# RECORDS

OF

# THE GEOLOGICAL SURVEY OF INDIA.

## VOLUME XXIX.

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OF

# THE GEOLOGICAL SURVEY OF INDIA.

Part I.] 1896. February.

## ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1895.

The actual area which was geologically surveyed during the past year is much below the amount which could have been estimated for under favourable circumstances, though perhaps not below the amount of surveys in square miles, done during each of the last few years. This, however, may easily be accounted for by the fact that not only were several officers withdrawn from survey work proper and employed on so-called economic inquiries, but there were several vacancies on the staff, which could only recently be filled up.

At the beginning of the year the officers were distributed as shown in the last Annual Report on page 1 of the Records, Vol. XXVIII.

Mr. H. H. Hayden joined the Department as Assistant Superintendent on the 21st February, too late to take up field work, and he was therefore detained at head-quarters to learn the vernacular language and to assist in laboratory work.

Messrs. Vredenburg and Grimes were appointed Assistant Superintendents by the Secretary of State to fill vacancies on the staff; both jointed head-quarters on the 16th October 1895.

During the year three officers proceeded on furlough, namely, Mr. LaTouche on the 19th March, Mr. Bose on the 15th May, and Dr. Noetling on the 1st July 1895.

At the beginning of the present camping season the staff of the survey was distributed as follows:—

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|---|---|
| Mr. R. D. OLDHAM with Messrs. DATTA, VREDENBURG and GRIMES | Rewah. |
| Mr. MIDDLEMISS with " SMITH | Madras. |

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|---|---|
| Mr. HOLLAND . . . | . Head-quarters. |
| „ HAYDEN . . . | . Burma. |
| Mr. ANDERSON with Dr. WARTH and LALA HIRA LAL | Chota Nagpore. |
| LALA KISHEN SINGH . | . Baluchistán. |

During the hot weather months and the rainy season most of the officers returned to Calcutta to work up their reports and maps; Mr. Middlemiss returned to Madras at the beginning of the monsoon to continue field work.

Mr. Oldham, with Mr. Holland, proceeded to Naini Tal at the close of the monsoon to report on the stability of the hill-sides of that station.

I myself proceeded on inspection when opportunities offered, and I performed the following tours :—

During March to Chota Nagpore and Central Provinces.

During June to Naini Tal at the request of the Government of the North-Western Provinces.

During July and August to the Central Provinces and Madras.

During October to Naini Tal.

Summary of work accomplished.

In the following pages I give an outline of the work performed in the field and laboratory.

*Bengal.*
Mr. Anderson.
Dr. Warth.
Lala Hira Lal.

As already reported in my Annual Report for 1894, the mineralogical survey of Chota Nagpore has been begun by Mr. Anderson, the mining expert of this Department. During the camping season ending during April of 1895 he explored a considerable area of Chota Nagpore. He made traverses in many directions, beginning with the country around Borobhum, and from thence to Dhadka, Moholia and Chaibassa. East of Borobhum, to a distance of about 12 miles, the transition rocks are much intruded by dykes and masses of a hornblendic rock, probably diorite. Associated with these intrusions are innumerable quartz-reefs, many of which were tested, but show no traces of gold. Almost all the reefs of this area have generally a north and south strike, many of them occurring as joint reefs in the dykes. In the country between the Cupergadi Ghat and Chaibassa, similar dykes associated with quartz-reefs occur, but they also show no traces of gold.

I visited Mr. Anderson during March, when his first and rapid traverses were drawing to a close. A quotation from his February report will afford an idea of the work and the geological nature of the ground gone over. "During the month of February I made an examination of the country around Chaibassa, Seraikela and Sim. At the first-mentioned place the boundary between the transitions and metamorphic series runs close past the town in a north and south direction. In the neighbourhood of this boundary the rocks, particularly those of the transition series, are seamed with quartz veins. To the north and north-west of the town the outcrops of these veins are not at all well defined but usually form a series of small circular or elongated hills, composed superficially of nothing but small fragments of quartz. In some parts these hills occur in numbers close together and cover considerable local areas. Almost anywhere in such areas the broken quartz debris, when crushed or washed, show minute traces of gold. The absence of defined outcrops would materially increase the expense and time of prospecting this area, because so much work would require to be done in trenching through the superficial debris to get at the actual reef outcrops."

During this camping season prospecting work has begun in earnest, sufficient funds having been sanctioned by the Government of India for the purchase of the requisite plant, tools, etc. A five stamp prospecting battery with all the necessary outfit has been procured, workmen are being engaged and practical investigations are being carried out in three separate mining camps. So far the traces of gold found in quartz-reefs are not encouraging, but nothing definite can be said about the prospects of finding it in payable quantities eventually, as only 70 reefs have been examined up to date.

An interesting and probably useful find of blue corundum has been made by Dr. Warth on the Balarampur-Borobhum road; it occurs in a vein of kyanite, and when opportunity offers this find will be followed up.

*Rewah.*
Messrs. Oldham, Datta, Vredenburg, and Grimes.

The area mapped during the field season of 1894 to 1895 was very small, little more than 700 square miles; this insufficiency may be accounted for inasmuch that both officers (Messrs. Oldham and Datta) were new to the district and were only partially acquainted with the rocks they met with during the progress of work. A considerable time was also lost by Mr. Oldham in inspecting previous work done by Messrs. Hughes, Bose and Smith in Rewah and in trying to reconcile it with his own observations and views. The result has led to some modifications of views held hitherto with regard to the so-called Vindhyan system; the chief point made out is the separation of the Lower Vindhyans (Sub-Kymores) from the Upper Vindhyans. The latter will, according to Mr. Oldham, henceforth represent the Vindhyan system proper, whilst the strata below them and above the transition rocks are to be called, as was done by Mr. Medlicott originally, the Semri series. The Vindhyans rest unconformably upon the Semri series, but it will have to be established whether in spite of the unconformability, which is only seen locally; the two series are separated from each other by a general break in deposition of the beds composing the same. Mr. Oldham has stated his views in a paper in Records, Vol. XXVIII.[1]

Besides working on the Vindhyan rocks Mr. Oldham also examined a small coal-field in the eastern part of Rewah which Mr. Smith had surveyed some years ago; the Barakar age of the rocks has now been established, as they contain *Vertebraria*, *Glossopteris*, *Schizoneura*, etc. Two coal-seams have been found, respectively of 6 feet and 5 feet 6 inches 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.

Mr. Datta devoted the greater part of his attention to mapping the lower Vindhyans, or, as Mr. Oldham calls them once more, the Semri series. The work has been done in detail and some additions are made to our knowledge of

[1] p. 139.—On some outliers of the Vindhyan system south of the Son and their relation to the so-called lower Vindhyans.

this series. A preliminary description of the area has been given by him in a paper in the Records, Vol. XXVIII.[1]

During November Mr. Oldham took up work once more in Rewah, his staff being augmented by Messrs. Vredenburg and Grimes. So far the work of the party has not progressed far enough to add new facts to those already reviewed.

*Central Provinces.*
Mr. P. N. Bose.

Mr. Bose continued work south-west and west of Raipur in the Central Provinces, from where he returned to head-quarters on the 6th April. He sent in a progress report from which it appears that the main features of the geological structure of that portion of the Central Provinces consists of a base of crystalline rocks, granites, and gneisses with great intrusions of felsites, on the denuded surface of which lie patches, often of large extent, of "Vindhyans"; two lithologically distinct facies of the lower division of this system have been distinguished by Mr. Bose,—the eastern or Chattisgarh facies and the western or Bhan dara rocks. The former are already known as the "Chandarpurs," whilst he proposes to call the latter the "Bagh Nadi" sandstones, a distinction which I do not consider necessary, as apparently these two facies are of the same age. There can be little or no doubt whatever that the entire sequence of beds in both areas belongs to the lower Vindhyans, as known hitherto, and my own inspection of these rocks is in conformity with this view.

Mr. Bose had taken up work in the Central Provinces as early as 1884, and has always insisted on having discovered an unconformity between the lower Vindhyans and the so-called Chilpis, a series of strata doubtfully correlated with transitions elsewhere. One of the localities specially mentioned by him was the country around Warorband, about ten miles south-east of the Dongarghar station on the Bengal-Nagpur Railway. Mr. Bose had been several times over this area, and during last field season he reported that he had obtained confirmatory evidence of his former assertion. I may here mention that Mr. Medlicott, who knew the ground, strongly differed from this view, but that Dr. King, although he thought (Records, XVIII, page 190) that the evidence was unsatisfactory, on a later occasion expressed his opinion that this unconformity had been established. The question of unconformity or otherwise remains to-day much where it was before, but during a short inspection of Mr. Bose's work during March I ascertained that the so-called Chilpi beds have no existence at Warorband itself. Believing that an inspection of that locality which he had repeatedly visited, and the survey of which he had revised as late as last season, would afford a fair test of his work, I proceeded to the place in March last, and during a few days' stay walked over the neighbouring country,—which is fairly open,—in company with Mr. Bose. I started from Dongarghar station, which I may here mention is situated on granite, which forms particularly characteristic "tors" and rugged hills in the neighbourhood, some of which are crowned with temples. The granite is seen *in situ* not only there but for miles around, and the road (ten miles) to Warorband passes almost entirely over it. There are dykes and intrusions of felsites and diorites seen in this area along with numerous and conspicuous quartz-reefs.

According to Mr. Bose we should have a sequence of older beds (Chilpis,

[1] p. 144.—Notes on a portion of the lower Vindhyan area of the Sone Valley.

consisting of grits and conglomerates, etc.) dipping at a higher angle below the Chattisgarh lower Vindhyans, the former being associated with eruptive rocks.

What I actually found was that the country about west of Warorband consists of granite, with wide belts and intrusions of felsites and diorites; these igneous rocks have long ridges of reef-quartz running nearly north and south, and on an abraded surface of these rocks rest immediately beds of the lower Vindhyans (so-called), which form the basin-like Chattisgarh series of strata, the western margin of which is slightly raised, thus dipping from 20 to 30° east and east-south-east, gradually flattening out, and even in some cases forming undulating anticlinals. The lowermost beds consist of brownish-red to purplish indurated quartz-sandstones, with strings of grits and in some places breccias and conglomerates, which strongly reminded me of the Rotas (Sone) basal conglomerate of the lower Vindhyans. The grits are not confined to beds nor to the base of the series, but as is usual in such a lithological facies, occur in strings and irregular beds at various horizons. The upper beds of this system consist of the Chattisgarh limestones, with which we have no concern here. Nowhere could be discovered any sedimentary or metamorphic rock which might have been identified with an older system than the Vindhyans, and although I am quite ready to admit that the igneous series of rocks which forms the base of the lower Vindhyans here, may be intrusive in a "transition" system, of which the Chilpis may be a local development, yet neither at Warorband nor anywhere in that neighbourhood is there any evidence of such a system, and the lower Vindhyans rest directly upon the granitic and in other places upon a felsitic or dioritic base. It seems that Mr. Bose had taken four distinct rocks as parts of the assumed "transition" series; first, the (probably) pseudomorphic quartz. which forms such numerous and most conspicuous reefs in that area and which in some places forms actually the base of the lower Vindhyans, and which being much crushed at places, has occasionally the appearance of a breccia and even grit.—that is to say, if not very closely observed; secondly, for some reason he looked upon the basal grits and conglomerates of the lower Vindhyans, where raised at a higher angle, as forming an older and unconformable series of rocks to the same beds, where the dip flattens out, or is even slightly reversed in cases of shallow synclinals, and this was the case at a point east of the Warorband lake itself; thirdly, an exposure of diorite weathering concentrically and showing that leafy condition, which in hand-specimens is often at first misleading, was mapped as intrusive in phyllites, the latter being the weathered and pseudoschistoze portion of the diorite; and lastly, Mr. Bose had identified and mapped as grits and shales of the Chilpis, a long and most conspicuous ridge made up of typical felsite. After a most careful inspection I may assert most confidently that at all events there are no "transitions" or "Chilpis" or any older sedimentary strata below the lower Vindhyans at Warorband, but that the latter rest directly upon an eroded surface of igneous rocks. That the "Chilpi Ghat series" may elsewhere underlie the lower Vindhyans unconformably is thereby not disproved of course.

The continuance of the geological survey of the Central Provinces has to be postponed owing to the fact that Mr. Bose has gone on two years' furlough.

*N.-W. Provinces. Naini Tal.* Messrs. Oldham and Holland.

After return from field work in Rewah and before the beginning of the rainy season, Mr. Oldham was deputed to Naini Tal to serve as member on the Committee appointed to report on the safety of Government House Hill. The examination was conducted during May and most of June; Mr. Oldham has sent in his report to the Government of the North-West Provinces, but the following extract from his diary for June expresses his views in outline: "The facts collected, when compared with those observed on my previous examinations leave no doubt that there is a steady downhill creep of the outer portion of the hill for a depth of probably about 50 feet. The main surfaces of separation unfortunately reach the summit under the Government House and the constant settlements which have taken place in the past, at an annually increasing rate, impressed me with the danger of a further settlement taking place, which might be sufficient to endanger the house."

As other members of the Committee dissented from this view, the Government of the North-West Provinces requested that I should give my opinion, and I proceeded to Naini Tal accordingly. Whilst I fully agree with Mr. Oldham in believing that the entire hill slope below Government House is in a more or less dangerous condition and that some day slips on a large scale may occur there, yet I did not feel convinced that distinct proofs existed of later and more extended developments of certain cracks in the hill, which had been reported on many years ago. In the absence of positive proofs that the hill-side exhibited greater signs of danger now than it did for some years past, I did not advise the Government to evacuate the hill, but to stringently enforce certain recommendations which had been made by previous committees, and also to carry out extended drainage works. One of my reasons in advising Government thus, was, that immediately after the rains a further and more detailed examination of all the hill-sides of Naini Tal was to be made by officers of the department, when the question would be finally settled. This was done during October and part of November of this year. A large scale contoured map of the station had been made by the Survey of India, and Messrs. Oldham and Holland conducted their detailed inquiries, which will be embodied in an exhaustive memoir and which ought to dispose finally of the question of the safety of this hill-station.

*Madras.* Messrs. Middlemiss and F. H. Smith.

The investigations, chiefly of a petrological character, which Mr. Middlemiss pursued during 1894, were continued also during the past year, and they have added much to our knowledge of the occurrence and distribution of the magnesites and corundum o the Madras Presidency. Many of his observations are of great interest and have therefore been more fully dealt with in "notes" published in the "Records." He has sent a preliminary report, rather fully worked out, which will be published in the "Records." This cold season he is assisted by F. H. Smith, and it was hoped that the special work on which Mr. Middlemiss has now been engaged for about two years would be accelerated, but unfortunately Mr. Smith has been seriously ill with fever since his arrival in the Madras Presidency.

*Sind.* Mr. LaTouche. Lala Hira Lal.

The trial boring for oil which was commenced two years ago, progressed satisfactorily, if slow, till the 19th March of the past year, on which date Mr. LaTouche handed over the work to Lala Hira Lal, Sub-Assistant of the Geological Survey of India, and proceeded on furlough for eighteen months. The latter was only very few days responsible for the direction of the boring, arrangements having been made to hand the same over to the North-Western Railway authorities, which was finally effected on the 25th March. Mr. LaTouche has given a short report on the boring in the May number of the Records.

The personnel of the works consisted of Mr. LaTouche with Lala Hira Lal of the Department, the latter only having joined 25th October 1894; and two American drillers, Messers. Cremer and Eady. The last named was engaged at the special representation of Mr. LaTouche, who urged the advisability of working more continuously.

When Mr. LaTouche handed over the boring to the North-Western Railway authorities it had reached a depth of about 1,100 feet, and since then it was brought down to 1,500 feet, without, however, obtaining any trace of oil. The chisel has passed through some limestone bands latterly, which may be the beds of the lower nummulitic, but to be certain, I have recommended that the boring be brought about 200 feet lower.

*Salt.*—While superintending the boring at Sukkur, Mr. LaTouche 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.

*Baluchistán and North-Western Frontier.*
Mr. F. H. Smith.
Lala Hira Lal.
Lala Kishen Singh.

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 unable 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.

Later on, after returning from the Tochi pass, to which he was deputed on special duty, he traversed the country lying between Déra Gházi Khán and Ziárat. His observations were only made *en route* and consequently must be fragmentary. He reports that between Karwada to Mekhtar he traversed about 30 miles of middle and lower nummulitic rocks, sandstones and limestones with numerous shale partings. East of Mekhtar these beds rest apparently conformably on "belemnite beds" (upper cretaceous). From thence to some distance west of Loralai he observed all the rock facies which we already know to exist in those parts, *i.e.*, sections from the jurassic limestone to nummulitic, but he had no time then to further examine the country, the season being too far advanced. The high range north of the Sháhrig valley, generally known as the Kaliphát range and which rise to upwards of 10,000 feet, seems to show in places a complete section beginning with the jurassic massive limestone, overlaid by cretaceous rocks and capped by the lower nummulitic limestone. The existence there of jurassic beds is an interesting fact.

During June Mr. Smith examined some of the high ground west of Ziárat, especially the Pil range, through which a fine section is laid bare by the tangi (defile) north of Mangi; the range is made up of a great thickness of massive limestone (about 3,000 feet), which he identifies with the jurassic beds seen further east, and which is overlaid by well-developed "belemnite beds" (*i e.*, lower and upper cretaceous), the whole being covered by the hard grey lower nummulitic limestone.

*Hills east of Sibi.*—Lala Hira Lal, after handing over the Sukkur boring to the North-Western Railway authorities, was ordered to Baluchistán, and to survey the low ranges east of Sibi. He was engaged during May and June in geologically surveying the low hill ranges east and north-east of Sibi, which task was successfully accomplished. The rocks met with belong to the tertiary system and recent deposits. Upper nummulitic limestones were met with occasionally, but the rest seem to consist of very large thicknesses of Siwalik sandstones, shales and conglomerates only. Some fossils were collected by this officer, but apparently good specimens are very rare and as usual in those parts, the Siwaliks contain little more than fragmentary remains of vertebrates, amongst which are very few which will permit a specific determination.

*Hills near Quetta.*—Lala Kishen Singh was engaged during the last quarter of the year in examining the south-western extension of the Murdar hill near Quetta, which he found to consist of massive limestone, probably of jurassic and lower cretaceous age, the only clue to its structure apparently being a band of upper cretaceous belemnite beds. He also examined the northern end of the Chehiltan range; the section of it had already been worked out during previous field seasons. It includes strata from the upper jurassic to lower nummulitic age.

*Tochi Pass.*—Mr. Smith was deputed to join the Tochi delimitation camp during February and March, and he has furnished a short preliminary report,[1] the main features of which shew that the section seen along the Tochi route resembles closely that of the Sulaimán section, and that some of the rocks are very similar to those found in Baluchistán.

The section commences on its eastern limit with a series of Siwaliks, which dip eastwards under the recent deposits of the Bannu plain. The Siwaliks, both upper and lower, are of immense thickness, the lower beds alone showing a normal section of vertically dipping strata of 2 miles in length. Below them is a thin band, 170 feet, of white nummulitic limestone, beneath which follows a great thickness of shales and limestones, in which Mr. Smith did not discover any determinable fossils, but which he suspects to represent the entire middle and lower eocene divisions. The lowest beds of this sequence form an anticlinal ridge of dark grey unfossiliferous shaly limestone of unknown age. These lower tertiary rocks form a wide belt, some 30 miles from east to west, and include the Laram range. Near Mahomed Khél, the lower beds of the series become suddenly mixed with intrusive and also interbedded igneous rocks, chiefly diorites, gabbros, and serpentines. North of Sheranni this igneous series is overlaid by white nummulitic limestone

[1] Records, Vol. XXVIII, page 106.

and shales, and at Dotoi, 10 miles west of Sheranni, the same igneous series is overlaid by blue slaty shales with thin nummulitic bands.

In some respects this description recalls the flysch-like series of rocks of the Kōjak and Peshin ranges.

*Burma.*
Dr. F. Noetling.
Dr. H. Warth.
Mr. H. H Hayden.

*Oil.*—The inquiry into the occurrence and nature of the earth-oil of the Yenangyoung neighbourhood has at last been brought to a successful close by Dr. F. Noetling, who was engaged on the work for several years but with interruptions. That officer returned from Burma in March of this year and has handed in a very voluminous and exhaustive report, fully illustrated with sections, views and maps now in the press.

*Gems.*—Dr. Warth was deputed to Burma to report on a tract of country north-west of Mogoung, where rubies had been discovered, and which area had been declared a "stone tract" by the Government of Burma. A long delay at Rangoon, owing to a medical examination which that officer had to undergo, prolonged the inquiry far into the hot weather and had therefore to be confined to the "stone tract" alone.

His report may be summed up as follows: The area consists of crystalline rocks, chiefly granitic and igneous, inclosing patches of metamorphic rocks amongst which a crystalline limestone is especially noticeable, which contains the same minerals as found in the Mogok and Sagyin areas, and which is probably also here the original matrix of the rubies, which are now dug up by natives from the surrounding alluvium. The latter forms the "stone tract" proper, may be about ten square miles in extent, and does not seem to be very rich in gems.

Mr. H. H. Hayden was posted to Burma during this field-season, and he started work in the ruby-tract of the Sagyin hills during November. His researches carried out under somewhat trying conditions, which the dense vegetation aggravates, are of considerable interest. The main results obtained so far are as follows:—

The rocks of the area are chiefly of two kinds, namely crystalline, consisting of gneiss and schists, and overlving the same, limestone which is considerably altered and contains many and interesting minerals, including spinel and ruby. The latter occur chiefly in a veinstuff which fills joints and fissures, and out of which the natives obtain the gems. One of the most interesting facts established by Mr. Hayden is that the limestone rests on the schists and gneiss, the junction being marked by the presence of a conglomerate associated with a limestone breccia, thus proving without doubt that this coarsely crystalline limestone is of sedimentary origin.

Publications.

Vol. II of Series XIII of the Palæontologia Indica has at last been published, and Dr. Waagen's description of the fossils from the Ceratite beds will henceforth form a standard work on the lower trias of the Salt Range.

The publication of this classic volume was so long delayed and so much new light has been shed upon the lower trias fauna of India within recent years, that a review of the results of Dr. Waagen's researches becomes imperatively necessary. I am informed that the learned Professor is preparing such a summary, which will probably be first published in Europe.

Of the Series XV on Himálayan Fossils, part 2 of Vol. II has already appeared, descriptive of the Cephalopoda of the Muschelkalk. The material which Dr. Diener had at his disposal, which includes all the specimens collected from those beds in the Himálayas up to date, is so complete that we are in a position to correlate these beds with perfect accuracy. It is a matter of especial satisfaction to me that the examination of these interesting fossils has confirmed my division of the trias of the Central Himálayas, founded as it was, chiefly upon stratigraphical grounds.

Part 1 of the same volume, on the Cephalopoda of the lower trias by the same author, is in a forward condition and ought to be published at an early date. All the plates illustrating the same are completed and the manuscript is ready for the press.

Dr. Noetling has prepared several parts of a new Series XVI of the Palæontologia Indica to illustrate the fauna of Baluchistán and North-Western frontier, which await only the completion of the plates, to be issued.

Several memoirs are in course of publication; part 1 of Vol. XXVII on "Marine fossils from the Miocene of Upper Burma" by Dr. Noetling has been published, and part 2 is in the press.

Gondwanas in South America.

A discovery of vast interest to Indian Geologists has been made during the year to which I must allude here; it is the discovery of a Gondwana flora[1] in coal-bearing deposits in Argentina, made by Dr. Kurtz, Professor at the University of Cordoba. The flora, with several species identical with such out of the Indian Gondwanas, occurs in beds, which overlie,—though in what manner is not known yet,—a series of beds containing a true carboniferous (Culm) flora. But the most interesting fact is that in Argentina *Neuropteridium validum* is found in the same beds with *Lepitodendron*, as I am informed by Dr. Kurtz, who has promised to give me further and more concise particulars.

Museum and Laboratory.

Mr. Holland, the curator, was absent on privilege leave from March 12th to June 27th and later on duty at Naini Tal, from which he returned on 13th November, but he has since been engaged in arranging the rock and mineral collections belonging to the Department.

The collection of rocks now amounts to over 16,000 specimens and they have been registered and partially arranged. Satisfactory progress has been made also in the classification and description of the collection. The miscroscopic characters of about 500 specimens of the crystalline rocks have been worked out, which will enable Mr. Holland to form a preliminary sketch of the classification of this group, which, though so largely represented in India, has hitherto received little more than superficial attention in the field, when as in previous years, the specimens in the collection were found to be types new to petrology, or were found to offer important evidence concerning unsettled petrographical problems. Mr. Holland has taken the opportunity, where possible, of utilizing the college vacations for the purpose of tracing out their field relations, and of collecting fresh material for confirming or correcting the microscopic work in the laboratory. As a result of work of this nature, the examination of the field relations of the new types of

[1] Records, Vol. XXVIII, p. 111.

peridotites discovered by Mr. Holland and referred to in my last annual report has enabled him, in conjunction with Dr. Saise, to completely describe them and to revise a map showing the nature and distribution of the intrusive rocks in, and the crystalline series around, the coal-field of Giridih.[1]

The interesting forms of metamorphism displayed by the crystalline rocks around this coal-field having been found to result in the production of garnets in pyroxenic type, the remaining pyroxenic rocks of India, and specially those of the Madras Presidency, whose presence and wide distribution in Southern India were first noticed by Mr. Holland in 1892, have been examined with special reference to the origin of this mineral which is so remarkably abundant in this country. In a paper contributed to the current number of the Records Mr. Holland has traced out the development of the garnets in these pyroxenic rocks, and, from the evidence obtained from widely separated areas in India, he concludes that the reaction-borders often confused with Kelyphite, and occurring so frequently associated with the garnets of pyroxenic rocks, represent a stage in the development, and not, as has generally been supposed, in the destruction of garnets. Mr. Holland has contributed another paper to the same number of the Records in which he has from the evidence of the specimens collected by himself in Madras combated the views expressed by Mr. Lacroix concerning the nature of the acicular inclusions giving rise to the phenomena of asterism, so frequently characteristic of Indian gem-garnets.

Amongst the specimens of interest added during the year are eight new meteorites.

Mr. Holland reports most satisfactorily on the work done during the year in the laboratory and museum by his assistant, Mr. T. R. Blyth.

The additions to the library during the past year amount to 1,949 volumes, of which 1,149 were acquired by presentation and 800 by purchase.

Library.

C. L. GRIESBACH,

*Director, Geological Survey of India.*

CALCUTTA,

*The 31st January 1895.*

[1] Records, XXVIII. p. 121.

*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 1895.*

ADELAIDE.—Royal Society of South Australia.
ALBANY.—Adirondack Survey.
„ New York State Museum.
BALLARAT.—School of Mines.
BALTIMORE.—Johns Hopkins University.
BASEL.—Naturforschende Gesellschaft.
BATAVIA.—Kon. Natuur Kundige Vereeniging in Nederl.—Indie.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—Deutsche Geologische Gesellschaft.
„ K. Preuss. Acad. der Wissenschaften.
„ K. Preuss Geologische Landesanstalt.
POLOGNA.—Reale Accademia delle Scienze dell' Istituto.
BOMBAY.—Meteorological Department, Government of Bombay.
„ Natural History Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—Society of Natural History.
BRESLAU.—Schlesische Gesellschaft für Vaterländische Cultur.
BRISBANE.—Royal Geographical Society of Australia.
„ Royal Society of Queensland.
BRUSSELS.—Academie Royale des Sciences.
„ Société Belge de Geographie.
„ Société Belge de Geologie de Paleontologie et d' Hydrolog.
BUDAPEST.—Kön. Ungarische Geologische Anstalt.
„ Ungarische National-Museum.
BUENOS AIRES.—Acad. National de Ciencias en Cordoba (Republica Argentina).
BUFFALO.—Society of Natural Sciences.
CAEN.—Société Linnéenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of India.
„ Asiatic Society of Bengal.
„ Calcutta University.
„ Editor, The Indian and Eastern Engineer.
„ Meteorological Department, Government of India.
„ Survey of India.
CAMBRIDGE.—Philosophical Society.
„ University of Cambridge.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CANADA.—Hamilton Association.
CHRISTIANA.—Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Academie Royale des Sciences.
„ Kong. Danske Videnskabernes Selskab.
DEHRA DUN.—Great Trigonometrical Survey.

DES MOINES.—Iowa Geological Survey.
DIJON.—Academie des Sciences, Arts et Belles-Lettres.
DRESDEN.—Naturwissenschaftliche Gesells. Isis.
DUBLIN.—Royal Irish Academy.
EDINBURGH.—Geological Society.
„ Royal Scottish Geographical Society.
„ Royal Scottish Society of Arts.
FREIBURG.—Naturforschende Gesellschaft.
GENEVA.—Société de Physique.
GLASGOW.—Glasgow University.
GOTHA.—Editor, Petermann's Geographische Mittheilungen.
GÖTTINGEN.—K. Gesells. der Wissenschaften.
HALLE.—Naturforschende Gesellschaft.
„ Academia Cæsarea Leop.-Carol. Naturæ Curiosorum.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Société Vaudoise des Sciences Naturelles.
LIÈGE.—Société Géol. de Belgique.
LILLE.—Société Géologique du Nord.
LISBON.—Section des Travaux Géol. du Portugal.
LIVERPOOL.—Geological Society.
LONDON.—Iron and Steel Institute.
„ Linnean Society of London.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoölogical Society.
MADRID.—Reale Academia de Ciencias.
„ 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 Wissens.
NAPLES.—Reale Academia delle Science Fisiche e Matematiche.
NEWCASTLE-UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
„ Editor, American Journal of Science.
NEW YORK.—Academy of Sciences.
OTTAWA.—Geological and Natural History Survey of Canada.
„ Royal Society.
OXFORD.—University Museum.
PARIS.—Department of Mines.
„ Editor, Annuaire Géologique Universel.

PARIS.—Ministere des Travaux Publics.
" Museum d' Histoire Naturelle.
" Société de Géographie.
" Société Géologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
" American Philosophical Society.
" Franklin Institute.
" Wagner Free Institute of Science.
PISA.—Societa Toscana di Scienze Naturali.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Scienze.
" " Comitato Geologico d' Italia.
SACRAMENTO.—California State Mining Bureau.
SAINT PETERSBURG.—Académie Imperiale des Sciences.
" Comité Géologique.
" Russische Kaiserliche Mineralogische Gesellschal
SALEM.—American Association for the Advancement of Sci
SAN FRANCISCO.—California Academy of Sciences.
S. PAULO.—Commissao Geographica e Geologica.
SPRINGFIELD.—Illinois State Museum of Natural History.
STOCKHOLM.—Kongliga Svenska Vetenskaps Akadémie.
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.
TURIN.—Osservatorio della R. Universita di Torino.
" Reale Accad. delle Scienze di Torino.
UPSALA.—Upsala University.
VENICE.—Reale Istituto Veneto di Scienze.
VIENNA.—K. Akad. der Wissens.
" K. K. Geographische Gesellschaft.
" K. K. Geologische Reichsanstalt.
" K. K. Naturhistorisches Hof-Museum.
WASHINGTON.—Smithsonian Institution.
" United States Department of Agriculture.
" " " Geological Survey.
" " " Mint.
WELLINGTON.—Mining Department, New Zealand.
" 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, N.-W. Provinces and Oudh, and the Punjab.

The Chief Commissioners of Assam, Burma, and the Central Provinces.

The Resident, Mysore.

## *On the Acicular inclusions in Indian Garnets. By* THOMAS H. HOLLAND, A. R. C. S., F. G. S., *Deputy Superintendent, Geological Survey of India.*

### I. INTRODUCTION.

1. In his detailed description of the rocks collected in 1819 by Leschenault de la Tour in the South of India, M. A. Lacroix has figured and described, in a basic pyroxenic gneiss, garnets containing acicular inclusions which he considers, from their high, positive, double refraction and straight extinction, to be rutile.[1] To the arrangement of these inclusions in systems mutually intersecting at angles of 60° M. Lacroix ascribes the asterism so frequently exhibited by Indian garnets.

2. During my work in South India I have found at various places in the Madras Presidency garnets in pyroxenic rocks of all degrees of acidity from granites to pyroxenites. In the smaller masses which rise above the plains at Pallavaram near Madras, at Mailam in South Arcot district, at Wallavanad in Travancore and in the Madura district the garnets, as well as the associated constituents of the rocks, are often free of these inclusions, but the rocks in the Nilgiri hills, which attain heights of 8,000 feet, and in the Shevaroys of Salem district are crowded with minute hair-like inclusions which appear in the quartz, felspar and garnet alike, whilst the pyroxenes, which are constant constituents throughout the whole series of these rocks, are schillerized with plates and rods like those in the well-known hypersthene of Paul's Island.

3. The occurrence of these hair-like inclusions in an isotropic mineral like garnet affords special facilities for the investigation of their optical properties. Whilst their characters agree in so many respects with those described by Lacroix, I find that instead of being referable to a uniaxial mineral like rutile they exhibit unmistakeable characters of a mineral crystallizing in the monoclinic system, and thus, whilst exhibiting in some sections extinction parallel to the long axis of the needles (orthopinacoidal sections), in other cases (clinopinacoidal sections) extinction angles as wide as 39° have frequently been measured.

### II. CRYSTALLOGRAPHIC DISPOSITION OF THE NEEDLES.

4. The disposition of these needles with reference to the crystallographic orientation of their host, the garnet, is of an extremely interesting nature. Not only are the needles arranged with a constant relation between the direction of their long axes and the forms of the cubic system in which the garnet crystallizes, but the plane of symmetry, and consequently the orthopinacoidal plane, of each minute needle are arranged in definite crystallographic positions within the garnet—a circumstance quite in agreement with the definite crystallographic disposition of the products of schillerization in felspars, pyroxenes, olivines and other minerals which have been described on several occasions by Professor Judd. I regard these needles in the garnet, and what are probably the same things in the associated felspars, pyroxenes and quartz, as secondary in origin and belonging to the same

[1] *Bull. de la Soc. Min. de Fr.*, Vol. XII (1889), p. 311, and *Rec. Geol. Surv. Ind.*, Vol. XXIV (1891), p. 176.

class as the inclusions which according to Professor Judd are the cause of the phenomena of schillerization.

5. Besides the sections in which the acicular inclusions appear to intersect one another at various angles I have found some which can be arranged in three distinct classes, and in which the disposition of the needles is capable of a very simple crystallographic explanation.

If we assume the long axes of the inclusions to be parallel to the long diagonal of the rhombus forming the face of the rhombic dodecahedron—the form in which the garnet crystallizes—or, which is the same thing, parallel to the solid edges of the octahedron, we obtain definite intersections exhibited in sections cut parallel to the octahedron, the cube and the rhombic dodecahedron respectively as follows:—

(1) In sections parallel to the *octahedron* there are three sets of needles lying in the plane of section and intersecting one another at angles of 60° (system *a*).

(2) Sections parallel to the *cube* exhibit two sets of needles lying in the plane of section and crossing one another at right angles (system *b*). Two other sets (system *c*) lying apparently at 45° to those belonging to system *b* will be seen, when examined with high powers, to be lying oblique to the plane of section, and consequently will as a rule appear to be shorter than those of system *b*, their maximum length in fact can never exceed

$$\sqrt{2} \times \textit{thickness of section.}$$

(3) Sections parallel to the *rhombic dodecahedron* display two systems of inclusions. One system (system *d*) lies in the plane of section and is crossed by a second system (system *e*) at an apparent angle whose tangent is $\sqrt{2}$, that is 54°16′. The two sets of system *e* consequently intersect one another at angles of $2 \times (90° - 54°16') = 71°28'$, and its supplement.

## III. OPTICAL ORIENTATION OF THE NEEDLES.

6. As the needles are monoclinic in crystallization and their lateral as well as vertical axes have a constant crystallographic disposition within their host the garnet, the optical characters exhibited by these three classes of sections are also different, and, assuming the long axis of each needle to be its vertical crystallographic axis, the positions of the orthodiagonal *axis* and the clinopinacoidal *plane* are easily determined.

(1) Sections of garnet cut parallel to the face of the cube and examined between crossed Nicols show system *b* lying in the plane of section and exhibiting an extinction angle as great as 39°. System *c*, however, apparently intersecting these at an angle of 45°, and seen by high powers to be lying oblique to the plane of section, exhibit straight extinction. Taking the plane of symmetry to be the optic axial plane, as is usual in monoclinic minerals, this plane must be parallel to the cube faces and exhibit the maximum extinction angle.

(2) In sections parallel to the octahedron all the needles (which have been referred to as system *a*) are cut obliquely to the plane of symmetry, and the extinction angle is consequently somewhere between zero and the maximum. Numerous measurements made on these sections gave results varying between 18° and 25°.

(3) Sections parallel to the rhombic dodecahedron give straight extinctions for system *d*, and oblique extinctions less than the maximum for system *e*.

7. The monoclinic acicular inclusions in the garnets are thus arranged as follows :—

*Vertical axis* of the needle parallel to the *edge of the octahedron* of the garnet.
*Orthopinacoid* parallel to the *rhombic dodecahedron*.
*Clinopinacoid* parallel to the *cube*.

That is to say, they are arranged with their orthopinacoidal faces lying on the cleavage planes of the garnet and with their long (vertical) axes parallel to the long diagonal of the rhombus. I am indebted to my colleague Mr. H. H. Hayden for having verified each of these conclusions in thin sections of garnetiferous pyroxenic rocks collected by myself at Nagaramalai, near Salem, and at Coonoor in the Nilgiri Hills.

8. Diller has described what appear to be similar inclusions in the garnets of a loose fragment of granulite found near the peridotite of Elliott County, Kentucky. According to Diller these inclusions are arranged at angles of 45° to one another, and are distinctly monoclinic with a maximum extinction angle of 30°.[1] If my conclusions are correct these inclusions should correspond to the two systems of needles *b* and *c* which I have recognised in sections cut parallel to the face of the cube (para. 5).

9. Lacroix states that the needles which he found in the garnets of the Salem pyroxenic gneiss show the positive double refraction of rutile. I find on examination of the monoclinic needles in my own specimens with a quartz-wedge that the axis of minimum optical elasticity $\mathfrak{c}$ lies at 39° to the vertical crystallographic axis *c* ; there would therefore be an appearance of thickening on placing a quartz wedge with its axis parallel to an orthopinacoidal section. The straight extinction of such a section and its behaviour under the quartz-wedge would thus agree precisely with the characters of a uniaxial positive mineral like rutile ; but that the mineral which forms these needles is biaxial is demonstrated beyond all possible question by the very wide extinction-angle and by the cross-sections which, although mere points, show strong double refraction.

10. I have, however, found needles of a mineral which show the straight extinction and strong, positive, double refraction of rutile in the augite-diorite forming the main mass of Parasnath in Bengal. But these are invariably shorter and form clusters in the centre of the garnet without displaying any recognisable regularity of crystallographic disposition within their host. Even in the same section they are not likely to be mistaken for the monoclinic needles that characterise the garnets in the Madras pyroxenic rocks.

11. According to Lacroix in hexagonal sections of these garnets the inclusions are arranged with parallelism to the sides of the hexagon ; but unfortunately the

[1] *Bull. U S. Geol. Surv.*, No. 38 (1887), p. 27.

figure given by him does not show the crystal outlines with sufficient clearness to illustrate this statement. Although as the result of my investigations, I should not expect this to be the case, I have never found a garnet in the Madras rocks exhibiting its proper crystalline outlines, and have consequently been unable to make a direct test of this statement.

12. Whilst it is not possible to determine with certainty the species of mineral which forms the inclusions under consideration, their optical characters, so far as they can be investigated, are suggestive of those of sphene, in which also the axis $\mathfrak{c}$ meets the vertical crystallographic axis $c$ at about an angle of 39°, although of course it does not necessarily follow that the vertical axis in this mineral would follow the direction of greatest elongation. A chemical test, however, made by Mr. Hayden and myself showed that the garnets contain small though unmistakeable traces of titanium.

13. The quartz and felspar which accompany the garnet, or occur in the associated pyroxenic rocks in the Nilgiri and Shevaroy hill-masses, are often crowded with fine hairs of a nature presumably similar to those occurring in the garnets. There seems little doubt that the blue colour of the quartz and the moonstone opalescene, which so frequently characterises the felspar of the more coarsely-grained charnockites, are due to the presence of these inclusions, whose definite crystallographic disposal suggests their secondary origin in common with the ordinary products of schillerization.

14. It is not without interest that in garnets with striated faces the striations are parallel to the longer diagonal of the rhomb faces, which I have shown to be the position of the hair-like inclusions, and according to Descloizeaux asterism has generally been observed in garnets having such striated faces. There seems little doubt, as Lacroix suggests, that the asterism exhibited by some Indian garnets is due to the fine hair-like inclusions which exhibit such a perfectly symmetrical disposition not only of the long axes but also of the lateral axes of crystals so minute that their cross-sections, even with high powers, appear as mere points of light in the isotropic ground-mass of their host the garnet. I can recollect no prettier illustration of Professor Judd's generalization concerning the secondary changes brought about by agents of statical metamorphism acting on the minerals of deep-seated rocks and giving rise to the phenomena which he has described under the name of schillerization.

## CONCLUSION.

15. The hair-like inclusions which give rise to the phenomena of asterism in Indian garnets are not rutile as stated by Lacroix, but are monoclinic in crystallization, exhibit a high double refraction and show an extinction angle as wide as 39° ($\mathfrak{c} \wedge c$) to the long axes of the needles. They are arranged with remarkable regularity of crystallographic disposition within their host the garnet, having their long axes parallel to the edge of the octahedron, their orthopinacoidal faces parallel to the face of the rhombic dodecahedron and their clinopinacoids parallel to the cube. They are considered to be secondary in origin along with the similar hair-like inclusions which give rise to the phenomena of schillerization in the associated blue quartz, moonstone and hypersthene of the pyroxenic rocks in which the garnets occur.

## *On the Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks,* by THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With plate 1.)

## CONTENTS.



## A. THE ORIGIN AND GROWTH OF GARNETS.

### I.—INTRODUCTION.

1. Garnets occur in rocks of every degree of acidity from granites to peridotites, and the ordinary iron-alumina garnet is well-known as one of the commonest amongst the products of the contact-metamorphism of aluminous rocks. Whilst its secondary origin can be so easily proved in the slates and schists which have been changed by proximity to igneous intrusions, the origin of garnet when a constituent of igneous rocks and of the crystalline types generally cannot always be so satisfactorily determined. As a rule, it is impossible to settle from the rock specimen *per se* whether the garnet is a primary or a secondary constituent; but from its more frequent occurrence in the gneissose crystallines than in rocks of massive habit, it is more generally grouped—though seldom with better reason than analogy—amongst the constituents of secondary origin.

2. The very prevalent occurrence of garnets amongst the pyroxenic granulites of South India, to which I have paid considerable attention during the last four years, has led me to make a more widely extended investigation amongst the garnetiferous rocks of this country with a view to obtaining more exact evidence concerning the origin of this mineral. I have considered this investigation the more necessary on account of the fact that Dr. J. Lehmann, in his classical work *Die Entstehung der altkrystallinischen Schiefergesteine*, has recorded the frequent

occurrence of garnet in the pyroxene-granulites of Saxony, which appear in many respects to closely resemble the Madras series. But whereas Dr. Lehmann considers the garnet, where it is surrounded with reaction-borders resembling Schrauf's kelyphite, to be passing into pyroxene, I have been led to a totally different conclusion with regard to the pyroxenic rocks which I have studied in India, and in which reaction-borders, apparently quite similar in character, are frequently found between the pyroxene and garnet. These, it seems to me, afford, so far as the Indian rocks are concerned, most decisive evidence in favour of regarding the garnets as secondary in origin and derived from the pyroxene which was amongst the original constituents of the rock.

3. That this conclusion is capable of wider application cannot of course be claimed, but it seems to me that in many cases where reaction-borders around garnets have been described, the precise evidence concerning the *direction* of the change might have been studied with advantage. The mere fact that the proportionate area of garnet core and reaction-border varies from cases in which the border is proportionately narrow to those in which the garnet forms merely a small nucleus, or even totally disappears, is no proof whatever that the reaction-border is formed at the expense of the garnet. As the garnets are most irregular in shape every one of these stages might be obtained by sections through the centre, near the surface, or along a flat face of the crystal which is so surrounded by a reaction-zone.

4. It should also be understood that these conclusions have no bearing whatever on previously-stated views concerning the nature of the *kelyphite* rims which surround the pyropes described in many peridotites, nor has it necessarily any connection with the evidence obtained from the Saxon pyroxenic rocks; but as I find it necessary to consider the garnets of secondary origin in all the pyroxenic rocks which I have so far studied in India, it may be advisable to state in detail the steps by which I have been led to this conclusion, the more so because the processes by which pyroxenes are converted into garnets seem to have been described, so far as I can find, in one case only. Brauns in 1888 described the formation of a lime-iron garnet in the palæopicrite of Bottenhorn as an alteration form of augite in which chemical analysis indicated a removal of alumina.[1] Beside this the literature at my disposal in Calcutta has not revealed a single case of a garnet formed from pyroxene, although the contrary has been asserted in more than one instance.

5. The evidence obtained from the same material also offers a very simple explanation of the origin of the *micropegmatitic intergrowths* of garnet with such white minerals as quartz and felspar. The micropegmatitic structure is consequently in these instances considered to be of secondary origin.

## II.—THE REACTION-BORDERS OF GARNETS.

6. The fibrous zones which surround the pyrope in olivine-rocks were first described by Schrauf as a primary constituent of pyrogenic origin to which he gave the name *kelyphite*,[2] but von Lasaulx showed that these borders are in some cases,

[1] *Zeitschr. d. d. geol. Ges.*, Vol. XL (1888), p. 475.

[2] *Zeitschr. f. Kryst.*, Vol. VI (1882), pp. 333 and 358; also *Neues Jahrb. f. Min.*, 1884 (II), p. 21.

mixtures of different minerals, generally members of the pyroxene-amphibole group and of secondary origin.[1] Becke found similar borders around the garnet of Steineck composed of picotite and several members of the pyroxene-amphibole group.[2] Diller found the pyropes in the Elliott County peridotite composed largely of biotite,[3] whilst von Camerlander described in the granulites of Prachatitz a micropegmatitic intergrowth of augite and plagioclase forming a border around garnet.[4]

7. Seeing kelyphite has been found to be a mixture of minerals so variable in composition, and especially as in all cases described it has been regarded as a product of the *destruction* of garnet by reaction with olivine or pyroxene, either during or subsequent to consolidation, I shall avoid altogether the use of the term in connection with the fibrous zones which surround the garnets in the cases about to be described, for these I consider to represent the products not of destruction but a stage in the *development* of the garnets with which they are associated. They will be referred to therefore merely as *reaction-borders.*

8. Lacroix has described radiate zones composed of micropegmatitic intergrowths of hornblende and felspar around garnets in an eclogite from Gerscao-en-Plounevez, Finisterre.[5] He has also figured and described a radiate fringe around garnets in a pyroxenic rock from the Salem district,[6] but has offered no explanation of the origin of the phenomena in these cases.

9. The reaction-borders measure about ·04 mm. across and are composed of two distinct layers, an inner (garnet side) layer of colourless mineral in which clavulate and vermiform pieces of a pale green actinolite are arranged approximately perpendicular to the garnet surface, giving with the low powers an appearance of radiate fibrous structure. The colourless mineral with crossed nicols shows colours about equal to those of the felspars in the same sections, and display lamellar twinning bands. The outer zone consists of a narrow band of magnetite-granules forming a margin to the pyroxene.

## III.—THE ROCKS IN WHICH THE GARNETS OCCUR.

10. The specimens which it is proposed to select as examples for the study of the origin and growth of garnets have been obtained in two principal areas separated from one another by distances of at least 700 miles.

The first group of rocks occurs as large dykes and bosses of diorites amongst the gneisses and schists of Chota Nagpore and the Sonthal Pergunnahs in Bengal. These rocks by their resistance to agents of denudation are conspicuous as hummocks and even high hills in the neighbourhood of our coal-fields. As they can often be traced up to the boundary faults, but are never intruded into the stratified rocks of Lower Gondwana age within the field, it is presumed that they are older than the deposits of that system. In nearly all cases which I have examined, these can be shown to have been derived from original pyroxene-plagioclase rocks, which show

[1] *Sitzungsber. der Niederrhein. Ges. f. Natur und Heilkunde*, 3rd July, 1882.
[2] *Tschermak's min. u. petr. Mitt.*, Vol. IV (1882), p. 324.
[3] *Bull. U. S. Geol. Survey*, No. 38 (1887), p. 15.
[4] *Jahrb. d. k. k. geol. Reichanstalt*, Vol. XXXVII (1887), p. 133.
[5] *Bull. de la Soc. Min. de Fr.*, Vol. XII (1889), p. 142.
[6] *Ibid.*, p. 322; also *Rec. Geol. Surv. Ind.*, Vol. XXIV (1891), p. 183.

a strong family likeness in the field and apparently belong to a petrographical province of pre-Gondwana age. A closer examination reveals some very interesting differences in the changes which they have suffered by the various agents of metamorphism.

The dynamical metamorphism to which some of these rocks have been subjected has resulted in the production of well-foliated epidiorites and hornblende-schists. In others, where earth-movements have been preceded by the production of sodic chloride inclusions along the twin-planes of the felspar, scapolite is conspicuous amongst the new minerals;[1] but those in which garnets have developed show slighter, though decided, signs only of deformation by dynamical agencies. To this last mentioned group belong some dykes at Mongrodih near Giridih, some rocks collected by the late Mr. Fedden in the Ijri valley of Manbhúm, and the main mass of Parasnath, a sacred hill rising to a height of 4,479 feet on the borders of the Hazaribagh and Manbhúm districts.

11. The second group of rocks forms the great hill-masses of the Madras Presidency——the Nilgiris, Shevaroys, Palnis, Anaimalais, Western Ghats and Cape Comorin. These rocks, although varying so widely in silica percentage from acid granites to pyroxenites and even peridotites, present a most remarkable and unmistakeable family likeness in the field.

Microscopic examination shows that without a single exception the unaltered forms are characterized by the presence of a rhombic pyroxene approaching hypersthene in composition, which may occur in very small proportions, as in charnockite, or may make up almost the entire rock, as in some pyroxenites. The hypersthene may be the sole representative of the group of ferro-magnesian silicates, or it may be accompanied by augite, hornblende, biotite, graphite and garnet. Sometimes it is replaced entirely by garnet in rocks which I hope to show are beyond question altered forms of the pyroxenic series.

## IV.—EVIDENCES OF THE GROWTH OF GARNET.

12. The special features in the structure of these rocks which appear to corroborate one another in the evidence they offer in favour of the growth of garnet at the expense of the pyroxenic constituent, may be considered under the following heads:—

(1) Limitation of the reaction-borders.
(2) Uralitization (amphibolization) of the pyroxenes near the garnets.
(3) Schillerization of the pyroxenes.
(4) Parallel growth of adjacent garnet crystals.
(5) Field relations of the pyroxenic and garnetiferous rocks.
(6) Chemical changes involved in the formation of garnet.

### *1. Limitation of the Reaction-borders.*

13. The reaction-border appears wherever the garnet meets the pyroxene or, more strictly speaking, its paramorph hornblende, but there is not a trace of it where the garnet comes in contact with felspar or quartz. This of course only shows that there is some kind of reaction between the garnet and the pyroxene;

[1] See Holland and Saise. "On the Igneous Rocks of the Giridih (Kurhurbaree) Coalfield and their Contact Effects." *Rec. Geol. Surv. Ind.*, Vol. XXVIII (1895), p. 121.

but the fact that opposite the pyroxene the garnet bulges out to meet the latter is a circumstance which would naturally be expected if we regard the pyroxene as the source of the garnet material.

Fig. 1 illustrates a case in which the garnet, fringed by a reaction-border, bellies out in this manner opposite the pyroxene, whilst colourless felspar fills a bay in the garnet, which at this point is without a reaction-border. This case will be referred to again in describing the origin of the micropegmatitic intergrowth of garnet and felspar.

### 2. *Uralitization (Amphibolization) of the Pyroxenes near the Garnets.*

14. The formation of these reaction-borders between the garnet and pyroxenes seems to be always accompanied by the formation of hornblende, which lies between the unaltered augite and the reaction-zone, and which seems to be a preliminary change in the augite necessary to the development of the garnet. In parts of the rock free of garnets the augites show the characteristic signs of incipient uralitization in the form of green pleochroic patches. This conclusion is further supported by the fact that occasionally pale green augites, which do not show the slightest sign of amphibolization, abut against the garnet without a trace of a reaction-border.

If the opposite change—that is the formation of pyroxene from garnet—were in progress, we should have in this instance a case of the formation of hornblende from garnet followed by the transformation of the former mineral into augite—a change under the circumstances quite contrary to experience. The alteration of the pyroxene near the garnets is only an advanced stage of that which is seen to be commencing in nearly all the augites and is a case of ordinary amphibolization. That such is the real direction of change is even more clearly demonstrated by the next point of evidence.

### (3) *Schillerization of the Pyroxenes.*

15. The original augite, in the rocks for instance from Parasnath and the Ijri valley, are darkened, often almost blackened, with minute rods and plates regularly arranged as in diallage and forming an ordinary example of schillerization, whilst the hornblende, which has been derived from this augite, is free of such inclusions. The schillerization of the ferromagnesian constituent must, therefore, have occurred before its amphibolization, and as the amphibolization appears to be a constant accompaniment of, and probably an essential preliminary to, the development of the garnet, the schillerization must have occurred also before the formation of the latter mineral. If the opposite change had occurred we should have a case of the transformation of garnet into a clear green hornblende, followed by the change of green hornblende into schillerized augite. In view of Professor Judd's explanation of the phenomena of schillerization such an alternative explanation of the facts may be safely rejected without further discussion. There is no doubt that the amphibolization of the schillerized augite is accompanied by the absorption of the secondary ferruginous products, the iron of which enters into the composition of the hornblende, and then of the final product, garnet.

The relative positions of the minerals in the rock are thus—

| | | | |
|---|---|---|---|
| *Schillerised Augite.* | *Clear green Hornblende.* | *Reaction border.* | *Garnet.* |

→

### (4) *Parallel growth of adjacent Garnet-crystals.*

16. In the Manbhúm rocks the large garnets are clear and pink in their centres, but towards the margin, where they approach the ferromagnesian mineral, numerous vermiform, radially-arranged cavities destroy the transparency of their selvages. Beyond—that is, outside—these zones of cavities the crystal-outlines of the garnet can be traced, and these by repeated alternation of forms give rise to saw-like outlines like those which characterize a section of "Babel" quartz. Beyond this crystal-outline there is a zone of felspar and vermiform actinolite which often penetrates the crystal limits and communicates with the vermiform cavities forming the zone immediately inside the faces of the garnets. It is evidently along this zone that the change is proceeding.

Here and there clusters of minute garnets are to be seen which offer equally instructive evidence. These are often so small that they are darkened throughout by the vermiform cavities and indeed in many cases are but imperfect rhombic dodecahedral clearings in the hornblendic material, but in which with the higher powers of the miscroscope it is not difficult to pick out the isotropic garnet from the imperfectly cleared dirt and cavities. From this stage, as the clear central area enlarges and shows the garnet pink colour, we can trace every gradation up to the largest crystals in which this selvage only covers a small fraction of the total area of the section. It is clear that as growth proceeds the proximal ends of the vermiform cavities are gradually obliterated by deposition of garnet substance in crystallographic continuity with the skeleton, and so the central area grows simultaneously with the extension of the crystal borders amongst the hornblendic material around.

Wherever the garnet comes into contact with felspar instead of a ferro-magnesian mineral, there is no such development of crystal-form nor is there a zone of vermiform cavities: the clear pink garnet is simply moulded on to the older felspar. It is only opposite the pyroxene—that is where growth can proceed without interruption—that the crystal-outlines occur. If the reaction-zones represented decom position of the garnet we should naturally expect irregular corrosion of the crystal, whereas we have well-shaped crystals and this only where the reaction-borders occur.

Wherever patches of small young garnets are found growing around isolated centres, it is frequently found that several of them may develope with crystallographic parallelism and on meeting form one large crystal. This interesting occurrence is more strikingly exemplified by patches of small crystals which form in the neighbourhood of a large one with their faces parallel to those of the large crystal and consequently to one another (Fig. 3).

17. The parallel growth of these minute crystals around the larger and probably older individuals forms a very pretty illustration of the influence a crystal exerts beyond the limits of its own faces. In a case where free movement of the material is possible, as in molten material, the surrounding magma is impoverished by removal of the crystallizing substance, and in this way we get in the tachylytes a clear zone of glass around each magnetite-crystal, whilst beyond this zone the glass is darkened by magnetite-dust. The pink film around the growing cobalt-chloride crystals in a blue solution of the salt forms a still more striking illustration of what O. Lehmann calls *der Hof des Krystalles.*[1]

When crystal-growth takes place *after* the consolidation of the substance and as

[1] *Zeitschr. f. Kryst.*, Vol. I, p. 99.

a secondary change, the "sphere" of the crystal influence is indicated, as might be expected, not by removal of material, but by parallel development from isolated centres confined to fairly well-defined limits around the central crystal, as exemplified by the beautiful instances of garnets in the Manbhúm pyroxenic rock.

18. The growth of garnets in these pyroxenic rocks which show no signs of exposure to extreme temperatures since their primary consolidation, is comparable to the well-known secondary enlargements of such minerals as hornblende (Becke, Van Hise, Harker, Bonney), augite (Van Hise, Merrill), plagioclase-felspar (Judd) and orthoclase (Haworth, Holland).

### (5) *Field relations of the Pyroxenic and Garnetiferous rocks.*

19. One of the most interesting types of the South Indian pyroxenic rocks is a granite composed essentially of quartz, orthoclase largely in the form of microcline, hypersthene, and always considerable quantities of opaque iron-oxides. This rock which possesses a striking individuality both in the field and under the microscope, I have described elsewhere under the name of *charnockite.*[1] As a rule it is compact and brittle with a very characteristic dark grey or green clour; but near its junctions with the norite, with which it is always associated, it changes very rapidly, almost suddenly, to a dirty white colour, becomes granular in structure, crushes easily under the hammer, shows a slight but distinct foliation, and is seen then to be sprinkled with garnets.

Under the microscope these changes in macroscopic characters are seen to be accompanied by corresponding changes in microscopic structure. Instead of the perfect granitic structure which characterises the unaltered rock, the weaker minerals are seen to be crushed and surrounded with selvages of mylonite, whilst the quartz-crystals show very marked "undulose" extinctions which invariably characterise rocks subjected to pressure.

But that this is an altered form of charnockite there would be little doubt even if the fact could not be demonstrated beyond question in the field. The quartz, microcline and black iron-ores are recognisable in precisely the same proportions, but instead of hypersthene there are irregularly-shaped, pink garnets, which bear to the rest of the rock a proportion, so far as determinable by sections, identical with that of the original hypersthene. That the garnets in this case have been formed from the hypersthene as one among the unmistakeable results of the metamorphism of charnockite there can be no question. Examples of this kind are most beautifully illustrated in the low hills immediately east of the railway station at Pallavaram near Madras, and at Coonoor in the Nilgiri hills.

Simultaneous with the appearance of a granulitic structure and other signs of pressure, the hypersthene has given place to pink garnet. A similar association has been recorded by Mr. Teall in the gneissose granite of Beinn Vuroch, where the ordinary granite differs from the gneissose forms in the presence of garnet accompanied by a granulitic structure in the latter varieties.[2]

I have recently traced up a dyke near Kidgeree, in the Hazaribágh district, from a compact pyroxenic type to a foliated garnetiferous one in which the pyroxene has completely disappeared.

[1] *Journ. As. Soc. Beng.*, Vol. LXII (1893), p. 162.
[2] Brit. Petrography (1888), p. 326.

### 6. *Chemical changes involved in the formation of Garnet.*

20. It would of course be extremely interesting to trace the precise chemical changes which accompany the transformation of pyroxene into garnet; but the latter mineral is so intergrown with felspar and crowded with inclusions that separation of sufficient clean material for chemical analysis was found to be impracticable.

21. There is no doubt, however, that the change is not a simple paramorphic one. The garnet contains less silica and probably a smaller proportion of lime and alumina than the pyroxene from which it is derived. The excess of silica combines with the alumina, lime and small quantities of alkalies present in the pyroxene to form the plagioclase felspar which is so frequently intergrown in a pegmatoidal manner with the garnet. The chemical constituents of the pyroxene are thus re-arranged to form two minerals—one more basic and the other more siliceous than the original. As the more garnetiferous portions of the slides invariably contain more felspar than the portions where the pyroxene has suffered no change, the microscopic evidence confirms this conclusion.

22. Another microscopic character which has a direct bearing on the chemical question is the depth of colour of the garnets. In the Madras rocks the colour of the pink garnet is most strikingly similar to the pink of the highly pleochroic hypersthenes in the same slide, so much so that without moving the polariser sections of the latter mineral might very easily be mistaken for garnets. In some quartz-biotite-norites from Isa Pallavaram, near Madras, the iron seems to have been principally used up by the biotite, whilst the rhombic pyroxene and the associated garnet too are almost colourless. The more basic rocks, approaching pyroxenites in composition, from Nagaramalai, in the Salem district, contain, on the other hand, highly-pleochroic hypersthenes with deep pink or even red garnets. Some of the rocks of the Nilgiris also contain deeply-coloured garnets associated with highly pleochroic rhombic pyroxenes that approach amblystegite in composition. As the pink colour of the garnets and the intense pleochroism of hypersthenes are dependent, though not in direct proportion of course, on the percentage of iron present, this simultaneous increase of intensity of colour would naturally be expected.

23. The facts cited under this head do not prove the *direction* of the chemical changes which have taken place amongst the rock-constituents, but as they indicate a constant chemical relation between the pyroxene and the garnet in the same rock, they are so far in agreement with the previously-stated evidence.

## B.—MICROPEGMATITIC INTERGROWTHS OF GARNET WITH OTHER MINERALS.

24. The structure produced by the intergrowth of quartz and felspar in graphic granite has, since its first description on a microscopic scale by Zirkel in 1871, been known under such names as micropegmatitic (Michel-Lévy), granophyric (Rosenbusch) and implication-structure (Zirkel), whilst special types of it are known as ocellar structure (Fischer), centric structure (Becke), and pseudo-spherolithic structure (Rosenbusch).

Although the most common example of these structures is produced by the intergrowth of quartz and felspar, other minerals are found mutually entangled in a precisely similar manner.

25. Becke has mentioned cases of a micropegmatitic intergrowth of garnet and felspar in augite gneiss,[1] and Lacroix has described and figured a similar intergrowth of garnet and quartz in one of the pyroxenic rocks of Ceylon.[2] Heddle has mentioned the occurrence of quartz-inclusions in garnet giving apparently a similar structure.[3]

26. The commonest examples of the structure, namely, those produced by the intergrowth of quartz and felspar, have generally been considered to have originated during the primary consolidation of the rock by simultaneous crystallization of quartz and felspar in the proportions of an eutectic mixture.[4]

27. But in 1883 Irving suggested the secondary origin of the quartz in the micropegmatitic structures of some granites and augite-syenites near Lake Superior.[5] Professor Judd showed the secondary origin of the quartz in similar structures and associated with the felspars of some Mull and Portsoy gabbros.[6] In 1889 the same author produced further evidence in support of his original conclusion and showed the connection between these structures and the secondary growth of minerals in igneous rocks after their consolidation.[7] Further examples of the same structure, considered to be connected with the secondary silicification of rocks, have been described by Miss Raisin in some nodular felstones of the Lleyn in Wales,[8] and by myself in some rhyolites from Korea.[9]

28. The pyroxenic rocks of Chota Nagpore, in which I have just described the growth of garnets, afford most striking cases of micropegmatitic intergrowths of garnet with plagioclase, and less often with quartz, about the secondary origin of which there seems to me little room for doubt. These intergrowths are moreover, as in the examples mentioned by Professor Judd, directly dependent on the enlargement of the minerals after the primary consolidation of the rocks (Fig. 4).

29. It has already been mentioned that numerous small garnets are found springing up in the vicinity of larger masses, sometimes isolated and sometimes in clusters. Now, wherever patches of these small garnets are found the isolated crystals grow, as already described, with crystallographic parallelism to one another (para. 16). The bearing of this fact on the origin of the micropegmatitic structure is obvious; the growth from isolated centres continues until the crystals, already in parallel groupings, meet and join as one, whilst the felspar, formed as a by-product in the decomposition of the pyroxene and growing at irregular intervals, becomes enveloped in a continuous framework of garnet.

30. It has already been remarked, too, that the so-called reaction-borders appear only between the garnet and the ferromagnesian constituent undergoing change, whilst the former mineral shows a very definite and simple outline where it

[1] *Tschermak's min. und petr. Mitth.*, Vol. IV. (1882), p. 406.

[2] *Bull. de la Soc. Min. de Fr*, Vol. XII (1889), p. 317, and *Rec. Geol. Surv. Ind.*, Vol. XXIV (1891), p. 179.

[3] *Min. Mag.*, Vol. II (1878), p. 230.

[4] See Teall, Brit. Petrography (1888), p. 391.

[5] *U. S. Geol. Surv. Monograph* No. V, "The copper-bearing rocks of Lake Superior," p. 114.

[6] *Quart. Journ., Geol. Soc.*, Vol. XLII (1886), pp. 72 and 95.

[7] *Ibid.*, Vol. XLV (1889), p. 175.

[8] *Ibid.*, Vol. XLV (1889), p. 252.

[9] *Ibid.*, Vol. XLVII (1891), p. 177.

comes in contact with the felspar (para. 13). In this way growth occurs only opposite the ferromagnesian constituent, and the garnet bellies out in such areas, with the result that the bays and inlets are filled with felspar. A continuation of this process results in the complete envelopment of the felspar and its consequent appearance in section as isolated crystals. As might be expected, the crystal-outlines of the garnet are exhibited only when the pyroxene is sufficiently abundant to allow of free growth, whilst development is proportionately interrupted when such minerals as felspar and quartz are present in quantity. Both these processes are specially well illustrated in the garnetiferous rocks of Manbhúm and in the rocks of Parasnath.

31. Although a certain quantity of felspar and quartz occurs amongst the primary constituents of the Manbhúm and Parasnath rocks a larger quantity is formed as a by-product in the re-arrangement of the pyroxene-molecules. Hence it is that garnet is more frequently intergrown with felspar and quartz than with the more basic minerals. The minerals intergrown are thus produced simultaneously by secondary changes in a pyroxenic rock, and the average composition of the mixture of garnet and white mineral formed is approximately that of the original ferromagnesian silicate which has undergone the chemical re-arrangement of molecules.

## V.—SUMMARY OF CONCLUSIONS.

32. The garnets occurring so abundantly in the pyroxenic rocks of India frequently exhibit fibrous reaction-borders generally composed of felspar, actinolite and sometimes magnetite, and display a radiate arrangement of the fibres similar to the structure characteristic of Schrauf's kelyphite.

33. The reaction-border occurs only between the garnet and a ferromagnesian silicate, never between garnet and felspar or quartz (para. 13).

34. The ferromagnesian silicate nearest the garnet is generally green actinolite which can be traced out in some cases (Manbhúm, Parasnath) to augite, and is evidently derived from the latter mineral by the ordinary process of amphibolization (para. 14).

35. The augite undergoing the paramorphic change into hornblende is darkened by the minute regularly-arranged inclusions which characterize diallage and present the ordinary phenomena of schillerization. The passage into hornblende is accompanied by the absorption of these dark ferruginous inclusions and clear green actinolite is the result (para. 15).

36. Where the rock is composed almost entirely of pyroxene changing to hornblende, the garnets develope with a regular crystalline outline, and several crystals developing in close proximity often exhibit crystallographic parallelism to one another. Where felspar and quartz occur in quantity as primary constituents, the garnet exhibits no crystal-outline, but is moulded on the white minerals, and the line of contact in such cases never shows a reaction-border (para. 16).

37. The garnets are frequently found bellying out opposite the pyroxenes, whilst felspar and quartz occupy the bays and inlets. A continuation of the growth of the garnet results in the gradual enclosure of such felspar and quartz crystals and their consequent appearance in section as isolated masses (para. 30).

38. The alteration of the original schillerized pyroxene is, therefore, not a simple paramorphic change, but is a decomposition which results in the simultaneous formation of a more basic mineral, garnet, and a more acid one, felspar.

39. The simultaneous development of these two minerals results in their micropegmatitic intergrowth. In the case of the felspar the similarity of optical orientation of isolated portions proves their crystallographic parallelism. In the case of the intergrown garnet the occurence of numerous small crystals developing around a larger central one exhibiting parallelism of crystal-outline with the larger central garnet and with one another, results in the ultimate formation of one large crystal of garnet, in which both original felspar and quartz, as well as the secondary felspar formed during the destruction of the pyroxene, become entangled to produce a micropegmatitic structure (paras. 29 and 31).

40. The micropegmatitic structure is thus considered to be of secondary origin as has recently been shown to be true for similar cases of the more common intergrowth of quartz and felspar.

41. The development of felspar as a by-product during the formation of garnet from pyroxene explains the more frequent record of micropegmatitic intergrowths of garnet with felspar than with any other mineral.

42. The reaction-border occurring around garnets may therefore represent a stage in the *development* of garnet from the products of the molecular disintegration of original ferromagnesian silicates, and does not always indicate the *destruction* of garnet as has generally been considered to be the case with kelyphite borders.

43. The evidence offered by the microscopic characters briefly indicated in the previous paragraphs is corroborated by the field relations of the pyroxenic and garnetiferous rocks. Compact pyroxenic rocks, with a perfect granitic structure, become friable and imperfectly foliated near their margins, where the pyroxene disappears, garnet, in about the same proportions, takes its place, and the rock becomes granulitic in structure (para. 19).

## VI. EXPLANATION OF PLATE.

FIG. 1. Garnet crystal with reaction-border which only occurs between the garnet and the pyroxene, or, more strictly speaking, its paramorph hornblende. Along the bay, which is filled in with felspar, the outline of the garnet is a simple one without reaction-border. In this section the pyroxene, which is darkened by schillerization products, is amphibolized opposite the reaction-borders only, the portion abutting against the felspar being unaltered. In *pyroxene-diorite* from Parasnath, Bengal. Rock No. 9.-328. Slide No. 1154. Magnified by 43 diameters.

FIG. 2. Garnet crystals, large and small, developing in amphibole derived from pyroxene with crystallographic parallelism and showing reaction-borders. In *garnetiferous pyroxenite*, from the Ijri valley, Manbhum, Bengal. Rock No. 3·23. Slide No. 1376. Magnified by 25 diameters.

FIG. 3. Small garnets growing with crystallographic parallelism to a larger neighbour with reaction-borders. There are large numbers of such small crystals growing around the large one although beyond the limits of the field photographed. Slide No. 1976. Magnified by 43 diameters.

FIG. 4. Micropegmatitic intergrowth of garnet and felspar. The optical continuity of the isolated sections of the felspar is shown by parallel twin-bands when examined between crossed Nicols. Slide No. 1376. Magnified by 20 diameters.

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*Part 2.*—On the geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive Group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

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*Part 4.*—On the occurrence of petroleum in India. On the petroleum exploration at Khátan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Meza valley, Upper Burma.

### Vol. XX, 1887.

*Part 1.*—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-Garhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

*Part 2.*—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

*Part 3.*—The retirement of Mr. Medlicott. Notice of J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

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*Part 1.*—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of nodular stones obtained by trawling off Colombo.

*Part 2.*—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sangar Marg and Mehowgale coal-fields, Kashmir.

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## Vol. XXII, 1889.

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RECORDS

OF

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*Notes on the* Ultra-basic rocks *and* derived minerals *of the* Chalk (magnesite) hills *and other localities near* Salem, Madras: *by* C. S. MIDDLEMISS, B.A., *Superintendent, Geological Survey of India* (with plates 2—6).

## INTRODUCTION.

In substance, and with but slight alteration in form, these preliminary notes have already appeared in a report on the magnesite areas near Salem, prepared by me at the request of the Madras Government last year (1895). My investigations were, of course, chiefly directed to the magnesite, serpentine and chromite, from an economical stand-point; but I naturally gave some attention to the geological aspects under which they appeared, inasmuch as, from their comparative rarity rocks of the class from which such minerals are derived are always objects of interest to the geologist.

The following notes have reference to three separate localities, namely :—

(1) The two areas of the Chalk hills.
(2) That of the north-west end of Kanjamallai.
(3) That near Valaiyapatti in the Námakkal taluk.

Of these three areas the first is by far the most important. They will be taken for description in the above order.

### (1) CHALK HILLS.

The two areas embraced under the above name have been described by Messrs. King and Foote in their Memoir (*Mem. G. S. of India*, vol. IV, pt. 2, 1864). The same areas were cursorily examined by Mr. Holland quite recently, and described (*Rec. G. S. of India*, vol. XXV, p. 135, 1892).

Whilst the two former observers gave a fairly detailed description of the mode of occurrence of the magnesite, with remarks on the accompanying minerals, Mr. Holland was able to come to more definite and accurate conclusions regarding the mode of origin of the magnesite, chromite, etc.—conclusions which have been abundantly confirmed and illustrated by my own visit.

In taking up work myself on these extremely interesting rocks, it was evident (considering that a generally descriptive account, and an up-to-date theory of them existed already) that any advance that I could make on the work of my predecessors must be in the direction of greater precision as regards detailed surveying of the minerals and rocks of the area. My line of action was therefore clear, and the first step towards it was to obtain a detailed topographical map. This I found not to exist; and so, as the shortest way out of the difficulty, I set to work and planetabled the two magnesite areas of the Chalk hills myself on the scale of 6 inches to 1 mile, showing sketched contours of 10 feet. A reduction of the map, geologically coloured, accompanies this report (Plate 2.)

Position and area.

The Chalk hills lie a few miles north of Salem town. They comprise two areas, a smaller one to the south, through which at its south-west end the Madras Railway and the road to Omalur pass, and a larger one to the north-east of the latter, and which keeps a position to the east of the railway and road. The former contains about $1\frac{1}{4}$ square miles and the latter (so far as shown in my map) about $3\frac{1}{2}$ square miles. It extends, however, further away in a north-easterly direction.

Orography.

The hills rise gently from the plains, and expose a set of low undulating surfaces, generally bare of vegetation and without water. They are streaked with white, owing to the veins of magnesite (carbonate of magnesia) from which (erroneously) the name "Chalk" hills is taken.

General geological structure.

The structure of the two magnesite areas may be summarised as follows:—

(1) The plains surrounding the Chalk hills are composed of an ancient gneissic series, wrapped into folds with a N. E.—S. W. strike. These rocks form part of the great crystalline foundation of south India. They vary enormously in mineral composition at different places, but in the vicinity of the Chalk hills they usually have hornblende as the dark mineral. Their foliation is a marked characteristic: a foliation both fine and coarse, and rendered very apparent by the varying quantities of hornblende present in each layer. A hand-specimen may shew no hornblende at all, or a finely banded condition of it with felspar and quartz, or it may be composed entirely of hornblende. In certain places, as along the high ridge to the south of the north magnesite area, garnets of great size or in nests appear thickly distributed along the more hornblendic bands. Perhaps the greatest structural difference between these old gneisses and the presumably younger ultra-basic intrusions, which are the subject of this paper, is to be found in the greatly foliated condition of the former, and the total absence of any such in the latter. Indeed generally throughout South India, this distinction applies between the gneissic foundation and the intrusive rocks, whether ultra-basic, as here, basic as found in the great plexus of trap dykes that cut through the country, or acidic, as is found in the masses and veins of coarse granite which form considerable hills. In any and every case the younger intrusive rocks remain perfectly unfoliated and non-schistose from core to edge: they have no linear arrangement of their minerals, and no tendency to any uniform orientation of the long axes of those minerals.

(2) The two areas of the Chalk hills are essentially two such great intrusive masses of olivine-chromite rock, and other olivine-bearing rocks, which, from their containing little or no felspar or quartz, belong to the peridotite, or ultra-basic group of rocks, such as dunites, picrites, etc. These rocks, owing to the unstable mineral olivine, have undergone enormous mineral change, whereby, first the dunite became serpentinised more or less completely, and secondly, the serpentinised product was further altered with the formation of magnesite, chalcedony, etc.

The evidence for the intrusive nature of these ultra-basic masses may be best seen along the south-west side of the north area, where the junction line with the old gneisses is distinctly seen to cut obliquely across the foliation of the latter. The age of these intrusive rocks remains at present undeterminable.

The Dunite and its contained mineral Chromite.

Mr. Holland was the first to detect the presence of dunite in the specimens which he collected in the Chalk hills and north-west of Kanjamallai hill. (See foot-note at page 144 of Mr. Holland's paper.)

This rock, first known from the Dun mountain, New Zealand, is composed entirely of olivine and chromite, and as such, in an unaltered condition, it is found at many places in the Chalk hills where the rock has resisted the metamorphic influences tending to convert it into serpentine. The top of "J" hill and of "Tent" hill, and the western end of the south area are examples of places where the rock of a grey or greenish-grey colour, may be observed. The grey rock (colourless in thin section), such as is found on the summit of "J" hill and near "KK" hill might be at first sight mistaken for a quartzite until the high specific gravity arouses suspicion.

The microscope shows the rock to be composed almost entirely of a coarsely crystalline aggregate of olivine, felted together, and with minute black crystalline grains of chromite dotted through it.

A chemical analysis of the "J" hill specimen No. 10·189, made in the Geological laboratory at Calcutta by Mr. Blyth, gave—

| | |
|---|---|
| Silica | 39·10 |
| Magnesia | 48·26 |
| | 87·36 |
| Iron and alumina<br>Manganese<br>Chromium<br>Moisture, etc. | 12·64 |
| | 100·00 |
| Specific gravity | 3·176 |

I give below, for comparison, an analysis of the dunite of the Dun mountain (Von Hochstetter)—

| | |
|---|---|
| Silica | 42·80 |
| Magnesia | 47·38 |
| Ferrous oxide (after the chromite had been removed). | 9·40 |

I next give that of oriental olivine, taken from Dana's Mineralogy—

| | |
|---|---|
| Silica | 39·73 |
| Magnesia | 50·13 |
| Ferrous oxide | 9·19 |
| Specific gravity | 3·351 |

There can be no doubt that originally nearly the whole of the Chalk hills area was composed of this extreme form of peridotite known as dunite. But mineral changes rapidly set in, and the two first of these changes that must be noticed are (*a*) the alteration, partially or wholly, of the olivine into serpentine, and (*b*) the segregation of the chromite into nodules and veins. With regard to the change of olivine into serpentine, I need say very little. It can be followed most perfectly under the microscope by a series of transitional sections showing, first, a few veins of the latter anastomosing among and penetrating the crystals of olivine, afterwards breaking them up, then separating them into isolated small grains set like islands in a sea of serpentine, and which at last become very small and finally disappear. The subsequent changes which brought about the conversion of much of the serpentine into magnesite have effectually destroyed any ornamental qualities it might have possessed, by giving it a dull earthy appearance. Only here and there do there occur a few minute veins, a finger thick, of a pale apple-green serpentine, which might, if they had been on a larger scale, have been of economic use. Picrolite or fibrous serpentine, is also found in veins here and there.

Coming to the chromite, originally discovered by Mr. Heath, and worked by the Porto Novo Company, the only observations we have as to its mode of occurrence are those made a long time ago by Newbold, and those of recent date by Holland. The former found the mineral in very thin veins, either lying among the magnesite of the veins or between it and the walls of the veins. The observations were drawn from an examination of the mines near the chimney on the accompanying map (Plate 2). Holland corroborated Newbold's observations in this respect—see *Journal, Roy. Asiatic Soc.*, vol. VII, 1843, pp. 167—171. Of the three shafts marked on my map the middle one is the largest, and though I explored this carefully, I could find no trace of the mineral left in the crumbling rock-walls of the shaft.

In some small pits sunk along the position of the line marked chromite vein on the map (some of which appear to have been enlarged lately), I was able to see the position of several veins of the chromite. Three vertical parallel veins a quarter of an inch, 1 inch, and ½ inch wide respectively, and separated by a few inches of serpentinised matrix, occur striking E. 20° N. at a position on the map N.W. 5° N, from the chimney, and distant about 650 yards (see pl. 5, fig. 1). Nearly horizontal magnesite veins may be seen interrupting and cutting across both the matrix and the chromite veins. In one place a vein of magnesite has not only interrupted, but also displaced, the middle vein of chromite, showing that the magnesite was, in this case, the last to form.

What is undoubtedly a continuation of the same vein towards the E. 20° N. is to be seen at several points between 900 and 1,000 yards off. At no other places in this north area was chromite found *in situ*.

It will be seen from the map, however, that in this area a little east of the chimney there is a space of country from which six stream-beds radiate in different directions. In every one of these stream beds, and especially in their higher parts, chromite, in lumps, varying from one foot to one inch or even less across, may be picked up (the places where such have been found are indicated on the map by dots).

It is clear, therefore, that the area drained by these streams is penetrated by chromite veins. Unfortunately my data are too scanty for any attempt to estimate the amount of chromite available to the miner; nothing but a practical test within the area of, say, 1,000 yards radius from the chimney would settle this all-important question. Geology has gone as far as it can, unaided, in the matter.

In the southern area of the Chalk hills the map similarly shows, by means of dots, the places where chromite has been picked up at the surface. No chromite, actually *in situ*, is known in this area; but the indications of it in the stream between "Tent" hill and "Green bush" hill, and in the one to the south-west of "Tent" hill, show that the centre of this area is approximately the true location of the chromite. No mines have been worked in the area, but I have no doubt that if extensive quarrying of the magnesite is ever carried out, chromite veins will in due course be laid bare.

As for the quality of the ore, the nodules and lumps as picked up among the hills show that it is practically a granular-crystalline aggregate of the pure mineral, chromate of iron, the theoretical composition of which, as given by Dana, is—

| | |
|---|---|
| Chromium sesquioxide . . . . . | 68·0 |
| Iron protoxide . . . . . . . . | 32·0 |
| | 100·0 |

but chromite varies much in the amount of the sesquioxide present, 50 per cent. being considered a very good quality of ore.

The actual analysis of the ore, as found in the north area of the Chalk hills, is given in Newbold's paper referred to above. It was made by Mr. E. Solly, and gave—

| | | |
|---|---|---|
| Chromium sesquioxide . . . | 49·00 | per cent. |
| Which is about equivalent to chromic acid | 57·00 | „ |
| Or to cent. per cent. of chromate of potash. | | |

The following description of the method of working and transporting the ore to the coast is taken from Newbold's report:—

"The ore is separated from the rock by means of pickaxes, chisels, wedges, and hammers; "sorted and piled up into little heaps on the ground in front of the huts occupied by the "superintendents, where it remains until the Cauvery becomes navigable; that is, from the "end of June till the end of September. It is then sent down by land to Moganoor, a place "on the river about 40 miles southerly from Salem, whence it is boated to Porto Novo on the "Coromandel coast. Thence it is shipped to Europe by the Porto Novo Iron Company."

About 100 tons are said to have been extracted from the mines, one block of which weighed two tons, but it was found that the export of the crude ore to England did not pay owing to the quantities available from Scotland, Styria, etc. At a depth of 50 or 60 feet from the surface water was met with, and it is not impossible that it was this difficulty which helped largely to stop the work, inasmuch as no better means of removing the water were used than buckets and ropes.

Other ultra-basic and basic rocks of the Chalk hills.

Besides the dunite, and its more immediately derived serpentine and chromite-veins, there occur, somewhat sparingly, examples of other less basic rocks. They are generally black or of dark colour, and stand out in rounded lumps, having escaped the great alteration which the dunite has suffered. They are represented on the map by a purple colour. Many of these in the north area are situated round the margins of the dunite intrusion. One remarkable one is found to the east of "Green bush" hill in the south area. The latter No. $\frac{10}{181}$ is a very coarse aggregation of diopside, olivine and biotite. The first two minerals are in a granular-crystalline state, whilst the biotite fills in the interspaces. Apparently genetically related to the preceding specimen is $\frac{10}{188}$ from the cart track N.N.E. of knoll "C." It also contains diopside and olivine in more or less idiomorphic crystalline granules; there is a small amount of biotite; and all these minerals are set in a groundmass of small felspar crystals. The diopside is schillerized in a remarkable way. Similar rocks are found in the stream-bed S.S.W. of K, *e. g.*, $\frac{10}{197}$.

The Magnesite veins.

I come now to the mineral which is most abundantly represented in the Chalk hills, that is, the magnesite, or carbonate of magnesia. Its general characteristics, mode of occurrence, and appearance have been described by many observers, among whom may be mentioned Newbold (*Journal, Roy. Asiatic Soc.*, vol. VII, page 161, 1842), King and Foote in their memoir cited above, and lastly Holland. The descriptions of the earlier observers stand good at the present day, if we simply substitute the more correct mineralogical descriptions of the rocks from which it was originally derived in the place of the hornblende-schists, micaceous and massive talcose schists, basalts, etc., of these observers. The mistake made by them (perfectly intelligible before the microscope was regularly employed for the examination of rocks by means of thin sections) was of a simple nature. They looked upon the area of the Chalk hills as primarily a focus of metamorphism, brought about by a locally intense extravasation of hot acid waters or vapours, which were sufficient to change the otherwise stable minerals in the gneissic rocks surrounding the area. Mr. Holland's and my own researches, on the other hand, have simplified the matter considerably by the discovery that the rock forming the groundwork of the Chalk hills areas is entirely different from the surrounding gneissic rocks; that it is in fact, as has been described above, a nearly pure olivine rock in various stages of alteration. The fact of such an olivine rock having at one time been erupted into the older gneisses in this part of the country is in itself sufficient to account for the secondary masses of serpentine and veins of magnesite, without having recourse to hot acid waters emerging at particular places; inasmuch as it is the nature of olivine rocks to rapidly undergo changes into serpentine and magnesite. The mineral is of such an unstable nature as to readily lend itself to these changes under normal subterranean or surface conditions (without calling into play any special metamorphosing agents), whilst the ordinary gneisses of the country, and the less basic rocks surrounding the area, remained practically unaltered.

I need say very little, therefore, as to the general occurrence of the magnesite here, except that it appears in veins, which although they have, in places, a tendency to a particular alignment along what were probably originally joint planes in the dunite, are nevertheless as a rule completely irregular in their disposition. The number of veins, and the corresponding quantity of the magnesite, were points to which I particularly directed my attention; and which I have endeavoured to represent on the accompanying map. The uncoloured part of the map where topographical detail is given embraces the whole area where the dunite is found and stands for that in which the magnesite is least in evidence or absent altogether. The cross-shaded portion is that in which there is a fair amount of the magnesite; whilst the deep-blue wash represents the parts richest in magnesite. I have been compelled for diagrammatic purposes to draw the boundaries of the different areas as sharp, but I need scarcely remark that in nature there are no such hard and fast lines; the richer and the poorer rock grading into each other.

(1) The richest areas (coloured blue) are, generally speaking, the western end of the north area, and the south side of the south area. I estimate that the proportion, by volume, of the magnesite in the rock in these richest parts is about one-half or one-third of the whole rock.

(2) The moderately rich area (cross-shaded) occupies generally the more central parts of the Chalk hills; and I estimate that the proportion, by volume, of magnesite here is only from one-sixth to one-tenth, or even less, of the whole rock.

(3) The poorest area (uncoloured) merely shows a few thin veins and patches of the magnesite here and there, and impossible of estimation.

The total area embraced under heading No. (1) above, in the two parts of the Chalk hills taken together, amounts to about 620,000 square yards, that under heading No. (2) amounts to about 5,536,000 square yards.

Considered altogether, the amount of magnesite in these hills is practically unlimited. The richest portions (as visible at the surface) stand up in rough lumpy hillocks, sometimes, as in the case of the hills at the western end of the north area, rising as much as 100 to 140 feet above the plains, whilst in other parts, as the south edge of the south area, they rise only to 30, 40, or 60 feet above the plains. Hence the mineral (if any demand for it ever does arise) can be worked in open quarries and taken away to the rail. The quarries could all be reached by a light tramway, or by carts.

Two outline views of the two areas are appended to this report to show the configuration of the country (Plate 6), and two photographs to illustrate the surface appearance of the magnesite veins (Plates 3 and 4).

## (2) KANJAMALLAI AREA.

Mr. Holland (*Rec. G. S. of India*, vol. XXV, p. 142) was the first, I believe, to draw attention to the presence of ultrabasic rocks and magnesite in small amount at the north-west end of the Kanjamallai hill in a depression at the head of a little stream running down to Sithaswaran kovil (temple). Therein also he remarks on the possibility of finding chromite associated with the magnesite.

On visiting this part myself last season, I found the rocks as described by Mr. Holland. But the amount of the purer olivine-chromite, ultra-basic, intrusive rock (dunite) as found at the surface was, however, extremely small. It is of a pale greenish-yellow colour and crumbles easily. Veins of magnesite run through it. In close relation with it was a brilliant dark-green rock composed of enstatite and a bright-green pyroxene (diopside), a rock which is also found in the extreme north-east parts of the north magnesite area of the Chalk hills, on the east side of the double-peaked Nagramallai hill (not represented on the map).

Mr. Holland's prediction as to the possible finding of chromite here was verified by my coming upon a band of it about 4 inches thick among the magnesite and decomposed ultra-basic rock. It was only exposed for the short distance of about 3 yards.

The whole exposed area of these rocks in this locality is in length not more than ¾ mile and in breadth ¼ mile. It appears to follow round the eastern end of the depression at the north-west end of Kanjamallai in the angle formed by the main ridge and low continuation of it south of Sithaswaran kovil (temple). I could not find any trace of it anywhere else on the Kanjamallai ridge.

To the south of Kanjamallai hill, and running parallel to, and north of, the Salem-Sankaridrug road, there is a little row of hills composed chiefly of talcose schists and dunite, with a mere trace of magnesite among them. The talcose rock was locally worked as pot-stone for making rude vessels (feeding troughs for cattle, etc.).

Both these two areas are too small to be considered as of any importance from the magnesite they contain; but the chromite of the former, and the pot-stone of the latter, may be considered as of some economic value. The chromite is in close proximity to a thick bed of magnetite.

This paper does not profess to deal with the iron ores of Kanjamallai, but I may mention that a few average specimens from the lowest and thickest band of magnetite schist at the south foot of Kanjamallai were analysed in the Geological laboratory by Mr. Blyth and gave:—

No. 10·212 (a fine-grained, almost aphanitic rock, a large specimen of which I sent to the Madras Museum).—

| | |
|---|---|
| Specific gravity | 3·365 |
| Per cent. of iron | 35·00 |

No. 10·243—

| | |
|---|---|
| Specific gravity | 3·531 |
| Per cent. of iron | 34·390 |

No. 10·239 (a coarsely crystalline quartz-magnetite rock):—

| | |
|---|---|
| Specific gravity | 3·538 |
| Per cent. of iron | 36·66 |

### (3) THE VALAIYPATTI AREA.

This locality is one of those described by King and Foote in their memoir cited above, p. 96. The amount of magnesite present is extremely small. The ultra-basic rocks which have given rise to the magnesite are the same as those last described from north-west end of Kanjamallai, but I did not find any of the pure olivine rock analogous to the dunite of Chalk hills.

The actual locality is a little south (from half to one mile) of Palappatti of the one-inch map of the Namakkal taluk (Madras Survey). The magnesite is exposed over an area of one mile by half a mile, and it is developed among rocks which contain a considerable quantity of enstatite, with green pyroxene (diopside).

Besides this particular area there is actually at Valaiyapatti, another occurrence of similar rocks, which stretch away in a long narrow band east and west of the town. They form little hills rising sometimes steeply, and forming a discontinuous chain. With them east of the town occurs a rock of an extremely acid type, a very coarse red or pink and white pegmatoid rock or graphic granite, composed of quartz and felspar, which have crystallised together simultaneously.

These are all the localities with magnesite that I have so far visited. The first is the only one in which the mineral is developed in sufficient force to be of any practical use.

*Preliminary notes*[1] *on some* Corundum localities *in the* Salem and Coimbatore districts, Madras: by C. S. MIDDLEMISS, B.A., *Geological Survey of India.* (With plates 7, 8 and 9.)

## I.—INTRODUCTION.

In these notes I shall merely endeavour to give a concise account of such facts as to the distribution and occurrence of corundum in the districts referred to under the above heading, as have up to the present been investigated by me. All discussion of theoretical questions arising from them, except in so far as such questions bear on the distribution of the mineral, will be left for a future more complete report, when these investigations have been brought to a close.

A few remarks of a general nature have already been made by me in my progress report for the working season 1893-94, and reproduced in substance in the annual report of the Geological Survey for the year 1894 (*Rec. G. S. of India*, vol. XXVIII, pt. 1, p. 3). I need not do more here than refer to them, as all important details contained therein will be embodied in the present report.

Corundum localities visited by me.

A list of corundum localities, as represented by specimens in the Madras Museum, was kindly furnished me by Dr. Warth (then officiating as Superintendent of the Museum) on my arrival in Madras. Of those the following is a list of the localities where corundum has been examined by me:—

(1) Sithampundi or Sittampundi, near Solasiramani (Sholasigamani) Námakkal taluk, Salem district.
(2) Paparapatti and neighbourhood, Dharmapuri taluk, Salem district.
(3) Rengopuram, Dharmapuri taluk, Salem district.
(4) Road from Dharmapuri to Morappur.
(5) Selangapalaiyam, Bhaváni taluk, Coimbatore district.
(6) Gopichettipalaiyam, Coimbatore district.
(7) Karutapalaiyam, Coimbatore district.

The following localities, though they have been quoted as corundum localities, have proved not to contain corundum in some cases, or else local information on the subject was found to be wanting:—

(8) Yellagiri hills, near Jalarpet.
(9) Neringipet, Coimbatore district.
(10) Chinnamallai, Coimbatore district.
(11) Kanjikovil, Coimbatore district.

With regard to the Yellagiri hills, I was in the first place unable to obtain any information from the local officials of Tirupatur, as to the occurrence of any corundum there. On visiting the hills themselves, and making enquiries both in the villages at the foot and on the summit of the plateau, I was similarly unable to elicit any information on the subject. A necessarily somewhat hurried personal investigation of the geology of the hills was also without success. I found the hills to be composed of a great intrusive mass of a rather medium-grained granite,

[1] With few slight alterations these notes are a reprint of a report written for, and published by, the Madras Government, 1895.

slightly pinkish in colour, but sometimes white and sometimes deep flesh-colour. Here and there on slabs of the rock exposed along the rolling, plateau-like summit were to be seen large, porphyritic crystals of felspar which at once catch the eye in the sunlight. It may possibly be the case that these crystals have been mistaken for corundum.

Neringipet I have not as yet visited, but the Bhavani Tahsildar informed me that the reported find there was a mistake.

Chinnamallai is a long, low hill-range of ironstone (magnetite-schist, etc.) among gneisses. I could find no one in the neighbourhood who knew anything about corundum occurring in the neighbourhood, nor was I successful in discovering any trace of it myself.

At Kanjikovil, I was directed by the Bhaváni Sheristadar to a number of shallow pits situated about 2½ miles along the Satyamangalam road from Sittodu. Here I found a quantity of grey and blueish grey kyanite crystals scattered through the rock, in the soil, and in the debris thrown out of the pits. It is possible that this mineral was mistaken for corundum; and it is even possible that similar finds of blueish varieties gave rise to the report mentioned by Newbold (see on) that sapphires have been found in the valley of the Cauvery.[1]

## II. DESCRIPTIONS OF THE LOCALITIES.

### (1) *Sittampundi area.*

This locality lies a little east of the Cauvery river, and about five miles to the south of the boundary dividing the Tiruchengódu taluk from the Námakkal taluk. It has apparently been known for a very long time. Specimens of corundum and of the enclosing rock from it were described by Count de Bournon (*Phil. Trans. Roy. Socy.*, 1802, p. 282), and the place was visited by Captain Newbold and reported on by him (*Journal, Roy. Asiatic Socy.*, vol. VII, p. 224). Lastly Dr. Warth of the Geological Survey visited and reported on it in two letters to the Madras Government, Nos. 540 and 606, dated 24th June and 16th July 1892, respectively.

Area.

The size of the area productive in corundum was given by Dr. Warth as 771 acres, but the village officers gave 1,000 acres as the estimated amount. It was also stated to be about four miles long and two miles broad in its widest part.

The part examined by me was about two miles long and varied in width from 100 yards to 1,000 yards. It lies south-west, south, and south-east of Sittampundi village, occupying a slightly elevated bit of rising ground running with its long axis west-north-west, and east-south-east at distances varying, according to the position, of from 1 mile to ½ mile from the village.

It was in December 1893 that I began my corundum investigations in the district at this place, first on account of its being the one about which most information was obtainable. The following summary is based on the observations then made in the field, and on the subsequent examination of the rocks and minerals in the laboratory.

[1] In view, however, of the discovery by Dr. Warth of blue corundum in a vein of kyanite in Chota Nagpur this place may be worth while visiting again (see *Records*, vol. XXIX, p. 50).

Rocks of the neighbourhood.

The rocks to the north of the corundum area consist generally of a great series of biotite gneissic rocks, covering large areas, and with bosses and veins of a coarse, reddish granite bursting through them and often forming picturesque crags and precipitous hills, such as that at Tiruchengodu town, and the similar hills in the vicinity.

Actual matrix of the corundum.

But the actual rock present at the corundum workings differs from the above in being a gneiss or gneissic rock, of a pale silvery or pearly grey colour, streaked with black, and consisting of anorthite (indianite) and hornblende, chiefly, with accessory minerals garnet, and minute quantities of chondrodite (?). In structure the rock is a crystalline granular aggregate of anorthite, with rather elongated prisms of hornblende, sparsely or numerously arranged with their long axes roughly parallel to the foliation.

The rock is well foliated in bands which generally run perfectly straight, and which differ in the relative amounts of the pale mineral (anorthite) and of the dark mineral (hornblende) present. (See Plate 7, fig. 1.)

In some places the hornblende, in others the anorthite, make up nearly the whole rock. Garnets also become locally very numerous. The specific gravity of a specimen with but little hornblende and garnet was found to be 2·824. In this respect it closely resembles anorthite, the specific gravity being a little higher than that of the latter on account of the hornblende.

It is among this gneiss that the corundum appears, dotted about at random among it like porphyritic crystals of orthoclase in a granite. The mineralogical composition, structure, and general appearance of the rock-matrix here is plainly the same as that recorded by Count de Bournon from the Salem district, and named "Indianite" by him. The microscopical examination of the two rocks shows them to be practically identical.

Other minerals associated with the gneiss.

In some sort of association with the anorthite-gneiss, which is not disclosed by any exposures on the ground, there must occur a very coarse binary granite consisting of quartz and pink or flesh-coloured orthoclase-felspar, inasmuch as large pieces of the latter, and beautifully clear, smaller fragments of the former are found scattered over the ground in perfectly fresh lumps and showing no trace of rolling by the action of water.

On each side of the *in situ* gneiss, which forms the rising ground, there are gentle slopes of the same rocks, partly or wholly buried under surface material formed of the broken-up gneiss and with here and there a recent calcareous pisolitic tufa, derived no doubt from the decomposition of the lime-felspar (anorthite).

The corundum of the area.

The corundum occurs in two ways in the area:—

(1) In the bed-rocks as described above.
(2) In the gentle slope of debris along with the weathered pieces of the bed-rock.

It is of a pale greenish-gray, rarely flesh colour, and occurs sparsely distributed among the parts of the gneiss which are richer in anorthite. It takes the form of irregular lumps averaging from one-fourth to one inch in diameter. They do not, as a rule, show the prismatic and pyramidal faces, though some specimens from this locality in the Survey Museum are in the form of short six-sided prisms characteristic of corundum. They exhibit, however, rhombohedral cleavage, which may be detected as fine and very regular lines crossing one another at an angle of about 95 degrees, and ruled as it were at fairly regular intervals. These fine lines crossing one another in this distinct way are a good practical distinction in the field between this mineral and pieces of orthoclase, or other felspar, especially in the case of the flesh-coloured corundum, which at first sight may be easily confounded with the flesh-coloured felspar referred to in the previous paragraph. It is possible that some of the lines may indicate repeated twinning, but the difficulty of cutting microscopic sections or of getting sufficiently thin cleavage flakes of the mineral, make it at present impossible to decide this point.

Nearly all these pieces of the mineral are surrounded by a shell of calcite from one-fourth to one-eighth inch thick, in which they lie among the matrix. This shell appears to be left by the crystallising out of the alumina (corundum) from the lime-bearing felspar (anorthite).

The corundum found in the debris slopes is the same as that of the matrix rock, inasmuch as the former is simply derived from the latter by weathering.

Red corundum or ruby of the area.

Besides the grey corundum noted above, and the flesh-coloured variety into which it passes, there are to be found fragments, generally minute, of red corundum, which very locally pass into ruby. The brighter coloured pieces of these, which are but seldom larger than one-fourth of an inch in diameter, were found by me only in the more hornblendic layers of the gneiss; and they lie in it surrounded by a shell of anorthite partly converted into calcite. These pieces are not generally transparent, but dull and opaque, and of a red currant colour. But here and there minute points of a fairly translucent red colour may be detected, and I have no doubt that occasionally rubies of value have been extracted from these rocks, as is reported traditionally and by Newbold (*Journal, Roy. Asiatic Socy.*, vol. VII, p. 224).

Old corundum workings.

The grey and the flesh-coloured corundum are found all over the area to the south-west, south, and south-east of Sittampundi, referred to in page 40. The native workers have in some cases taken the trouble to break up the rock-matrix along the more rocky parts of the rising ground, and so to extract the mineral from its shell of carbonate of lime. But more generally it has been gathered by merely grubbing among the debris between the *in situ* outcrops and along the slopes. Shallow excavations of this sort a foot or two deep are to be met with all over the area. Women chiefly, but men also, take part in the search, which they conduct with the help of a small digging implement and a basket. The searchers pick about among the talus until they find traces of corundum. They then set to work to dig out a basketful of the material which is then gone over by hand, the fragments of corundum being selected readily and with certainty by those accustomed to the work.

I was informed that the grey corundum was sold locally at the rate of eight seers for the rupee, and that a man can collect that much in about fifteen days. The red corundum with occasional clear ruby particles is more locally distributed and I only know of one set of small workings and pits at a point one and a half miles south-east by east of Sittampundi and S. 8° E. of Anagherry hill. There are several openings along one line of strike running north-west by west and extending for about 100 yards, but most of them have since been filled up by the falling-in of the sides. One mine was about fifteen feet deep, cut out along the strike, and from two to three feet wide. It had been much deeper (several yards I was told) but had subsquently been partly filled in with rubbish from above. Two years ago, I was told, this mine was worked, and the red corundum sold in Tiruchengodu for 1, 2, 3 and 4 rupees, according to the colour, transparency, and size of the pieces. Figure 2, plate 7, is a rough sketch-section of the mine.

Emery.

A piece of emery was picked up by me at the surface of the ground south-west of Sittampundi, but the rock was not found *in situ* any where.

Uses of corundum.

There seems to be no doubt about the practical uses to which corundum can be put as an abrading and polishing agent by armourers and lapidaries in the country. Mr. Ball surmises (Manual of the Geol. of India, pt. III), that the consumption of corundum in India must be considerable, though possibly it was larger formerly than now, as the trade of the armourer is possibly not so active now as it used to be.

Quantity of corundum available.

It is not possible without making some careful test experiments on a fairly large scale to say how much corundum, relative to the matrix, there is present. I was only able to make a few experiments with a few coolies in collecting the mineral from the surface from which an average of about ½lb. for one coolie working one day can be deduced.

Mining on a large scale.

If mining on a large scale in the bed-rock be ever undertaken and found profitable, we might expect a gradual extension of the productive area by the laying bare of rocks along the same strike, and by enlarging the present area of solid rock exposed after the surface debris has been cleared away. Hence my remarks in my letter to the Government of Madras of 25th October 1894, recommending that all facilities should be given to the leasing of the mines, so that their productiveness may be tested and data be obtained for future guidance. Inasmuch as the ordinary corundum occurs distributed in the bed-rock in the manner I have indicated, and not in veins or lodes in small and restricted places, there is no probability that the mineral will suffer a rapid exhaustion; because it is certain that the part now visible above the alluvium is only a fraction of what lies hidden beneath it.

### (2) *Paparapatti area.*

Paparapatti lies ten miles north-west of Dharmapuri town. In a direct line one and a half miles away to the west-north-west is a range of rugged hills, and between the two there stretches an alluvial plain with rock out-cropping here and there. Most of this plain is taken up with cultivation. The corundum is widely distributed over the area. As an indication of what is already known of its distribution, I have traced an outline map from the one inch Survey map and marked with crosses the places where corundum has been actually seen and found by me (Plate 9). It does not follow that this represents the limit of this corundum locality, but no information as to the extension of the areas could be obtained at the time of my visit, which was cut somewhat short by a pressing demand from the Madras Government to visit the magnesite area of the Chalk hills near Salem.

Nature of the neighbouring rock.

As in the Sittampundi area the surrounding rocks of this neighbourhood are gneisses, or gnessic rocks, with biotite as the dark mineral present. They are well foliated, with a foliation-strike approximately N. N. E.—W. S. W., that is to say, agreeing with the general trend of the hill range to the west of Paparapatti. At the actual corundum localities there is, however, no appearance of a hornblende-anorthite rock such as is the matrix at Sittampundi. The rock, a biotite-gneiss, still continues the same in character over the whole area, with the exception of a very local change, to be alluded to presently. Veins of a very coarse granite with red felspar and clear white quartz penetrate the gneiss, as well as veins of a closer-textured purplish granite. There are other intrusive veins of dark compact trap.

The matrix of the corundum.

The actual matrix of the corundum in this area is apparently an altered form of the biotite-gneiss. Elliptical (in section) or lenticular portions of the gneiss appear to have had their minerals re-arranged and altered; the dark mineral biotite segregates into an outer layer surrounding the lenticular portion, whilst the central parts of it remain more purely formed of deep flesh-coloured orthoclase (finely crystalline, and showing under the microscope a fine micro-perthitic intergrowth of possibly plagioclase) the amount of which varies with the amount of corundum present. Along with this changed appearance of the gneiss the foliation of the rock in these lenticular patches becomes much less pronounced and occasionally disappears altogether.

The size of these patches is sometimes as much as 3 or 4 feet long by six inches or a foot across where actually seen in the rock; but that they are in some parts much larger is shown by the huge lumps of the changed rock found lying on the hill-side.

On the hill-sides W. N. W. of Paparapatti the *in situ* gneiss containing these presumably altered lenticles, with corundum developed additionally, may be seen but rarely. Even then the hill-side is so completely broken up and weathered into loose, tumbled blocks that it is quite impossible to get any approach to a natural section showing the true relation between the areas of altered and unaltered rock.

The corundum itself.

The corundum here differs entirely in appearance from that of Sittampundi. It is of a deep purplish-brown or sometimes dark greenish-grey colour, and it is always regularly crystallised into hexagonal prisms with a great number of variously inclined pyramidal faces imperfectly developed, and so giving the prism an elongated barrel, or even spindle shape (see plate 7, fig. 3). These elongated prisms lie towards the central parts of the lenticular patches of changed gneiss last described, arranged in any direction, but generally with a tendency to an imperfect parallelism of their long axes with the long direction of the lenticle, which itself again is roughly parallel to the foliation of the surrounding gneiss.

The size of the corundum crystals, cleavage, etc.

In size they vary from extremely minute grains and crystals, only visible in a microscopic section, to large crystals, several inches long and from ½ to 1 inch in diameter. The characteristic, rhombohedral cleavage is easily made manifest by breaking the crystals and sometimes as in the crystal figured (fig. 3) traces of the cleavage planes are visible on the prism faces. Occasionally also a combination of the rhombohedron and prism may be seen in a single crystal.

Shell of orthoclase round the corundum.

Besides the generally altered rock in which the corundum is embedded, each crystal is immediately surrounded by a shell of more compact orthoclase, generally flesh-coloured but sometimes white, having a thickness of from $\frac{1}{4}$ to $\frac{1}{8}$ inch. When a corundum crystal has been broken out or has dropped out from the rock, the place where it lay can always be distinctly recognised by this shell which remains behind.

Arrangement of the corundum-bearing rock in lines.

It is clear from the map that the outcrops of the rock in which corundum occurs lie in successive lines, roughly parallel to the strike of the gneiss, namely, N. N. E.—S. S. W. This seems to show that the particular bed, or band, of the gneiss fruitful in corundum, is repeated by the foldings of the rocks, so that it appears several times at the surface. Should this tentative conclusion be correct, it has a practical bearing on the amount of corundum in the locality, because it makes it very probable that the lines of fruitful rock which have continued as far as shown on the map will also continue further in the same direction in either continuous or broken outcrop.

Native ways of obtaining the mineral.

There are two ways of getting the mineral here corresponding to the case of Sittampundi, *viz.*, (1) by working the bed-rock and (2) by digging in the talus of débris at the foot of the hills and slopes. No extensive working of the bed-rock has been practised; but the richer lumps have been broken up, when not too hard or too large for demolition by hand. Numerous shallow pits in the débris and half-decomposed rock have been made. In general, it may be said that the mineral is gathered in an unsystematic, casual way, not as a regular pursuit, but only during the hot weather or at times when the soil from an agricultural point of view requires no attention; also during times of scarcity. A good deal is also gathered at ploughing times and at any time, especially after rain, by being picked up when met with without special search. By these means at certain times the mineral is accumulated and sold in the market as a regular article of commerce. Merchants from Madras and Bombay, it is said, buy large quantities of it at intervals when the local collections have accumulated.

Working on a large scale systematically.

As in the case of Sittampundi, it is impossible to say whether working the mineral systematically would pay. Such a question can only be decided by actual experiment carried on in such a way that the correct average percentage of corundum obtainable from a given amount of rock may be deduced. Towards the south-west of the corundum-bearing area there is a stream of water which is said to be perennial. This could be turned to account in sifting the more finely distributed particles of corundum in the matrix after breaking up and gentle pounding. These minute grains at present over-looked are as valuable as, or possibly more so, than the larger fragments, volume for volume; inasmuch as the corundum must first be reduced to the granular form before it can be used as an abrading agent.

Conclusion.

On the whole this area near Paparapatti is a decidedly promising one. The amount of corundum present in the rock appears to be sometimes considerable, and the area of known outcrops is a large one.

### (3) *Rengopuram.*

Locality limited.

So far as I know personally, and also by report, this locality is an isolated and limited one. At the same time it should be remembered that negative evidence goes for very little in such a matter as the recognizing of small pieces of corundum, and especially in uncultivated forest land, where the soil is never disturbed.

The actual place of the corundum is two miles N. by E. of Rengopuram, a village on the outskirts of the forest land near Penagaram.

Two pits.

Here are to be seen two pits a few yards apart. The newer of the two is about 15 feet long by 8 feet broad, and 5—8 feet deep, and is sunk through a rock composed of alternate layers of a felspathic rock and a hornblende gneiss. I could find no corundum in the rock itself although I made a careful and prolonged search. The villagers and servants with me were equally unsuccessful. The mineral was, however, abundant in the surface débris overlying the edges of the mine. It is possible that this surface material may have come from a more distant point by a movement of soil-cap down the slope. The difficulty was to account for the mine which had been carried down some distance into the bed-rock.

The corundum colour, form, etc.

The corundum here is of a greenish grey colour and is very much rounded and waterworn into holes, and even slightly honey-combed (facts supporting the belief that it came from some distance). Hexagonal short prisms were the prevailing forms which it assumed, and most of these showed a tendency to break up parallel to the basal plane, thus forming irregular plates. There is no good basal cleavage, however, the rhombohedral cleavage being the only noticeable one.

### (4) *Road from Dharmapuri to Morappur near 6th milestone.*

The first of the two localities embraced under the above heading lies one mile south of the 6th milestone from Dharmapuri, at the foot of a low hill a little west of the foot-path. The nature of the rock, and the mode of occurrence of the corundum resemble entirely those of the Paparapatti area. The exposure shows signs of having been worked within a radius of a few yards. I could not find, or hear of any other exposures of the same rock in the neighbourhood. The low hill range west of the Mukkunur range and that range itself are petrologically of different constitution. Here as before, however, negative evidence counts for very little. A band of the corundum-bearing rock may continue from this outcrop though hidden from view at present.

The other locatity is two miles north of the same milestone. There is no good exposure of the rock. A few fragments in a field alone reveal a few bits of corundum of a dark grey colour set in a very fine-grained, fissile rock almost resembling a phyllite or schist.

### (5) *Selangapalaiyam.*

Locality.

The first locality I visited in Coimbatore district was the above. The corundum occurs scattered in fragments and rolled pieces in a field extending from near Chinnanayakkanur to Selangapalaiyam.

Nature of the enclosing rock.

The solid rock of the neighbourhood is very imperfectly seen. There are no rocky masses and no quarries. So far as one can gather from fragmentary observations, the rock of the country here is a muscovite-biotite gneiss, with wavy foliation, and with veins of a coarse binary pinkish graphic granite penetrating it irregularly.

The corundum, and mode of gathering.

The fragments of corundum are of a pale greyish green colour, sometimes brown outside. It has no crystalline form, but is in irregular lumps varying in size from ½ inch to 1 and 2 inches across. Nearly all are rolled, but the rhombohedral cleavage is generally distinguishable.

The village karnam of Selangapalaiyam informed me that it was not gathered systematically, but picked up from the fields chiefly by women, during the rains. Perhaps 25 or 30 maunds were gathered annually.

### (6) *Gopichettipalaiyam.*

Locality.

This is a limited locality like the last and is simply a field, from the surface of which the mineral is gathered. The village magistrate owns the field, No. 94, which is about half a mile north of the travellers' bungalow.

Bed-rock Corundum.

The only rock seen *in situ* was a disintegrated and much altered hornblende-gneiss. The corundum is of a dark brown colour, more nearly resembling that of Paparapatti than anything else. There was a fairly large quantity of it scattered over the field, the few of us present easily picking up pieces of the size of walnuts. Old picked-over heaps of rubbish lined the edge of the field. The Revenue Inspector informed me that this was the only field near in which the mineral was found; that a contractor from Madras came annually and took away all the corundum he could find; that the latter employed 30 or 40 coolie women who worked for three months last year (1894) and collected altogether two large cart-loads; that each woman could collect ½ to 1 Madras measure (= Rs. 80 weight) every day.

This field struck me as being singularly productive. The rock beneath is probably very rich.

### (7) *Karutapalaiyam.*

Locality.

The above village lies about two miles W. N. W. of Sivamallai, a prominent temple-crowned hill in the Kangyam taluk. Between the village and the hill there stretches a row of six or seven small rocky hillocks composed of the same gneiss as the hill itself. The hillocks in fact are structurally a W. N. W. continuation of the Sivamallai mass.

The neighbouring rocks.

Two rocks of different composition and structure are connected with the appearance of corundum at this place. The one is the pale grey gneiss of the Sivamallai hill, and the other a coarse granite intruded as veins into the gneiss.

The former is a very felspathic rock which in appearance resembles the anorthite rock of Sittampundi. It is composed almost wholly of plagioclase felspar and microcline in a granular condition. A small quantity of biotite or of hornblende and iron-oxide, with another minute mineral in small octahedra, zircon (?), occur as accessories. The last was brought to me as corundum by some of the Sivamallai villagers.

The whole rock weathers into large pale ochre-coloured blocks forming small tors.

Along the northern foot of these hillocks, between Karutapallaiyam and the Tiruppur-Kangyam road and extending for a distance of one mile, there are a series of holes and trenches made by the owners of the lands, which reveal the coarse granite alluded to above. It is a dark red, white, and black non-foliated rock, composed of red or deep flesh-coloured felspar which is a form of orthoclase with minute intergrowths of probably plagioclase, quartz, in sometimes very clear lumps, and biotite in large nests of small plates.

The corundum occurring in the coarse granite.

It is in this extremely coarse red granite that the corundum is found as large, well-preserved, six-sided crystals of a dark or light greenish-grey colour. The mineral appears in this completely unaltered rock as if it were a normal mineralogical constituent, or at least accessory, of the granite. It possesses no shell of any other mineral as in the case of the Sittampundi and other localities where the corundum is found in its matrix. There is nothing to suggest in this case that the corundum was formed subsequently to the matrix in which it lies; nothing to suggest a secondary origin for it.

This area is still under investigation, but in the meanwhile it is noteworthy that corundum is dug chiefly in the granite along the line of contact (or very near it) with the gneiss.

This is not the place to introduce theories; but should the mineral be afterwards shown to be a contact phenomenon, then its presence in the gneiss at Sittampundi as a secondary mineral, and its presence in the granite of Sivamallai as one of the same age as its matrix, would be explained.

Mining the corundum: numerous holes and trenches.

The mining or digging out of the corundum near Karutapallaiyam is quite an active industry (1895) on a small scale. The fields on the northern side of the row of rocky hillocks of waste land have been taken up, not for the purpose of cultivation, but for corundum mining. There are a number of irregular holes and some few regular trenches, the latter following W. by N.—E. by S. (the direction of strike of the gneiss and of the intrusive veins of the granite) or at right angles to this direction. One of these was 30 yards long, 2 yards wide, and 20 feet deep. Another trench was dug along a direction N. E. by E. for 15 yards. It was 20 feet deep and 2 yards wide, and it followed the junction of the granite with the gneiss which here dipped 60° N.W. The largest and most productive working was close to the village of Karutapallaiyam. Here were obtained some very large crystals of corundum 6—8 inches across. I was shown a basketful of the mineral weighing about 14 seers (28 lbs.) gathered during the day of eight hours by four men, their wives and little children.

A past generation are reported to have made a very good thing out of the corundum of this place, when the stuff sold for Rs. 40 per podi = 192 Madras measures.

Now, I was told, only Rs. 30 would be obtained for the same amount; I cannot say how much confidence is to be placed in these figures.

On the whole I think this locality is perhaps the most promising that I have so far seen. It is the only one I saw in private land that was in active working.

Other localities near this place.

At Padyur, Shigrispalaiyam and Kundyankovil in the vicinity the mineral is reported. They will be visited in due course.

SUMMARY AND GENERAL REMARKS.

Varied matrix of the corundum.

From the preceding account, it is clear that the corundum deposits of Salem and Coimbatore, so far as they have been at present examined, are not confined to one well-marked stratum of rock, of a constant composition and definite horizon. The matrix may be, as we have seen, (1) anorthite gneiss, (2) orthoclase gneiss, (3) a fine-grained schist, (4) a coarse graphic granite.

Thus the nature of the bed-rock of any area would not be a guide as to whether corundum might be found there or not.

It seems possible, however, that the presence in or near of a coarse granite, intrusive among the bed-rock, does represent a condition without which corundum fails to appear. Further discussion of this point is reserved at present.

Mode of distribution of the mineral in its various matrices.

A scattered distribution.

Throughout the seven areas already examined the mode of distribution of the mineral in the matrix is generally the same, that is to say it is a scattered distribution; the crystals, lumps, or grains are dispersed at intervals through the rock-like plums in a pudding, or porphyritic crystals in an igneous rock. The particulars of this distribution in the various cases under notice are of practical importance. (1) The richness of the rock varies within certain limits (which cannot be obtained without a prolonged practical test. (2) The presence or absence of a shell of a softer mineral, *e.g.*, calcite round the corundum, determines the ease or otherwise with which it can be extracted pure from the rock. For instance the Sittampundi rock is poorer than the Karutapallaiyam rock, but the former can be got out nearly pure whilst a heap of the latter is generally half felspar.

No beds of massive corundum as at Rewah.

Nowhere in the areas that I have seen does the mineral become massive and aggregated into layers or beds as in the well-known Rewah deposits of Pipra, described in 1872—1873 by Mallet (*Records G. S. of India*, vol. V., p. 20, and vol. VI., p. 43), where a bed of several yards thick (maximum thirty yards) is traceable for ½ mile.

As all corundum must be reduced to a granular coarse powder before it can be used by lapidaries, etc., it is open to question whether a scattered distribution or a massive occurrence is the more easily manipulated form. Massive corundum would certainly present difficulties to the simple form of working adopted at present by the natives of Salem and Coimbatore.

It may be mentioned that the so-called "sand vein" of corundum at Culsagee and Laurel Creek, United States, which is loose and incoherent, and can be worked by the hydraulic process, is preferred to the more massive crystalline lumps, as it saves the labour of pulverizing (see Mineral Resources of U. S. by T. M. Chatard, p. 714).

At Sittampundi, rubies have been found as detailed before in this report. Sapphires are also mentioned by Newbold as having been found in the valley of the Cauvery (*Journal, Roy. Asiatic Soc.*, vol. VIII., p. 153). This is rather a wide field, and so far I have been unable to corroborate the statement.

Gem forms of corundum.

It may be mentioned, however, that the form and shape of the crystals in the Paparapatti and Karutapallaiyam areas and their mode of distribution very much resemble the like conditions under which the sapphires of Zanskar in Kashmir appear. In our area the colours differ by being of a dark greenish or reddish grey, whilst in Zanskar, they are of a bluish grey, which locally becomes a deep violet-blue (sapphire). The colouring of such minerals, depending as it does on accidental impurities in them, may easily vary. The finding of sapphires in the corundum areas of Salem and Coimbatore is therefore quite possible.

Corundum occurrences in these districts similar in appearance to that of the sapphires in Zanskar.

The mode of occurrence of the corundum in Salem and Coimbatore in rock masses which appear only at intervals above the alluvium, but which have a very extended distribution, shows that the area of productive rock is practially inexhaustible. As a petty article of commerce, therefore, so long as corundum is used in the arts, it will be worked in a desultory way. Whether it will ever rise to be an important item in the trade of the Presidency or not, depends on so many causes and conditions of demand, labour, opportunity, fashion, capital, boom, etc., that I can give no opinion thereon.

Inexhaustible supply of corundum.

## *On the occurrence of* blue Corundum *and* Kyanite *in the* Manbhum District, Bengal. *By* H. WARTH, D. SC., *Deputy Superintendent, Geological Survey of India.*

Near the village of Salbanni, four miles east-south-east of Balarampur on the Bengal Nagpur Railway, I found in October, 1895, a large vein of kyanite with blue corundum exposed in a road-cutting. The vein follows the strike of the rocks and the boundary line between the transitions and metamorphics, running a little to the south of east. This boundary is described in Ball's memoir on Manbhum and Singbhum as being formed by a fault rock of pseudomorphic, and sometimes massive, quartz, which contains much limonite and in some places copper.

The kyanite occurs with micaceous beds in coarse-grained quartz-rock, which forms here a slightly elevated broad ridge parallel and close to the boundary, about one-fourth mile to the north of the ridge of fine-grained splintery quartzite with which the transition rocks terminate.

The coarse-grained quartz-rock contains much tourmaline, rendering whole beds of the quartz banded or entirely black. Tourmaline is also abundant in the quartzite which extends about one mile further from the kyanite vein on the side of the metamorphics. These quartzites are invaded by a number of small veins of pegmatite associated with schist and dykes of hornblendic rocks. On the other side of the boundary I found the usual association slate and quartzite which constitute the transition area to the south-east of Barahabhúm. The quartzite forms at the boundary a straight ridge parallel to the strike of the rocks, running for a mile or more with a constant bearing of E. 10° S. and W. 10° N., whilst the dip is to northwards. Dioritic intrusive rocks which are abundant were seen in one case to follow the strike of the bedded rocks and even to weather and peal off in the direction of the strike.

Near the kyanite vein I also found on the surface of the ground occasional crystals of rutile. They were well developed, tetragonal combinations, sometimes half an inch in thickness, sometimes forming geniculate twins. The kyanite vein shown in the road-cutting near Salbanni is about two feet thick, and the crystals measure sometimes nine inches in length and are of a pale and sometimes variegated blue colour. They are intergrown with colourless mica and crystals of corundum. The latter crystals are usually simple tapering prisms from half an inch to three inches in thickness, and are arranged without discoverable crystallographic regularity in the kyanite. A layer of mica, one-eighth to one-fourth inch thickness, usually forms a coating between the corundum and the kyanite. The corundum is of an exquisite deep blue colour. Some of the largest crystals, one particularly of six inches length and 3℔ in weight, being of dark sapphire blue throughout. Others are blue at the margins and colourless in the centre, and in still others the colouring is irregularly distributed, a feature characteristic of real sapphires such as occur in Cashmere. Small portions of some of the blue crystals are transparent, but in the majority the transparency is destroyed by cleavage and twinning planes.

The kyanite vein was traced to a distance of three miles on either side of Salbanni. The greatest thickness of the vein was observed about one mile to the west-north-west of Salbanni near the village of Girgirdeeh. Some blocks were here exposed which were parts of a vein 40 inches thick. The blades of kyanite were vertical to the walls of the vein, and on both sides as well as in the middle there was a 2-inch layer of mica. I also observed tourmaline, but the corundum occurred only in traces.

Corundum was also observed near the village of Gobindpur, about two miles west-north-west of Salbanni. In the opposite direction I examined the section along the road from Barahabhúm direct to Purulia. Neither kyanite nor corundum however were observed, but this might be due to accidental covering by alluvium, and the whole of the boundary would have to be examined before the corundum and kyanite occurrence could be limited with certainty to the above-mentioned length of six miles.

## *On the papers by* DR. KOSSMAT[1] and DR. KURTZ,[2] *and on the ancient Geography of "Gondwána-land," by* W. T. BLANFORD, LL.D., F.R.S.

Translations of two important palæontological papers have appeared in the second and third parts respectively of the 'Records' for 1895. The first, by Dr. Franz Kossmat, deals with "the importance of the cretaceous rocks of Southern India in estimating the geographical conditions during later cretaceous times," the second, by Dr. F. Kurtz, contains an extract from "contributions to Argentine Palæophytology," and treats of "the existence of the Lower Gondwána flora in the Argentine Republic."

At the first glance it would almost appear as if the first paper had but little connection with the Geology of India, and the second paper none at all, and in one sense this is true. But there is nothing more remarkable in the history of Indian Geology for the last 30 or 40 years than the light which has been alternately shed upon India by discoveries in other countries, especially in the continental masses of the southern hemisphere, and reflected from India upon the southern continents. Dr. Kossmat's paper confirms in the strongest and most convincing manner a theory suggested by certain details of Indian cretaceous palæontology, and traced out originally by Indian Geologists, and Dr. Kurtz's discovery makes known a great extension in upper palæozoic times of the southern continent, of which India formed part, and which is widely known by an Indian name, the Gondwána land of Suess.

There are points in both papers on which a few remarks may be added. This is especially the case with Dr. Kurtz's paper, because there are other recent discoveries in South American Geology of interest to Indian Geologists. It is, however, convenient to refer to Dr. Kossmat's paper first, as it was the earlier in date, and the first remark to be made may be regarded as a criticism.

### DR. KOSSMAT'S PAPER.

Dr. Kossmat appears to have overlooked the fact that the distinction of the uppermost portion of the cretaceous system, the beds with *Nautilus danicus*, as the Ninnyur group, the original suggestion of which distinction he attributes to Mons. H. Leveillé, in 1889[3] was clearly indicated in my brother's (Mr. H. F. Blanford's) original memoir,[4] and still more distinctly in the "Manual of the Geology of India."[5] In fact M. Leveillé took all his data about the Ninnyur group from the Manual, for he expressly stated that in the ground examined by him near Pondicherry he was unable to distinguish the two groups, Ariyalur and Ninnyur, although he believed that both occurred. That the Ninnyur beds should be separated from the Ariyalur groups as a higher subdivision was, I know, my brother's decided

[1] *Records*, Vol. XXVIII, Pt. 2, p. 39.
[2] *Ibid.*, Pt. 3, p. 111.
[3] *Bull. Soc. Geol., France.*, XVIII, p. 146.
[4] *Mem., Geol. Surv., Ind.*, IV, p. 141 (1862).
[5] 1st Ed., p. 287; 2nd Ed., p. 243.

opinion, for I have often heard him speak on the subject. That the Ninnyur beds have not been more clearly distinguished in the *Palæontologia Indica* is probably due to the fact that the magnificent description of the South Indian cretaceous fossils is an unfinished work. It had always been Stoliczka's hope and expectation (as was mentioned in the Manual, 1st Ed., p. 273, foot-note), after finishing the description of the collections made by the survey, to visit the localities from which they were derived, and to study the rocks, which he had never seen on the ground. Had he done so, questions like the separation of the Ninnyur beds and the relations to each other of the Valadayur and Ariyalur beds of Pondicherry would have been decided long since. Unfortunately Dr. Stoliczka's description of the South Indian cretaceous fauna was only completed just before his departure in 1873 with the Mission to Yarkand, which proved fatal to him.

As regards the union of the Ariyalur and Valudayur beds of Pondicherry, in favour of which Dr. Kossmat expresses himself very strongly, it should not be forgotten that in the area mentioned the beds dip at low angles and are very rarely seen, being greatly concealed by surface accumulations, also that the majority of the fossils have been picked up on the surface of the ground in a way that renders it difficult, unless their origin can be determined by mineral character, to say exactly from what bed they have been derived. My brother came to the conclusion that the two groups were distinct, after a thorough examination of the ground, and pointed out (*Mem., G. S. I.*, IV, p. 155) that the Valudayur beds differed both lithologically and palæontologically from the overlying Ariyalurs, and that the latter contained pebbles derived from the former. The great advance that has taken place in the knowledge of cretaceous ammonites since my brother and Stoliczka wrote, may fully justify Dr. Kossmat's conclusion that the Valudayur beds are not of Utatur age but newer, without proving that they should be united with the overlying Ariyalur strata. It is never quite safe to reject conclusions formed on examination of rocks in the field without re-examination.

These questions, however, though of local interest, are comparatively trivial. The importance of Dr. Kossmat's paper to Geology in its truest and highest sense—to the history of the world—is due to the manner in which, by a masterly study of the distribution of ammonites and other cephalopoda, he has traced out the old coast-lines of cretaceous continents and has confirmed the opinion expressed in the Manual of 1879[1] that a land barrier must have extended in cretaceous times from India to South Africa[2] across the Indian Ocean, and that the cretaceous beds of Trichinopoly and those of the Nerbudda were on opposite sides of this barrier.

Since its first publication various discoveries have contributed to support the view just noticed. The evidence brought forward in favour of a land connection between India and South Africa, by way of the Maldives and Mascarene islands, in both newer palæozoic and mesozoic times, was strongly confirmed by Neumayr's[3]

[1] Introduction, p. XXXIX, also remarks on pp. LXVIII and LXXII, also p. 297.

[2] In the translation of Dr. Kossmat's paper, *Records*, XXVIII, p. 42, "Die Annahme einer ehemaligen Landverbindung zwischen Sudindien and Hochafrica" is represented by "the theory of the former existence of land between the south of India and the north of Africa. I would suggest that by Hochafrica Dr. Kossmat means the African highlands, not the north of Africa. There is land connection between Southern India and Northern Africa at the present day.

[3] *Denkschr. K. K. Ak. Wiss. Wien. M. N. Kl. Bd.* I (1885), p. 132, map 1.

perfectly independent evidence from jurassic data, published in 1885, and in 1890 I brought[1] forward some additional facts, mainly zoological, leading to the same conclusion. Lately a very remarkable addition to the evidence has been furnished by Admiral Wharton, Hydrographer to the Admiralty. In his Presidential address to the Section of Geography in the British Association at Oxford[2] he points out that the north-western part of the Indian Ocean is apparently cut off from the main oceanic basin by a shallow belt probably extending from the Seychelle Islands to the Maldives, it being of course understood that the Seychelles are also connected by comparatively shallow tracts with Madagascar and Africa and the Maldives with India. The isolation of the north-western basin is inferred from the warmer temperature of the deep water. It is a well-known fact that where free circulation takes place between the depths of tropical and temperate oceans and the seas of Arctic or Antarctic regions the bottom temperature is much lower than when belts of shallower water intervene to prevent the heavy cold currents of arctic derivation from flowing into any oceanic tract.

There is no more certain test of theory than independent evidence. In this case the inference from purely palæontological data that a belt of land must have connected India with South Africa in pre-tertiary times has already received some confirmation from the present distribution of animals, and now, from a totally different quarter, and from a branch of scientific enquiry entirely unconnected with biology or geology, comes this striking confirmation of the original hypothesis. It is scarcely necessary to point out that if, in cretaceous times, a land area extended from India to Africa, and if sufficient depression took place in the tertiary era to submerge the whole of the connecting tract beneath the sea, just such a comparatively shallow barrier between the depths of the main Indian Ocean and its north-western portion would probably remain, as is now indicated by the temperature of the deep water.

Another most interesting part of the evidence brought forward by Dr. Kossmat is that relative to the distinctions between the cretaceous fauna of the Atlantic coasts of America and the contemporary fauna of the Pacific, the latter, as was shewn by Stoliczka to some extent, being intimately connected with that of India. The resemblance of the cretaceous faunas in India and California, it may be remembered, is by no means confined to cephalopoda. The natural inference would appear to be that North and South America were united in cretaceous times. It is evident that the union was broken up very early in the tertiary era, for the eocene mammals of Argentina are quite different from those of the United States, and it is not improbable that temporary connections during small portions of cretaceous time between the Atlantic and Pacific, rather than persistent arms of the sea from one ocean to the other, may account for some of the occurrences of Atlantic forms on the Pacific Coast to which Dr. Kossmat refers, as in the similar case of identical upper jurassic or lower neocomian fossils (*Trigonia Smeei*, *T. ventricosa*) occurring on both sides of the Indian Peninsula. The question of the ancient Physical Geography of the great western continent is, however, of secondary importance to Indian geologists.

[1] *Quart. Jour., Geol. Soc. Proceedings*, pp. 88-99.
[2] *Rep., Brit. Assoc*, 1894, p. 706.

## DR. KURTZ'S PAPER.

Before passing on to any remarks on the discovery in Argentina, I should add that I have learned from Mr. Griesbach that important additions have been made, since the publication of Dr. Kurtz's paper, to the number of Lower Gondwána plant-fossils that have been found there. These must add greatly to the importance of the flora and can scarcely fail to throw some additional light on its affinities and perhaps on the distribution of land in upper palæozoic times.

Meantime it may be useful to recapitulate the principal facts already ascertained concerning the occurrence of plants with Gondwána affinities in South America. It was known as long since as 1876,[1] that an *Estheria*, identified with that found in the Kámthi beds at Mángli, south of Nágpur, together with certain fossil plants, regarded as of rhætic age, had been found in the Argentine Republic. The plants were the following :—

*ALGÆ*:
*Chondrites mareyesiacus*, Gein.

*FUNGI*:
*Xylonites sp. Conf. X. Zamitæ*, Göpp.

*FILICES*:
*Thinnfeldia crassinervis*, Gein.
*Th. ? tenuinervis*, Gein.
*P..chypteris stelzneriana*, Gein.
*Otopteris argentinica*, Gein.
*Hymenophyllites mendozaensis*, Gein.
*H.* sp.
*Baiera*[2] *tæniata*, Braun.
*Pecopteris tenuis*, Schouw, Brogn.
*Tæniopteris mareyesiaca*, Gein.

*CYCADEAE*:
*Pterophyllum oeynhausianum*, Göpp.

*CONIFERAE*:
*Palissya brauni*, Endl. var. minor, Gein.
*Sphænolepis rhætica*, Gein.

There were also found scales of *Semionotus* (a Ganoid fish).

Of these plants *Baiera tæniata*, *Pterophyllum œynhausianum* and *Palissya brauni* were represented as identical with European rhætic plants and *Pecopteris tenuis* with a liassic form. No species was at first identified with any form belonging to the Indian or Australian fossil flora. As regards *Estheria mangaliensis*, the discovery of which in Argentina was prominently noticed in the Records by Dr. Feistmantel,[3] no great weight can be attached to the identification of these small crustaceans, of which many closely-allied species have been described. Thus the connection between the "Rhætic" flora of Argentina and the

[1] Beitrag zur Geologie u. Palæontologie der Argentinischen Republik. Palæontologische Theil, II Abth. Ueber rhætische Pflanzen u. Thierreste in den Argentinischen Provinzen La Rioja, San Juan und Mendoza. Von Dr. H. B. Geinitz. Cassel. 1876.

[2] This genus is now regarded by many palæobotanists as a conifer allied to Gingko (*Salisburia*).

[3] *Rec. G. S. I.*, 1877, X, p. 26.

Upper Gondwana flora of India was quite insufficient at the time when the first edition of the "Manual" was published in 1879 to deserve notice.

In fact the first addition to our knowledge of the Argentine flora that had a really important bearing on its Gondwána affinities was the identification in 1880 by Nathorst of *Thinnfeldia crassinervis*, Gein. with *Pecopteris odontopteroides*, Morris, an identification confirmed by Feistmantel[1] who had already pointed out the similarity of the two forms. The importance of this fossil plant, which appears to be as widely distributed in the upper Gondwánas as *Glossopteris browniana* is in the lower, was at that time gradually attracting attention, as the same species had been found, although rarely, in India, and its occurrence had just before been noticed in the Stormberg beds of South Africa, in which it appears to be as common and characteristic as in the Hawkesbury beds of Australia and in the "Rhætic" of Argentina.

The next noteworthy contribution to our knowledge of Argentine fossil botany was by Dr. Szajnocha in 1888.[2] He described a collection from Cacheuta in the province of Mendoza containing the species below enumerated.

*Equisetaceæ.*
*Schizoneura hoerensis* ? Hisinger.
*Filices.*
*Sphenopteris elongata*, Carruthers.
*Pecopteris Schönleiniana*, Brogn.
*Neuropteris remota* ? Presl.
*Thinnfeldia odontopteroides*, Morris.
*Thinnfeldia lancifolia*, Morris.
*Tæniopteris mareysiaca*, Geinitz.
*Cardiopteris Zuberi*, n. sp.
*Cycadeæ.*
*Podozamites aff. ensis*, Nathorst.
*Podozamites schenckii*, Heer.
*Zeugophyllites elongatus*, Morris.

Besides fragments of *Pterophyllum* and *Ctenophyllum*, and *Estheria mangaliensis* in abundance.

The plants described by Geinitz were found in several localities, the beds at some of which, as Dr. Szajnocha pointed out, were perhaps of rather later date than those of Cacheuta. This, however, is not of much importance. The striking fact is that amongst the eleven species identified by Szajnocha, no less than five, *Sphenopteris elongata*, *Pecopteris schönleiniana* (*P. lobifolia* Morr.), *Thinnfeldia odontopteroides*, *T. lancifolia*, and *Zeugophyllites elongatus*, are characteristic Australian types, and that several of them occur in the upper Gondwána of India and in the Stromberg beds of South Africa.

Then, in 1888, a letter from Mr. Orville A. Derby, Director of the Geological Section of the National Museum at Rio de Janeiro, was published by Dr. Waagen,[3] who, it will be remembered, had, in the previous year, written an important paper on the Carboniferous Glacial period (*Carbone Eiszeit*), of which paper a translation appeared in the Records for 1888, p. 89. In this paper (Records, t. c., p. 129)

[1] *Pal. Ind.*, Ser. XII, vol. III, pt. 2, p. 85.

[2] Ueber fossile Pflanzenreste aus Cacheuta in der Argentinischen Republic. *Sitzungber. K. Akad. Wiss. Wien*, Math. Naturw. Cl. XCVII. Abth. 1, p. 219.

[3] *Neu. Jahrb. f. Min.*, etc. 1888, II, p. 172. Translated in *Records*, *G. S. I.*, 1889, p. 69.

Waagen stated that, so far as he was aware, South America was the only continental mass in which glacial formations had not been observed, either in carboniferous or permian deposits. Mr. Derby, however, described certain beds of carboniferous age, in the province of San Paulo in Southern Brazil, containing rolled pebbles from the size of a fist to quadruple the size of a man's head, embedded in the finest shale; in another place in the same province, near the town of Itu, isolated rounded blocks, some of them a foot and a half in diameter or more, in excessively fine sandy shale. In yet another place even larger blocks, apparently derived from shale, were seen, some of them more than a metre in diameter and consisting of gneiss, granite, and hard conglomerate all mingled together. In short, there can be very little doubt that the beds discovered by Mr. Derby exhibit the characteristic features of the Talchir boulder bed, and if the peculiar character of the latter is due to glacial agency, the same agency must have influenced the formation of the Brazilian deposit. The boulder beds of San Paulo are 300 or 400 miles north of the localities in Rio Grande do Sul, where fossil plants have been discovered, but so far as can be judged from Mr. Derby's papers the formation is the same.

And now these discoveries, one after the other, of the exceptional characters that have made the Indian, Australian and South African beds famous in the history of Geological Science, have been completed by the recognition in South America of that remarkable and characteristic flora which first drew attention to the whole question. It is curious how the typical forms of the Lower and of the Upper Gondwanas have been gradually traced in India, Australia and South Africa, how in each case a peculiar boulder bed has been found associated with them, and how every one of the same peculiar features has now been met with in South America. Not the least remarkable fact, moreover, is the peculiarly Indian facies of the Argentine flora, the association of *Neuropteridium validum*, Feistm. *Gangamopteris cyclopteroides*, Feistm., and *Noeggerathiopsis hisolpi*, Feistm., being characteristic of the Karharbari beds of Western Bengal, and one of the species *Neuropteridium validum*, not having hitherto been found in Australia or South Africa so far as I am aware.

It has long been understood that coal-bearing beds with *Lepidodendron* and other fossil plants of the ordinary northern carboniferous type occur in southern Brazil. What these plants really are will appear presently, but their existence made it far from remarkable that lower carboniferous (culm) forms should be discovered in Argentina. The latter were described by Szajnocha [1] in 1891, and some additions have recently been made by Dr. Kurtz. The principal forms belong to the genera *Archæocalamites*, *Lepidodendron*, *Rhacopteris*, *Cordaites*, and *Bodrychiopsis* and shew considerable similarity to plants from the same horizon in Australia, though not the same amount of identity as is exhibited by the Upper and Lower Gondwána fossils.

On one occasion before this the occurrence of a Lower Gondwána flora in South America appears to have been noticed. This was by Dr. A. Hettner[2] in 1891. He described the coal measures of southern Brazil, and stated that he had obtained from them fossil plants belonging to the *Glossopteris* flora.

[1] *Sitzungsb. Kais. Akad. Wiss. Wien.* Math-naturw. Cl., Vol. C, Abth. I, p. 199.
[2] *Zeitschr. d. Gesellsch. f. Erdkunde*, XXVI, pp. 91, 124.

Nearly 30 years ago, Mr. N. Plant brought from the southern parts of the province of Rio Grande do Sul, the southernmost part of Brazil, a number of fossil plants, of which three species were described by Mr. W. Carruthers[1] as :—

*Flemingites pedroanus*
*Noeggerathia obovata*
*Odontopteris plantiana.*

The plants have always been regarded as typically carboniferous, and to this, so far as geological age is concerned, there can be no objection. But quite recently Prof. R. Zeiller[2] has pointed out that, whilst the *Flemingites* is clearly a form of *Lepidodendron*, *Odontopteris plantiana* bears a certain resemblance to *Neuropteridium validum*, and *Noeggerathia obovata* offers a remarkable similarity to *Euryphyllum whittyanum*, another Karharbári fossil plant. He also adds that he has examined the specimens noticed by Dr. Hettner as pertaining to the *Glossopteris* flora, and has ascertained that they comprise *Gangamopteris cyclopteroides* var. *attenuata* associated with *Lepidophloios laricinus* and a *Lepidodendron*.

The remarkable discoveries in South America succeed each other with such rapidity that it is difficult to grasp their import. Quite recently I heard from Mr. Griesbach that Dr. Kurtz had found a *Lepidodendron* associated with the Glossopteris flora in Argentina. The same appears to be the case in southern Brazil, and strange to say the evidence has been on record since 1869, though, until Prof. Zeiller re-examined the facts, their real importance was unsuspected. It is one of the weird tricks of fate that Mr. Carruthers, who has persistently held the doctrine that the *Glossopteris* flora belongs to a much later period of the world's history than the *Lepidodendron* flora of the coal measures, should himself have been the first to describe, without knowing it, a group of fossil plants containing representatives of both and affording parts of the conclusive proof that the two co-existed.

It should not be forgotten that this discovery of the association in the same bed of the Gondwána and carboniferous flora is something very different from the curious mixture of Upper and Lower Gondwána types described some years ago by Prof. Zeiller from Tonquin,[3] because the European forms there found associated were liassic or rhætic, and some of these are commonly met with in Upper Gondwána beds.

When a large tract in a distant continent has been annexed to one of the great Empires of the world, some time elapses before the importance of the new colony is fully recognised. It is the same with our latest addition to Gondwána land. A glance at the Globe, or at a map of the South Polar area, will shew how the addition of South America up to the Tropic of Capricorn changes the general aspect of the region with which the Gondwána flora has hitherto been associated.[4]

[1] *Geol. Mag.*, 1869, p. 151, pls. V, VI.

[2] *C. R.*, Dec. 16, 1895; *C. R. Séances. Soc. Geol., France*, 1895, p. CXCVII.

[3] *Bull. Soc. Geol., France*, Ser. III, Vol. XI, p. 456.

[4] If the beds of San Paulo are really of glacial origin, it is clear that Mr. R. D. Oldham's proposal (Manual, 2nd Ed., p. 212, and references there quoted) to explain the remarkable occurrences of upper palæozoic boulder beds in India by a change in the direction of the Earth's axis and in the position of the poles must be abandoned. The subject has been treated by Neumayr (*Erdgeschichte*, Vol. ii, p. 197) who shews (of course without taking the discoveries in South America into consideration) that, assuming the most favourable position for the South Pole, the places in North-Western India, South Africa, and South-East Australia, where boulder beds are known to occur, would all be in comparatively low latitudes within 30° to 35° of the Equator. As Neumayr himself suggested a change in the direction of the

From a number of circumstances connected with the distribution of life it has for some time been suspected that connections between certain of the southern continents and the Antarctic land must have existed at times. One of the most remarkable facts in favour of this conclusion is the discovery in Argentina of remains of marsupial carnivora related to those now living in Australia, no similar forms having hitherto been detected amongst the fossil remains of the northern hemisphere.

It does not necessarily follow that the whole area in which the Gondwána flora has been discovered was part of one unbroken continental tract at the same time. There is no doubt that seeds of some plants survive transport by sea, and spores of ferns may be carried to a considerable distance by wind. At the same time it is probable that there was either actual land connection or a near approach to it, whilst there can be no question that some barrier must have interposed between the tracts in which the dominant forms were *Lepidodendron* and *Sigillaria* and the lands of the *Glossopteris* flora. The barrier may have been the Thetys of Suess,[1] that ocean of which the Mediterranean of the present day is a shrunken relic, and it is not without interest to observe that the recent re-examination of the pelagic trias fauna, by Mojsisovics, Waagen, and Diener,[2] has led to the conclusion that the outlines of the Pacific Ocean were laid down in pre-triassic times, whilst the contours of the Atlantic and Indian Oceans are of more recent dates. And here may be noted one of those curious side lights thrown upon these very interesting questions of ancient geography from a totally different source. In the same Presidential address to the Geographical Section of the British Association at Oxford, to which reference has already been made, Admiral Wharton shows how two waves caused by the eruption of Krakatoa in 1883 were noticed by a French observing party at Cape Horn, and how it was ascertained that one of the waves which came from the westward or by the Southern Pacific arrived sooner than the other which travelled by the Indian and Southern Atlantic Oceans, each wave having to pass round the Antarctic land and the distance being nearly the same in each case. It was shewn that the retardation of the western wave was probably due to the shallower water of the South Atlantic, a condition which is consistent with the hypothesis that there may have been land in that area, whilst the Southern Pacific was part of the great ocean.

The discovery, in several different parts of South America, of *Gangamopteris* and *Neuropteridium*, associated in the same beds with *Lepidodendron*, may perhaps imply that a land connection existed in newer Palæozoic times in the American area between the continent of the northern hemisphere and Gondwána land. But further information is required before this view can be accepted. If there is really a commingling of the *Lepidodendron* and *Glossopteris* flora in Southern Brazil and Argentina, several additional representations of the rich coal-measure flora of Europe and North America will assuredly be discovered in the area. At the same time it is important to note that in South America, for the first time, representatives of the two great floras are found associated in the same beds, and a final and conclusive proof afforded of their contemporaneous existence.

Earth's axis in miocene times to account for the peculiar flora of Japan, he had no prejudice against the hypothesis.

[1] *Natural Science*, March 1893, p. 183.

[2] *Sitzb. K. Akad. Wiss. Wien.* Math-natur Cl., CIV, Abth. I, p. 1302 (Dec. 1895).

## *Notes from the Geological Survey of India.*

*Gondwana rocks.*

REWAH.—The party under the superintendence of Mr. Oldham have continued the mapping of the Gondwana areas in South-East Rewah. The Talchirs, previously marked by Mr. Smith, were found near the western limit of sheet No. 476 (lat. 24°12′, long. 82°21′) to lie in a very flat synclinal, resting on an irregular surface of schists, and not more than 100 feet in thickness. Less than a mile away, beds of Upper Gondwana age were found resting directly on the granite. The occurrence of these strata in immediate contact with the granite, without the intervention of the Talchirs or Damudas, and so close to the Talchir rocks, indicates a great unconformity somewhere between the two. It remains to be determined whether this unconformity is above or below the Damuda series. Not the least interesting find in connection with the work in this area is the occurrence in the Talchir boulder-bed of smoothed and striated boulders, similar to those resulting from the action of modern glaciers. A large area has been added to the known outcrop of the Damudas, together with the determination of several seams of coal, from amongst which a fair collection of fossils has been made.

*Crystalline rocks.*

MADRAS.—Mr. Middlemiss, assisted by Mr. Smith, has largely extended the recorded occurrences of magnetite and hæmatite beds in the northern taluks of Salem and Coimbatore districts. Several new corundum localities have also been discovered in the Hosur taluk of the Salem district, which are both interesting and economically important, forming a structural continuation northwards, as anticipated in a paper in the present number of the Records (p. 43 ), of the promising outcrops near Paparapatti in the Dharmapuri taluk of the same district. The Bargur hill range in Coimbatore district was found to form one great *massif* with the hills north of Satyamangalam, and are composed of various members of the interesting hypersthene-bearing series first noticed in South India by Mr. Holland in 1892, and similar to the main masses of the Shevaroys, Nilgiris, Palnis and other large hill-masses of the Madras Presidency. The hypersthene-bearing rocks of the Bargur hills under consideration are well-foliated, having a foliation strike of NNE.——SSW., which would carry them across the Satyamangalam-Bhavani plain, the prevailing gneisses of which, however, are of a totally different composition. Although this sudden appearance of the hypersthenic series along a line making a considerable angle with their foliation-strike is at present a question unsolved, it is not without significant bearing on Mr. Holland's conclusion, as the result of a rapid tour over the Southern Presidency, that the peculiar phenomena exhibited by these rocks in the field and under the microscope can best be explained as the result of circumstances similar to those attending the intrusion and consolidation of the more generally recognised plutonic types of igneous rocks.

*1. Crystalline rocks.*

BURMA.—Mr. Hayden has recorded some interesting facts in connection with his survey of the Sagyin ruby-tract. The crystalline limestone, in which such minerals as ruby, spinel, rubellite and schorl occur, is found to be separated from the gneisses by a conglomerate composed of blocks of limestone, gneiss and quartzite. The gneiss near this junction is highly graphitic and much decomposed. In the country to the N.E. of the Sagyin hills the gneisses and quartz-rock are associated with a siliceous rock, which gradually becomes more calcareous until it passes into limestone, and this is succeeded by further siliceous bands and a rich and valuable graphite-bearing gneiss.

2. *Tertiary rocks.*—Mr. Hayden has examined the Mithwe coalfield of Upper Burma in which he finds the Tertiary shales, sandstones and conglomerates with thin seams of coal to be greatly compressed by earth-movements, as well as altered by the intrusions and outflows of a diallage-rock approaching gabbro and serpentine.

PETROLOGICAL NOTES.—Whilst classifying the collection of rocks in the Museum, Mr. Holland has found that the contemporaneous lava-flows of the Transition systems of India exhibit some interesting similarities in their microscopic characters. So far as they have been examined at present they seem to be divisible into three main groups:—

*1. Volcanic rocks of the Transitions.*

(1) Contemporaneous flows of the Dharwar system, which originally were pyroxene-plagioclase rocks; but now generally converted into epidiorites and hornblende-schists.

(2) The olivine-bearing Jootoor lava-flow of the Kadapahs.

(3) The pyroxene-plagioclase rocks with micrographic quartz, occurring as lava-flows in the Kadapahs, Gwaliors and Bijawars.

The *first group* (the Dharwar group) seems to have its corresponding series represented in the Transitions of Manbhum and Singhbhum in S.W. Bengal, and the dioritic dykes of the same area.

The *second group* forms an extremely interesting set of rocks in which olivine, enstatite, augite, biotite and plagioclase form the constituents. The plagioclase is generally in small quantity, when the rock approaches the saxonites in composition; it is the last formed mineral, growing ophitically around the ferromagnesian constituents and forming a well-defined reaction border where it comes in contact with the olivine. A beautifully clear specimen of this rock, occurring as a dyke in the crystallines, was collected by Mr. Datta in South Rewah during the season 1894-95, and Mr. Holland has found a similar rock occurring as dykes in various parts of the Madras Presidency.

The *third group* is even more interesting than the former two. The specimens are characterised by the most unusual occurrence of micrographic quartz in a pyroxene-plagioclase rock, and this character is constant, not only in various lava-flows, but in a large number of the dykes, which break through the crystalline rocks of South India, and which, from their peculiar distribution have long been suspected as the underground representatives of the Kadapah lava-flows. Whilst fully recognising the unsatisfactory nature of correlation by unsupported petrological characters, it seems likely that we have in this little-suspected form of evidence further reasons for dividing the great thickness of the Kadapah system, and separating a lower portion to be regarded as contemporaneous with the Gwalior system of the North.

It is a curious fact that in precisely similar rocks occurring as sheets in the slates of Naini Tal there is the same occurrence of micrographic quartz; but our facts so far are by no means sufficient to make any attempt at correlating the unfossiliferous rocks of the Himalayas with the great azoic systems of Peninsular India.

Besides the interest which rocks so exceptional in petrological character naturally create, the identification of the lava-flows with their underground dyke-representatives enables us to distinguish three distinct petrographical provinces, each of very ancient date, and it is the recognition of the peculiarities of contemporaneous, but widely-separated, volcanic outbursts that affords evidence in stratigraphical correlation which, in the absence of fossil remains, is by no means to be despised.

2. *Massive Minerals.*—Professor JUDD, C.B., F.R.S., has published two interesting papers in the *Mineralogical Magazine* (Vol. XI, pp. 49 and 56, 1895), in which he has described the mineralogical characters of the massive corundum and fibrolite-rock found in Mysore by Mr. Holland, and the well-known purple corundum deposit of South Rewah described by Mr. Mallet (*Records*, Vols. V and VI). The same distinguished author has also described in the same paper a peculiar fibrous schorl-rock, which was obtained by Mr. Bosworth-Smith in the Kolar gold-field and in the auriferous areas of Chota Nagpore. Large quantities of this rock have been collected by Mr. Anderson during his recent survey of the gold-bearing tracts of Chota Nagpore.

C. L. GRIESBACH,

*Director, Geological Survey of India.*

CALCUTTA;

*1st May 1896.*

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Cleavage crystals of muscovite, from the Buriakhan mine, Kurama, 6 miles from Dumcha, Hazaribagh District.

PRESENTED BY G. B. MCINTOSH,—BALMER, LAWRIE & CO., CALCUTTA.

specimens of muscovite and biotite with muscovite, from between Padong and Kalimpong, Darjiling District.

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Specimens of corundum in kyanite, and mica schist with tourmaline, in which the corundum and kyanite occur, from near Balarampur, B. N. Railway, Manbhum District.

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Two large blocks of manganese ore, from Gosalpur, Jabalpur District.

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PRESENTED BY T. WATSON,—DON, WATSON & CO., CALCUTTA.

Specimens of muscovite, beryl and coarse pegmatite, from Bendee and Umbakold, Hazaribagh District.

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BRONN, *Dr. H. G.*—Klassen und Ordnungen des Thier—Reichs. Band II, Abth. III, lief. 20—21, and III, Supplement, lief. 4—5. 8° Leipzig, 1895-1896.

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KLEIN, *Dr. H. J.*—Jahrbuch der Astronomie und Geophysik. Jahrgang VI. 8° Leipzig, 1895.

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*Part 4*.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

VOL. XIII, 1880.

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*Part 4*.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The reh soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

VOL. XIV, 1881.

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*Part 2*.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

*Part 3*.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, north-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

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*Part 2.*—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

*Part 3.*—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

*Part 4.*—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

### Vol. XVI, 1883.

*Part 1.*—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

*Part 2.*—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

*Part 3.*—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

*Part 4.*—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in the North-Western Provinces and Oudh.

### Vol. XVII, 1884.

*Part 1.*—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta parganas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

*Part 2.*—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On the re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

*Part 3.*—On the microscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Khorassan. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, South-west Khasia Hills. Additional notes on the Umaria coal-field.

*Part 4.*—On the Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and Phosphatic rocks at Musuri. Work at the Billa Surgam caves.

### Vol. XVIII, 1885.

*Part 1.*—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field-notes.

*Part 2.*—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). On the Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud volcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

*Part 3.*—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and Chandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Burma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

*Part 4.*—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th, 1885. On the Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

VOL. XIX, 1886.

*Part 1.*—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the petrological character of the Amphibolites and Quartz-Diorites of the Sutlej valley.

*Part 2.*—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive Group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

*Part 3.*—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

*Part 4.*—On the occurrence of petroleum in India. On the petroleum exploration at Khátan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Meza valley, Upper Burma.

VOL. XX, 1887.

*Part 1.*—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-Garhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

*Part 2.*—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

*Part 3.*—The retirement of Mr. Medlicott. Notice of J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

*Part 4.*—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section II. The iron industry of the western portion of the district of Raipur. Notes on Upper Burma. Boring exploration in the Chhattisgarh coal-fields. (Second notice.) Some remarks on Pressure Metamorphism, with reference to the foliation of the Himalayan Gneissose-Granite. A list and index of papers on Himalayan Geology and Microscopic Petrology, published in the preceding volumes of the Records of the Geological Survey of India.

VOL. XXI, 1888.

*Part 1.*—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of nodular stones obtained by trawling off Colombo.

*Part 2.*—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sargar Marg and Mehowgale coal-fields, Kashmir.

*Part 3.*—The Manganese Iron and Mangnnese Ores of Jabalpur. 'The Carboniferous Glacial Period.' The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region of the Lower Himalayas.

*Part 4.*—On Indian fossil vertebrates. On the geology of the North-west Himalayas. On blown-sand rock sculpture. Re-discovery of Nummulites in Zanskar. On some mica-traps from Barakar and Raniganj.

## Vol. XXII, 1889.

*Part 1.*—Annual report for 1888. The Dharwar System, the chief auriferous rock-series in South India. (Second notice.) On the Wajra Karur diamonds, and on M. Chaper's alleged discovery of diamonds in pegmatite near that place. On the generic position of the so-called Plesiosaurus Indicus. On flexible sandstone or Itacolumite, with special reference to its nature and mode of occurrence in India, and the cause of its flexibility. On Siwalik and Narbada Chelonia.

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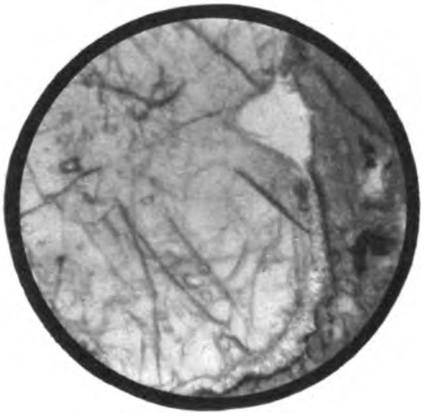

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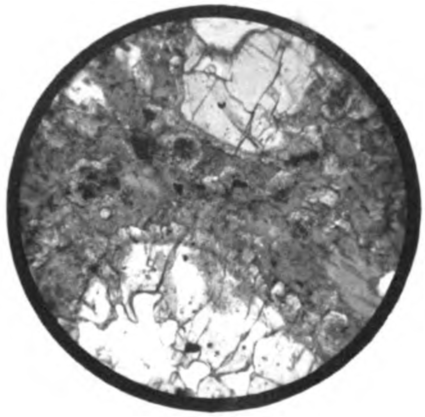

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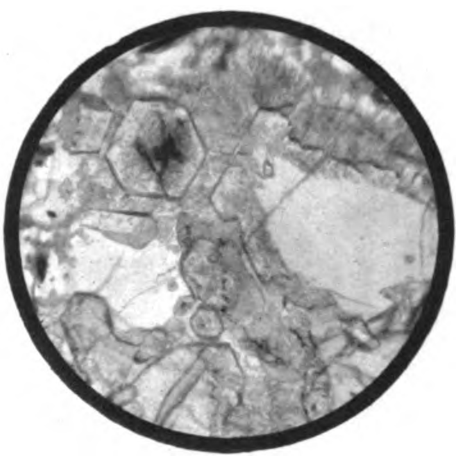

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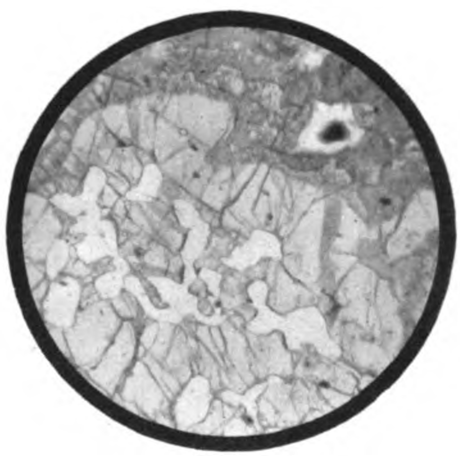

Fig. 4.

SECTIONS OF ROCKS, SHOWING THE GROWTH OF GARNETS.

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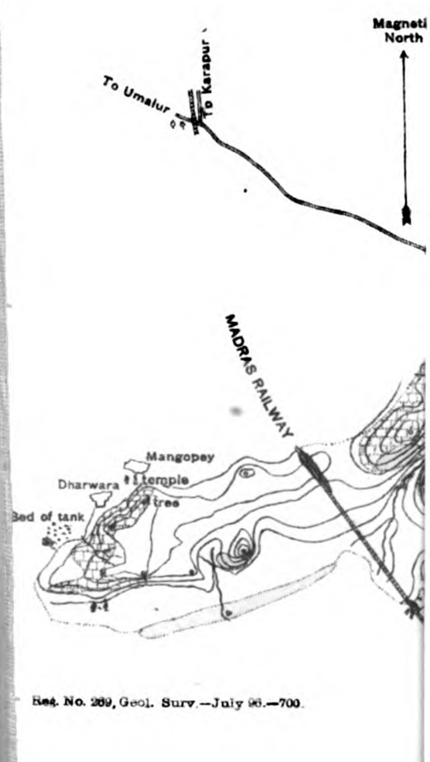


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VIEW IN THE CHALK HILLS, SHEWING MAGNESITE VEINS.

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VEINS OF MAGNESITE IN DUNITE.

C. S. Middlemiss.

Records, Vol: XXIX. Pl. V.

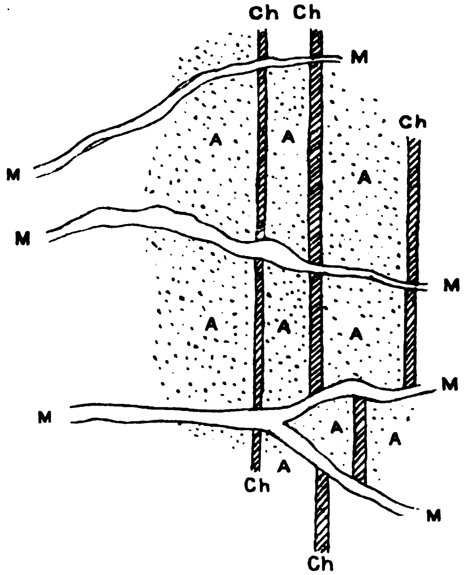
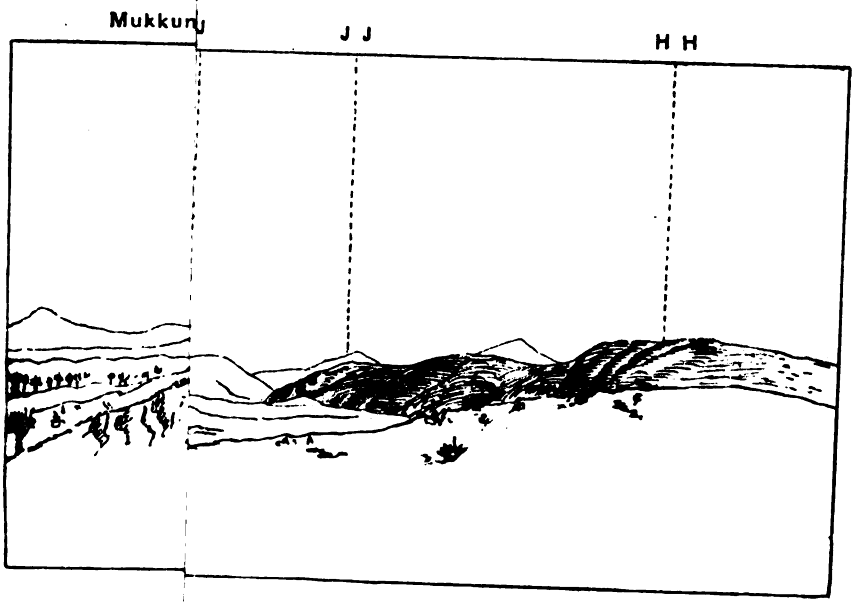


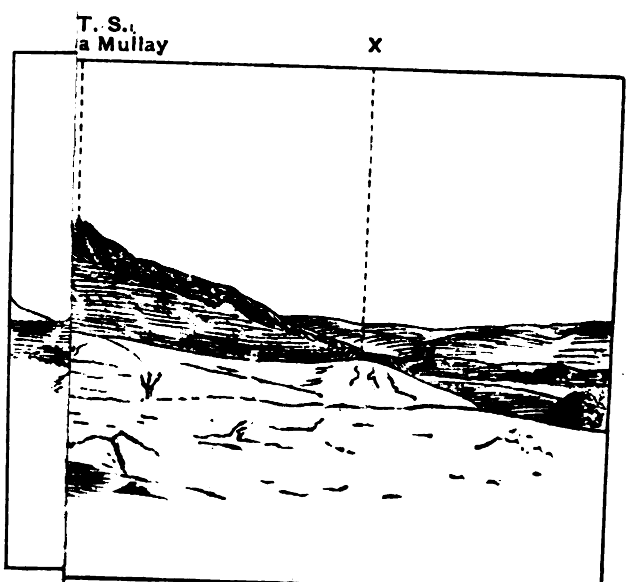

FIG. 1.

A = Serpentinised Dunite.
Ch = Veins of Chromite.
M = do.: Magnesite.

C. S. Middlemiss

Records, Vol. XXIX, Plate VI.

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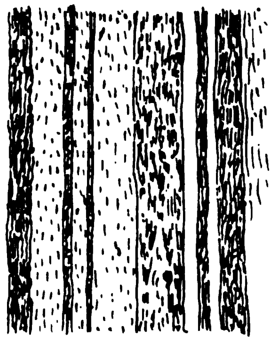

FIG. 1.

BANDED ANORTHITE HORNBLENDE GNEISS

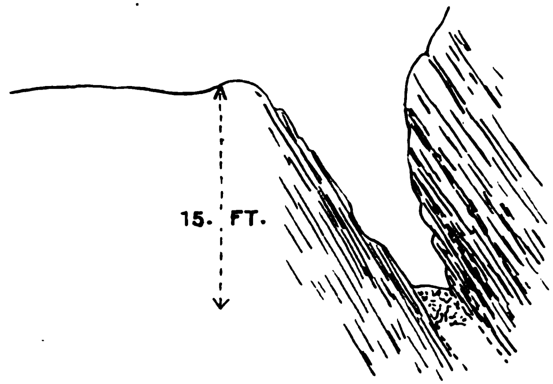


FIG. 2.

RED CORUNDUM MINE

(Section across)

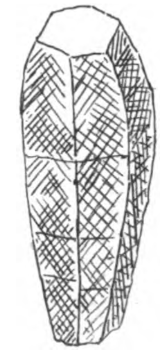

FIG. 3.

CRYSTAL OF OORUNDUM

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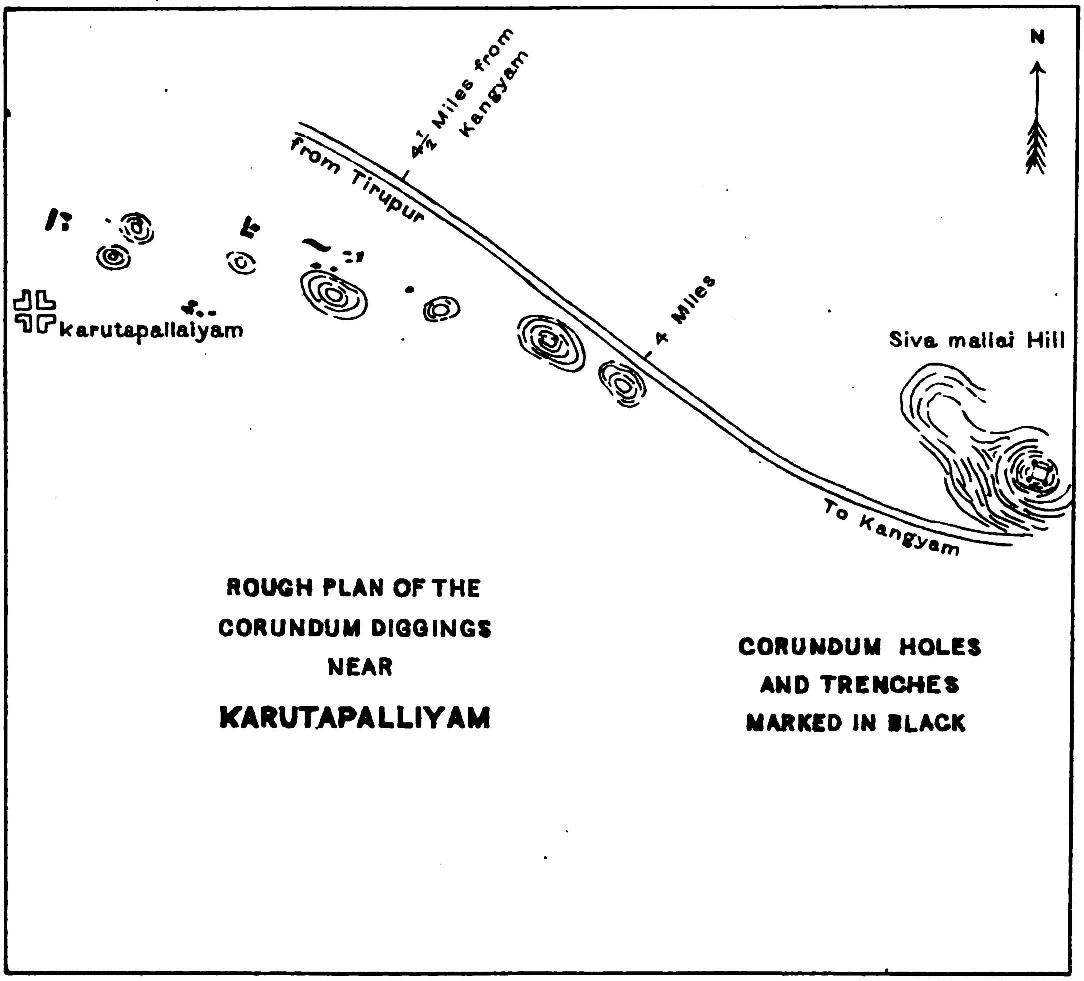

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