constituents with the production of serpentine, followed invariably by rhombohedral carbonates and sometimes by secondary quartz. At the surface, oxidation of the iron compounds and removal of the alkalies and alkaline earths in solution leave a buff-coloured or rusty soft clay in which mica seems about the last mineral to lose its original characters.

[7] Holland. *Rec. Geol. Surv. Ind.*, Vol. XXVII, p. 133.

[8] Holland. *Loc. cit.*, p. 129.

Distribution and Geological age of the Peridotites.

29. Dykes of the mica-peridotite are found cutting through the hill seams and the Kurhurbaree upper seam; but it is in the lower seam that the intrusions are most numerous, and here they spread out in great sheets destroying the coal over large areas. As might be expected the greater pressure at lower depths forced the molten material along the bedding planes of the least resisting rock, namely, the coal.

30. On the accompanying map we have indicated the position of 19 peridotite dykes so far as they are traceable at the surface. These show a general tendency to run east and west. Whilst they cross the older faults in the lower seam they do not break through the boundary faults, as is the case with the younger basaltic intrusion. The intrusions are therefore younger than some of the faults *within* the coalfield but are probably older than the *boundary faults* of the field. This agrees with a suggestion we have already made that the statical metamorphism of the pre-damuda pyroxene-felspar rock of the adjoining area occurred at the time of the intrusion of this chlor-apatite bearing peridotite and the subsequent movements which changed the former rock into a hornblende-scapolite granulite brought about the great faults, which dropped the Giridih coalfield into its present position. It is certainly very significant to note with reference to this suggestion that where the original pyroxene-felspar rock was furthest removed from these peridotite intrusions, as at Chepo, there is not the slightest sign of scapolite in the foliated hornblendic rocks.

31. One of the dykes only (the Buriadih dyke, No. 2 on list) passes into the crystallines; and the boundary of the coalfield at this point is a natural one, not faulted.

32. The highest strata amongst the Damudas at Giridih are cut by the peridotite dykes. Passing to the Raniganj coalfield we find the youngest Damuda beds there, namely, the Raniganj-stage, are also invaded by this rock; but beyond this we have no reliable evidence for fixing with greater precision the *oldest* limit of the intrusion. The *youngest* limit is determined by the basalts which, following Dr. Blanford, we regard as Rajmahal in age. We have thus a peridotite intrusion probably contemporaneous with the formation of some part of the Panchet group.

33. *Catalogue of the Mica-peridotite dykes in the coalfield.*

No.	Name of dyke.	Direction.	Thickness.	REMARKS.
1	Dandidih . . .	NW—SE	3 feet	
2	Buriadih . . .	NW—SE	1 foot	No. 6 of Hughes.
3	Chunka . . .	NW—SE	2 feet	
4	Khandiha . . .	NNW—SSE	2 „	No. 8 of Hughes.

No.	Name of dyke.	Direction.	Thickness.	REMARKS.
5	Kopa	NNW—SSE	2 „	No. 15 of Hughes.
6	Baniadih . . .	NW—SE	1 foot	
7	Bungalow pit Buniadih .	W—E	1½ „	No. 10 of Hughes.
8	Domahani . . .	W—E	1 „	„ 11 „ „
9	Jubilee pit . . .	W—E	6 inches	„ 10 „ „
10	Bhaddoah hill . .	W—E	1 foot	
11	Sariabad . . .	W—E	1 „	
12	Gapae	WSW—ENE	1 „	
13	Satighat . . .	NW—SE	1 „	No. 13 of Hughes.
14	Bittagarha . . .	ENE—WSW	1 „	
15	Jogitand . . .	ENE—WSW	1 „	
16	Jogitand—Lunki . .	WNW—ESE	1—5 feet	No. 5 of Hughes.
17	Chaitadih . . .	WNW—ESE	1 foot	
18	Mowlichopah . .	N—S	2 feet	No. 1 of Hughes.
19	Birwadih . . .	W—E	1 foot	

(2) BASALTS.

34. The greater thickness and the spheroidal weathering of the hard, black or dark-grey basalts are characters which serve to distinguish without difficulty the dykes of this rock from those of the mica-peridotite with which, within the limits of the coalfield, they are so frequently associated. These dykes sometimes attain a thickness of 100 feet, and yet nowhere has the action of this rock on the strata produced results in any way comparable to the effects of the much narrower intrusions of the mica-periodotite. So far as we know, the basalts never spread as sheets along the bedding planes of the sedimentary strata which have been invaded.

35. Specimens of the basaltic rocks have an average specific gravity of 2·99. Under the microscope they are seen to be composed of *olivine*, partially decomposed with the formation of green and yellow serpentine, *plagioclase felspar* in lath-shaped crystals, *magnetite*, often developed around the felspars, and included by the pale brown *augite*, which is developed ophitically around the crystals of earlier consolidation. There is always a residue of feathery microlites in a hyalopilitic matrix.

Occurrence and geological age of the basalts.

36. The basalts cut through the faults within the limits of the coalfield and strike across the boundary faults into the adjoining crystalline series. Where their junctions with the peridotites have been exposed and examined, it is seen that the

latter rocks are displaced and cut through, proving the basalt to be distinctly younger than the mica-peridotites. (See fig. 1). Seeing they cut across the boundary faults, they may be regarded as younger than the coalfield as a whole.

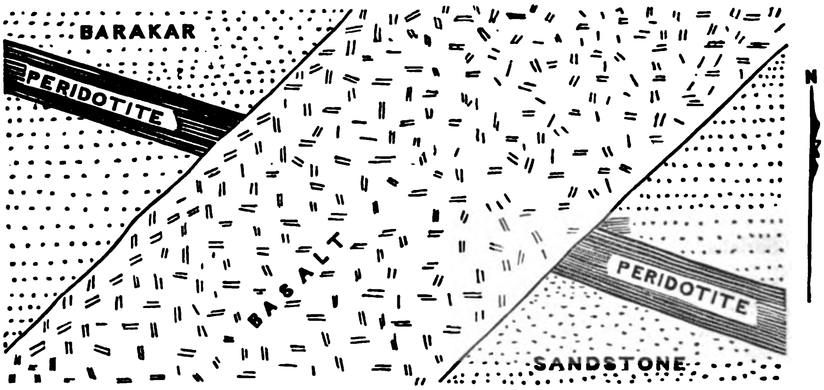

Fig. 1. Plan showing the Baniadih-Komaljore dyke of basalt crossing the Jogitand-Lunki dyke of peridotite.

Following the conclusions of Dr. Blanford concerning the age of the augitic dykes of the Raniganj coalfield[9] and of subsequent workers in other Bengal coalfields, it seems safe from analogy to consider these basalts to be the dyke representatives of the petrologically similar basaltic outflows of Rajmahal age.

37. The following is a list of the six basaltic dykes mapped :—

No.	Name of Dyke.	General direction.	Thickness.	Remarks.
1	Pandadih . . .	E—W	20 feet.	In the crystallines.
2	Maniktand . .	NW—SE	50 "	No. 14 of Hughes.
3	Dhobidih-Mowatand .	NW—SE	5—100 "	" 12 " "
4	Baniadih-Komaljore .	NE—SW	5—100 "	No. 9 " "
5	Baniadih . . .	NW—SE	30 "	......
6	Kopa-Kabribad .	E—W ESE—WNW	5— 50 "	No. 7 of Hughes.

38. The two sets of intrusive rocks just considered—the mica-peridotites and the basalts—are associated with one another in nearly all the coalfields of Bengal, and we have shown that the more basic eruption has been the first to be intruded. As all workers agree in considering the basalts to be of Rajmahal age, and we have shown that the peridotites are younger than the Raniganj stage, these two sets of intrusions cannot differ very greatly in geological age. But they are nevertheless quite distinct in order of eruption. They are equally distinct in petrological

[9] *Mem. Geol. Surv. Ind.*, Vol. III, pp. 141—149.

characters and mode of occurrence; and we do not see that there is any proof of their having been derived from a common magma, although this has been assumed so frequently during the last two or three years as a necessary premise for explaining the irruption in order of basicity of igneous rocks associated with one another within the limits of comparatively small areas. The older set of intrusions are represented by mica-peridotite as the leading petrological type; they occur in all the coalfields of Bengal from Raniganj to Darjeeling, and are of about Panchet age. In places by the introduction of felspar, these pass into basalts, but of a type which could never be mistaken for the Rajmahal rocks. The younger group of intrusions are basalts with olivine passing into augite-plagioclase rocks; they stretch to considerable distances around Raniganj, and belong to a petrographical province of Rajmahal age. It would be a great convenience if we had some conveniently short nomenclature to express the geological age, geographical limits, and petrological facies of petrographical provinces so marked as these cases presented to us in Bengal.

Relations of the peridotites and basalts.

(3) COMPARISON WITH SOUTH AFRICAN INTRUSIONS.

39. In studying the post-Damuda intrusive rocks of this and the other coalfields of Bengal, it is impossible to overlook the apparent parallelism with the igneous rocks which invade the Karoo system of South Africa. Although the South African beds have not been sufficiently investigated to allow of great precision in correlating the various groups there represented with the Gondwanas of India, the palæontological and lithological characters of the deposits leave no doubt about the Karoo system being homotaxially equivalent to the lower and a portion of the upper Gondwana system in India.

40. The rocks intrusive into the Karoo beds belong to two groups:—

(1) The diamond-bearing peridotite breaking through the Ecca beds and Kimberley shales.

(2) The basaltic rocks which break through the whole series and form contemporaneous lava-flows capping the Stormberg beds.

41. In India we know beyond question that the peridotites are older than the associated basalts. In Africa we only know that they break through the older strata and are not found in the higher beds.

42. In India the basaltic dykes break through the whole of the lower Gondwanas and are considered to be the underground representatives of the Rajmahal lava-flows. The basalts of South Africa traverse in like manner the complete Karoo system from the Ecca stage to the Stormberg beds.[10] Whilst it is not yet possible to fix exactly the position, and especially the youngest limit, of the Stormberg beds, they are certainly not older than the Panchets and are probably not far removed in age from the Rajmahals.

43. Whilst admitting, therefore, that the evidence is but fragmentary, we consider that the facts of stratigraphical distribution and petrological features, so far as they are known, are sufficient to warrant as a tentative conclusion the existence of one, if not two, petrographical provinces of Gondwana age extending from South

[10] Green *Quart. Journ. Geol. Soc.*, Vol. XLIV, (1888), p. 239.

Africa to India. The oldest of these was characterised by peridotites, and these were followed, at a period not far removed, by enormous outflows of basalts and augite-andesites.

IV.—CONTACT-EFFECTS.

44. The intrusions of peridotites and basalts into the Damuda strata have given rise, as already stated, to very marked contact-metamorphism, especially in conjunction with the former group of igneous rocks. The results, as might be expected, are most striking amongst the coals, whilst the sandstones have been hardened by baking and even partial fusion, and the shales merely baked.

1. Contact-Metamorphism of the Coal.

45. Even the narrow dykes of peridotite, where they pass through the coal seams, are bordered with a zone of beautifully columnar coke two or three feet thick on either side of the dyke. The volatile bituminous matter having been driven off, the resulting contraction in the mass produced a columnar structure with injections of thin films of the igneous rock along the cracks.

46. The series of proximate assays given below are of altered coal taken at gradually increasing distances from the margin of the peridotite dyke, and compared in each case with specimens of unaltered coal from the same seam.

Series A.

47. Specimens taken from lower seam, south of No. 7 Jogitand shaft, Giridih coalfield:—

Thickness of peridotite dyke, 4 feet.
Thickness of coked zone, 3 feet 6 inches.

	Numbered from the Dyke outwards.					
	1	2	3	4	5	6
Volatile matter (excluding moisture.)	4·10	4·89	6·40	6·80	15·45	20·71
Fixed carbon . .	64·63	74·36	71·79	80·69	74·31	67·46
Ash	31·27	20·75	21·81	12·51	10·24	11·83
Total .	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake. Ash, light brown.	Does not cake. Ash, light reddish brown.	Does not cake. Ash, light brown.	Does not cake. Ash, light reddish brown.	Cakes, but not strongly. Ash, light reddish brown.	Cakes strongly. Ash, light brown.

Series B.

48. Specimens taken from lower seam on northern side of No. 7 Jogitand shaft, Giridih coalfield:—

Thickness of peridotite dyke, 3 feet.
Thickness of zone of altered coal, 3 feet.

	NUMBERED FROM THE DYKE OUTWARDS.					
	1	2	3	4	5	6
Volatile matter (excluding moisture).	5·31	4·95	6·71	4·84	8·01	19·10
Fixed carbon . .	71·51	72·84	77·70	83·29	78·72	59·43
Ash	23·18	22·21	15·59	11·87	13·27	21·47
TOTAL .	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake.	Does not cake.	Does not cake.	Does not cake.	Does not cake.	Cakes, but not strongly.

49. An examination of these assays leads to the following general conclusions:—

(1) There is a loss of bituminous matter as the igneous rock is approached.

(2) The fixed carbon at first increases in proportion to the loss of the volatile constituents until close to the dyke the fixed carbon again decreases, which we presume to be due to its oxidation and replacement by inorganic bases.

(3) The ash increases in percentage as the dyke is approached, and this increase is far greater than would be due to the simple removal of volatile matters (*vide infra*, para. 52).

50. These conclusions are more uniformly illustrated by considering the averages of assays of adjacent pairs of samples and compared as follows with a sample of unaltered coal from the same seam:—

Series A.

	NUMBERED FROM THE DYKE OUTWARDS.				
	1 and 2.	3 and 4.	5 and 6.	Two specimens at 4 feet from dyke.	Specimen at 10 feet from dyke.
Volatile matter . .	4·49	6·60	18·08	22·12	24·70
Fixed carbon . . .	69·50	76·24	70·89	66·60	65·99
Ash	26·01	17·16	11·03	11·28	9·31
	100·00	100·00	100·00	100·00	100·00
	Do not cake.	Do not cake.	Cake.	Cake strongly.	Cakes strongly.

Series B.

	1 and 2.	3 and 4.	5 and 6.	Two specimens at 4 feet from dyke.	Specimen at 10 feet from dyke.
Volatile matter . .	5·13	5·77	13·55	26·40	27·80
Fixed carbon . . .	72·18	80·50	69·08	66·65	66·16
Ash	22·69	13·73	17·37	6·95	6·04
	100·00	100·00	100·00	100·00	100·00
	Do not cake.	Do not cake.	No. 6 cakes slightly.	Cake strongly.	Cakes strongly.

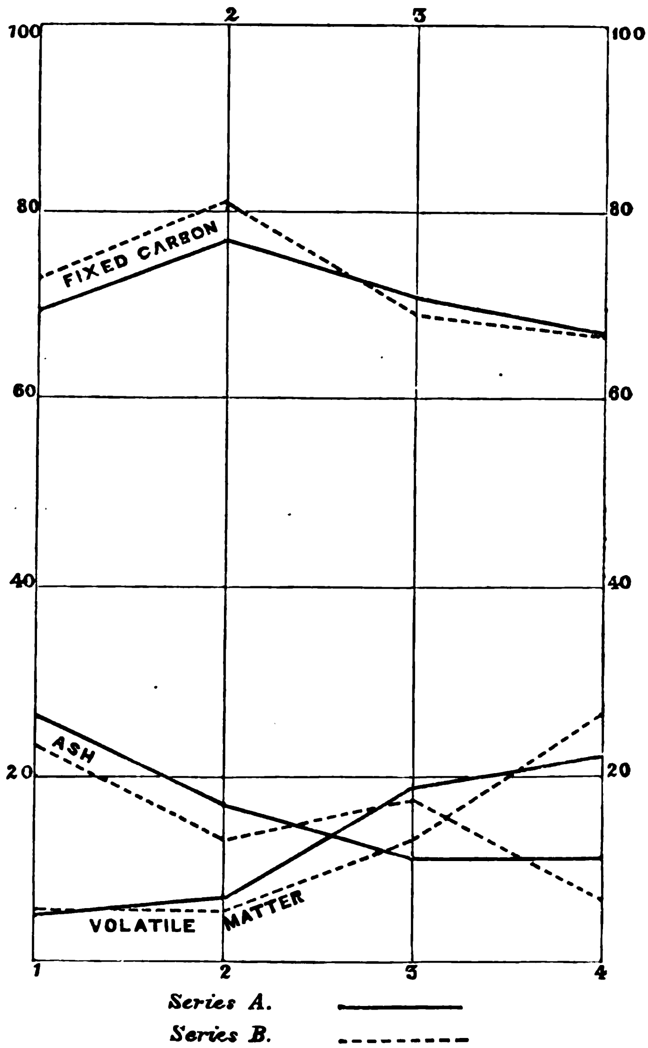

Fig. 2. Diagram showing variation in composition of the coal to a distance of , eet from the dyke.

51. The following assays of specimens kindly supplied by Mr. F. J. Agabeg from a coal seam invaded by peridotite in pit No. 2, Cheranpore colliery, Asansol, show a similar series of results :—

	No. 1. Average of 4 samples into which veins of trap have ramified near dyke.	No. 2. Average of 2 samples outside the former group.	No. 3. Unaltered coal from the same seam.
Volatile matter	6·44	11·55	31·40
Fixed carbon	49·37	69·86	58·65
Ash	44·19	18·59	9·95
	100·00	100·00	100·00

52. If the increase in the percentage of ash were due simply to proportionate removal of the volatile constituents, we should expect a maximum in each case as follows :—

Series A :— . . . . 13·7 per cent. Ash
,, B :— . . . . 8·8 ,, ,, ,,
Cheranpore :— . . . . . . 13·2 ,, ,, ,,

Whereas we have 31·27, 23·18 and 44·19 per. cent. respectively.

Increase of Ash percentage.

Sir I. Lowthian Bell in discussing the origin of the bases in the "white post" lying above the basalt in Durham colliery considers that bases are sublimated from the highly heated basalt at the time of its intrusion in the molten state.[11] Whilst this may have taken place in the case of our still more highly heated peridotites, we consider that in this particular case the largest portion of the inorganic material has been introduced subsequent to the consolidation of the igneous rock by infiltration of solutions into the coke which is naturally more vesicular where it has lost most of its bituminous matter. The peridotites are all highly decomposed in the small dykes and on the selvages of the larger masses, and the deposition of rhombohedral carbonates and quartz in place of the original olivines is sufficient evidence of the re-arrangement of bases which has been brought about in the rock by secondary causes since consolidation.

CONTACT-METAMORPHISM OF SANDSTONES.

Fusion of the Felspathic sandstones.

53. About the most remarkable amongst the effects of contact-metamorphism are the changes produced in the Barakar sandstones. Hardening of the sandstones is common enough wherever they come within range of the peridotite sheets, but in some places, where the sandstones are felspathic and with partially kaolinised felspars, there has been a partial fusion produced, with the result that the quartz and felspar crystals have been rounded and corroded in bays and inlets like the phenomena so common in the rhyolitic lavas. The glass formed by the fusion is crowded with radially arranged microlites, and generally so strikingly recalls the

[11] *Proc. Roy. Soc.*, Vol. XXIII (1875), p. 543.

appearance of a rhyolite that we found it necessary to reassure ourselves by repeated field examination that we had not by chance sampled a hitherto undetected acid lava-flow. There is no doubt, however, about the nature of the rock with which we are dealing. It can be traced out to sandstones which are merely baked or fritted and thence to the loose characteristic Barakar sandstones with decomposed felspars. The signs of fusion discovered by the microscope are after all only in agreement with other evidences which point to the very high temperature of the peridotite intrusion, and taking this fact in connection with the tendency of this peridotite to spread in sheets amongst the sedimentary rocks, we see an explanation for the beds of hardened sandstone which so puzzled earlier observers that they were often described by the vague term "trappoid sandstones" and have even been considered "traps" —a blunder the more easily made by the field-worker from the way in which these hardened sandstones form ridges running across the country and breaking with a cuboidal jointing so common in trap-flows.

54. It is interesting to note that Mr. Hughes also, as long ago as 1866, explained the occurrence of similar hardened ridges as the result of "trappean action" in the Jherriah coalfied, where they also show a columnar structure.[13]

We have figured and described a slide showing the results of the partial fusion of a sandstone which is associated with the peridotite plexus of Bhaddoah hill (plate I, fig. 6).

V.—SUMMARY OF RESULTS.

55. The igneous rocks of the Giridih area may be divided into two groups :—

1st.—*Eurites* and *pyroxene-plagioclase* rocks which were intruded amongst the crystalline rocks before the deposition of the strata of the Damuda epoch.

2nd.—*Mica-peridotites* and *basalts* which have invaded the Damuda series.

56. The pyroxene-plagioclase rocks have undergone two sets of changes. On the north of the coalfield they have passed into *uralite-diorites* and *epidiorites* with the formation of much *scapolite*. On the south they have changed into epidiorites, and hornblende-schists *without* the development of scapolite.

57. The *statical metamorphism* of the plagioclase in the plagioclase-augite rock probably took place at the time of the intrusion of the apatite-bearing mica peridotite, and the subsequent *dynamical metamorphism* attended with the development of scapolite was probably contemporary with the formation of the great boundary faults of the coalfield.

58. The *mica-peridotites* are remarkable for the large quantities of *apatite* they contain, sometimes amounting to over 11 per cent. These rocks are post-Damuda though pre-Rajmahal in age. They form long narrow dykes in the younger strata and spread out in wide sheets at greater depths.

59. The *basalts* occur in wider dykes breaking across the peridotites and are regarded as the underground representatives of the Rajmahal lava-flows.

60. There is a striking parallelism between the post-Damuda intrusions of Bengal and those invading the Gondwana rocks of South Africa, where the diamond-bearing peridotite of Kimberley is succeeded by enormous outflows of basalt.

61. The effects of *contact metamorphism* of the mica-peridotite are far more

[13] *Mem. Geol. Surv. Ind.*, Vol. V, p. 323.

striking than those of the basalts, although the latter form very much thicker dykes. The former rock we conclude was introduced at a very much higher temperature.

62. Amongst the contact effects the partial fusion of the felspathic sandstone is a feature worthy of record. During the coking of the coals the loss of bituminous matter has been accompanied by a more than proportionate increase in the percentage of ash, the additional inorganic material having been introduced by infiltration into the vesicular coke of salts in solution subsequent to the consolidation of the igneous rock.

VI.—EXPLANATION OF MAP AND PLATE. 5

MAP.—The stratified rocks (Talchirs and Barakars) are confined to a basin-shaped depression of about 11 square miles with two inliers of crystalline rocks (shaded in pink) in the north-west corner. Outside the boundary of the sedimentary rocks, which are sometimes cut off by a fault and sometimes limited by a natural boundary, the country consists of various crystalline rocks, felspathic gneiss and mica-schists being specially common. Quartz veins and veins of coarse graphic granite frequently occur in these. The direction of foliation of the crystalline rocks varies within small limits, but generally conforms to the direction of the main faults which bound the coal-field on its northern and southern margins, besides dividing it in a parallel direction near the centre. The northern boundary fault coincides for some distance with a dyke of eurite, the face of which probably affords a plane of low resistance. The position of the diorites has been marked at Chepo Hill and Gujiadih on the south, at Bonkhoonju on the north, and at Paharidih, Birwadih and Mongrodih on the east. Wherever these rocks are foliated, the foliation is parallel to the general foliation of the crystalline series around, and, consequently, to the direction of the great faults of the field. The diorite forming the conical mass at Bonkhoonju is not foliated, but the gneisses dip on both sides towards the hill, forming a syncline whose axis runs about east-north-east and west-south-west (*vide* paragraphs 10—21). Catalogues of the peridotite and basalt dykes are given in the text (paragraphs 33 and 37). Their position and names are plainly indicated on the map. The positions of property boundaries (indicated by thin lines joining the pillars) are shown for the purpose of finding in the field any required outcrop, as some of the dykes are so small and decomposed that they are not often easily detected.

PLATE. 5 *A series of photographs of thin sections under the microscope.*

FIG. 1. *Pyroxene-plagioclase rock* from Mongrodih near Giridih. Magnified × 20 diameters. The white felspars in long flat crystals are surrounded, with an imperfect ophitic arrangement, by augite. Some of the pyroxene, probably rhombic in some cases, has formed very fine mesh-work fringes on changing to hornblende and by reaction with the adjoining felspars, which latter have consequently lost their sharp outlines. Opaque iron-ores often occur in the patches of granular hornblende and sometimes form the nucleus of a garnet

aggregate. The change to green hornblende has taken place along the margins of nearly all the pyroxenes, as shown by the large crystal on the left.

FIG. 2. *Epidiorite with scapolite.* Mongrodih, near Giridih. Magnified × 20 diameters. The rock consists of a granular aggregate of hornblende scapolite, felspar and quartz. The scapolite may be recognised amongst the colourless constituents by the slight streakiness produced by incipient decomposition. This rock occurs near the margins of the mass of which fig. 1 represents the centre. The rock represented by fig. 1 consists of pyroxene and plagioclase, the latter constituent containing a series of cavities infilled with sodic chloride solution. As the result of subsequent dynamical metamorphism, the ophitic intergrowths shown in fig. 1 have been destroyed, the augites changed into granular hornblende, and the mixture of plagioclase and sodic chloride converted into scapolite with a small residue of clear felspar and quartz.

FIGS. 3 & 4. Crystals of *plagioclase-felspar* from the pyroxene-plagioclase rock of Mongrodih. Magnified × 37 diameters. Fig. 3 under ordinary light shows the bands of secondary inclusions of sodic chloride, which, when viewed between crossed nicols (fig. 4), are seen to coincide with the planes of composition of the lamellar twins. The statical metamorphism has thus resulted in the solution of the felspars along the planes of composition, which are regarded by Professor Judd as planes of chemical instability. The felspars in this rock afford very striking illustrations of the production of this form of schillerization along the planes between the twin-lamellæ (*cf.* Judd *Min. Mag.*, Vol. VIII (1889), pp. 189, 197).

FIG. 5. *Epidiorite* approaching *hornblende-schist*, Gujiadih, south of the Giridih coal-field. Magnified × 20 diameters. This is one of the extreme results of the metamorphism of the pyroxene-diorites, which, near the southern margin of the coal-field, are changed into well foliated hornblendic and granulitic rocks *without* the development of the scapolite that so frequently characterises the corresponding types on the north and east.

FIG. 6. *Felspathic sandstone*, partially fused by an intrusion of peridotite. Bhaddoah hill, magnified × 20 diameters. The quartz crystals have been corroded into bays and channels by the fused hydrated silicates, and the cooling of the latter has given rise to radial arrangement of black microlites precisely similar to those in the imperfectly crystallized matrix of many rhyolites.

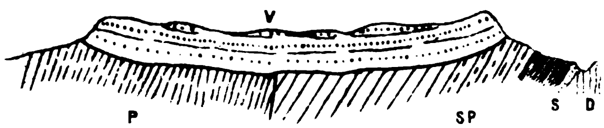

FIG. 1. SECTION THROUGH EAST END OF THE KHARÁRA OUTLIER.

Sb, Basal Beds. V, Vindhyan. SP, Porcellanites of the Sub-Kaimur series.

P, Beds older than Sub-Kaimur.

FIG. 2. SECTION NORTH WEST OF BARHATA.

Lettering as in fig. 1.

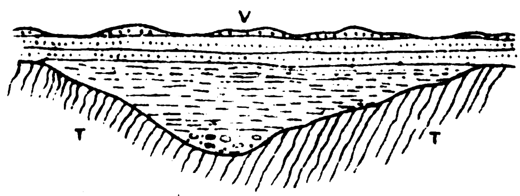

FIG. 3. SECTION AT RIGHT ANGLES TO 2

Scale of Sections 2" = 1 Mile.

Reg No 473, Dir., Geol. Surveys – Sept 95. – 660. Imp. S. I. O., Calcutta.

On some outliers *of the* Vindhyan system South *of the* Son and their relation *to the* so called lower *Vindhyans: by* R. D. OLDHAM, A.R.S.M., F.G.S., *Superintendent, Geological Survey of India* (with plate 5).

It has long been known that the Vindhyan system proper is underlaid, in Bundelkhand as in the Son valley, by a series of shales and limestones, regarded as conformable to the overlying system of sandstones, though their true relationship had not been fully cleared up. This series of shales and limestone was consequently accepted as a member of the Vindhyan system under the designation of lower Vindhyan.

The earliest published reference to these rocks is in a communication by the late Dr. T. Oldham to the Asiatic Society in 1856. In this the term Vindhyan was first proposed[1] for the system of sandstones and associated shales and limestones to which it is still applied. The beds below the Kaimur sandstone, which were subsequently accepted as lower Vindhyan, are there separated from the Vindhyans, under the name of 'Sub-Kymore,' a term proposed by Mr. H. B. Medlicott[2] to cover all the rocks below the Kaimur sandstone.

The next reference to these rocks is in Mr. Medlicott's memoir on Bundelkhand, where a very similar series of rocks is exposed in a corresponding position. The name 'Sub-Kymore' is abandoned and the series in question named Semri.[3] Reasons are given at one place[4] for considering the Semri beds as conformable with the Kaimur sandstone, but in other passages irregularities in the distribution of the upper groups of the Semri series are described, which do not seem compatible with complete conformity. Apart from this, the Kaimur conglomerate is said to contain pebbles of the chert-like shale of the lower Semri groups.[5] The observations recorded indicate a relation between the Kaimur sandstone and the underlying beds very similar to that which is found in the Son valley.

In the same volume the beds below the Kaimur sandstone in the Son valley are referred to by Mr. J. G. Medlicott under the name of Sub-Kymore;[6] no details are given, and, as in the original publication,[7] the term was evidently used to include rocks that are now separated as transition besides those which have come to be called lower Vindhyan.

This term was first publicly used in 1869 by Mr. F. R. Mallet in his account of the Vindhyan system[8], or series as it was then called; and in introducing the name it is said that recent investigations had established the identity of the Semri series of Bundelkhand and the Sub-Kaimur series of the Son valley, "at the same time establishing their close connection with the formation hitherto known as the Vindhyan. This connection, although close, is not sufficiently so to warrant our including both in one series. Hence the latter are now called *Upper Vindhyan*, the Semris and

[1] *Jour. As. Soc. Beng.*, XXV, 251 (1856).
[2] *Ibid*, p. 253.
[3] *Mem. Geol. Surv. Ind.*, II, p 6 (1860).
[4] *Ibid*, p. 13.
[5] *Ibid*, p. 28.
[6] *Mem. Geol. Surv. Ind.*, II, 138 (1860).
[7] *Jour. As. Soc. Beng.*, XXV, 253 (1856).
[8] *Mem. Geol. Surv. Ind.*, VII, 27 (1869).

Sub-Kymores being distinguished as *Lower Vindhyan*."[9] In the descriptive portion of the memoir a closer connection is described than these words would suggest, facts and arguments being detailed which would indicate a complete conformity between the two series.[10] These are, firstly, the parallelism of dip observed along the boundary of the two series; and secondly, the absence of any signs of erosion on a contact section seen in the Dargaoti valley. At the same time other observations are recorded which are hardly compatible with complete conformity, but as it will be necessary to recur to this subject further on, its consideration will be deferred for the present.

In the first edition of the Manual of the Geology of India Mr. Medlicott's description of the Vindhyan series follows that of Mr. Mallet so far as the Son valley is concerned, and it is definitely stated[11] that the upper Vindhyans in this area conformably overlie the lower. This is to a slight degree qualified in another passage,[12] but the general impression left by the description is that there is no break of any importance between the two, and that the lower Vindhyans, so called, form part of the same great system of deposits as the upper.

When preparing the second edition of the Manual, I was struck by the indications of an unconformity, which are to be found in the original descriptions, and though the description of a region and system with which I had no personal acquaintance was left unchanged, except for some condensation, I felt it necessary to lay more stress on the possibility of an unconformable break between the two series and to question[13] the propriety of classing them together under one system.

Such was the state of our knowledge of these rocks till, during the last working season, upper Vindhyan outliers were found south of the Son, which have an important bearing on the relation of the so called lower Vindhyans with the Vindhyans proper. The subject is far from worked out and the region is still under survey, but some of the facts are clearly enough established to be worth publishing, in view of the interest attaching to this system.

The existence of Vindhyan outliers in the Son valley south of the boundary of the main area has long been known, and several are indicated on the map accompanying Mr. Mallet's memoir, but they had always been regarded as belonging to the so called lower Vindhyans.[14] During the past season several of these have been more or less completely examined, and it was found that they are of two distinct types and belong to two distinct series. We have firstly patches of unmistakable 'lower Vindhyan' rocks, highly disturbed and folded or faulted among the older transitions, and secondly outliers of much less disturbed and often nearly horizontal sandstones and conglomerates, which in one place were found to rest unconformably on the beds of the 'lower Vindhyans.' From their degree of induration these sandstones must be separated from the Gondwanas and, being younger than the 'lower Vindhyans,' may be referred to some horizon of the true or upper Vindhyans, which they resemble in lithological character and degree of induration.

[9] *Mem. Geol. Surv. Ind.*, VII, 27 (1869).
[10] *Ibid*, p. 46 ff.
[11] *Manual of the Geology of India*, 1st ed., 1879, I, p. 81.
[12] *Ibid*, p 90.
[13] *Manual*, 2nd ed., p. 98.
[14] *Mem. Geol. Surv. of Ind.*, VII, 45, *Manual*, 1st ed., p. 79.

We have accordingly south of the Son representatives of two series which to the north are apparently conformable, and as it will be inconvenient to call these by the same name, I propose, for the present, to resume the name of Sub-Kaimur for the 'lower Vindhyans.'

The only outlier which has been completely surveyed is that which lies west of the Samdin and south and east of the Son. Its position is indicated in the map accompanying Mr. Mallet's memoir, and it is at once the most westerly and the largest of those which must be ascribed to the newer series of rocks, or upper Vindhyans. Along its south-eastern margin a few small outlying patches of the same series are found, but to the north none exist between it and the Gidela outlier of the Kaimur scarp.

The outlier referred to is 12 miles long from east-north-east to west-south-west, of irregular shape, varying from half a mile to three miles in width, about the middle of which rises the Kharára G. T. S. Round the whole length of its boundary, except for a couple of miles where this is faulted, the outlier rests in obvious unconformity on the older underlying rocks. The rocks of which it is composed consist essentially of hard sandstones, white or red, many of which resemble the sandstones of the upper Vindhyans, more especially of the Kaimur group, though the series as a whole differs in the large number of pebbles it contains and in the frequent presence of a considerable proportion of felspathic material, whether as distinct grains of felspar or as a fine-grained felspathic paste. The pebbles are mostly of white vein quartz, generally small and ill rounded or angular, scattered through the sandstone matrix; at times however and in certain beds, which are not always at the bottom of the series, larger and better rounded pebbles are found in such abundance as to constitute a conglomerate. When this is the case a considerable proportion are found to consist of a bright red jasper, and the rock then resembles the descriptions of the Kaimur conglomerate.

Reserving more detailed description till a general account of the unsurveyed area in Rewah can be given, there are two sections which may be referred to here. The first of these is in the Samdin valley below Sejári village. Just below this village the Samdin flows over a barrier of vertically dipping quartzites of the Bijáwar type, the layers being separated by papery films of micaceous iron ore. Immediately north of this there is a thin layer of breccia, followed by conglomeratic sandstone, hardly visible in the stream bed, but easily seen a short way off on either side, followed by shales, by the porcellanic beds of the Sub-Kaimur series and by sandstones above these, the ascending section being cut off by a fault with an upthrow to the north. These Sub-Kaimur beds are at the western extremity of a long narrow outlier which has been traced, with a width dwindling from a mile and a quarter to nothing, for a distance of 25 miles to east-north-eastwards; the southern boundary being throughout natural and the northern faulted.

West of the Samdin the Sub-Kaimurs form the slope of a hill, capped by the eastern scarp of the Kharára outlier, the relations of the two series being indicated in the section No. 1 on the accompanying plate. This section is an absolutely decisive one, establishing beyond possibility of doubt that the sandstones and conglomerates of the outlier are distinct from those of the basal group of the Sub-Kairmur series to which they have been referred in previous publications.[15] The

[15] Memoirs, VII. 33.

observations of these outliers on which all previous accounts are based appear to have been made by Mr. Medlicott during a rapid march up the Son valley, the only record of which is contained in a manuscript report. Speaking of this Kharára outlier he says: 'On a first examination of this region from the north side, as actually occurred to me, one is disposed to look upon the rock of the high ridge as an overlapping remnant of an *upper* band of sandstone. For some time I entertained the conjecture that it might even be an upper Vindhyan rock.' This conjecture was abandoned for reasons which it is needless to detail here, and the sandstones of the outlier were ultimately accepted as identical with those of the basal group of the Sub-Kaimur series to the north, which, it must be acknowledged, they very closely resemble. Had Mr. Medlicott crossed the section in the Samdin, there can be no doubt that he would have adhered to his original conjecture, for here it is impossible to regard the two as identical. The Sub-Kaimur basal conglomerate and sandstone in the Samdin valley near Sejári is very much thinner than the same rock at the boundary of the main exposure, not five miles off; the thickness varies very much, but nowhere exceeds 100 feet, and the rock itself is a dirty sandstone containing small and scattered pebbles. The outcrop cannot be traced up the talus slope into actual contact with the outlier on the hill slope: it seems in fact to be cut off by a fault, but it is found within less than a quarter of a mile of the hard, clean, white, sandstones of the hill top, at whose base is a conglomerate containing numerous rounded boulders of quartz and scarlet jasper as large as a man's head, cemented by a clean silicious matrix. Even if these rocks did not rest unconformably on Sub-Kaimur beds, the great contrast in thickness and character of the two sandstones and conglomerates would leave no room for doubting their distinctness.

The other section to be considered is near the western end of the outlier and is interesting as showing the conditions under which the rocks composing the outlier were deposited. North-west of Barhata village the sandstones do not rest directly upon the older rocks, but are underlaid by a breccia composed of angular fragments of the underlying slates, a few inches in diameter, through which are scattered blocks of vein quartz running to as much as a foot in diameter. Towards its base this rock is almost devoid of fine grained matrix, but it passes by a gradual increase of sand and decrease of slate fragments into the overlying sandstone. The breccia, which is evidently an indurated fan deposit, attains a maximum thickness of over 700 feet, and is underlaid by a coarse conglomerate containing many ill-rounded pebbles of jasper, and numerous white quartz pebbles of six inches and more in diameter, besides darker and less conspicuous pebbles of quartzite, the whole being cemented by a matrix of dark red sandstone.

The section just described is figured in No. 2 of the plate, but these rocks below the sandstone do not continue along the outcrop to the east or to the west. The conglomerate is the first to disappear, its whole extent being less than quarter of a mile. The breccia extends further, but it too gradually thins out and disappears at three-quarters of a mile to the eastwards and half a mile to the west, as is indicated on the section No. 3, drawn at right angles to No. 2.

The explanation of these sections is evidently that the sandstones were deposited on a deeply eroded surface. At the bottom of the valley we have a coarse conglomerate deposited by a rapid torrent; this is succeeded by a fan deposit which gradually filled up the whole valley, and was itself covered up by the sandy deposits which obscured all the pre-existing irregularities of the surface, and converted what was once hill and valley into a broad sandy plain.

A similar lesson is taught by the Dádri outlier, about fifty miles east by north from the eastern extremity of that just described. West of it there runs in an east by north direction a ridge of vertical Bijáwar quartzites, which owes its prominence to the comparative softness of the rocks on either side. Just west of the boundary of the sandstone outlier this is breached by a cross valley, but is continued on the plateau as a low ridge, rising out of the sandstones on either side, which runs for a couple of miles before being finally covered up. Here it is evident that the older rocks had undergone practically all the disturbance they now exhibit before the still nearly horizontal sandstones had been deposited, and had, besides, been exposed to sub-aerial denudation for a period long enough to produce an uneven surface in which the harder beds were represented by elevations and the softer by depressions of the surface.

These remarks regarding the relation of the outliers to the older rocks apply to the Sub-Kaimurs almost as much as to the transition rocks, for the amount of disturbance they have undergone in their outliers is great, and they had shared in the same denudation to which the transition rocks were exposed. It would consequently be difficult to find a more decided unconformity than that between the sandstone outliers on the hill tops, and the Sub-Kaimur series in their proximity, and a question arises as to the age of the former. To this only one answer seems possible: they are certainly of later date than the Sub-Kaimur series, and it would be preposterous to suppose that these indurated and ancient looking sandstones could be the same as the soft sandstones of the Gondwana series. It would be almost equally absurd to suppose they form a separate series of deposits by themselves not referable to any other in the neighbourhood, and the only alternative is to regard them as outliers of the upper Vindhyans, for which they might easily pass. They cannot be identified with any specific horizon of that series, and though they resemble the Kaimur groups more than any of the upper sandstones, no importance need be attached to this, as the points of resemblance are probably the result of their being in either case the bottom beds of the series.

Accepting this identification, it would be natural to suppose that the facts given above would settle definitely the distinctness of the so called 'lower' from the 'upper' Vindhyans or Vindhyans proper. Such a conclusion must not however be too hastily adopted. In the second edition of the Manual of the Geology of India I have pointed out that the nature of the north-west boundary of the Vindhyans towards the Aravalli mountains presents some analogy with that of the tertiary and recent deposits of the Gangetic valley to the Himalayas, and suggested that the Vindhyans may have been formed during the compression and elevation of that range from its debris.[16] Now along the edge of the Himalayas we have instances of upper members of the tertiary series resting in unconformable contact on the upturned and denuded edges of the lower ones, while not far off may be found a continuous conformable section uniting the two. Similarly, it might be supposed that in the Son valley we had the upper members of the Vindhyan system overlapping on to the eroded edges of the lower beds, which had been involved in the mountain forming

[16] *Manual*, 2nd ed., p. 103.

processes going on along the margin of the basin of deposition, and this unconformity at the margin need not be incompatible with a complete conformity of the two further away from that margin.

There is, however, one flaw in the analogy, which appears to be a serious one. Along the southern margin of the Himalayas the general dip is northwards, and the outliers of the tertiary beds have for the most part a natural boundary to the south and a faulted boundary to the north, the upthrow being on the north, or mountain, side of the fault. In the Sub-Kaimur outliers the conditions are reversed, the natural boundary is to the south, the faulted are to the north, that is to say, both dip and upthrow are away from what should have been the mountain range and towards the basin of deposition. These facts point to the period of disturbance as having been altogether anterior to, and not contemporaneous with, the deposition of the upper Vindhyans; and if we add to this the indications that are to be found in the published description, and still more so in manuscript reports, of both overlap and transgression along the southern boundary of the main area of the Vindhyans, it is at any rate conceivable that there is a real unconformity there, in spite of the apparent conformity, on individual sections, which has been recorded.

The final settlement of this question must await a re-examination of the boundary of the Vindhyans proper, at present the case for the inclusion of the Sub-Kaimur series with them has been greatly weakened, and until we have more positive evidence of conformity along the main boundary of the two, it will be well to abandon the question begging name of 'lower Vindhyan' for the Sub-Kaimur series.

Notes on a portion *of the* Lower Vindhyan area *of the* Sone Valley, *by* P. N. DATTA, B. SC., F. G. S., *Geological Survey of India.*

Area defined.

The area, on the examination of which these notes are based, is that portion of the Rewah State in Central India which extends on the one hand from the Kaimur Range on the north to the Sone river on the south, and on the other from the stream by Hinaota, 12½ miles W. by S. of Ramnagar on the west to the neighbourhood of Churhat on the east.

The Lower Vindhyans of the Sone Valley as classified by Mr. Mallet.

The rocks of the Sone Valley designated 'Sub-Kaimur' by Mr. Medlicott and regarded as the equivalent of his 'Semri' system of the Bundelkhand area, have been described by Mr. F. R. Mallet as the Lower Vindhyans. In his memoir on these Lower Vindhyan rocks of the Sone Valley, Mr. Mallet arranges and classifies them into the following 'sub-divisions'[1]:—

(Descending order.)

11. Limestone.
10. Shales.
9. Limestone.
8. Shales, sandstone.
7. Limestone.

6. **Shaly sandstone.**
5. **Porcellanic shales.**
4. **Trappoid beds.**
3. **Porcellanic shales.**
2. **Limestone.**
1. **Conglomerate and calcareous sandstone.**

The classification of the Lower Vindhyans, as now proposed.

From the inconstancy of some members of the Lower Vindhyan rocks and the absence of such well-defined divisions as are noticeable in the Upper Vindhyans, the Lower Vindhyans have not been regarded as susceptible of arrangement into well-marked divisions like the Upper Vindhyans. From the detailed examination of the portion of the Lower Vindhyan ground under notice, however, it seems quite feasible to classify the rocks into the following well-marked divisions:—

(In descending order).

IV. Rhotas division.
III. Kheinjua division.
II. Porcellanic division.
I. Conglomeratic division.

Origin of the divisional names.

The term 'Rhotas' has been suggested from the ancient fort of Rhotasgurh[1], while 'Kheinjua'[2] has been proposed from the Kheinjua Hills which show these rocks. I propose the name 'Porcellanic' for the next underlying division of beds from the prevailing and well-marked porcellanic character of the rocks. From the absence, in this limited area, of a particular locality or land-mark where the beds which underlie the porcellanic division and form the base of the system, are well shown, I am at a difficulty to suggest at present a more suitable name than that of 'Conglomeratic' for these beds forming the bottom division of the system. We might name the division from the well-marked range which occurs between Saria and Bela, marking the edge of the basin and exhibiting well the bottom conglomerate and quartzite. But unfortunately the range is not named in the map at all. Hence the term 'Conglomeratic' has been chosen provisionally.

Thus we have the Lower Vindhyans classified into the following four divisions:—

IV. Rhotas	division,	including	Nos. 11, 10 and 9[3]	of Mr. Mallet's 'sub-divisions.'
III. Kheinjua	,,	,,	,, 8, 7 and 6[4]	,, ,, ,,
II. Porcellanic	,,	,,	,, 5, 4 and 3[5]	,, ,, ,,
I. Conglomeratic		,,	,, 2 and 1[6]	,, ,, ,,

Distinctive characters of the several divisions.

Distinctive characters of the different divisions.—While the Rhotas division is mostly calcareous—it is entirely so in the area under notice,—and the Kheinjuas are essentially argillaceous shales with sandstones, the peculiar feature of the beds

[1] Mem. G. S. I., Vol. VII, p. 28.
Manual, 1st Ed., Pt. I, p. 78.
,, 2nd Ed., p. 95.
[2] This term appears to have been first adopted on the field maps of Mr. W. L. Willson, late of the Geological Survey.
[3] Mem. G. S. I. VII, pp. 28, 42, 43.
[4] ,, ,, ,, pp. 28, 38—41.
[5] ,, ,, ,, pp. 28, 35—38.
[6] ,, ,, ,, pp. 28, 31—35.

composing the Porcellanic division is indicated by the name itself. The bottom division is mainly arenaceous, the calcareous and argillaceous element being present only to a very subordinate extent.

IV.—RHOTAS DIVISION.

Rhotas division.

In the area under notice the shales No. 10 of Mallet's are nowhere developed. Thus the division bed consists entirely of thin-bedded limestone. The bottom beds of the division exhibit a tendency towards concretionary character, well formed calcareous concretions being often developed.

Crystals of quartz have been found developed in the drusy cavities in the limestone in some places.

Much local puckering and crumpling is observable in these thin-bedded limestone beds, but the topmost beds—those by the junction with the Kaimur beds—show no evidence of disturbance.

III.—KHEINJUA DIVISION.

Kheinjua division. Sub-divided into 8 series.

The sub-divisions 8, 7 and 6 make up this division. But in the area under consideration it is divisible into the following well-marked series :—

(In descending order.)

i. *Argillaceous shales*, containing calcareous concretions with intercalated limestone beds. Arenaceous element almost absent.

ii. *Limestone band*—
Limestone pure ; no arenaceous or argillaceous element present.

iii. *Shales*—Arenaceous and argillaceous, with thin-bedded sandstone ; ripple-marked ; no calcareous beds.

iv. *Limestone with shales*—
Limestone very impure and ripple-marked ; shales reddish, sometimes calcareous, at other times not.

v. *Shales*—
Arenaceous and argillaceous ; much ripple-marked, and with quartzitic thin bands of sandstone.

vi. *Sandstone*—
Thick-bedded, compact and quartzitic.

vii. *Limestone with shales*—
Limestone purer than No. iv ; shales greenish and non-calcareous.

viii. *Shales and sandstones*—
Sandstone generally thin-bedded ; shales greenish and laminated.

Persistence or otherwise of the several calcareous series in the division.

Of these series (i to viii) the limestone No. ii has been traced as far as Rampur, where it dies out. The series No. iv persists throughout the area, while the limestone vii is not traceable beyond "Ucheyra" of map, near Marjátpur ; but a limestone appears again about this horizon at 2 miles S. E. by S. of Rampur (Lat. 24°19′ N., Long 81° 32′.5 E.) and continues eastwards, becoming concealed under the alluvium at the eastern extremity of the area.

II.—PORCELLANIC DIVISION.

This division is divisible into—

Divided into three sub-divisions.

Upper Porcellanic shales,	corresponding to	No. 5	of Mallet.
Trappoid beds	"	" 4 "	"
Lower Porcellanic shales	"	" 3 "	"

Looked at broadly, the bulk of the division is composed of the fine-grained porcellanic shales, and in their midst, and rather nearer the base than the top, we find a band of coarser rocks to which the name "Trappoid" has been applied. The upper porcellanic shales have a considerable quantity of ordinary argillaceous shales, very little altered, intercalated in them. The "trappoids" are thoroughly well bedded, in beds often of the same thickness as the porcellanic shales They do not form a well definable band by themselves, but occur intercalated with the finer-grained porcellanics. The trappoids are generally of a bluish color, but vary in fineness of grain, some being like exceedingly fine-grained quartzites, while others are much more coarse and gritty, with the quartz grains generally rounded. Felspar is present, but is scarcer in certain parts than in others. No hornblende could, however, be detected in the area under notice.

I.—CONGLOMERATIC DIVISION.

COMPRISES { No. 2. Limestone.
No. 1. Conglomeratic and calcareous sandstone.

Further subdivision yet impracticable from want of good exposures in this area.

As no exposures were available in the area in question for a minute examination of the constituents of Mr. Mallet's 'subdivision' No. 1, *viz.*, the conglomeratic and calcareous sandstone, the 'subdivision' has been allowed for the present to stand as it was. The limestone, coming in just above the conglomeratic and calcareous sandstone, does not seem very prominent or remarkable in any way, but on the other hand seems to be of a very inconstant and variable character. So it seems preferable to take in the Limestone No. 2 with the 'Conglomeratic and calcareous sandstone' beds, and form the two into one division. It seems all the more reasonable to do so, as we find it stated that the lowest two 'subdivisions' (*viz.*, No. 2 Limestone and No. 1 conglomeratic and calcareous sandstone) appear to be in some measure equivalent to each other[7], a conclusion presumably based on an examination of the rocks over the whole area.

General composition of the conglomeratic division.

Although for want of suitable exposures in this area a proper subdivision of the division has not yet been possible, the following is the general composition of the division. The limestone (limestone "No. 2") passes into a dark bluish earthy rock, ferruginous in places; shale, sandstone with quartz and ferruginous bands and quartzitic sandstone, light to dark grey and fine-grained to coarsish, are next seen, while lower down, ferruginous calcareous beds with pale greenish shale passing down into a greenish argillaceous shaly sandstone come in close above the quartzite which forms the range between Bela and Saria. This quartzite, which is thick-bedded, compact and hard, and reddish to white in colour, has hardly any pebbles in its upper part, but becomes conglomeratic in the lower part, the pebbles being of white and reddish quartz, red jasper and quartzite.

Conformability of the several divisions of the Lower Vindhyans and relation to Upper Vindhyans.

All these divisions, IV to I, which make up the Lower Vindhyans, are conformable to one another. As to the relations of the Lower Vindhyans (1) to the rocks that underlie the system and (2) those that overlie the system :—

[7] Manual, 2nd ed., p. 95.

(1) The lower junction of the bottom conglomerate (division I) of the Lower Vindhyans (or Semri) rests unconformably upon a gneiss in the area under examination.

(2) The upper junction of the Lower Vindhyans (that is, the Kaimur-Rhotas junction) has been stated to be unconformable on these grounds :—

(*a*) That the Kaimur beds overlap the Lower Vindhyans.

(*b*) The occurrence of Lower Vindhyan debris in the Kaimur beds 100 ft. or more from the base of the Upper Vindhyans [8]

(*c*) The existence of a sharp line of division between the Kaimur and the Rhotas, especially in the sudden and abrupt change from the fine-grained deposits of the Rhotas to the coarse sandstone of the Kaimur.[9]

Overlap does not necessarily prove unconformity.

With reference to the unconformity from overlap, it is apparent that overlap need not always imply unconformity. The existence of overlap would not by itself prove any unconformability if unsupported by other evidence.

Denudation unconformity.

As to erosion-unconformity. The occurrence of Lower Vindhyan debris 100 ft. or more above the base of the Kaimurs has found neither confirmation nor negation from my personal observations in this area. For, though in the course of my examination, I cannot say I could detect any such Lower Vindhyan debris in the Kaimur beds, it must be remembered that the slopes of the Kaimur scarp in the area in question are exceedingly unfavourable for close examination. The Kaimur conglomerate is absent in this area.

No Kaimur-Rhotas contact proving erosion could be detected here.

Whenever the state of exposure allowed an examination of the ground to be made, I never succeeded in coming upon a contact of the Rhotas limestone with the rocks above indicating erosion-unconformity. The shales[10] overlying the Rhotas limestone certainly seemed thicker in some places than in others, but whether this was due to the original variability in the thickness of the shaly deposit, or to denudation of the underlying limestone rock in places (where the accumulation of shales would thus be greater than elsewhere) before the deposition of the shales, or to local depression in the rim of the basin which would thus take out of sight some of the lower beds, it was difficult to make sure. Should there have been denudation in the case, the contact between the limestone below and the shales above ought to show evidence of erosion somewhere or other. But although I did not succeed in coming upon an exposure proving the denudation of the limestone before the deposition of the shales, this does not of course disprove its existence, having regard to the nature of the ground.

Disturbance of Rhotas limestone not anterior to deposition of the Kaimurs.

There is certainly much evidence of disturbance in the beds of the Rhotas limestone, often in close vicinity to the base of the Kaimurs which are, however, quite undisturbed. That the Rhotas limestone might have been disturbed and contorted before the deposition of the Kaimurs is contradicted by

[8] Mem. G. S. I, VII, pp. 47 and 50 ; Manual, 2nd ed., p. 99.

[9] Mem. G. S. I., VII, p. 47 ; Manual, 2nd ed., p. 99.

[10] These are the Bijaigarh shales in all probability.

the invariable complete parallelism of the topmost Rhotas limestone with the Kaimurs, which has been observed in this area wherever a clear point of junction has permitted an examination.

As to unconformity from abrupt change in lithological character.

With regard to the unconformity as inferable from sudden change in lithological character from the Rhotas into the Kaimur beds, the examination of this junction in the area under report has been found to be attended with circumstances of considerable disadvantage, for the débris from the steeper parts of the Kaimur scarp form in most places a talus along the lower slopes of the scarp, rendering it a most difficult task to come upon an exposure showing a clear point of junction of the Rhotas limestone with the Kaimur rocks. The following are some of the localities where the sections at or near the junction were found to be instructive.

Section at Gursari ghat.

Gursari ghat.—Here the siliceous shales [11] (the shales that overlie the Rhotas) are seen to pass normally into the Kaimur sandstone of the scarp. The junction of the shales with the Rhotas is, however, concealed here.

Section by Hinaota.

Scarp-slopes by Hinaota.—(Approximate position, Long. 81° 19'E, Lat. 24° 18'N.). The exposure here too is not perfect, but the Rhotas limestone seems to pass into a fine-grained homogeneous shale which, when freshly broken or exposed, is green, but turns bluish chalky white on exposure to the air. Such a rock is what we should expect to meet with as a passage rock from a limestone. For a little space up the slopes, above the foregoing shale, the ground is covered, but the shales that are exposed a little higher up are somewhat siliceous, and these pass above into the thick-bedded sandstone of the Kaimur scarp.

Exposure by Daorahra.

Foot of scarp-slopes, N. W. Daorahra.—Near Boorgaona. The homogeneous shale referred to as being met with in the last mentioned locality is also exposed here. But neither the junction of the Rhotas limestone with this shale, nor the passage of this rock into the siliceous shales and sandstone above, is traceable here.

Section by Majgama.

Scarp-slopes N. W. of Majgama.—The foot of the spurs is occupied by the Rhotas limestone. A little way up (*i.e.*, after a short blank section) a finely laminated soft shale, white, grey to blackish is seen (the shale is occasionally blackish enough to look carbonaceous). These soft shales pass upwards into shales somewhat harder, the colour being yellowish to brownish-grey, with a faint approach to a porcellanic look.[12] Beyond this point a talus of sandstone obscures the section, but the thick-bedded sandstone of the scarp is close above.

Section at Reiwas Hill.

Reiwas Hill.—(4½ miles N. by E. of Rampur, Lat. 24°24'·5 N, Long. 81°33' E.) At the S. E. extremity of this hill, although the exact point of junction (Kaimur-Rhotas) is not to be seen, the uppermost Rhotas limestone as well as the shales above are well exposed. Just above the uppermost limestone, a few feet of blank section covered over with shale débris, intervenes, beyond which occurs a laminated shale, somewhat blackish

[11] The shales coming in immediately above the Rhotas limestone in this area are probably Bijagarh shales, as already indicated.

[12] One is here reminded of the circumstance that south of Saranga, near Mirgaoti, we find a limestone passing down through a white earthy rock into a porcellanic shaly rock.

in colour in places, and very slightly, if at all, siliceous. This shale is succeeded by some more shales which are earthy and somewhat porcellanic. Over these comes in the thick-bedded sandstone. The dip of the limestone as well as of the shales above is N. 15° W. at 11°.)

The above sections show conformity, and indicate gradual passage.

In all these instances not only is a perfect conformity observable between the Rhotas limestone and the Kaimur beds, but also a gradual passage indicated from the one into the other.

Conclusions with regard to upper boundary of the Lower Vindhyans.

Thus so far as the materials at hand will enable one to judge, this is what we can conclude with regard to the Kaimur-Rhotas junction in the area under notice—

1. That no dip unconformity is observable along this junction, but on the contrary:—
2. Wherever the section is fairly clear, there exists a complete dip conformity between the Rhotas limestone and the Kaimur rocks.
3. That no physical break in the form of abrupt change in the lithological character of the rocks is to be observed, but, on the other hand, from the few cases where the sections have been found to be tolerably clear, the indications all point in the other direction, namely, that there is a physical continuity in the passage from the Rhotas into the Kaimur beds above.

Lower Kaimur sandstone absent in this area.

In conclusion, it may be observed that if the shales which come in immediately above the Rhotas limestone are the Bijaigarh shales, then the Lower Kaimur sandstone, as well as the Kaimur conglomerate, is absent in this area. How far, however, the absence of the Lower Kaimur sandstone may be accounted for by the supposition that the lower part of the Bijaigarh shales may represent here the Lower Kaimur sandstone, that is, how far the case may here be one of only normal lateral replacement is a matter that can only be decided after more extended observation. The conglomerate, however, though it is absent here, certainly indicates a physical break. The occurrence of the conglomerate, however, above the Bijaigarh shales carries the break to the base of the Upper Kaimur beds, that is, some way up from the Rhotas-Kaimur junction. So the conglomerate as an evidence of a break is not of much account so far as the horizon of the boundary-line as hitherto assigned between the Upper and Lower Vindhyans is concerned, being placed, as it is, some distance above it.

Its absence may be due to normal lateral displacement by Bijaigarh shales.

Upper Kaimur conglomerate proves no break at Rhotas-Kaimur junction.

Note on DR. FRITZ NOETLING'S paper *on the Tertiary system in Burma in the Records of the Geological Survey of India for 1895, Part 2:* by Mr. THEOBALD, *late Superintendent, Geological Survey of India.*

Having read with much interest the above paper, there are a few remarks I should like to make, as in one case the author attributes to me, as a "logical outcome" views I never contemplated for a moment, and in another matter it seems desirable to elicit more clearly than at present whether Dr. Noetling's correction of a previous statement of mine, really can claim to be any correction at all.

I make no objection to Dr. Noetling terming the beds previously named by me "*Fossil wood group*," the Irrawaddi division, although I cannot agree with Dr. Noetling that the name bestowed by me was "by no means appropriate," because Fossil wood was found abundantly in certain post-tertiary beds also. The term proposed by myself emphasized and pointed to the fact that in the beds so called the Fossil wood existed *in situ*, and that they were the original depository of the Fossil wood, which in the newer beds was simply derivative and the result of the re-arrangement of the materials of the Fossil wood group proper.—(p. 76 l. c.). At page 83, Dr. Noetling takes exception to a suggestion of mine that the silica with which the fossil trunks of trees had been mineralized might have been derived from springs discharging into the water, wherein I supposed the trees to have floated prior to their entrenchment. "The logical outcome of this theory is that, wherever a single specimen of a silicified log is found *in situ*, we are bound to suppose that just underneath that very log a spring rose in order to petrify it, and having done its work, disappeared without leaving behind it any other traces of its activity." Now Dr. Noetling is fully justified in calling this absurd, but he is wholly wrong in calling it the "*logical outcome*" of anything I said, wrote or thought in the matter! The silica may or may not have been supplied by springs as I suggested, but all I had in my mind was the precisely analogous case of the flint in chalk which was clearly *nascent* or in solution in the cretaceous sea, and in its gelatinous condition gathered round and mineralized any organic substance lying fortuitously at the bottom, as I supposed the silica to have done in the water wherein the fossil trunks in the 'Fossil wood group' as I termed it, did in the waters wherein they floated—before their ultimate mineralization. At page 84, Dr. Noetling makes an important correction of a statement of mine, where he says that Mr. Theobald's "statement that the silicified wood is never bored by Xylophagus mollusca is *absolutely erroneous*." Of course I am glad to be corrected in a mistake of this kind, but in this case I am not so sure if Dr. Noetling has corrected me! By referring to my Report (Memoirs, Vol. X, p. 66) it will be seen that the fossil wood to which I refer is that of the "*silicified trunks*" which Dr. Noetling admits are embedded in a freshwater formation (p. 86, l. c.) as instanced by the absence of marine organisms. The question hence arises, does the fossil wood of which Dr. Noetling says he has "repeatedly found large pieces riddled by the borings of these mollusca" refer to the silicified trunks, to which *my statement referred*, from the topmost division of my 'Fossil wood group,' or does it refer to logs of fossil wood from the marine beds of Dr. Noetling's Pegu group, as if so it ceases to be a correction of any statement of mine whatever? I have not myself noticed in Pegu any perforated wood whatever, but that such should occur in beds of the character of the marine beds of the Pegu division of Dr. Noetling is of the highest probability, but as matters stand it seems by no means evident that my assertion touching the silicified trunks of my 'Fossil wood group' has received any real correction from any observation of Dr. Noetling—at least within the area to which my remarks were confined—it being of course quite possible that the homologous beds of the Fossil wood group of Pegu might in Upper Burma be represented by beds of an estuarine character rather than a lacustrine or fluviatile one, in which case Dr. Noetling's observation would be perfectly correct, without implying any correction of my own.

Notes from the Geological Survey of India.

I. Madras.— Mr. Middlemiss reports having met several corundum pits in the Sivamallai district of Coimbatore, and in some of these shallow pits magnetic iron ore also appears, concentrated into lumps among the felspar, forming a rich rock with a specific gravity of 3·95. Magnetic iron ore was found as a schist and standing up as a small hill near Hallagomallai. The same rock was also found forming the Chinnamallai (Sennamallai) hill-range near Peranturei, the strike in the rocks coinciding with the long axis of the range.

Mr. Middlemiss also examined the extensive marble beds near Madukarai, which are regularly banded with the ordinary gneisses of the area, and with which they seem to be in structural connection. The deposit appears on the Coimbatore-Madukarai road near the 6th milestone from the former place; its outcrop is roughly elliptical, the major axis running NE to south-east from the point mentioned to within 1½ miles of Kurichi village. The total length of the outcrop is about 7 miles, and the breadth varies from ½ mile to 50 or 100 yards. It is thickest on the north-west and north-east sides. The marble is greyish white, dark slate grey and flesh-coloured pink, and forms a very valuable building stone, hitherto but little used locally.

II. Burma.—During the early part of this year Dr. H. Warth examined the so-called Nanyaseik ruby tract in the Mogoung district; the area selected by the Burma Government and proclaimed a gem tract is about 80 square miles, although Dr. Warth estimates the actual area over which gems are found in the alluvial deposits as about 10 square miles only. His report will be published hereafter, but the main facts are the following:—

1. He found, in parts of the district examined, sandstone without fossils, which I believe to be the tertiary sandstone with coal seams mentioned by Dr. Noetling (Records Vol. XXVI, Pt. 1, p. 28).

2. A series of acid igneous rocks, most interesting lithologically.

3. Granitic rocks which inclose beds of metamorphic (crystalline) limestone: the latter is of importance, as it is the original matrix of the gems. Dr. Warth is of opinion that this limestone is the same and contains the same minerals as the coarsely crystalline limestone found at the Mogok and Sagyin ruby mines in Burma.

Good rubies and well-coloured spinels with some saphires have been found in the alluvial deposits of the "Nanyaseik gem tract."

III. Baluchistan.—Sub-Assistant Hira Lall surveyed geologically part of the Mari and Bugti hills east of Sibi, and has furnished a report, which will eventually be incorporated in the final Report on the Geology of Baluchistán; it is of interest to note that the great flexures into which the rocks of Baluchistán have been laid are continued into these hills; the sections seen are much the same as already reported on from the country further west and north-west (Records, Vol. XXV, Pt. 1, p. 18), and most of the beds from the massive jurassic limestone to the upper Siwalik conglomerates have been recognized.

CALCUTTA;
The 1st November 1895.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

DONATIONS TO THE MUSEUM.

FROM 1ST NOVEMBER 1894 TO 31ST JANUARY 1895.

Seven specimens of ozokerite, from Boryslaw, Galicia; 1 of slickenside in conglomerate (magura sandstein), from Czarnoozeki near Krosno, Galicia; 1 of Oil-bearing sandstone, from old shaft, Ober Hieroglyphen, Schiefer, Bobrka Oil-field near Krosno, Galicia; 1 of Diorite with iron pyrites, from Bussein bridge, between Somirx and Dissentis, Vorder Rhine; 1 Faceted pebble from the Boulder Bed of Mount Chel Salt Range, Punjab; 2 Striated pebbles from Ramsay's . "Glacial breccia," Abberley; 3 Limestone pebbles, pitted, crushed and scratched by earth movements, from the Nagel fluh of the Molasse, St. Gallen, Switzerland; 3 quartzite pebbles facetted by natural sand blast, Copitz, near Dresden.

PRESENTED BY R. D. OLDHAM, A.R.S.M., F.G.S.,
SUPERINTENDENT, GEOLOGICAL SURVEY OF INDIA.

Octahedral crystals of magnetite, from Shamsunderpúr, Bankúra District.

PRESENTED BY N. BELLETTY.

Specimens of mica from the Dhatu Mines, Pananoa hill, 5 miles S. W. of Nawadih, E. I. R.

PRESENTED BY J. D. JONES.

ADDITIONS TO THE LIBRARY.

FROM 1ST OCTOBER TO 31ST DECEMBER 1894.

Titles of Books. *Donors.*

BRONN, *Dr. H. G.*—Klassen und Ordnungen des Thier-Reichs. Band II, Abth. 3, lief. 17-18; and IV, lief. 36-37. 8° Leipzig, 1894.

LEYMERIE, *A.*—Description Geologique et Palæontologique des Pyrénées et de la Haute-Garonne. With Map and Atlas. 8° Toulouse, 1881.

PERIODICALS, SERIALS, ETC.

American Geologist. Vol. XIV, No. 2. 8° Minneapolis, 1894.

American Journal of Science. Vol. XLVIII, Nos. 285-288. 8° New Haven, 1894.

American Naturalist. Vol. XXIII, No. 273; XXV, Nos. 297, 298 and 300; XXVI, No. 302; and XXVIII, Nos. 333-335. 8° Philadelphia, 1894.

Annalen der Physik and Chemie. Neue Folge, Band LIII, heft 3-4. 8° Leipzig, 1894.

Annals and Magazine of Natural History. 6th series, Vol. XIV, Nos. 82-83. 8° London, 1894.

Athenæum. Nos. 3490-3501. 4° London, 1894.

Titles of Books. *Donors.*

Beiblätter zu den Annalen der Physik und Chemie. Band XVIII, Nos. 9-10. 8° Leipzig, 1894.

Chemical News. Vol. LXX, Nos. 1816-1827. 8° London, 1894.

Colliery Guardian. Vol. LXVIII, Nos. 1759-1770, Fol. London, 1894.

Geological Magazine. New series, Decade IV, Vol. I, Nos. 10-11. 8° London, 1894.

Industries and Iron. Vol. XVII, Nos. 1131-1142. 4° London, 1894.

London, Edinburgh and Dublin Philosophical Magazine and Journal of Science. 5th series, Vol. XXXVIII, Nos. 233-234. 8° London, 1894.

Mining Journal. Vol. LXIV, Nos. 3081-3092. Fol. London, 1894.

Natural Science. Vol. V, No. 30. 8° London and New York, 1894.

Nature. Vol. L, No. 1298 to Vol. LI, No. 1309. 4° London, 1894.

Neues Jahrbuch für Mineralogie, Geologie und Palæontologie. Band II, heft 3; and Beilage—Band IX, heft. 2. 8° Stuttgart, 1894.

Oil and Colourman's Journal. Vol. XV, Nos. 170-171. 8° London, 1894.

Palæontologische Abhandlungen. Neue Folge, Band II, heft 5. 4° Jena, 1894.

Petermann's Geographischer Mittheilungen. Band XL, Nos. 9-11. 4° Gotha, 1894.
THE EDITOR.

Scientific American. Vol. LXXI, Nos. 9-20. Fol. New York, 1894.

Scientific American. Supplement. Vol. XXXVIII, Nos. 974-985. Fol. New York, 1894.

The Indian Engineer. Vol. XXI, No. 390 to Vol. XXII, No. 401. 4° Calcutta, 1894.
THE EDITOR.

Zeitschrift für Krystallographie und Mineralogie. Band XXIII, heft 4-6. 8° Leipzig, 1894.

Zeitschrift für praktische geologie. Jahrgang 1894, heft 9-11. 8° Berlin, 1894.

GOVERNMENT SELECTIONS, REPORTS, ETC.

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 in the year ending 31st March 1894. Vols. I and II, No. 28. 4° Calcutta, 1894. GOVERNMENT OF INDIA.

„ History of Services of Officers holding gazetted appointments in the Home, Foreign, Revenue and Agricultural, and Legislative Departments, corrected to 1st July 1894. 8° Calcutta, 1894.
GOVERNMENT OF INDIA.

„ Monthly Weather Review, June to August 1894. 4° Calcutta, 1894.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Register of original observations, reduced and corrected, June to August 1894. 4° Calcutta, 1894.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Report on the administration of the Meteorological Department of the Government of India, in 1893-94. 4° Calcutta, 1894.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Selections from the Records of the Government of India, Foreign Department. Nos. 312—313. Flsc. Calcutta, 1894. FOREIGN DEPARTMENT.

PUNJAB.—Gazetteer of the Lahore District, 1893-94. 8° Lahore, 1894.
PUNJAB GOVERNMENT.

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TRANSACTIONS, PROCEEDINGS, ETC., OF SOCIETIES, SURVEYS, ETC.

ADELAIDE.—Transactions of the Royal Society of South Australia. Vol. XVIII 8° Adelaide, 1894. THE SOCIETY.

BERLIN.—Verhandlungen der Gesellschaft für Erdkunde zu Berlin. Band XXI., Nos. 7—8. 8° Berlin, 1894.

„ Zeitschrift der Deutschen Geologischen Gesellschaft. Band XLV, heft. 4, and XLVI, heft 1. 8° Berlin, 1894. THE SOCIETY.

BRISBANE.—Proceedings and Transactions of the Queensland Branch of the Royal Geographical Society of Australia. Vol. IX. 8° Brisbane, 1894. THE SOCIETY.

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BRISTOL.—Proceedings of the Bristol Naturalists' Society. New series, Vol. VII, part 3, and List of Officers. 8° Bristol, 1894. THE SOCIETY.

BRUSSELS.—Bulletin de la Societe Royale Belge de Geographie. Annee XVIII, Nos. 2-3, 8° Bruxelles, 1894. THE SOCIETY.

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„ Proceedings of the Asiatic Society of Bengal. No. 8. 8° Calcutta, 1894. THE SOCIETY.

„ Proceedings and Journal of the Agricultural and Horticultural Society of India. Vol. X. July to September 1894. 8° Calcutta, 1894. THE SOCIETY.

„ Records of the Geological Survey of India. Vol. XXVII, part 4. 8° Calcutta, 1894. GEOLOGICAL SURVEY OF INDIA.

„ Survey of India Department Notes for September and October 1894. Flsc. Calcutta, 1894. SURVEY OF INDIA DEPARTMENT.

CAMBRIDGE, MASS.—Bulletin of the Museum of Comparative Zoology. Vol. XXV, Nos. 7—10. 8° Cambridge, Mass., 1894. THE MUSEUM.

DEHRA DUN.—Spirit-Levelled Heights. No. 1, Burma, Season 1892-93. 8° Dehrā Dun, 1894. GREAT TRIGONOMETRICAL SURVEY OF INDIA.

DRESDEN.—Sitzungsberichte und Abhandlungen der Naturwissenschaften Gesellschaft, Isis in Dresden. Jahrg. 1894, January to June. 8° Dresden, 1894. ISIS SOCIETY.

DUBLIN.—Transactions of the Royal Irish Academy. Vol. XXX, parts 13-14. 4° Dublin, 1894. THE ACADEMY.

EDINBURGH.—The Scottish Geographical Magazine. Vol. X, Nos. 10—11. 8° Edinburgh, 1894. THE SOCIETY.

„ Transactions of the Edinburgh Geological Society. Vol. VII, pt. 1. 8° Edinburgh, 1894. THE SOCIETY.

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GLASGOW.—Proceedings of the Philosophical Society of Glasgow. Vol. XXV of 1893-94. 8° Glasgow, 1894. THE SOCIETY.

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GÖTTINGEN.—Nachrichten von der Königl. Gesellschaft der Wiesenschaften zu Göttingen. Mathematisch-physikalische Klasse. No. 3. 8° Göttingen, 1894. THE SOCIETY.

LEIDE.—Annales de L'École Polytechnique de Delft. Tome VIII, liv. 1–2. 8° Leide, 1894. ÉCOLE POLYTECHNIQUE DE DELFT.

LILLE.—Annales de la Société Geologique du Nord. Vol. XXI. 8° Lille, 1894. THE SOCIETY.

LONDON.—A Monograph of the British Phytophagous Hymenoptera Cynipidæ and Appendix). Vol. IV. By Peter Cameron. (Ray Society.) 8° London, 1893.

„ The Larvæ of the British Butterflies and Moths by (the late) William Buckler. Edited (in part) by (the late) H. T. Stainton, F.R.S. Vol V. (the second portion of the Noctudæ.) (Ray Society.) 8° London, 1893.

„ Journal of the Chemical Society. Nos. 382—384. 8° London, 1894.

„ Journal of the Linnean Society of London. Zoology, Vol. XXIV, Nos. 155—157; and Botany, Vol. XXVI, No. 177, and XXX, Nos. 205–208. 8° London, 1894. THE SOCIETY.

„ Proceedings of the Linnean Society for October 1893 and May 1894. With List of Fellows for 1893-94, and Catalogue of the Library of the Linnean Society. Part II. 8° London, 1894. THE SOCIETY.

„ Transactions of the Linnean Society. 2nd series, Botany, Vol. III, pts. 9-11, and IV, pt. 1; and Zoology, Vol. V, pt. 11, and VI, pts. 1—2, 8° London, 1894. THE SOCIETY.

„ Journal of the Society of Arts. Vol. XLII, No. 2182 to Vol. XLIII, No. 2193. 8° London, 1894. THE SOCIETY.

„ Proceedings of the Zoological Society of London. Part III. 8° London, 1894. THE SOCIETY.

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„ Proceedings of the Royal Society. Vol. LV, Nos. 334—335. 8° London, 1894. THE SOCIETY.

„ Quarterly Journal of the Geological Society. Vol. I, pt. 4; and List of Fellows on 1st Nov. 1894. 8° London, 1894. THE SOCIETY.

„ The Geographical Journal. Vol. IV, Nos. 4—5. 8° London, 1894. THE SOCIETY.

MADRID.—Boletin de la Sociedad Geografica de Madrid. Tome XXXVI, Nos. 9—10. 8° Madrid, 1894. THE SOCIETY.

MANCHESTER.—Memoirs and Proceedings of the Manchester Literary and Philosophical Society. Vol. VIII, No. 3. 8° Manchester, 1894. THE SOCIETY.

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MOSCOW.—Bulletin de la Société Imperiale des Naturalistes de Moscow. Anneé 1894. No. 2. 8° Moscow, 1894. THE SOCIETY.

NAPLES.—Rendiconto dell' Accademia delle Scienze Fisiche E Matematiche. Series II, Vol. VIII, fasc. 8—10. 4° Napoli, 1894. THE ACADEMY.

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NEWCASTLE-UPON-TYNE.—Transactions of the Federated Institution of Mining Engineers. Vol. VII, pts. 3–4. 8° Newcastle-upon-Tyne, 1894.

PARIS.—Annales des Mines. 9me série, Tome IV, livr. 7. 8° Paris, 1894.
DEPT. OF MINES, PARIS.

„ Bulletin de la Société de Géographie. 7me série, Tome XV, No. 2. 8° Paris, 1894. THE SOCIETY.

„ Comptes Rendus des Seances de la Société de Géographie, No. 15. 8° Paris, 1894. THE SOCIETY.

„ Bulletin de la Société Géologique de France. 3me série, Tome XXII, No. 5. 8° Paris, 1894. THE SOCIETY.

„ Mémoires pour servirá l'explication de la Carte géologique detailléе de la France. Deuxieme Partie. Paléontologie les Ammonites de la Craie Superieure. Par A, De Grossouvre. With Atlas. 4° Paris, 1893.
MINISTÈRE DES TRAVAUX PUBLICS.

PHILADELPHIA.—Journal of the Franklin Institute. Vol. CXXXVIII, Nos. 3—5 8° Philadelphia, 1894. THE INSTITUTE.

ROME.—Atti della Reale Accademia dei Lincei Rendiconti, Série V, Semestre II, Vol. III, fasc. 5—8. 8° Roma, 1894. THE ACADEMY.

SHANGHAI.—Journal of the China Branch of the Royal Asiatic Society. New series, Vol. XXVI. 8° Shanghai, 1894. THE SOCIETY.

SPRINGFIELD.—Bulletin of the Illinois State Museum of Natural History. No. 4. 8° Springfield, 1894. THE MUSEUM.

SYDNEY.—Proceedings of the Linnean Society of New South Wales. Vol. IX, part 1. 8° Sydney, 1894. THE SOCIETY.

TURIN.—Atti della R. Accademia delle Scienze di Torino. Vol. XXIX, disp. 11-15. 8° Turin, 1894. THE ACADEMY.

G. I. C. P. O.—No. 50 D. G. Survey.—26-2-94.—620.

pt. 2

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FROM 1ST FEBRUARY TO 30TH APRIL 1895.

Two large specimens of mica-apatite-peridotite, from Giridih.

PRESENTED BY DR. W. SAISE, A.R.S.M., F.G.S., MANAGER, E. I. RAILWAY. COLLIERIES.

Specimens of argentiferous copper-ore, from the Albert Silver Mine, Pretoria District, Transvaal.

PRESENTED BY TOM CLARIDGE, JOHANNESBURG, TRANSVAAL.

Specimens of auriferous quartz taken from 40 to 45 feet below surface, from an old mine on "Rees Reef," Pahardiah concession, Anandapur, Singbhum district, Chota Nagpore.

PRESENTED BY V. L. REES, CALCUTTA.

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Gold washed from sand, and sand containing gold, from 6 miles north-east of Hopin, Muh Valley Railway, Upper Burma; and a specimen of fossil wood from west of Hopin, Muh Valley Railway, Upper Burma.

PRESENTED BY A. F. JOHNSTON, SUPERVISOR, P. W. DEPT., RAILWAY BRANCH, MUH VALLEY RAILWAY, UPPER BURMA.

Three specimens of cassiterite from Cornwall, England.

PRESENTED BY J. R. HOSKEN, PENBRO BREAGE, CORNWALL.

A specimen of concretionary clay, from Katni, Jabalpur District; and decomposed felspathic breccia cemented with calcite, from Moosrakand, Raniganj.

PRESENTED BY JAS. CLEGHORN, CALCUTTA.

Pyritous dolomitic limestone, from the Khesra Valley, Waziristan.

PRESENTED BY PANDIT RAM RAKHAN MISSER, TRANSPORT AGENT, 2ND BRIGADE, WAZIRISTAN FIELD FORCE.

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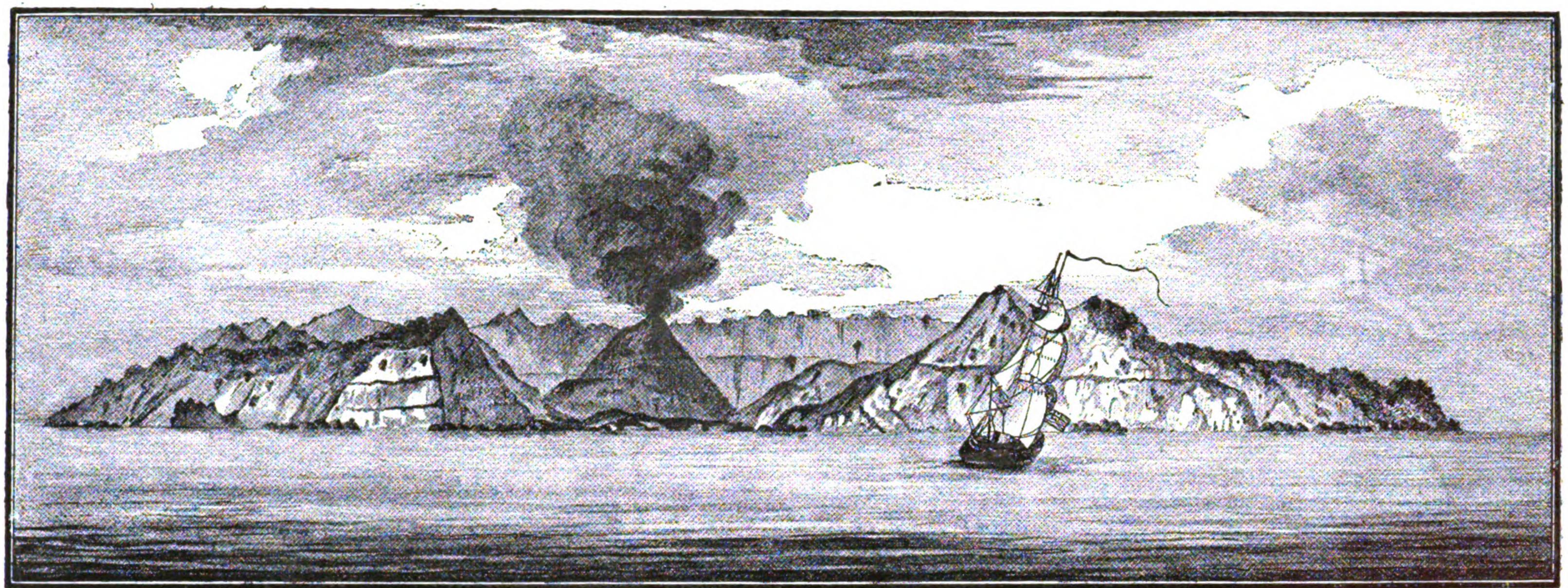

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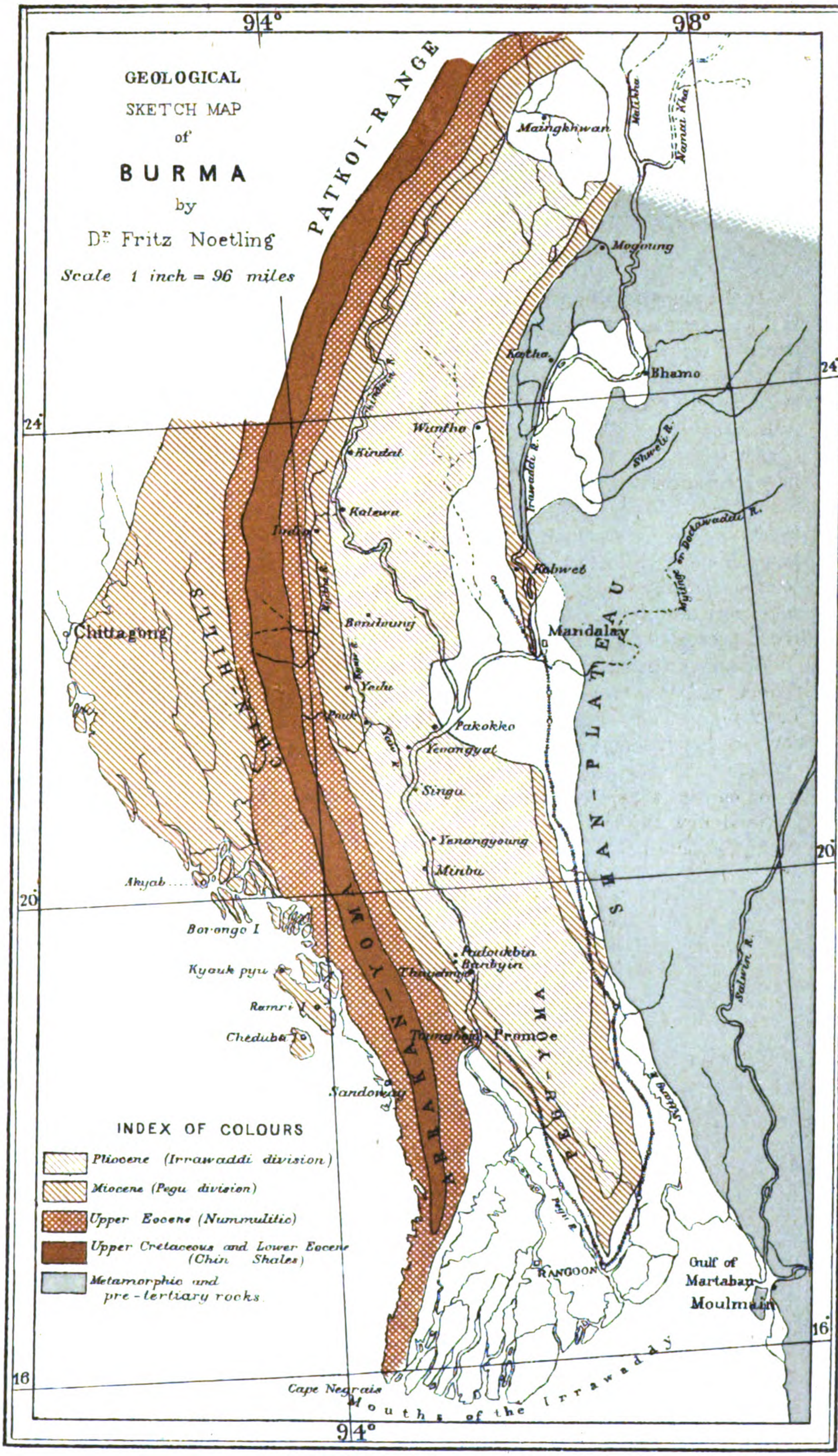

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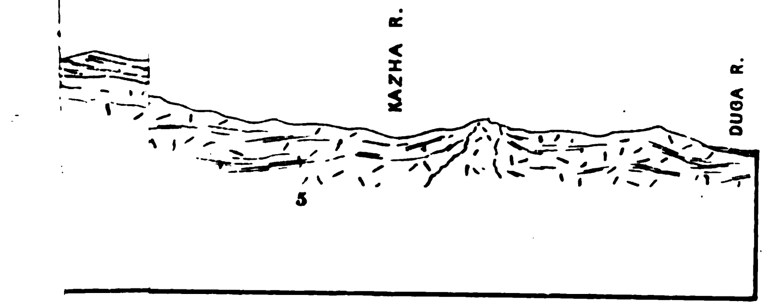

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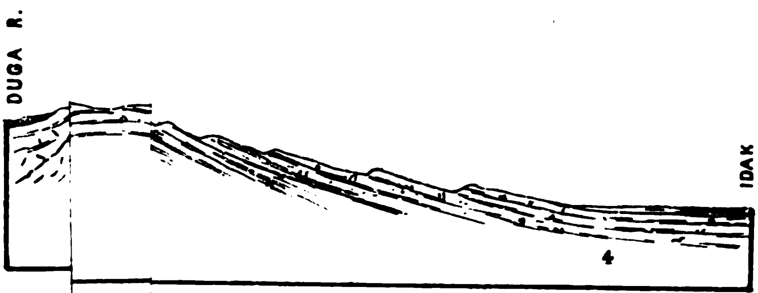

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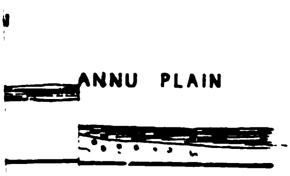

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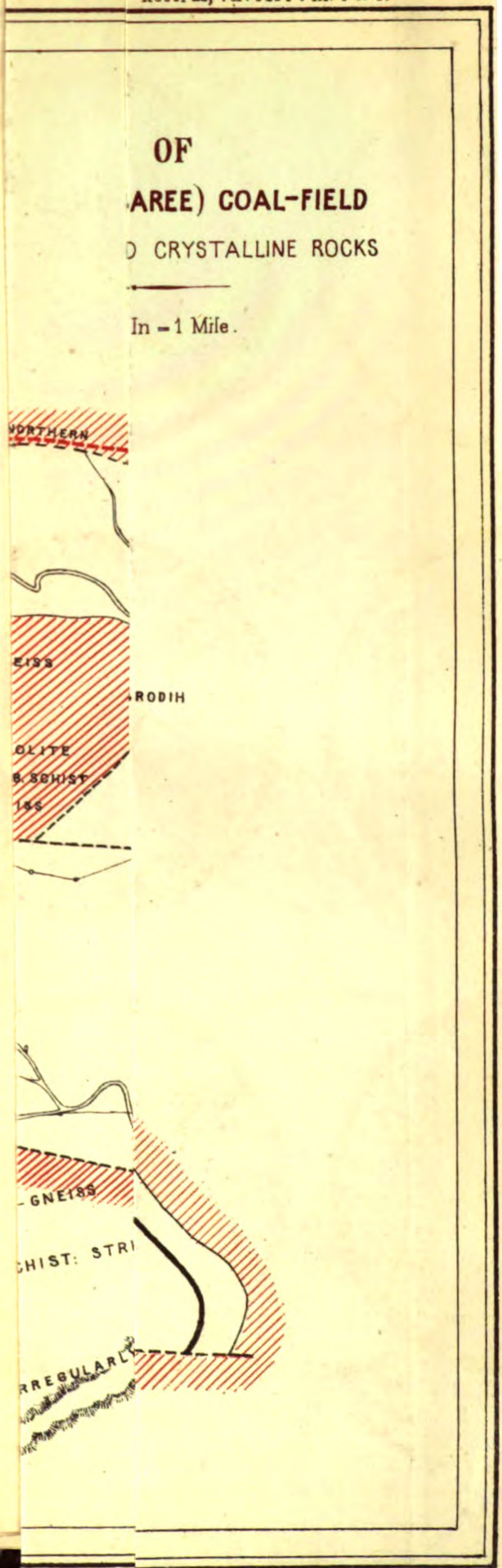
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Fig. 3.

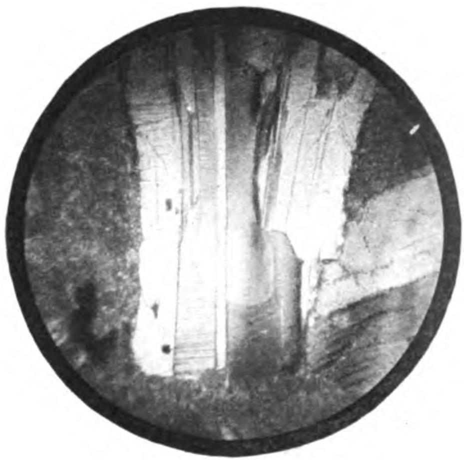

Fig. 4.

Fig. 5.

Fig 6.

ROCKS FROM THE GIRIDIH COALFIELD.

Photographs by W. J. Simmons & T. H. Holland.

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Survey of India Offices, Calcutta, Oct.

RECORDS

OF

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VOL. XXVIII, PART I.

1895.

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