RECORDS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

VOL. XVI.

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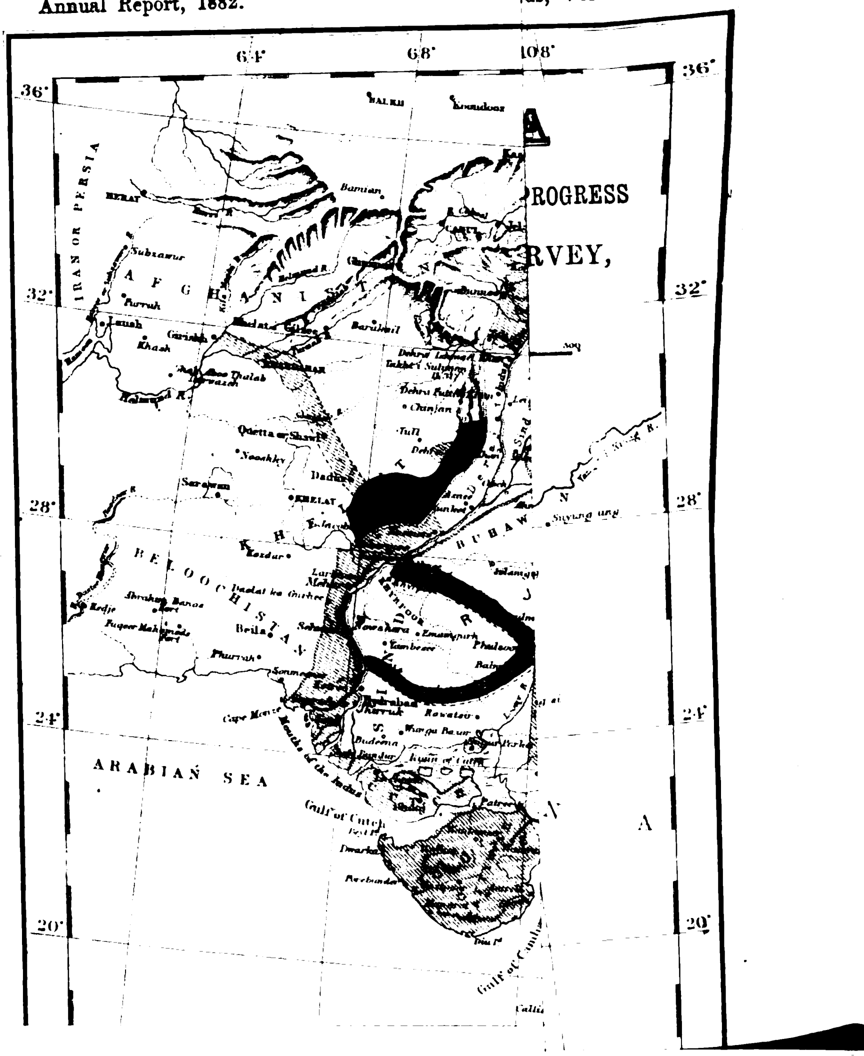
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Hydrabad
Kurrachee
ARABIAN SEA
Mouths of the Indus
Gulf of Cutch
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RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1883. [February.

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1882.

South Rewah: Umaria coal field.
Mr. Hughes.

The most important result of the past season's work has been the proving of the new coal field of Umaria at the west end of the South Rewah Gondwána basin, within 34 miles of Katni Station on the East Indian Railway. This field was mentioned in the last annual report, and Mr. Hughes had given a notice of it, in the Records for 1881 (Vol. XIV, pt. 4). The actual area of exposed coal measures is small (about 5 square miles), in an angle between the gneissic rocks and the great spread of newer Gondwána sandstone to the north-east. The outcrop of coal had been known for many years, but its appearance at the surface was not promising. All this area had been surveyed in 1872 by Mr. Hacket, without distinguishing the true coal measures; but, from what I had seen of the ground (in March 1869), on a preliminary inspection between Raniganj and Jabalpur, I was aware that further examination would be necessary before anything could be published. Mr. Hughes' success was then no chance find; he recognised a difference between the Umaria sandstone and that of the adjoining area, and he had close search made for fossils, from the evidence of which there was no longer any doubt of these rocks being on the horizon of the regular coal measures. He then at once marked sites for trial borings; and these were carried out with very commendable expedition by the local authorities. The results as to the extent, thickness, and quality of the coal are very promising. A notice of these borings was given by Mr. Hughes in the Records for August last. Railway surveys are now being made for a line from Katni to the coal field.

The field thus opened to enterprise is very extensive. Umaria is the nearest possible source of coal for the North-Western Provinces; and immediately east of it lies the immense coal field of Sohágpur, which district is also rich in agricultural produce and the natural entrepôt for the surrounding forest tracts. From Sohágpur southwards lies the least difficult line of communication between northern and southern India, into the plains of Chhattisgarh, leading down the Máhánadi valley to Cuttack, and up it over the plateau of Bastar to Vizagapatam.

Not the least important result of this new opening is the opportunity it gives for successful iron manufacture. I know of no spot in India where there is such an abundant supply of a variety of first class iron ores as in the neighbourhood of Katni. Much of the lime now used in Calcutta comes from Katni, and other requisites will probably be forthcoming, if the coal fulfils our expectations.

Mr. Hughes extended his survey of the Sohágpur coal field eastwards into Sirgujah. He reports in very encouraging terms of the services rendered by Sub-Assistant Hira Lal.

SHAHPUR COAL BORINGS.

In the annual report for 1877 (Rec. XI, p. 7) a notice was given of the explorations for coal in the Sátpura region carried on by the Central Provinces Government under my advice; and the concluding operations of those trials are given at page 97 of the Records for 1879 (Vol. XII). Most of those trials were near the northern edge of the basin close to the Narbada valley, and four of them were in interior valleys. In every case the object was to find the coal measures themselves, for the borings all started in rocks known to be of later formation, and in one case only, that close to Mohpáni, was there an outcrop of the coal measures anywhere near. None of them were successful; and it was then pointed out that the nearest ground where there was a direct prospect of coal was in the Shahpur field on the south side of the basin. The coal outcrops there had been reported on separately by three officers of the Survey (in 1859, 1866, and 1875), but none held out any promise of valuable seams. The latest of these surveys was by me (published with a map in Vol. VIII of the Records), and I then marked three sites for borings in different parts of the field, in view of future experimental exploration. These trials were taken up in February 1881, by the Public Works Department of the Central Provinces, and the last of them was closed on the 11th of October 1882 under my instructions. Two of them were made to a depth of 400 feet, and the third to 539 feet. They all passed through several coaly seams, with some thin bands of coal; but none were of sufficient promise to recommend the sinking of a trial shaft. I believe that all the coal-bearing measures were passed through in each boring, but the seams are even poorer than at their outcrops. The coal prospects in the Sátpura basin are thus for the present reduced (besides the Mohpáni mines) to the Pench valley field, of which Mr. Blanford gave a very encouraging report in 1866 (Records, Vol. XV, pt. 2, 1882). This field has naturally been left to the last on account of its comparative inaccessibility; but the engineering difficulties to be overcome are nothing like so great as those on the new Indore and Bhopal State Railways, and a line from Itarsi up the Tawa valley to the Pench would be in every respect the most favourable for crossing the Sátpura range between the Nárbada valley and Nágpur. Such a line would pass along the Shahpur coal field, and might lead to a further exploration of those measures.

ASSAM : DARANGGIRI COAL FIELD.
Mr. LaTouche.

The cretaceous coal field of Daranggiri in the Gáro hills, reported on by Mr. LaTouche (Records, Vol. XV, pt. 3) during last season, proved quite as good as was expected; the quantity is very considerable and the quality very serviceable ; but if the company now engaged in opening out the coal fields of Upper Assam achieves anything like the service it proposes, it would scarcely pay to work the much inferior coal of Daranggiri. Mr. LaTouche is now engaged in tracing the coal of the Jaintia hills eastwards, with reference to a project for a railway through North Cachar.

SOUTHERN INDIA.
Mr. Foote.

Mr. Foote was engaged in the districts of Mádura and Tinnevelly, principally in completing his map of the coastal region, and joining this work with that of Mr. King in Travancore. The principal features of the ground had been examined in previous seasons, so there is nothing particular to be noticed. A detailed account of this large area will be published during the current year. Late in the season Mr. Foote made a traverse across part of the Mysore gold fields, an account of which is published in the Records for November.

BILLA-SURGAM CAVES.

An object of much interest has long been awaiting investigation in the Madras Presidency, in the osseous cave-deposits of the Karnúl district. This interest is more than geological; at least, for a large section of the intelligent public early pre-historic man is their only link with geological studies. India has been a focus of great expectation in this matter, upon the assumed evolutional principle that the natural conditions in tropical or sub-tropical regions were most favourable for organic development, and because the earliest known civilisations had arisen in such regions. Nine years ago, in 1873, there was a momentary confirmation of those hopes, when an undoubtedly manufactured stone implement was found by Mr. Hacket in the beds of the Narbada valley containing remains of extinct varieties of mammals, deposits which had been considered by Falkoner and Dr. Oldham on palæontological grounds as of pliocene age. This 'find' (the word 'discovery' might well be reserved for the fruits of mental effort) gave fresh interest to the question of age of the Narbada osseous gravels, and from a purely geological (stratigraphical) discussion I gave reasons (Records, Vol. VI, pt. 3) showing that they are probably of late post-tertiary time—a view that has since been adopted. At the same time I ventured to impugn the *á priori* doctrine as to the birth-place of mankind, suggesting that, although the remains of the most man-like monkey might be found in tropical regions, we might rather expect to find traces of the most monkey-like man where now the least monkey-like men are found to flourish, taking mind as the characteristic. The early civilised peoples of tropical countries were probably not indigenous.

The cave-test has still to be applied. Some of the most interesting early human remains have been found in cave-deposits; and under the inspiration of the doctrine aforesaid, a party was got up a couple of years ago at private expense to explore caves in Borneo; but the success has not fulfilled the expectations. Apart the human question altogether (the special urgency of which is now rather popular than scientific), great biological interest attaches to any rich deposit of mammalian remains, and I am strongly urged to take some steps to have the Karnúl caves explored, for there can be no doubt of the information regarding them as announced by the distinguished pioneer of geology in Southern India, Captain Newbold, F.R.S. I have never failed to appreciate the importance of this matter, though I am aware of an impression abroad that I disregard palæontological interests, for which supposition there can be no better foundation than that I have never cared to dabble in matters that can only be profitably handled by experts. In October 1876, within six months of my taking charge of the Survey, I made official inquiries regarding the Billa-Surgam caves, as no notice was made of their whereabouts in the memoir and map descriptive of the Kadapa and Karnúl basin by Messrs. King and Foote. I intended that Mr. Lydekker should visit the caves and report with a view to further exploration. The Madras famine supervened, and no later opportunity offered without too great a sacrifice of current work.

Mr. Blanford makes conspicuous mention of these caves in the Manual of the Geology of India (page 381). Captain Newbold in 1844 described them as situated in latitude 15° 25′, longitude 78° 15′, which should be, as taken from a map of that date (Indian Atlas, Sheet No. 76, of 1842), about 7 miles to north-by-west from Banaganpilli. In the answer I received (dated 10th January 1877) from the Collector of Karnúl, this officer says :—" There is no place near Banaganpilli which goes by the name of Billa-Surgam and noted for any caves containing fossil stones. There is, however, a village called Bilum, 7 miles south-east of Owk in the Koilkuntla taluk, containing some caves, but the Deputy Collector who inspected them says they contain only slate stones." This position would be about 12 miles to south-by-west of Banaganpilli. Both these spots are in the Jamalmadgu limestone, of Messrs. King and Foote's classification, described by Newbold as the 'diamond limestone.'

It is most unlikely that an error of 18 miles would occur in his description of the position, but the coincidence of the similar name and the caves gives a strong presumption that Bilum is Newbold's locality, and that there is a printer's error in the statement of the latitude. He describes the mouths of the caves as from 46 to 60 feet high, falling rapidly to passages which it is necessary to traverse on hands and knees. This obscurity as to the occurrence of the caves offers some explanation of the omission of any mention of them in the published description of that ground; but I would notice the circumstance as an illustration of the condition of our work in India, the imperative object being to furnish in the first instance and as soon as possible a good general sketch of the geology of India. Had our geologists taken in 'cave-hunting' and the like, the map and manual published in 1879 might have appeared about the year 3000. There is, however, no failure of apprehension as to the supreme importance to advanced science of more detailed researches, and I hope to find an early opportunity for the exploration of the Billa-Surgam caves.

KHANDESH; CRETACEOUS: *Mr. Bose.*

Mr. Bose's second season's work in this ground has not added much to the fossil evidence upon which he indicated a correlation of the upper beds with the threefold division of the cretaceous rocks of Southern India, relegating the underlying Nimár sandstone to a lower cretaceous horizon, as mentioned in last year's annual report; nor is there any fresh observation to disturb that suggested arrangement. He gives some interesting facts showing the association of the Lameta beds with agglomerates of the trappean period; and his microscopic examination of the traps themselves has thrown new light upon the constitution of some of their subordinate varieties. When Mr. Bose was sent to that ground, it was hoped (without authority) that the new maps containing the north-western and south-western extensions of the cretaceous deposits in the Rewa-Kánta country would be available, so that the geological region might be described in one memoir. As there is even now no near prospect of those topographical maps being completed, Mr. Bose's work will be published up to date.

RAJPUTANA; *Mr. Hacket.*

In extension of his previous survey, Mr. Hacket took up work in the wilder parts of the Arvali range in southern Meywar, but in the end of January he was warned by the Political Agent that it would not be safe for him to continue in that part of the country on account of the unquiet state of the Bhils. Mr. Hacket employed the rest of the season very usefully in examining some intricate features along the Vindyan boundary to the north-east of Neemuch.

Sub-Assistant Kishen Singh has mapped a large area of the plateau of Málwa trap and Vindhyans about and north of Goona. The boundaries are, I believe, sufficiently approximate for those formations, and for present purposes; but little or no information is given regarding the rock features upon which a description of the area could be given.

KATTYWAR; *Mr. Fedden.*

Mr. Fedden surveyed a large area along the coastal region, from Bhávnágar to Madhapur, mostly of trap and post-tertiary rocks, with a remnant of tertiary beds on the western sea-margin. A few fossils were obtained from these at Piram (Perim) Island. The ossiferous conglomerates of this well-known locality are the highest beds of the section; but Mr. Fedden considers them to be closely associated with the deposits containing marine shells forming the adjoining coast, which he correlates with the Gáj horizon (of Sind). At Gogha, a little north of Piram, a boring was once made in these strata to a depth of 355 feet, stiff blue clay being the prevailing rock in the lower portion.

THE NORTH-WEST FRONTIER; *Mr. Blanford.*

The principal object of Mr. Blanford's work in the field season 1881-82 was to endeavour to trace northward the well-marked series of tertiary rocks found in Sind, and to follow the continuation of them, if possible, into the Punjab, where there is not the same clue to classification in the presence of marine beds above the eocene.

Before taking up this work, Mr. Blanford was called upon to report again upon the coal deposits to the west of Sibi; so he marched by the Bolán pass to Quetta, examining the coal seams of Mach on the road. From Quetta to Sibi he returned by the Harnai route, and visited the Sharag (or Sharigh) coal locality. From Sibi he skirted the western boundary of the Bhugti Hills, and then marched from Jacobabad to Harrand in the Punjab, through the heart of the Bhugti country. From Harrand he proceeded northward along the eastern flank of the

Sulimán range, to some distance north of Dera Gházi Khán. Here, in the middle of February, a severe attack of fever and liver compelled him to leave the field, and he shortly afterwards returned to Calcutta and was obliged to go to Europe on medical certificate.

A note, containing the results of Mr. Blanford's examination of the coal seams at Mach and Sharag was published in Part 3 of the Records for 1882. He considers the quality of the coal fair, but the quantity is insufficient for commercial purposes. The other results of his season's observations have been, besides making some important alterations in Mr. Griesbach's work about Quetta, to effect a preliminary exploration of the country from Quetta to Dera Gházi Khán, and to show that the post-eocene marine deposits of Sind do not continue north to the Punjab border. One of the unfossiliferous groups, however,—the Upper Nari,—is apparently persistent, and the uppermost system, Siwálik or Manchar, can be sub-divided, so that it is practicable to classify the rocks to a certain extent. It was found that the main chain of the Sulimán is composed of hard whitish sandstones, apparently cretaceous, overlying limestones and limestone-shales, with a few fossils belonging to the same system.

Had the work not been interrupted by illness near Dera Gházi Khán, Mr. Blanford would only have been able to examine the Sulimán range for about 30 miles further north. The whole of the area examined was beyond the British frontier; but, whereas, up to a certain point, a little north of that reached, access was practicable with the aid of the district officers and a small escort, further north the country is inhabited by Afghans, and is consequently inaccessible to Europeans. It may, consequently, be considered that the greater portion of the gap between Sind and the Punjab has been bridged over, so far as is practicable.

Some interesting fossils, mammalian and molluscan, were obtained from Lower Siwalik beds, at localities discovered by Captain Vicary nearly 40 years ago in the Bhugti hills. Mr. Blanford's descriptive memoir, with a map, will be published shortly.

MIDDLE HIMALAYA: *Mr. Griesbach.*

On the termination of his short leave in England Mr. Griesbach obtained permission to visit some places on the Continent, in order to see what process would be best for the reproduction of his views of Himalayan sections; but chiefly that he might examine certain foreign collections of fossils from the Himalaya and other parts of Asia for comparison with his own collection. On both points his trip was very serviceable; the collections made in Armenia by Staatsrath von Abich proved especially interesting, as having close relation to the fossils from certain zones in the Himalayan sections. Owing to some unforeseen official delays Mr. Griesbach was a little late in returning to India, which caused him much discomfort in having to cross the outer ranges of mountains after the rains had set in. With the Bhoteas of the frontier Mr. Griesbach experienced the usual difficulties in making arrangements for transport in the high uninhabited regions where his work principally lies. All his endeavours were in this way frustrated to cross the Mana pass, so he had to cover all the ground he could reach in that direction from the Niti pass, and then move to Nilang, where he had better success in making excursions northwards. The season was so far advanced that the Tibetan guards had left their stations beyond the passes, so this obstruction was removed, but the cold was intense.

MANIPUR: *Mr. Oldham.*

Mr. Oldham accomplished all that could be expected from his excursion with the Manipur-Burma Boundary Commission, having made a complete traverse of the main range into the great alluvial and tertiary basin of the Ningthi (? Namtonai of older maps) or Chindwin (Kyen-dwen), which seems to be a principal tributary of the Irrawadi. If there is any disappointment in the result, the credit (or discredit) of it must be set down to mistaken imagination, and I must confess to having made that mistake. I had, I may say, hoped that the Aracan Yoma of Mr. Theobald's Pegu Report would expand northwards as it approached the Himalayan massif; and that a deeper rock-section would be exposed, with perhaps a core of crystalline rocks, having their roots, even in outcrop, confluent with those of the great Himalayan elevation. The fact is just the reverse. Here, too, no fossils were found; but the rocks are with great probability identifiable with those 400 miles to the south, even to the serpentinous intrusive masses. Mr. Oldham supplemented his east-west traverse by marching from Manipur northward to Kohima in the Nága Hills, returning by the Assam Valley, and he found that newer tertiary rocks encroach more and more towards the axis of the range; so that it seems as if the older rocks may soon be altogether suppressed in that direction. It thus appears that this range is altogether a secondary one, a mere fender of the great Malayan crystalline axis. I need hardly add that I am more satisfied than if my prognostic had proved correct. Mr. Oldham's report has been ready since July, but there is some delay in procuring a map of the topographical survey of the new ground.

Publications.—Two parts of Volume XIX of the Memoirs were published during the year. The first is a description, with numerous illustrations, of the Cachar earthquake of 1869. The descriptive part was written shortly after the event by the late Dr. Oldham, from observations made by himself on the spot. The discussion of the data was supplied, and the whole edited, by Mr. R. D. Oldham. Part 2 is a descriptive catalogue of the thermal springs of India, and Part 3 (now in the Press) is a descriptive catalogue of Indian earthquakes. These also were compiled by Dr. Oldham; the data have now been revised and illustrative maps prepared by Mr. R. D. Oldham. These publications form a good starting point for seismological observation in India, preparations for which on a small scale are now in hand. Several other memoirs are well advanced towards publication, by Mr. Blanford, on the country between Quetta and Dera-Gházi-Khán; by Mr. Foote on a large area between Trichinopoli and Cape Comorin; and by Mr. Oldham on parts of Manipur and the Nága Hills.

Volume XV of the Records for 1882 contains numerous (28) papers of more or less practical importance or of scientific interest.

Five fasciculi of the Palæontologia Indica were brought out during the year:—Part 1, Vol. IV, of the Gondwána Flora by Dr. Feistmantel gives a description of the fossil-flora of the south Rewah basin. Mr. Lydekker describes the Siwálik and Narbada Equidæ in Vol. II, part 3 of the Tertiary Vertebrata series. Dr. Waagen's first fasciculus on the Brachiopoda of the Productus-limestone in the Salt-range is but a small instalment of this section of his work; but I have already received 30 plates of the sequel. The Brachiopoda form the most numerous and most intricate portion of this group of fossils, and the exhaustive study Dr. Waagen is giving of them will, I have no doubt, be gratefully acknowledged by all palæontologists. Two fasciculi on the fossil Echinoidea of Sind are contributed by Dr. Martin Duncan and Mr. Percy Sladen, to whom the Survey is greatly indebted for their voluntary assistance in this important branch of palæontological research.

Museum.—Of all field work in progress, the corresponding collections of specimens have been kept up to date. A full descriptive catalogue of the systematic series of minerals by Mr. Mallet is nearly through the Press.

Library.—The additions to the library were 1,461 volumes or parts of Volumes; 665 by purchase and 796 by donation or exchange. The titles of all these books as received are published regularly in the Quarterly Records. I think I can promise that the catalogue will be in print by the end of the present year. The preparation of it can only be carried on in the intervals of current work.

Mining Records.—One mining plan was received during the year, from the Raniganj Coal Association.

Seismological Observations.—Proposals have been made before now to establish seismometers in certain parts of India that are subject to comparatively frequent earthquakes. A chief difficulty has been, and must continue to be, to find competent and trustworthy observers at the suitable places. A small expenditure for the purpose has now been sanctioned, enough to set up some simple seismometers at a few stations in north-east Bengal and Assam where meteorological stations are already established, through which agency it is hoped some observations may be secured.

Personnel.—Mr. Blanford was obliged to take sick leave to Europe on the 25th of April, and, under medical advice, he has since been compelled to retire from the service, as no longer able to endure the exposure and fatigue required of the field geologist in India. After 27 years of so arduous a life this result is not surprising; he joined his appointment in India on the 1st of October 1855. From the beginning of his service, Mr. Blanford took a leading part in the work of the Survey; his report on the Talchir coal field is the first paper in our Memoirs, which have now extended to 19 volumes, containing numerous contributions from him. Besides his regular geological labours Mr. Blanford has done much work for the zoology of India, on which he is now a leading authority. He was twice deputed on missions out of India,—with the army to Abyssinia, and with the Seistan Boundary Commission to Persia. Of his researches in both countries he published a full account. He was twice (in 1878 and 1879) elected President of the Asiatic Society of Bengal, an honour never previously conferred on an officer of his standing. So long ago as 1874, he was elected (at his first nomination) a Fellow of the Royal Society, which is the highest non-official distinction an

Englishman can receive. In 1876, Dr. Oldham, on retirement, recommended Mr. Blanford to be his successor as Superintendent of the Geological Survey of India; of this he was only deprived by a small matter of seniority, and in recognition of his high claims Government rewarded him with a special personal remuneration above the pay of his appointment. Personally, as well as professionally, Mr. Blanford's departure will be much regretted by his colleagues in the Survey.

Mr. King was absent on furlough for the whole year. Mr. Wynne was obliged to take successive extensions of sick leave, and is still absent. Mr. Hughes obtained six months' leave on urgent private affairs on the 8th June, which has been extended in England for three months. Mr. Hacket left on furlough for two years on the 20th November. Mr. Lydekker was granted six months' leave on urgent private affairs from the 2nd March, and subsequently by the Secretary of State an extension for one year without pay. Privilege leave for various periods was granted: Mr. Mallet 42 days, Dr. Feistmantel 40 days, and Mr. Medlicott 3 months.

H. B. MEDLICOTT,

Superintendent, Geological Survey of India.

CALCUTTA,
The 23rd of January 1883.

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 1882.

AMSTERDAM.—Netherlands Colonial Department.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
" Royal Natural History Society, Netherlands.
BELFAST.—Natural History Society.
BERLIN.—German Geological Society.
" Royal Prussian Academy of Science.
BOLOGNA.—Academy of Sciences.
BOMBAY.—Meteorological Department, Western India.
BOSTON.—American Academy of Arts and Sciences.
" Society of Natural History.
BRESLAU.—Silesian Society of Natural History.
BRISTOL.—Bristol Museum.
" " Naturalists' Society.
BRUSSELS.—Geological Survey of Belgium.
" Royal Geographical Society of Belgium.
" Royal Malacological Society.
" Royal Natural History Museum of Belgium.
BUDAPEST.—Geological Institute, Hungary.
BUFFALO.—Society of Natural Sciences.
CAEN.—Linnean Society of Normandy.

CALCUTTA.—Agricultural and Horticultural Society.
,, Asiatic Society of Bengal.
,, Marine Survey.
,, Meteorological Department, Government of India.
CAMBRIDGE (MASS.).—Museum of Comparative Zoology.
CASSEL.—Society of Natural History.
CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
,, L'Association Géodésique Internationale Commission de la Norvège.
COPENHAGEN.—Royal Danish Academy.
DRESDEN.—Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
,, Royal Dublin Society.
,, Royal Irish Academy.
EDINBURGH.—Royal Scottish Society of Arts.
,, Royal Society of Edinburgh.
,, Signet Library.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Geological Society.
,, Philosophical Society.
GOTTINGEN.—Royal Society.
HALLE.—Natural History Society.
HARRISBURG.—Geological Survey of Pennsylvania.
LAUSANNE.—Vandois Society of Natural Science.
LIEGE.—Geological Society of Belgium.
LONDON.—Geological Society.
,, Iron and Steel Institute.
,, Linnean Society.
,, Royal Asiatic Society.
,, Royal Geographical Society.
,, Royal Institute of Great Britain.
,, Royal Society.
,, Society of Arts.
,, Zoological Society.
LYONS.—Museum of Natural Science.
MADISON.—Superintendent of Public Property.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
MELBOURNE.—Mining Department, Victoria.
,, Royal Society of Victoria.
MILAN.—Italian Society of Natural Science.
,, Royal Institute of Lombardy.
MONTREAL.—Geological Survey of Canada.
MOSCOW.—Imperial Society of Naturalists.
NAGPUR.—Nagpur Museum.

NEUCHATEL.—Society of Natural Sciences.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy.
„ American Journal of Science.
PARIS.—Academy of Sciences.
„ Geological Society of France.
„ Indo-Chinese Society.
„ Mining Department.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
PISA.—Society of Natural Sciences, Tuscany.
ROME.—Royal Geological Commission of Italy.
„ Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
SAINT PETERSBURG.—Imperial Academy of Sciences.
„ Imperial Russian Mineralogical Society.
SALEM (MASS.)—American Association for the Advancement of Science.
„ Essex Institute.
SHANGHAI.—North China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
SYDNEY.—Australian Museum.
„ Department of Mines, New South Wales.
„ Royal Society of New South Wales.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Science.
VENICE.—Royal Institute of Science, &c.
VIENNA.—Imperial Academy of Sciences.
„ Imperial Geological Institute.
WASHINGTON.—Smithsonian Institute.
„ United States Geographical Survey west of the 100th Meridian.
WELLINGTON.—New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ German Naturalists' Society.

The Governments of Bombay, Madras, North-Western Provinces and Oudh and the Punjab.

Chief Commissioners of Assam, British Burma, Central Provinces, and Coorg.

The Commissioner of Inland Customs.

The Residents at Hyderabad and Mysore.

The Surveyor General of India.

Departments of Finance and Commerce, Revenue and Agriculture, Foreign, Forest, and Home.

On the Genus Richthofenia, Kays, (Anomia Lawrenciana, Koninck,) *by* WILLIAM WAAGEN, PH.D., F.G.S. (*With* 2 *plates*).

IN one of the later numbers of the "Zeitschrift der Deutschen Geologischen Gesellschaft," M. E. Kayser publishes some notes on the fossils of the carboniferous limestone of Lo-ping in China, collected by Baron Richthofen, which fossils seem to be rather similar in type to those of the Productus-limestone of the Salt-range, the description of which is now in progress. He mentions one fossil in particular, the *Anomia Lawrenciana* of deKoninck, for which he proposes the generic denomination of *Richthofenia.*

M. Kayser regards this fossil as belonging to the Brachiopods, very likely somewhere near *Productus*, and this approximately agrees with what I considered it to be. I expressed this opinion in the last remarks appended to the third part of my "Salt-range Fossils" (p. 328); only I was at that time doubtful whether the fossil might not as well be considered a coral.

While preparing the description of the Brachiopods of the Salt-range Productus-limestone, I was obliged also to examine the *Anomia Lawrenciana* more in detail; and the result of this examination was so remarkable that I think it worth while to give a preliminary notice of this fossil, together with such figures as will be necessary to understand the description.

The fossil consists, as has been described already by deKoninck, of two valves, one larger and one smaller (Pl. II, *f.* 7, 8, 9). The larger valve is of a conical shape, with the apex fastened to some foreign body (Pl. I, *f.* 9). The smaller valve is flat, a little sunk into the larger one. The two valves articulate by a rather short straight hinge-line. This hinge-line, however, does not show in the outer appearance of the conical valve; it is only marked inside it. On both sides of the hinge-line, the smaller valve is cut out in a semi-circle to receive thickened parts of the shell of the larger valve. The outer side of the larger valve is rugose, provided with many concentric wrinkles, and bears a variable number of hollow, depressed, diverging, tortuous tubes, which, on the one hand, resemble the root-like appendages of some rugose corals, and, on the other, can be compared to the hollow spines of some *Producti*. The resemblance to the latter is chiefly striking because of the silky lustre of the shell-substance of which they are composed. On the whole, the shell of the fossil is dull when quite intact, and of a silky lustre when the outmost layer of the shell is worn off. Then also appears a very close punctation, similar to that occurring in the shell of *Productus*, which is barely visible to the naked eye.

The punctures are not all equal; some larger ones are disseminated irregularly between great numbers of smaller ones (Pl. I, *f.* 3). As has been mentioned above, the punctures appear only when the outermost layers of the shell are removed. The punctured part does not lie immediately below the epidermoidal shell-layer, but succeeds a very thin layer, also already exhibiting a silky lustre, which shows a very close vertical striation, and is composed of numerous very fine excavated lines (Pl. II, *f.* 8 *b*). Sometimes this striation is even visible on the outermost dull layer of the shell. Both these layers, the dull one as well as the striated one, are entirely lost in the greater number of specimens.

On the smaller (flat) valve the hollow tubes, which are so very characteristic of the larger valve, are altogether absent. When the shell-substance of this valve is perfectly preserved, it is strewn over with very numerous small papillæ which project slightly from the surface of the shell (Pl. II *f.* 9).

On its interior side this smaller valve bears a distinct, but not very high, median septum, which extends from near the margin opposite the hinge-line, to nearly the middle of the valve. Here, in most specimens, it is replaced by two parallel ridges, which in other specimens, however, are combined in one broader septum. On both sides of these ridges large, more or less rounded impressions appear, which are very strongly marked, and distinctly indented on the side nearest the hinge-line; on the side opposite to it they are less strongly marked, but seem to be also indented (Pl. I, *f.* 1*c.*; Pl. II, *f.* 2). On the hinge-line itself there are, vertical to it, two short, thick and prominent parallel ridges, not dissimilar to hinge-teeth, which are, however, about equally high through their whole extent. They are not in connection with the median septum, but are separated from it by a smooth space. They do not protrude much above the hinge-line. On the whole, they might possibly be compared to the very developed cardinal process of the smaller valve of *Productus*, but the similarity is, in fact, only a very distant one. On both sides of these ridges not a trace of dental grooves can be observed. Neither the reniform bodies, which are such prominent features in the smaller valve of *Productus*, nor distinct dental grooves exist on the sides of the short ridges on the hinge-line. Near the outer margin of this smaller valve there are thorny processes, more or less numerous, directed towards the interior of the shell, similar to those seen in some *Producti* (Pl. II, *f.* 2).

Far more complicated is the structure of the larger valve. It consists of two different parts; the lower, from the apex of the valve up to about the middle of its height, being composed of very numerous narrow water-chambers, divided off by very thin shelly partitions, and the upper forming a large hollow for the reception of the animal. The partitions in the lower part of the shell are very irregular, exactly like the partitions existing in rugose corals. They are, on the whole, convex below, and concave above; not so, however, for their whole extent, as about in their middle they are bent upwards, forming something like a columella, such as exists in many corals. This formation of a columella is caused by the presence of three vertical septa (Pl. I, *f.* 2, 4, 5), which extend from the apex of the shell, through all the partitions, up to the body chamber. By these septa a vertical triangular space is divided off within the larger valve of this fossil, the base of the triangle being formed by the hinge-line, whilst its apex lies in the middle of the shell, where the three vertical septa, which converge towards this centre from both ends of the hinge-line, unite. The median of the three vertical septa extends from the centre towards the hinge-line, without, however, ever uniting with it. All the space between the vertical septa and the hinge-line is also filled up by shelly partitions.

The animal chamber (Pl. I, *f.* 1) is tolerably large; the bottom of it is, however, situated at very different levels. The triangular space marked off by the vertical septa is much more shallow than the remainder of the chamber; but the latter also is not even, as from the centre of the shell a rounded crest extends, forming a shallow saddle, to the wall opposite the hinge-line. On each side of this crest is a deep hollow which occupies the whole lateral parts of the body chamber. The whole bottom is covered by irregular tolerably minute grooving.

The three vertical septa project into the body chamber as three high upright plates, which converge towards the centre of the shell and are highest near this centre. Their upper margins are denticulate. They do not unite, but remain somewhat apart from each other. On the other side, between them and the hinge-line, there is an ascending plane, none of the plates thus reaching the hinge-line. Of these plates or septa, the median one is the highest. The two lateral are limited on their inner side by very deep narrow grooves; from the median one, on the contrary, on both sides start some low secondary septa, which show, on the whole, a pinnate arrangement. They disappear again, however, before reaching the grooves mentioned above.

The hinge-line is quite straight, and shows only in the middle a slight rounded sinuation for the reception of the two thick terminating branches of the median septum in the smaller valve. Not a trace of any kind of teeth for articulation with the smaller valve is observable.

The inside of the outer walls of the body chamber is provided at very irregular and unequal distances, with tolerably broad and sharp, but not very prominent vertical septa, some of which begin a short distance below the upper border of the chamber, and disappear before reaching the bottom, whilst others begin lower down and then reach down to the bottom of the chamber. The upper termination of each of them bears a round foramen, which forms the entrance to the hollow tubes which can be observed on the outer side of the shell and have been mentioned above (Pl. I, fig. 2). This foramen, however, does not pierce the wall directly, but the tube descends nearly vertically and appears only in the vicinity of the apex at the outer side of the shell.

All round the upper border of the animal-chamber a thickened margin can be observed, which has some similarity to a pallial impression (Pl. I, figs. 1, 8). Of muscular scars nothing can be observed either on the bottom or on the walls of the chamber.

The substance of the shell is of a very singular structure. It is composed in the larger conical valve of three layers. The outer one is very thin, dull and compact outside, and of a silky lustre inside, provided with the characteristic striation and punctation mentioned above. The median layer, the thickest of all, though very irregular in its thickness, is composed of approximately hemispherical cells, such as can be observed in many rugose corals when the radial septa have been obliterated (Pl. I, figs. 2, 7; Pl. II, figs. 1, 5). These cells are arranged in ascending radial rows, and are interrupted at intervals by perfectly straight, radial, very pointedly conical shelly parts (Pl. II, fig. 4) which require further explanation. They begin on the outer shell-layer with a slightly broader base, and extend, in a more or less ascending direction, towards the inner portions of the shell. They are not round but polygonal. All do not with their sharply pointed ends reach the innermost shell-layers; indeed, most of them stop about half-way. Nor do all of them originate on the outer shell-layer, for some start from the wall of some cell in the median layer of the shell. They seem to be hollow and to form tubes, which apparently communicate with the larger pores, disseminated between the more minute punctation of the shell as described above; but I am not quite certain on these latter points. The hollow tubes which terminate in root-like processes as mentioned above penetrate this median part of the shell in a nearly vertical direction. The innermost layer of the shell is somewhat thicker than the outer one, but otherwise similar to it. The median and the outer layers of the shell fall off easily, and then internal casts of a strange description, which preserve the inner shell-layer, are produced (Pl. I, fig. 8).

In the flat smaller valve the median shell-layer is absent.

Under the microscope, with a magnifying power of 100 diameters and upwards, the whole shell can be seen to be composed of very thin lamellæ, which disunite for the formation of the cells and join together again in the outer layer of the shell. They are mostly vertical in the inner layer of the shell, bent nearly horizontal but irregularly outward in the median layer, and again vertically upward in the outer one.

Each lamella shows a very distinct striation vertical to its planes, caused apparently by prisms of which it is composed. These prisms are thus placed horizontally in the inner shell-layer from the inside of the shell to the outer, in the median layer vertically, and in the outer layer again horizontally.

Besides this striation fine canals can also be distinctly traced, which originate on the inner side of the shell and pierce the different lamellæ of which the shell is composed, causing thus the fine punctation of the inner shell-layer, similar to that occurring in *Productus*. The canals are, however, not simple, but distinctly and manifoldly ramified, and thus absolutely different from those occurring in *Productus*. They are more similar to the canals which pierce the shell of *Crania*. I do not think that these canals may be the work of boring *Thallophyta*. They seem to exhibit another character than the borings of those organisms. I shall, however, give detailed figures of these canals in my large work on the "Salt-range Fossils."

The fossil is gregarious in its occurrence in nature, and the individuals are often so closely packed together that the root-like appendages of one individual are fastened to the individuals around, but I never found two individuals entirely grown together.

These are the facts I have been able to ascertain relating to the structure of this fossil; it remains now to deduce from them the systematic position the fossil ought to occupy. As I have already formerly indicated, I was from the beginning doubtful whether the fossil ought rather to be considered a coral or a Brachiopod, and the views of palæontologists to whom I showed the specimens were quite equally divided between the two classes. Mons. Barrande, as well as Professor Valérin and Möller, were of opinion that this fossil was rather more related to the corals than to any other class of animals, whilst Professor Zittel and Professor Lindström seemed to be more in favour of the view which places it among the Brachiopods. The characters exhibited by the fossil are, indeed, of such a conflicting nature that it becomes extremely difficult to assign to it any place in the system.

In favour of the view which inclines to consider the fossil as a Brachiopod, the microscopic structure of the shell can be adduced above all. Its silky lustre is absolutely identical with that of the shell of *Productus*, though this lustre seems not to be effected in both cases by the same means. In the shell of *Productus* it is caused by obliquely ascending prisms, whilst in *Richthofenia* it depends apparently on the fine lamination of the shell as in *Placuna* or similar genera. Of great importance is the prismatic structure of the single laminæ of which the shell of *Richthofenia* is composed. Such a prismatic structure is, as far as I am aware, chiefly characteristic of molluscs or molluscoids. I certainly have not as yet observed this structure in corals. In *Calceola sandalina*, which seems the most kindred form among the corals, a microscopic section through the larger valve showed beautifully its construction of radial septa, but these septa exhibited all a granular, not a prismatic structure.

The punctation of the shell is also very similar to that of *Productus*, and so are the hollow root-like tubes which penetrate the shell-substance of the larger valve, and adhere to other bodies.

The smaller valve can also, on the whole, be very well compared to the same valve of *Productus*, though it remains doubtful whether the thick parallel ridges on the hinge-line of this valve in *Richthofenia* can at all be compared to a cardinal process, and whether the impressions on the valve can be taken as muscular impressions. Reniform bodies are most certainly absent.

Nevertheless, among all the Brachiopods the *Productidæ* are the only ones to which the genus *Richthofenia* might stand in any relation; other Brachiopods are certainly considerably less related to the present genus than the *Productidæ*.

But, though all the points indicated may be in favour of the Brachiopod nature of the present fossil, yet it cannot be denied that there exist also certain points of resemblance between *Richthofenia* and rugose corals. Any one who looks only for a moment at Pl. I, fig. 2, will be convinced of this similarity. The irregular partitions in the lower part of the larger valve; the columella-like part which is divided off by three vertical septa; these septa themselves, which can very well be compared with the primary and the two lateral septa of a rugose coral; the cellular structure of the shell; the septa-like ridges on the outer wall of the animal chambers which are in connection with the hollow canals which pierce the substance of the shell; and the tortuous tubes themselves into which the canals are prolonged on the outer side of the larger valve: all these characters remind one strongly of a rugose coral. There can be no doubt that on a first inspection, ignoring the silky lustre of the shell, one would far more likely be led to regard this fossil as a coral than as a Brachiopod.

There is, however, yet another character to be pointed out, which is even more conflicting than those hitherto adduced; this is the existence of something like a pallial impression round the upper margin of the larger valve, as figured in Pl. I, figs. 1*b* and 8*a*.

This character, as well as the very peculiar appearance of the partial cast as represented in Pl. I, fig. 8, and the longitudinal section, Pl. II, fig. 5, induced me to take yet another group of fossils into consideration for comparison; and these are the *Rudista* in a restricted sense, as defined by Stoliczka in his work on the cretaceous bivalves.

It is a very curious fact that with the *Rudista* the same difficulty prevailed as to their classification as with the present fossil. They had been considered by L. v. Buch as corals, by d'Orbigny as Brachiopods, and recently they are placed by most men of science in the bivalves.

The points of similarity between *Richthofenia* and the *Rudista*, chiefly *Hippurites*, are not very numerous, it is true. It is chiefly the section which may be compared. If we cut open a specimen of *Richthofenia* from the hinge-line to the opposite wall, so as just to touch the median vertical septum (Plate II, fig. 5), we get a figure very similar to that which we obtain when we cut through a *Hippurites* so as to touch the first columellar fold (the hinge-fold and the second columellar fold being left untouched), Plate II, fig. 10. The partitions presented are very similar in both cases. They are bent up in the middle to form a kind of columella, and are separated from the outer walls of the shell by a sharp line in both cases. It is due to this latter circumstance in both cases that the outer walls of the shell fall off easily, and that such strange partial internal casts are formed.

Another point of similarity consists in the direction of the prisms, of which the substance of the shell is composed. The *Rudista* differ from all the other groups of *Pelecypoda* in having the prisms of their outer shell arranged vertically, that is to say, longitudinally to the whole extension of the shell. Just the same is the case in the median shell layer of *Richthofenia*, as has been explained above.

A third point of similarity of great importance exists in the pallial impression, which is common to *Richthofenia* and the *Rudista*; and, finally, it is not quite certain that the sinuations of the large valve of *Richthofenia* on both sides of the hinge-line, which stand in so close a connection to the lateral vertical septa may not be regarded as the beginning of the infoldings of the shell, which are so very characteristic for the *Rudista*.

All these points of similarity between the *Rudista* and *Richthofenia* are important, as they are in connection with the most striking characters of both fossils; and it cannot as yet be positively denied that *Richthofenia* might be a predecessor of the *Rudista*. To say anything positive on this point is at present impossible. The distance in time between *Richthofenia*, which comes probably from the limits between the carboniferous and permian formations, and the *Rudista*, which are for the greater part upper cretaceous, is so enormous, and every connecting link is as yet absent, that a very close affinity between the palæozoic and the cretaceous forms cannot be expected, and thus it will only be possible to prove the connection between the present fossil and the *Rudista*, if futher members of such a developmental series should be discovered.

As the case now stands, it will probably be most prudent in accordance with the microscopic structure of the shell to consider the fossil as something like a

Brachiopod. As far as my opinion goes, I am convinced that *Richthofenia* is a member of a series, which, branching off somewhere from the rugose corals, has reached in *Richthofenia* a Brachiopod-like stage, and is going to terminate its career as a Pelecypod, as one of the *Rudista*. But opinion is nothing in science, and proofs are everything. I hope that these lines will give an impulse to the elucidation of the very obscure relations of the fossil which has been the object of this paper.

EXPLANATION OF PLATES.

PLATE I.

RICHTHOFENIA LAWRENCIANA, Kon. sp.

Fig. 1. Silicified specimen from the upper region of the Middle Productus-limestone of Musa Kheyl. 1*a*, view of the body chamber straight from above; 1*b*, the same slightly oblique from the front; 1*c*, interior side of the smaller valve of the same specimen: all natural size.

„ 2. Natural section through a specimen from the coral beds of the Middle Productus-limestone of Virgal; the section being parallel to the hinge-line and just touching the termination of the three vertical septa. The cells in the walls of the animal chamber are not quite correctly represented.

„ 3. Portion of the shell surface enlarged 4 to 5 times to show the punctation, in a specimen from the upper region of the Middle Productus-limestone of Musa Kheyl.

„ 4. Fragmentary specimen from the Middle Productus-limestone of the Chittawán; 4*a*, natural section through the lower part of the animal chamber, showing the section of the three upright blades; 4*b*, artificial section, very oblique, lower down through the partitioned part of the shell, showing the vertical septa and the space that is limited off by them.

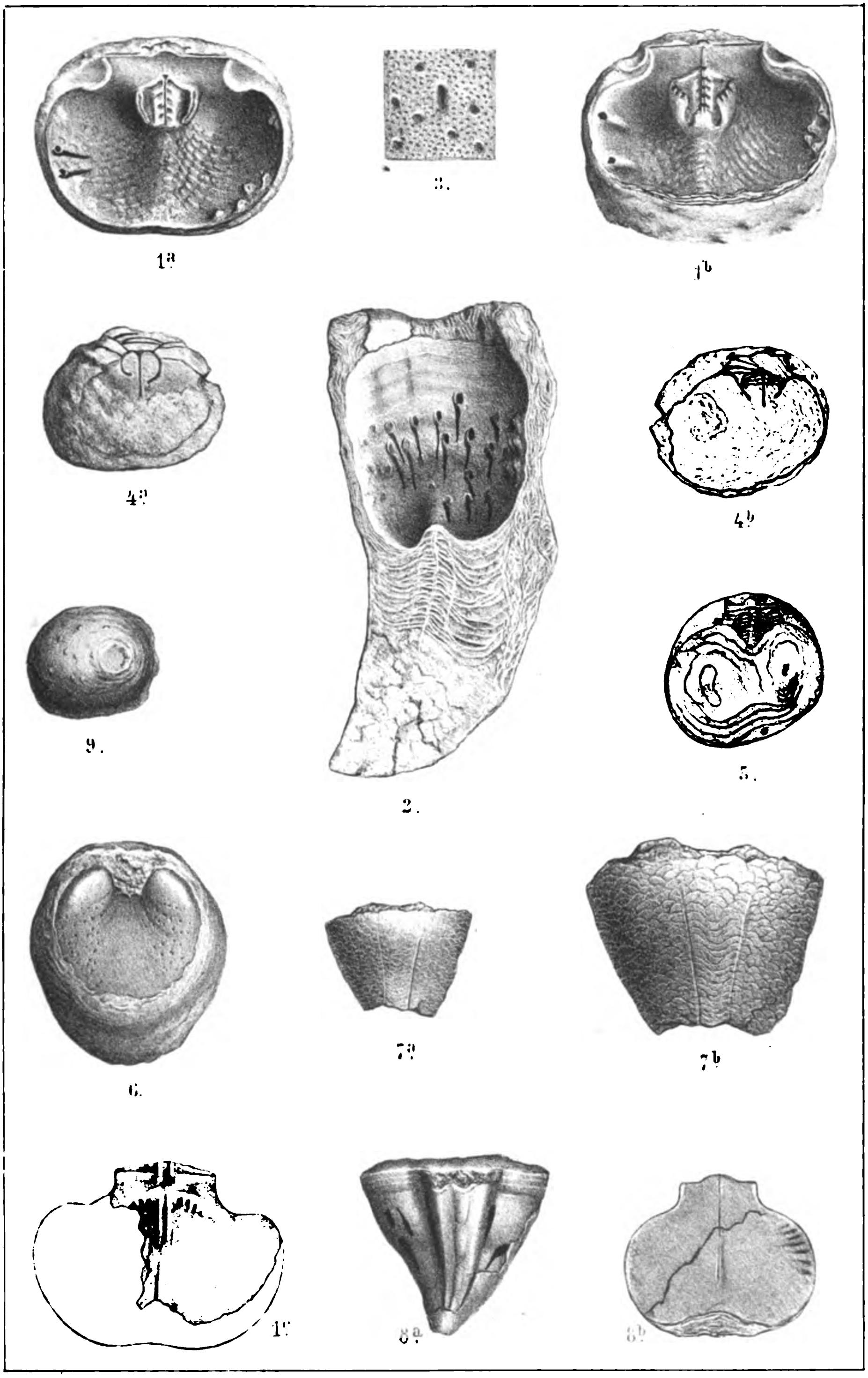
„ 5. Artificial transverse section through a specimen from the Lower Productus-limestone of Amb. The two lateral vertical septa unite in the middle.

„ 6. One of the partitions of the larger valve seen from below on a broken specimen from the Middle Productus-limestone of the Chittawán.

„ 7. Fragmentary specimen, showing the cellular structure of the median shell-layer, the outer layers having been removed by weathering; from the Middle Productus-limestone near Khura.

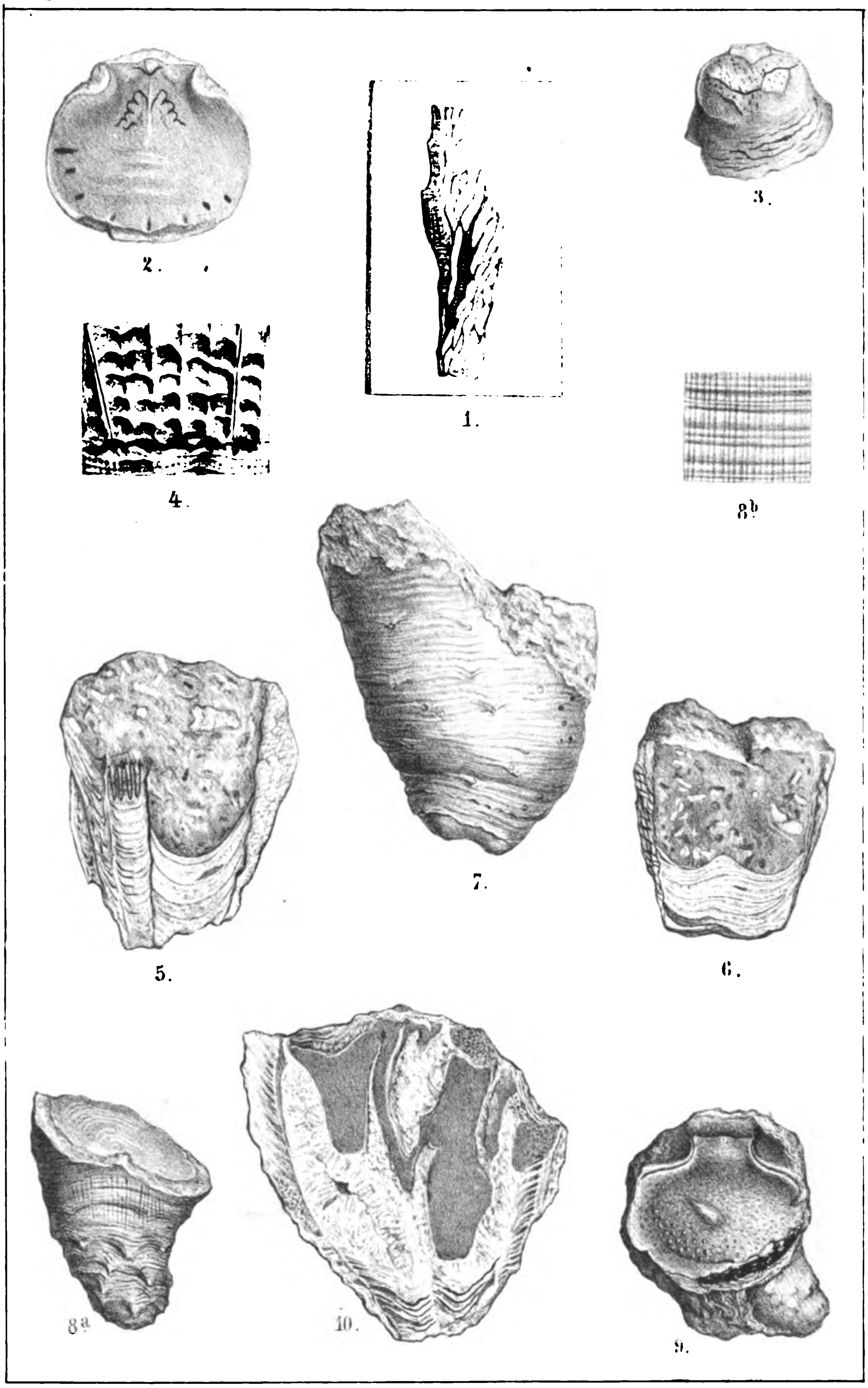
„ 8. Partial internal cast of a specimen from Musa Kheyl; *a*, view from the hinge-line; 8*b*, view from the smaller valve.

„ 9. Small specimen from the lowest beds of the Middle Productus-limestone of Katta from below, showing the point by which it has been fastened to the bottom of the sea.



A. Swoboda del. & lith.

Imp. Th. Bannwarth Vienne



A Swoboda del. & lith.

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PLATE II.

Figs. 1—9. RICHTHOFENIA LAWRENCIANA, Kon. sp.

Fig. 10. HIPPURITES, sp.

Fig. 1. Section through the shell of a specimen from the Lower Productus-limestone of Amb enlarged four times. To the right the outer, to the left the inner, side of the shell, at the lower extremity one of the shelly cones which traverse the shell substance; prisms slightly indicated.

„ 2. Internal cast of the smaller valve of a specimen from the Middle Productus-limestone of Musa Kheyl. The spines on the inside of the valve appear as deep grooves.

„ 3. Fragmentary specimen from the Middle Productus-limestone of the Chittawán, viewed from below, to show the irregularity of the partitions, the one figured being made up of five pieces.

„ 4. Fragment of the shell of a specimen from the Upper Productus-limestone (Cephalopoda bed) of Jabi, very obliquely weathered and enlarged about four times, to show the cells and the, in this case exceptionally numerous, shelly cones which are between them.

„ 5. Artificial section through a specimen from the Lower Productus-limestone of Amb. The section is vertical to the hinge-line, just missing the median vertical septum, but yet hitting at the upper end of the columella the secondary septa which are joined to the median one. Mineral matter partly intercalated between the partitions, as in all sections (Pl. I, fig. 2 ; and Pl. II, fig. 6).

„ 6. Artificial section through a specimen from the Lower Productus-limestone of Amb, the section being parallel to the hinge-line, missing the three vertical septa altogether.

„ 7. External view of a fragmentary but tolerably large specimen from the Middle Productus-limestone of the Chittawán.

„ 8. Specimen with exceptionally well preserved external surface of the larger valve, showing the longitudinal striation from the Lower Productus-limestone of Amb. 8*a*, lateral view, obliquely to the hinge-line ; 8*b*, portion of the surface enlarged.

„ 9. Specimen from the Lower Productus-limestone of Amb; view from above to show the smaller valve and the fine granulations by which this as well as the bent over parts of the larger valve is covered.

„ 10. Section through *Hippurites* sp. from the Gosau formation of the Neue Welt near Vienna, figured for comparison with fig. 5. (Property of the K. K. Geologische Reichsanstalt in Vienna.)

On the Geology of South Travancore, *by* R. BRUCE FOOTE, F.G.S., *Deputy Superintendent, Geological Survey of India.* (*With a plate and a map.*)

My colleague, Dr. King, was from various causes obliged to leave the survey of South Travancore, from Trevandrum to Cape Comorin, very unfinished, and it devolved upon me to close up the gap left, so as to join the general survey of this State with the work I had done in Tinnevelly district. The small map which accompanies this paper shows the tract omitted in Dr. King's map, appended to his two papers relating to Travancore, published last year (1882)[1]. The notes I have to offer refer mainly to the tract lying between the coast and the high road leading from Trevandrum into Tinnevelly district through the Arambuli (Aramunny) pass.

The topographical features of South Travancore differ as greatly from those of the adjacent part of South Tinnevelly as do the climates of the two districts. The flat, sandy, and often barren plains of Tinnevelly are replaced by a very broken, rugged country, out of which rise numerous hills and rocky ridges, the whole thickly covered by rich vegetation. With the exception of a couple of score of square miles immediately to the north of Cape Comorin, the whole of South Travancore lies westward of the watershed along the Southern Ghâts, which mountain range causes both the moist climate of Travancore and the dry climate of Tinnevelly, by intercepting from the latter practically the whole supply of rain brought by the south-west monsoon, and causing it to fall on their western slopes. A small tract around Cape Comorin, in the extreme south-east corner of Travancore, has a climate and shows a flora corresponding to the dry one of Tinnevelly. But within a very little distance to the westward a great change begins, and the climate and flora both assume an intermediate character, which may be traced over a tract extending from the Cape like a narrow wedge (in plan), having a base of some 20 to 25 miles along the coast, with its northern angle in the Arambuli pass. Close to the main mass of the mountains the change of climate and flora is far more abrupt, and really takes place within a distance of a very few miles, *e. g.*, near Mahendragiri, the most southerly high mass of the Ghâts (5,455 feet), where the change takes place in about 2 miles.

The country owes its shape to the erosion of the old crystalline rocks which has taken place on the most gigantic scale, proofs of which will be adduced further on. Dr. King, in his general sketch of the Travancore country, points out (p. 88) the *quasi-terraced* arrangement the country shows, descending by steps, as it were, from the mountains to the coast. This terrace arrangement is much less well marked, however, in South Travancore than further to the north-west. The several terrace steps are marked by the existence of some ridges near the coast higher than the general surface of the country further inland. The most conspicuous of these is a considerable mountain mass lying north and north-east of the old fort of Udagiri (Oodagerry).

[1] See *a.*—General sketch of the geology of Travancore State. By W. King, D. Sc., Deputy Superintendent (Madras), Geological Survey of India.

b.—The Warkilli beds and reported associated deposits at Quilon, in Travancore. By W. King, D. Sc., &c., (with a map). Records, Geological Survey of India, Vol. XV, pp. 87—102.

The real southern termination of the Southern Ghats occurs in north latitude 8° 15′, where the high mountains sink down into the Arambuli pass. Southward of the pass rises the perfectly detached Kathadi Malai, a fine rocky mass between 2,000 and 3,000 feet high, which sends off a rocky spur extending southwards with two breaks, for a distance of 7 or 8 miles, and terminating in the bold Murtawa hill, 4 miles north-west of Cape Comorin. The Cape itself consists of low gneiss rocks, backed up by a palm-grown sand-hill, about 100 feet high. A pair of very small rocky islands rise out of the sea a few hundred yards east of the Cape, but they are not shown in Atlas-sheet 63, any more than are various other rocks occurring off the coast opposite Muttum[1], Kolachel (Colachull), and Mel Madelatorai (Maila Muddalathoray), which are the culminating points of reefs formed by ridges of gneiss running parallel with the coast. At Kolachel, which is the seaport of South Travancore, the lie of the rocks is such that it would be easy to connect them by short rubble breakwaters, and thus to form a very useful little harbour in which coasting craft could easily lie up during the south-west monsoon.

It will be seen by the map that a broken band of younger rocks occupies a very great part of the tract lying between the coast and the Trevandrum-Tinnevelly high road above referred to. There can be no doubt that these younger rocks not very long since, geologically speaking, formed an unbroken belt which extended considerably further inland than at present. The denudation they have undergone has been very great, both vertically and laterally, and the remnants of them left are in various places of such trifling thickness that all traces of their former existence will soon be effaced. They show most in the western part of the area under description, where they form small plateaux, which are well marked, except to the north, on which side they lap on to the rising surface of the gneiss and thin out, or are lost sight of, in the Kabuk or pseudo-laterite formation, a rock resulting from the decomposition of ferruginous beds of gneiss. The surface of the plateaux, where not greatly eroded, is gently undulating and often supports a very dense and varied vegetation. The less compact portions of plateau surfaces are often cut into small, but very deep, rain gullies which render many places impassable for any but foot passengers.

The most striking feature in the flora of South Travancore is the immense forest of fan palms (*Borassus flabelliformis*), which covers great part of the country. The fan palms, or palmyras, attain here to much greater height than they generally do elsewhere. Trees measuring from 90 to 100 feet in height are not uncommon in places, and, with their stems greatly covered by white, or silvery, grey lichens they present a much finer appearance than the comparatively stunted specimens one is accustomed to see in the Carnatic, or on the Mysore and Deccan plateaux. Whether these Travancore trees owe any part of their greatly superior height to superior age, as compared with the palms in the great palmyra forest in South Tinnevelly, I could not make out; but the white colour of their stems, added

[1] These rocks, and especially one called the Crocodile rocks, were sources of great danger to the coasting ships, but that has been removed by the erection on the Muttum headland of a light-house just completed.

to their great height, certainly gives them a much more hoary and venerable appearance.

To the westward of the Cooletorary river the palmyra trees are less striking features in the landscape than to the eastward. Cashew nut trees (*Anacardium occidentale*) are also very largely cultivated, and attain to greater size than anywhere in the Carnatic. Jack (*Artocarpus integrifolium*) and Alexandrine laurel (*Calophyllum inophyllum*) are also very common trees in South Travancore. Coco and Areca palms are commonly planted in the sides of the numerous little narrow valleys which score the face of the country, each with a rice flat in the bottom.

The backwaters at the mouths of the several rivers, and the canals connecting them, are often thickly fringed with screw pine (*Pandanus odoratissimus*); and a large fern, *Acrostichum aureum* (Linn.), is generally very conspicuous among the smaller bushes standing in the shallow water. One of the finest displays of tropical vegetation I am acquainted with in South India may be seen to great advantage by going in a canoe up the Cooletorary river for 3 or 4 miles from its mouth at Tengapatanam (Taingupatnum). The varying effects of dense lofty palm groves, interspersed with large forest trees and fringed with *pandanus*, &c., along the water's edge, and backed by the beautiful blue outlines of Agastyamalai and other peaks of the Southern Ghâts cannot fail to delight the eye capable of appreciating a series of perfect landscapes. Near the upper end of the navigable reach the beauty of the scene is increased by the presence of great granite gneiss rocks towering up here and there in the forest on either side of the river. Two other views, specially worth seeing, should be mentioned when describing the topography of this picturesque country. The first of these is due north from the bar at Mannagudi, 4 miles west of Cape Comorin. The eye here ranges across a large sheet of fresh water, set among palms, making a glorious foreground to the mountains which rise to the north, Mahendragiri and the great mass of the Mutukulivayal plateau standing out boldly. The second view to which I wish to draw attention is to be seen from the white rock spit about 1½ mile north-eastward of Cape Comorin. From here the south end of the ghats is seen across a lovely bay, with broken rocks and surf in the immediate foreground. The bright blue waters of the bay set off the fine tints of the nearer mountains to perfection, while the noble outlines of Mahendragiri and its companion peaks form a back ground of wonderful beauty. The view on a good day far surpasses the best of the views across Bombay harbour, about which so much has been written. From the Cape itself the mountains are not seen at all, being shut out by sand-hills, topped by a forest of palmyras.

In the foreground of the view from white rock spit the most characteristic trees are umbrella trees (*Acacia planifrons*), the most typical trees of the arid Tinnevelly plains, which are seen across the bay stretching away far to the north-east. A few miles to the west of the Cape these trees become very rare or have disappeared entirely.

Very conspicuous features in the landscape of South Travancore, as seen from the deck of a vessel passing off the coast, are several patches of intensely red rock or sand standing close to the beach, but perched up at a considerable height above the water's edge. These are *teris*, or red blown sands, capping cliffs of red sandstone, both of which formations will be referred to at length further on.

The various geological formations to be found in South Travancore may, for convenience of reference, be arranged in a tabular scheme as below :—

RECENT ...	Blown sands: the red (teris), and the white (coast dunes). Soils; kankar deposits; ferruginous breccias (lateritic). Marine and estuarine beds.
TERTIARY ?	Sands and clays (Warkilli beds, ? Cuddalore sandstone.)
AZOIC ...	Gneissic series.

The Gneissic Series.

In no part of the peninsula, perhaps, is there a greater and finer display of the ancient crystalline rocks than in the Southern Gháts in their southern half, and in the great spurs and outlying masses on their western or southern side. The disposition of the beds in South Travancore, when laid down on the map, shows the existence of a great synclinal curve, probably an ellipse, the major axis of which passes through, or very near to, the great mass of Mahendragiri; while the north-western focus (if the ellipse be a complete one) will be found somewhere to the north-eastward of Allepy. I had inferred the existence of this great synclinal ellipse from studying the course of the great gneiss beds on the eastern foot and flanks of the mountains southward of Courtallum, and Mr. King's examination of the gneiss country across the Shenkotta pass and southward to Travancore independently demonstrated the existence of the central part of this huge synclinal fold. The topographical shape of the ground, as shown in Atlas-sheet 63, points strongly to the fold being a true ellipse, the extreme north-western extremity of which is probably hidden under the alluvial bed north of Allepy, while the extreme south-eastern apex lies most likely in the sea to the E-N-E of Cape Comorin. The curve of the coast from Cape Comorin north-westward to close up to Trevandrum coincides with the south side of the great synclinal, and the different ridges inland also coincide absolutely with the strike of the harder beds of the series. Several southerly dips were noted in the rocks on the coast westward of Kolachel, which looks as if the axis of an anticlinal had there been exposed, but they may possibly only represent trifling Vandyke-shaped bends or crumples, in the side of the great synclinal. To the north of the area under consideration the rocks roll over northward into a great anticlinal fold.

The true bedding of the gneiss on a large scale is extremely well displayed in the great outlying mass known as the Udagiri or "Murroovattoor" mountain. Both strike and dip are admirably seen from the travellers' bungalow at Nagar Kovil. One of the finest examples of a sheer naked wall of rock to be seen in South India is shown in the tremendous cliff forming the S. E. front of the Tiruvuna Malai, the great eastern spur of Mahendragiri. This bare precipice must be fully 2,000 feet or more in height, many hundred feet in the central part being absolutely vertical, or even overhanging a little. As might be expected, this great mass has attracted much notice; it forms the Cape Comorin of some sailors, and of Daniel's famous view of that cape, though in reality some 16 miles from the nearest point on the coast and 28 miles from the cape itself. Even the Hindu mind, generally so stolid about the beauties of landscape scenery, have connected this noble mountain with the name of Hanuman, the famous monkey god, who is said to have planted one foot on each of the two Peaks and to have jumped across the Gulf of Manar and alighted on Adam's Peak, a standing jump of 220 miles odd being a trifle for the long-tailed divinity.

Another grand precipice occurs on the south-east face of the Taduga Malai, at the western end of the Arambuli pass. The cliff-faces in both these splendid scarps coincide with great planes of jointing.

The predominant character of the gneiss rocks in this quarter is that of a well-bedded massive, quartzo-felspathic granite gneiss, with a very variable quantity of (generally black) mica and very numerous small red or pinkish garnets. This is the characteristic rock at Cape Comorin, and very generally throughout South Travancore, and Tinnevelly district as well.

Scattered grains of magnetic iron are commonly met with in the weathered rocks. No beds of magnetic iron were noted by me, but some may very likely occur, and would go far to account for the enormous quantities of black magnetite sand cast up on the beach at frequent intervals along the coast and of which the source is at present unknown, unless it has been brought by the south-westerly current prevailing during the south-west monsoon. The source of the garnets which form the crimson sand, which is of nearly equally common occurrence, is not far to seek, for it is hardly possible to find a bed of rock which does not abound in garnets. The so-called "fossil rice" found at the extreme point of land close to the cape is merely a local variation of the quartz grains set free by degradation of the rock. They assume the "rice" shape after undergoing partial trituration in the heavy surf which beats incessantly on the southern coast.

The sub-aërial decomposition of the felspatho-ferruginous varieties of the gneiss produces in the presence of much iron a pseudo-laterite rock very largely developed over the gneissic area described by Dr. King in his Sketch of the Geology of Travancore under the name of lateritised gneiss, a rock which is popularly called laterite in Travancore and kabuk in Ceylon. In numberless places this peculiar decomposition of the gneiss, which is pre-eminently characteristic of very moist climates, has altered the rock *in situ* to variable, but often considerable, depths, and the original quartz laminæ of the gneiss remain in their pristine position, and often to all appearance unaltered, enclosed in a ferruginous argillaceous mass formed by the alteration of the original felspar, mica, garnets, and magnetic iron. The colour of this generally soft mass varies exceedingly, from pale whitish pink to purple, red and many shades of reddish brown and brown according to the percentage of iron and the degree of oxidation the iron has undergone. The bright colours are seen in the freshly exposed kabuk or pseudo-laterite, but the mass becomes darker and mostly much harder as the hæmatite is converted into limonite by hydration, and more ferruginous matter is deposited, as very frequently happens, by infiltration. The pseudo-laterite formed by accumulation of decomposing argillo-ferruginous materials derived from distant points is to be distinguished generally by the absence of the quartz laminæ as such. The quartz grains are generally much smaller, and are scattered generally through the whole mass of new formed rock. One excellent example of the pseudo-laterite formed by the decomposition *in situ* is to be seen in a steep bank in the zoological gardens in Trevandrum, close to the Tapirs' den. Equally good examples are very common in many of the cuttings along the high road east of Trevandrum.

The washed-down form of pseudo-laterite often forms a rock intermediate in character between a true sub-aërial deposit and a true sedimentary one, and consequently by no means easy to classify properly. In fact, in a country subject to such a tremendous rainfall, the sub-aërial rocks must, here and there, graduate into sedimentary ones through a form which may be called "pluvio-detrital." Such pluvio-detrital forms occur very largely in South Travancore, but it is impossible in most cases to separate them from the true sedimentary formations they are in contact with.

The Warkilli or Cuddalore Sandstone Series.

The Cuddalore sandstone series, first distinguished on stratigraphical grounds as a separate geological group by Mr. H. F. Blanford, were by him supposed to be very probably of tertiary age. In the absence of sufficient palæontological evidence it was impossible to assign any more approximate position to these rocks, the silicified exogenous tree stems found at Tiruva-Karai, near Pondicherry, not being deemed of sufficient importance.

Other similar sandstone formations subsequently examined near Madras, in Rajahmundry district and on the Travancore coast near Quilon could, in the absence of all fossils, be assigned by myself and Dr. King only in a provisional way to the age of the Cuddalore rocks. Lithologically and petrologically these several sets of sandstones and associated clays, &c., show great resemblance, and their relative positions on or near the existing coast lines further justified their being provisionally associated, though separated by such great distances.

A very careful examination of the beds near Quilon by Dr. King, who had the advantage of seeing the fresh cutting made through plateaux of these rocks in connection with the new tunnel at Warkilli has unfortunately thrown no positive light on their true geological position. The vegetable remains associated with the lignite beds at base of the series proved insufficient to allow of determination of their own character, and consequently most unsuitable to assist in settling the homotaxy of the strata they occurred in. The sedimentary beds forming the belt of small plateaux fringing the coast of South Travancore must, on petrological grounds, be unhesitatingly regarded as extensions of the Quilon beds, or *Warkilli beds* of Dr. King. None of these formations which I traced from Villenjam, 9 miles south-east of Trevandrum, down to Cape Comorin, afforded the faintest trace of an organic body: thus, no light was thrown on the question of the geological age or homotaxy, but somewhat similar sandstones and grits are found on the Tinnevelly side of the extreme south end of the Ghâts range, and in a coarse gritty sandstone, much resembling some of the beds in Travancore, a bed of clay is intercalated, in which occur numerous specimens of *Arca rugosa* and a *Cytherea* of a living species. The locality where these fossils of recent species were found occurs on the right bank of the Nambi-Ar, about 2 miles above its mouth and a few hundred yards from the bank of the main stream. All the sub-fossil shells I found here are of living species; hence the deposits enclosing them cannot be regarded as tertiary; and if the agreement of these Nambi-Ar beds with the Warkilli and South Travancore beds on the one hand, and the Cuddalore, Madras, and Rajahmundry beds, be assumed, as they must be on petrological grounds, the Cuddalore sandstones and their equivalents elsewhere must be accepted as of post-tertiary age. As far as it goes, the evidence is clear and distinct; but more evidence is required as to the age of some of the intermediate connecting beds, such as those south and east of Kudan-Kulam.

The typical section of the Warkilli rocks near Quilon, given by Dr. King, shows the following series:—

	Feet.
Laterite	30 to 40
Sands and sandy clays or lithomarge	58
Alum clays	25
Lignite beds	7 to 15
Sands	
TOTAL ...	120 to 138

with which we may compare the series seen in the fine section formed by the beautiful cliffs in Karruchel bay, 11 miles south-east of Trevandrum.

The section here exposed shows the following series of formations:—

	Feet.
4. Soil—dark red, sandy loam, lateritic at base	8 to 10
3. Sandstone—hard, gritty, purplish or blackish	?
2. Sandstone—gritty, rather soft, false bedded, often clayey in parts (lithomargic), variegated; in colour red, reddish-brown, purplish-white-yellow	40 to 50
1. Sandstone—gritty, rather soft, false-bedded, red, purple, pink, white, variegated; shows many white clay galls producing a conglomeratic appearance in section	40
Base not seen, hidden by sandy beach.	

The total thickness of these beds I estimated at about 100 feet; the upper part is obscure, from pluvial action washing down the red soil over the dark grits. The middle and lower parts of the section are extremely distinct, and the colouring of the beds very vivid and beautiful; but the beds are by no means sharply defined.

The beds dip north-easterly (inland), and from the slope of the ground on the top of the cliff the angle of dip may be inferred to be from 25° to 30°. Further inland, near Pinnacolum, the dark gritty sandstones lie horizontally, at a considerably lower level than at the top of the Karruchel cliffs, but rise again eastward. The middle gritty series is exposed along the western side of the Karruchel lagoon, but is highly lateritised by weather action. Three miles, or so, to the north of the lagoon, purplish gritty beds show strongly and form a small well-marked plateau overlooking the valley in which lies the village of Cotukall. That the gritty beds are sometimes replaced by clays is shown by the materials turned out of two deep wells sunk into this plateau at two points several miles apart; one of these wells lies rather more than half a mile to the northward of Mullur (Mooltoor of sheet 63). Here the section, which is from 80 to 100 feet deep, passes through mottled gritty sandstone and into blue and white mottled clay. The other section revealing clays below the gritty beds is in a well sunk close to the new road from Valrampur (Vaulrampoor) to Puar (Powar), and some distance south of the place shown in the map as Vunpoyal[1]. The clay here is of a similar white and blue mottled colour.

A section in the low cliff forming the small bay immediately east of Villenjam shows a mottled vermiculated clayey rock showing mostly no bedding at all. Traces of bedding are, however, revealed as the cliff is followed southward by the appearance of thin bands of grit near the base of the section which rests on the underlying quartzo-felspathic garnetiferous gneiss. This mottled clayey rock I believe to represent the bluish-white-mottled clay turned out of the lower parts of the well section near Mullur before referred to. It is locally considerably discoloured and stained by the percolation of water through the overlying pseudo-lateritic, dark-red sand. As will be seen by any one who follows the coast line these Warkilli sandstones rest upon a very rugged and broken gneiss surface. Many great tors and knolls of granite gneiss protrude through the sandstone plateaux or tower over them from adjacent higher ridges, which have been completely denuded of the younger rocks.

The greater part of the surface of the tract occupied by these Warkilli beds west of the Neyar is thickly covered by sandy loam, generally of dark red colour, which conceals the sub-rock very effectually, excepting where the loam is deeply eroded. A well-marked patch of purplish grit forms a knoll, about a mile south-west of Valrampur. Traces of the former, more easterly, extension of these beds are to be seen at intervals along and to the north of the Trevandrum-Tinnevelly road between Valrampur and Neyatum Karai.

In the tract lying east of the Neyap few sections exhibiting the grits, &c., were met with, and all were small and unsatisfactory. The surface of the country is either largely covered with the deep red soil, or else the extremely broken surface of the gritty beds is extensively lateritised. The appearance of the country when seen from elevated points is, however, characteristically very different from the gneiss and kabuk tract lying to the northward. This may be well seen from Colatoor trigonometrical station hill, as also from the high ground close to Cauracode, but yet more strikingly from the Kodalam Pothia, a hill 2 miles west-north-west of Paurashalay. Sections in which the true character of the rock is to be seen occur on the high ground close to the junction of the new roads leading from Puar (Powaur) and Martanda Putentorai respectively to Paurashalay, also to the southward near Shoolaul (of map), where a large rain gully cuts deeply into the grits and underlying clayey beds; also along the ridge of high ground north and

[1] I failed utterly in identifying this and many other of the village names given on the map (sheet 63). It was very difficult to localise the positions of many phenomena I wished to record, even if landmarks existed on which to take bearings, owing to the extreme inadequacy of the map. The fact that the villages and hamlets generally straggle far and widely over the face of the country, instead of coinciding with any points indicated on the map, does not at all assist one in fixing one's whereabouts in the absence of landmarks.

north-east of the Yeldaseput of the map. Traces of the former eastward extension of the grits were noted on the eastern flank of the Kodalam Pothai, and on high ground half a mile or so to the northward of the cutcherry at Paurashalay. The beds composing this patch of Warkilli rocks have undergone greater superficial denudation than those in the Karruchel patch to the north-west.

In the small patch lying east of the Kuletorai (Cooletoray) river some instructive sections of hard dark grits and underlying clayey grits of the usual reddish, bluish, and white mottled colour are to be seen south of Killiur (Killioor). Some of the sections show regular miniature 'cañons' 15′ to 20′ deep, with vertical sides and numerous well formed pot-holes. Hard purplish grits show on the surface between Killioun and Pudukaddi (Poodoocudday) and soft mottled grits in a well section close east of the little D. P. W. bungalow at Tengapatnam, (Taingaputnum). At the southernmost point of this Killiur patch the grits become coarsely conglomeratic over a small area. A little to the north of this the grits, when resting on the basset edge of a bed of granular quartz rock, present the characters of a perfect arkose, made up of the angular gneiss debris. In places this arkose might be most easily mistaken for a granitic rock.

A distinctly conglomeratic character is shown by the grit beds close to Madalam (Muddaulum). This Madalam patch of Warkilli sandstones is on its southern side deeply cut into by a gully which exposes regular cliffs with from 35 to 40 feet of coarse or conglomeratic mottled grits, capped by thick red soil. The grits contain many large clay galls and lumps of blue or mottled colour.

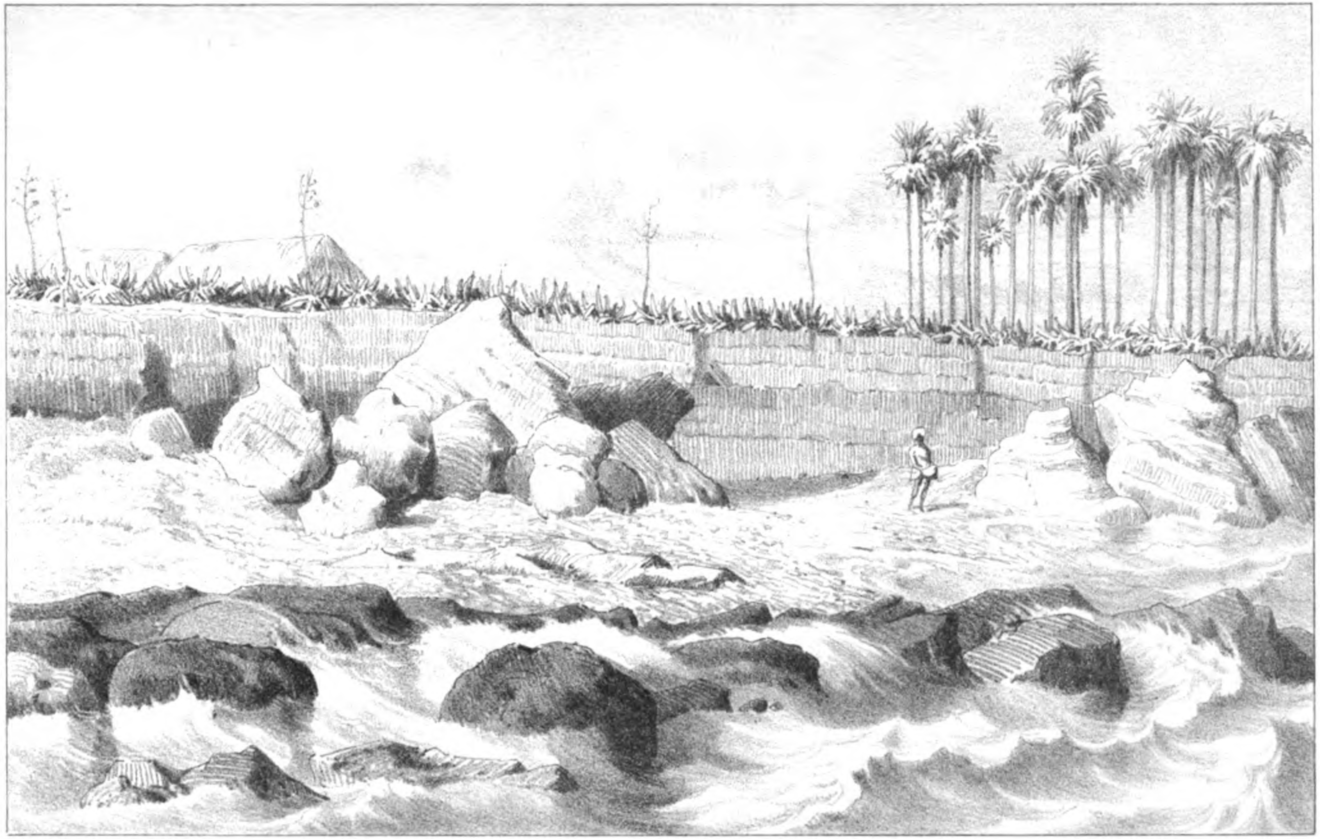
In the Kolachel (Collachull) patch the grits are extremely well exposed in deep cuttings (miniature cañons) made by the stream rising just west of Neyur. They are of the usual mottled description. Where seen at the eastern side of the patch near the Eranil (Yerraneel) cutcherry they are quite conglomeratic.

They are exposed also in a gully crossing the road which runs north from Kolachel to join the main road, and in a well-section on the high ground a mile north-eastward of the little town. The south-eastern part of the patch is entirely obscured by a great thickness of dark red soil. They peep out, however, below the red soil at the western end of the great tank 3 miles south of Eranil (Yerraneel).

A very thin bed of conglomeratic grit underlies the *teri*, or red sand-hill, capping the high ground north of the Muttum (Moottum) headland. Further east a few poor sections only of whitish or mottled grit prove the extension of the Warkilli beds in that direction, nor are they well seen again till close into Kotar, where they show in various wells and tanks, but are still better seen in a deep rain gully south of the travellers' bungalow at Nagar Koil, and in a broad cutting immediately to the east of the bungalow. The variegated gritty sandstones here seen are very characteristic, and strongly resemble some of the typical varieties in South Arcot and Madras districts.

To the south of Kotar the grits are to be seen in streambeds opening to the Purrakay tank, and in a series of deep rain gullies on the eastern slope of a large red soil plateau to the south-west of Purrakay.

A small patch of gritty sandstones of similar character to the above occurs immediately north and north-west of Cape Comorin. As a rule, they are badly



CLIFF SECTION WEST OF CAPE COMORIN.

exposed, being much masked by the red-blown sand of a small teri. The most accessible section is a small one seen in the bottom of a good-sized bowrie, a little south of the junction of the roads coming from Trevandrum and Palamcotta. This section can only be seen when the water in the bowrie is low. A considerable spread of similar greyish or slightly mottled grits is exposed about half a mile to the north-east of Cova Colum, and $1\frac{1}{2}$ miles north-west of the Cape. Lying between the two exposures just mentioned, but separated from either by spreads of blown sand, is a different looking vermiculated mottled grit of much softer character. This is extensively exposed in the banks of a nullah and head-water gullies falling into the Agusteshwar. The colour of this soft grit ranges from red, through buff to whitish. The beds roll to the northward. This grit is full of vermicular cavities filled with white or reddish kankar (impure carbonate of lime). The grit seems to graduate upward into a thick red gritty soil full of small whitish red, impure (gritty) calcareous concretions. There is good reason, however, for thinking that this graduation is merely apparent, and that the red gritty soil is only the base of a red sand-hill, or teri, undergoing change by percolation of calciferous water. A hard brown grit is exposed for a few square yards just north of the junction of the two roads above referred to. This rock has, except in colours, considerable resemblance to the red-white grit just described, and both probably overlie the pale mottled grits near Covacolum.

The last patch of grits to be mentioned forms almost the extreme easterly angle of the Travancore territory, and lies to the eastward of the southernmost group of hills and along its base. Not many sections of the grit are here exposed owing to a thick red soil formation which laps round the base of the hills, and is only cut through here and there by a deep rain gully or a well. The grits here seen are like those exposed near the travellers' bungalow at Nagar Koil, but show much more bedding and are almost shaly in parts. The colour of the grit is white, pale drab or grey mottled with red and brown in various shades. They lie in depressions in the gneiss, and were either always of much less importance and thickness than the beds to the west, or else have been denuded to a far greater extent. They are best seen in gullies to the south-west and west of Russhun Kristnapur, 7 miles north of Cape Comorin, and in the beds of the small nullahs west and north-west of Comaravaram opposite the mouth of the Arambuli pass. None of these Warkilli grit beds occurring between Trevandrum and Cape Comorin have yielded any organic remains as far as my research has gone, and I fear none will be obtained by subsequent explorers. The alum shales occurring in Dr. King's Warkilli section have not been traced in South Travancore, and I had not the good fortune to come across any lignite. It is said to occur not unfrequently to the south of Kolachel, and to be turned up by the people when ploughing their fields. I have no reason to doubt this, for it is extremely probable that some of the clayey beds should contain lignite. From the configuration of the ground, too, the paddy flatalong the southern boundary of the Kolachel grit patch would coincide in position with some of the clayey beds near the base of the series which are lignitiferous at Warkilli; and why not at Kolachel?

The recent discovery of lignite in the Cuddalore sandstones at Pondicherry adds greatly to the probability of the correctness of Dr. King's and my conclusion (arrived at by us separately and independently before we had an opportunity of comparing notes) that this gritty bed in Tinnevelly and Travancore should be regarded on the grounds of petrological resemblance and identity of geographical position as equivalents of the Cuddalore sandstones of the Coromandel coast.

The question of the age of these Cuddalore or Rajahmundry or Warkilli sandstones I propose to examine in the Memoir on the Geology of the Coastal region of Tinnevelly and Madura districts which I am now preparing.

The Marine Beds.

At Cape Comorin and two other places along the coast to the northward are formations of small extent but very considerable interest, which, by their mineral constitution and by the abundance of fossil marine shells they enclose, show themselves to be of marine origin, and thus prove that the coast line of the peninsula has undergone some little upheaval since they were deposited. These beds are to be seen close to the Cape at the base of a small cliff which occurs immediately south of the Residency bungalow, and only about 200 yards west of the Cape itself. The annexed plate is a truthful sketch of the little cliff, taken from a mass of gneiss rock projecting some little distance out to the south. The rocks seen in the surf, and immediately behind it on the beach, are all gneiss. The base of the small cliff is composed of friable gritty calcareous sandstone, full of comminuted shells. The base was not exposed at the time I examined this section, some heavy gale having piled up the beach sand against the foot of the cliff, and for this reason it was impossible to trace the probable connection of this sandstone with another exposed at a slightly lower level at a few yards distance to the west and just beyond the left-hand limit of the sketch. This lower bed is similar in mineral character, but very hard and tough, and offers great resistance to the surf, but has nevertheless been deeply honeycombed and in places quite undermined. The roof of the miniature caves thus formed have in some cases fallen in, but have been partly re-cemented by deposition of calcareous matter in the lines of fracture. To return to the cliff section, the basement sandstone is overlaid by a similar but slightly harder yellowish friable bed, which contains many unbroken shells (all of living species), in addition to a great quantity of comminuted ones. The base of the lower bed is hidden by sands, but from the proximity of the gneiss it cannot exceed 5 or 6 feet in thickness, while the overlying shelly bed measures about the same. It is overlaid in its turn by a massive bed, 6 to 10 feet thick locally, of a kind of travertine formed of altered blown sand, composed mainly of fully comminuted shells. This travertine contains immense numbers of shells and casts of *Helix vittata*, the commonest landshell in the south; it will be described specially further on. Owing to the soft character of the marine sandstones, the cliff has been much undermined by the tremendous surf which breaks on this coast in bad weather, and great masses of the hard travertine of the Helix bed have fallen on to the beach, as shown in the sketch, forming a partial breakwater against the inroads of the sea.

The shells contained in the upper sandstone bed were all found to be of living species, where sufficiently well preserved to admit of identification, the majority of the specimens are too ill preserved for specific identification. Four miles north-

north-east from "the Cape," as it is locally termed, stands the little stone-built fort of Watta Kotai (Wutta Kotha), which is built upon a small patch of calcareous sandstone, full of marine shells, exposed in the moat along the north face of the long curtain wall which joins Watta Kotai fort with the extensive series of fortifications known as "the Travancore lines." The marine limestone may be traced for nearly half a mile inland in the bottom of the moat. This marine bed is overlaid by a very thin bed of travertine limestone full of *Helix vittata;* it has been cut through in the formation of the moat. The thickness of the shelly marine bed is unknown, but the Helix bed is not seen to exceed 10″ or 1′ in thickness. As far as seen in the very small exposure, both formations lie nearly horizontally. Another small exposure of the marine bed occurs at the western end of a little backwater (not shown in the map) to the north of the port. The sandstone here contains many well preserved marine shells, all of living species; but further west, where the bed is exposed below theHelix bed in the moat the enclosed shells are all broken and comminuted. The surface of sandstone, as seen at the end of the little backwater, is raised but a very little distance above the sea level, probably not more than 4 or 5 feet at the outside. The rise of the ground along the moat is extremely small, and even at the furthest point from the sea at which the sandstones are exposed the elevation is probably not more than 10 or 12 feet at most, which would correspond with the top of the sandstones as seen in the little cliff at Cape Comorin.

About 2 miles north-east-by-north of Wattakotai fort a small patch of white shelly limestone occurs peeping out of the low belt of blown sand which fringes the coast at that spot. The village of Kanakapur which lies immediately to the north is the last within the Travancore boundary. The limestone only stands out a few inches above the surface of the surrounding sands, and no section could be found to show its thickness, but in point of elevation above the sea level it agrees perfectly with the Watta Kotai and Cape Comorin beds. The limestone which is fairly hard is quarried for economic purposes, and unless a good deal more of the bed than now meets the eye remains hidden under the sands, it will, before many years are over, have been removed by human agency.

The shell-remains occur as impressions and casts of great beauty and perfectness, but the shelly matter has disappeared entirely, being probably slightly more soluble than the enclosing limestone. The limestone contains a large number of specimens of *Helix vittata* which were evidently carried out to sea and there entombed in a shallow water formation. To any one who has noticed the enormous numbers of this Helix living in this neighbourhood, and in the southern districts generally, the large number of it occurring fossil in this marine bed will be a matter of no surprise.

The Blown Sands.

Two very marked varieties of Æolian rocks occur along or near the coast of South Travancore, as well as along that of Tinnevelly; they are the red sands, forming the well known *teris* of Tinnevelly, where they are developed on a far larger scale, and the white sands forming the coast dunes. In South Travancore, as far as my observation went, the red sand hills are no longer forming; all are undergoing the process of degradation by atmospheric agencies, at various rates of speed. The red sands have in many places ceased to yield to the influence of the winds and have arrived at a condition of fixity and compaction caused by the action of rain falling upon the loose sands percolating through them and during heavy showers flowing over their surfaces and washing the lighter clayey and smaller, though heavier, ferruginous particles down the slopes of the hills or into hollows on the surface, where, on drying, a fairly hard, often slightly glazed, surface of dark red loam has been formed. This loam is very fairly fertile and soon becomes covered with vegetation, which further tends to bind the mass together and render the surface secure from wind action. The loose sand, deprived of the clayey and finer ferruginous particles, would, unless unusually coarse in grain, be carried off by high winds elsewhere or remain in barren patches on the surface. I believe this process has gone on extensively over many parts of South Travancore, and explains the existence, on the surface of the country and resting indiscriminately on the gneiss and the younger rocks as the Warkilli sandstone, of the great thick sheets of pure red loam which have not been brought there by ordinary aqueous deposition nor formed *in situ* by the decomposition of the underlying rocks. The percolation of the rain-water through the mass has in many places given rise to the formation of concretionary ferruginous masses, which are often strongly lateritoid in their aspect. The quantity of clayey matter and of iron ore in the form of magnetic iron is very great in the sand of many of the teris. The greater quantity of the water falling on the teris, as on other blown sand surfaces, escapes by percolation, and it is a common phenomenon to find springs issuing around the foot of the sand mass during the rainy season and becoming dry in the hot or rainless season.

The teris in South Travancore which still retain their character as accumulations of moving red sands are four in number and all very small, the largest not measuring one square mile in area. They are all close to the coast and with one exception stand high and conspicuous to ships passing along at a fair distance. The largest and most conspicuous is that at Muttum which caps the high ground with the new light-house. The process of fixation has gone on here largely and the moving sands cover a much smaller space than does the fixed portion[1]. The same may be said of the teri resting on the south-eastern extremity of the Kolache (Colachul) sandstone plateau. To the north-west of Kolachel are two much smaller teris at the distances of 3 and 5½ miles respectively. In both of these also the area of the fixed sand far exceeds that of the loose. Especially is this the case in the more northerly teri near Mel Madalatorai (Maila Maddalaitoray). Here the fixed part has undergone tremendous erosion and is traversed by long and deep rain gullies, with vertical sides up to 20 or 25 feet high. Gullies on a yet larger scale are to be seen at the south-east corner of the Kolachel sandstone patch and at the eastern side of the Muttum patch. Very large but shallower gullies are to be seen at the south-east corner of the Nagarcoil patch, where there is a very large fixed teri.

[1] I have shown the extent of the unfixed or moving teris on the map; the fixed part I have treated as a soil and ignored accordingly.

The small teri immediately behind Cape Comorin is a very poor specimen of its kind, and, in fact, hardly deserves to rank as one owing to its pale colour and poverty in iron sand, but it will not do to class it as a coast dune, as it consists mainly of silicious sand, while the true dunes at the Cape consist mainly of calcareous sand composed of comminuted shells, corallines, nullipores, &c.

The sand of the typical teris is silicious or ferruginous (magnetic iron), the former being well rounded and coated with a film of red oxide of iron, which is removeable by boiling in nitric acid for a few seconds. Common as garnet sand is on the beaches of South Travancore, I never yet found a grain of it in the teri sand, where the latter was pure and had not been mixed with beach sand. Much difficulty exists as to the source whence the red sand was derived; but I will not attempt to discuss this question here, as I hope to treat it at much greater length than I could now, in a Memoir on the Geology of Tinnevelly and Madura districts which I have in preparation.

The coast dunes of South Travancore are, except close to the Cape, in no way remarkable. A large patch of small hillocks to the north-west of the mouth of the Kuletorai (Cooletoray) river was caused by the wind shifting a great mass of sand turned out wheu the new canal was dug and heaped up on the north bank of the canal.

Some tolerably high ridges occur 3 miles south-west of Kolachel. The sand here contains so much fine magnetic iron that it looks in parts of a dark grey colour, shading here and there almost into absolute black.

A considerable quantity of blown sand fringes the coast from the Muttum headland eastward to Cape Comorin, and between Pullum and Culladevella forms some considerable hills. At Covacolum the highly calcareous beach sand which forms many low hillocks has been solidified in several places into coarse shelly limestone. The Helix bed at Cape Comorin already referred to, when treating of the Marine-beds, is really an altered sand dune, the calcareous matter of which has, by percolation of acidulated water, been dissolved and re-deposited, on evaporation of the water, as a subaerial travertine. Countless thousands of *Helix vittata*, and a considerable number of shells of *Nanina tranquebarica*, the two commonest land shells in this part of India, have been inclosed and fossilised in the formation of this travertine, which is evidently in constant progress. The immense wealth of shellfish of all kinds, added to large quantities of corallines and nullipores, incessantly thrown up by the surf, furnishes an abundant supply of calcareous sand for the formation of this travertine, which forms a bank more than a mile long and rising some 80 feet or more above the sea at its highest point. Its inland extent cannot be ascertained, as it is covered by loose sands. It probably only extends 300 to 400 yards inland and abuts against a low ridge of gneiss.

Coral Reefs.

A few tiny fringing reefs are to be seen half to three-fourths of a mile west of the Cape, half in the surf at low tide, and wholly in it at high tide. They are now to be considered as dead reefs, abandoned by the polypes that built them. I examined most of them carefully, without finding any live coral, and was inclined to doubt the correctness of my inference, drawn from their tabular shape and many shallow basin-like cavities; but later on, when examining some identical fringing reefs off the Tinnevelly coast to the south of Kudung Kulam trigonometrical station (the south point of the Cape Comorin base-line), I found a considerable quantity of live coral lining the sides of the little basins, and equally large quantities of coral quite recently dead in adjoining basins.

A great deal of shell debris, sand and broken stone, is included in the mass of the reefs which in several places have formed around masses of rock standing in rather shallow water, and joined up many loose blocks of stone tossed on to them by the surf into tremendously coarse conglomerates. Some similar reefs, but of rather larger size, occur along the coast to north-east of Cape Comorin; in these the tabular mass extends from 10 to 40 and 50 feet in width, from the shore to the constantly surf-beaten outer edge. In one or two places parts of the reef had evidently been founded on sand, which had been washed away, leaving an unsupported surface of many square yards in extent, which the surf of the next high tide or first gale of wind would either break up or else again support with sand washed under it. These little reefs are worthy of much closer examination than I was able to bestow upon them.

The coral fauna of the Cape Comorin sea is on the whole a remarkably poor one, as far as one may judge by what is to be found thrown up on the beach. Dredging might reveal much more, but unfortunately no boats are to be found there, only Kattumarams (Catamarans), which would not be the most convenient form of craft from which to carry on scientific observations. The sea here is, however, so very rich in animal life in many forms, that it would assuredly afford a rich reward to any one having a suitable vessel at command. I obtained in a very short time a far larger number of species of shells here than at any other place on the Indian coast.

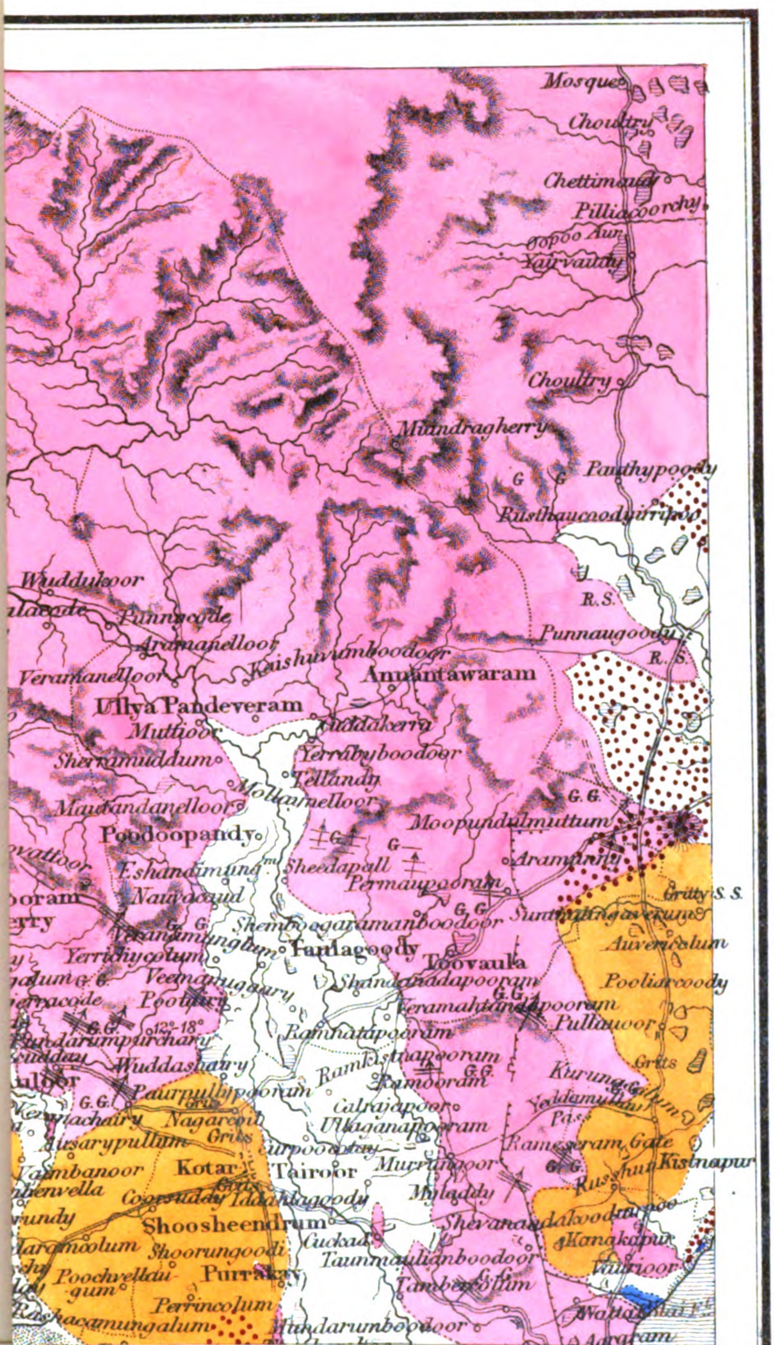
Soils.

The prevalent soils are red ones, varying in the quantity of their ferruginous element. The red soils seen inland near the main trunk road are chiefly formed of gneissic debris by subaerial decomposition. The origin of the deep red sandy or clayey loams has already been discussed (*ante*, page 32). They occupy no inconsiderable area. True alluvial soils occur very rarely, if at all, now-a-days; those which fill the bottoms of the many valleys and creeks in which paddy is cultivated being greatly altered from their original condition by centuries of cultivation, and the addition of various mineral, vegetable, and animal manures. Estuarine beds full of subfossil shells, *Cytherea*, *Pottamides*, *Melania*, &c., of living species are exposed in the salt pans at the mouth of the Kolachel nullah.

The alluvium in the valley of the Paleyar, which flows south from the west flank of Mahendragiri past Nagurkoil, is, where pure, a coarse gritty silt.

Economic Geology.

Valuable minerals and metals are conspicuous by their absence in the part of South Travancore I had the pleasure of exploring. I came across no sign of any mineral industry, except the preparation of sea-salt in the pans near Kolachel, and traces of an old iron smelling industry carried on formerly at foot of the now


Mosque
Choultry
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Aramanelloor
Annantawaram
Ullya Pandeveram
Muttioor
Yerrabyboodoor
Tellandy
Poodoopandy
Moopundulmuttum
Sheedapall
Permaupooram
G. G.
Gritty
S. S.
Poolincoody
Tamlagoody
Toovaula
Pullauoor
Wuddashairy
Nagarcoil
Kotar
Tairoor
Shoosheendrum
Perrincolum
Kistnapur

bare and rocky hills east and north-east of Myladdy and some 7 miles north-west-by-north of Cape Comorin. Judging from the large quantity of iron slag here remaining, the smelting industry must have been an important one for native workmen. I could get no information about it on the spot. I met with no existing iron smelting industry in the villages I traversed, probably because of the absence of rich supplies of iron ores. The supply of beautiful building stone is practically unlimited, but not much use seem to have been made of it. Travancore architects seeming to prefer the use of wood, the chief large stone buildings are the extensive fortifications erected to bar the way into the country from the eastward, and known as the Travancore lines. They are mostly built of gneiss, Wattakotai port already referred to being a very fine example of excellent well-cut masonry. At the extreme south end of the lines, where they abut on the sea near Cape Comorin, blocks of the marine sandstone have been employed in the walls to some extent, but have been much affected by weathering. The old fort at Udagiri (Oodagerry) is another extensive stone building.

Of the temples, which are usually fine specimens of stone work in South India, I have nothing to say. Non-Hindus may not approach them for fear of rousing the fury of the ultra-bigoted Brahmans, who unfortunately retain far too much power in Travancore, and exercise it to the detriment of the country generally.

Some of the hard sandstones of the Warkilli series have been used for building to a limited extent, and I noticed not far from Puar a good example, perfectly new, of a stone cattle-trough cut out of homogeneous pale, purple and white, hard lithomarge of very jaspideous appearance. I did not see a similar rock *in situ*, but it evidently came from some bed belonging to the Warkilli series.

Some notes on the Geology of Chamba *by* COLONEL C. A. McMAHON, F.G.S.

I propose, in the present paper, to give the results of some tours in the mountains adjoining Chamba, in continuation of my papers "on the geology of Dalhousie," and "on the section from Dalhousie to Pángi"; and I pre-suppose, on the part of the reader, a knowledge of the facts recorded in those papers.

In the first instance, I shall ask the reader to accompany me from Basaoli, over the Bánjal (Banjil) and Chattar Dhár passes, to Bhadarwár (Badrawar).

Leaving Basaoli, the Siwaliks continue with a steady N.-E. 5° E. dip all the way to Bhond (Pood). About half-way to the latter village, the coarse conglomerates of this series give way to red clays and massive sandstones, which in their turn are succeeded, near Bhond, by a fine-grained conglomerate, corresponding to the topmost Siwalik beds of the Danera-Dalhousie section.

At Bhond, the Siwaliks dip under indurated red clays and fine-grained sandstones of dark-grey colour. Both the clays and the sandstones are full of fine specks of a silvery mica. These rocks, I presume, represent the Dagshai and Kasauli groups of the Sirmur series. They dip N. 11° E., and extend as far as Seloo.

These beds are followed by a massive quartzite of whitish colour, dipping east and then by the slates and limestones of the carbo-triassic series, which have also an easterly dip. The limestones are the ribbed variety previously described, and they continue to the top of the Bánjal pass, the elevation of which is, according to my aneroid barometer, 6,325 feet above the sea. At the top of the pass the rocks dip S.-W. 11° S., but the dip is high and nearly vertical. The carboniferous slates become very black as the gneiss is neared.

About 2 miles below the top of the pass, on the northern side, the first outcrop of gneiss appears. The rock, as seen in this section, is a thoroughly crystalline gneiss, but it is never granitoid. Its dip is nearly perpendicular. The gneiss continues down to the Sewa river,—the river that flows from the Chattar Dhár into the Ravi,—and as the stream is approached the dip becomes more moderate.

On the descent to the Sewa there is a bed or dyke of fissile trap, about 20 feet wide, in the gneiss. It appears to be a decomposed diabase. It is of greenish-grey colour and its specific gravity is 2·95. Under the blowpipe it fuses readily to a black magnetic bead. The microscope reveals pieces of still unaltered angite here and there. Felspar may be traced in it, but it is greatly altered. A banded, or pseudo-foliated appearance, observable in this rock, is due probably to the infiltration of water along lines of cleavage due to traction or pressure. Along these lines minute granules of quartz—some of them of elongated form—are visible. This mineral is doubtless a secondary product. The quartz does not contain any fluid cavities which are very abundant in the quartz of the gneiss.

At the point where the road strikes the Sewa, the gneiss is succeeded by blue, micaceous slate, and as Bani is neared, the dip of the strata reverts to N. 11° W. The schistose rocks are of a type commonly seen in the neighbourhood of Dalhousie (as, for instance, on the road to Chuári), crumbling to a soft bluish-white powder, suggestive of french-chalk.

The outer band of gneiss is, in this section, some thousands of feet thick.

I observed no outcrop of the trappean zone in this section; it has apparently either thinned out, or has been cut off by a fault.

Schistose rocks, dipping N.-E. 15° N., all of which could be matched in the Dalhousie area, continue from Bani to Loong, where the "central gneiss" crops out on the right bank of the Sewa. It runs thence in a nearly straight line, following the direction of the river and keeping on the right bank through Chunchli (Chounchli), and crosses the Sewa some distance above the last-named village.

At first the slates, in contact with the "central gneiss," dipped E. 11° N. *away* from the granitic rock, but afterwards they became perpendicular.

The granitoid gneiss here is a porphyritic and perfectly granitic rock, much traversed by joints, but I could not make out any bedding. At one place I noticed that it had intruded between the bedding of the slates. It continues for some miles, when the slates re-appear, dipping N.-E. 11° E. *away* from the granite. The road, from this point, runs, almost along the boundary of the granite and slates, up to the top of the pass (elevation 9,650′). The granite is never far from the road, on the right bank of the stream; whilst the slates are seen on the left bank all the way up.

The granitoid gneiss continues to be seen on the left of the road for about

$2\frac{1}{2}$ miles down the north side of the pass. From this point the slates continue down to Bhadarwár. The dip remains unchanged.

The Kund Kaplás (Koond Kaplas), in many respects, seems to be an analogue of the Chor mountain of the Simla area. It is 14,241 feet high, the elevation of the Chor being 11,982 feet; and like the Chor it abuts on the plains and appears to be formed of "central gneiss." It will be seen from the observations made on this tour, that the "central gneiss" suddenly expands to a great width of outcrop as the "Kund Kaplás" is neared.

My route now leads back over the Padri[1] pass. The rocks seen *en route* are slates, and on the ascent of the pass they are quite typical "Simla slates;" dip, N.-E. 5° N.

About two-thirds of the way between Thanala (Tenala) and the top of the pass (elevation of top 9,700′), I encountered my old friend, the "Blaini conglomerate." It is quite typically developed, and the detailed description given of it in my paper on the Dalhousie and Pángi section applies equally well to the rock seen in this section. On the conglomerate there rests, 975 feet below the summit of the pass, about 50 or 60 feet of pale-blue limestone. Above the limestones slates re-appear.

On the descent of the pass, going east, the slates are vertical, or nearly so, having a very high dip, sometimes in the normal, or north-easterly direction, and sometimes in the reverse direction. This variable underlie prevails, along the line of strike, in an easterly direction, as far, at any rate, as Manjir.

The conglomerate re-appears on the road side, about half a mile below the top of the pass. It runs thence to near Langera (Langaira), almost in a line with the road, cropping up on the road side more than once. Near Langera the outcrop is of great thickness.

Where the road, near Langera, descends to within a few yards of the river, the conglomerate contains a boulder of granitoid gneiss 1′ 3″ long. Mr. Lydekker has already noted the presence of granitoid gneiss[2] boulders in the slates of the Pángi-Lahoul valley; and the discovery of a similar boulder in the silurian conglomerate, on this side of the snowy range, is interesting and important.

I saw numerous blocks of pale-blue limestone, weathering buff, in the vicinity of the conglomerate, between the top of the pass and Bhándal (Baundal), but I doubt if any of them were *in situ*. They probably indicate the presence of the carbo-triassic series in the mountains which bound the north-eastern side of the Siul[3] valley.

The conglomerate continues in the same general direction as the river the whole way to Bhándal. I counted ten outcrops of it, *in situ*, on the road side, between Langera and Bhándal. Some of these outcrops run with the road for a considerable distance.

[1] This word is not Pádri, but Padri, which means flat.

[2] The presence of granite, or syenite, boulders in the conglomerate at Gurais, in Kashmir, is also noted by Mr. Lydekker at p. 24, Vol. XII, Records.

[3] Kundi Marál (Kandi Marl), the name entered on the map, is not the name of the valley, as one would suppose, or the name of the river that runs through it, but the name of an encamping ground, where the peg to which a Raja's horse was tied is said to have grown miraculously into a big tree. Hence the name.

A calcareous band (weathering buff[1]) crops out about 4 miles to the S.-E. of Prangal (Prungli), and re-appears several times afterwards.

To the east of Bhándal the conglomerate runs with the road for some distance.

It will, perhaps, conduce to clearness, if I note in this place the several outcrops of this rock which I have, up to date, noted along the line of its strike in an easterly direction. On the ascent of the ridge between Dihur (Duire) and Manjir, the conglomerate crops out on the road side, and, crossing the ridge with the road, descends to the river between Manjir and Kandla.

In my paper on the Dalhousie and Pángi section, I did not note the occurrence of the conglomerate on the left bank of the river to the east of Manjir, as, owing probably to the predominance of vegetation, I did not see any outcrop *in situ;* but the conglomerate, I doubt not, in its eastward extension, passes somewhere in the neighbourhood of Balore.

I came across another good outcrop of the rock in the mouth of the Hulh (Hul) valley, (immediately north of Chamba), between the villages of Baroar and Chambi. Proceeding eastwards from Chamba up the Ravi river, the conglomerate again appears on the road side at the bend of the river, a little to the east of Gun (Guar). It continues thence in a nearly straight line to Chitráli (Chitralri) and Sowala, and curving round above Naukula, it passes a little above Aulansa (Hulans), and thence a little to the north of Grima, onwards through Suchai and Bauri (near Barmaor) to Poulda and Kund.

I have noted numerous outcrops along the line indicated, but it seems needless to describe them in detail. The country between the outcrops near Manjir and in the Hulh valley, and between the latter and Gun on the Ravi, I have not yet explored. I have, also, not been to the east of Harser, as the route I followed took me towards the sacred lake of Man Mhaish (Manimais).

It is interesting to note the continuous outcrop of the upper-silurian conglomerate along a line parallel to the granitoid gneiss, as it confirms the conclusion previously arrived at, that we have in the Dalhousie-Chamba section a normal sequence of silurian rocks resting on the granitoid gneiss.

Between Chamba and Dancho the dip is north-easterly. Near Harser, the dip, which had previously been moderate, becomes vertical, but between Harser and Dancho it again subsides into a N. E. dip.

Between Chamba and Mahila (Maila), the granitoid gneiss crosses to the right bank of the Ravi, at the bend of the river under Tandola, re-crossing to the left bank near Bania. It passes to the right bank, again, beyond Bania, and then continuing its course under Dalgara and above Korauh, it finally leaves the river near Mahila.

At the junction of the granitoid gneiss and the slates, the former is granitic and the latter is indurated, and sometimes silicious and massive. Under Dangera (Dalgara), near the junction of the two rocks, the slates are contorted, and there is a sudden reversal of dip, with more or less local faulting. At the actual

[1] Blue limestones, weathering buff, is a peculiarity which appears to be common to several bands of the carbo-triassic series and the Blaini limestone. It does not help to distinguish the two series.

junction the dip of the slates is normal. The plane of division between the schistose slates and the granitoid gneiss is not sharp, but the granitoid gneiss appears to be blended into the slates by imperfect intrusion.

I now ask the reader to return with me to Chamba, and accompany me up the Hulh valley.

Up to the outcrop of the conglomerate, between Baraur and Chambi, the rocks are silurians and the dip normal. After Chambi, the path (there is no made road, and consequently no good road-side sections) lies along a fertile and well-wooded valley. Vegetation is rich, and rocks, *in situ*, are only to be seen here and there. I saw no outcrop of limestone.

A little to the north of Hulh, I came upon trap resembling the Dalhousie rock, and it extended to about the level of Bhaloth (Balote). As I am not, at present, sure whether this outcrop of trap occurs to the north or to the south of the carbo-triassic series seen in force south of Kalel (Kalail), on the Chamba and Tisa road, I reserve further remarks on this section until I can explore the mountains round the Rundhurst station.

My route now lay up the Hulh valley, over the high ridge at its head, and thence down to Kalel. I was able to trace the boundary of the carbo-triassic series and the conglomerate. The latter runs a little to the north of Sairu, and continues parallel to the river, striking towards the ridge that terminates at the bifurcation of the stream. Numerous blocks of typical conglomerate fill the bed of the stream.

The section from Kalel to Tikri has been already described. My route now lay from Tikri to Himgiri (Himgir), and thence round the Himgiri station to Digi and Dihur, and back again along the river to Himgiri. The rocks about Tikri are silurians—micaceous schistose rocks, crumbling to a whitish soapy powder.

The northern boundary of the conglomerates runs a little south of Tikri (not the village above alluded to, but another village of the same name under Himgiri), and thence to Laura towards the Himgiri station, which it leaves a little on its right. The southern boundary of the conglomerate crosses the ridge west of Kalel at Dhar, and continues thence up the Gulel (Gulail) valley. I met with typical outcrops of the rock on the ridge east of Bila (under the Himgiri station), and again along the ridge above Gulel. I found another good outcrop on the ridge between Gulel and Tiloga.

The dip is normal until Himgiri is neared, when a S.-S.-W. dip sets in. To the west of Himgiri, this changes to a S.-W. 11° W. dip, and then becomes nearly perpendicular. Beyond this, the dip reverts to the N-E. Further on, it becomes high and wavers occasionally to the south-west, but eventually settles down to a N.-E. dip.

In contact with the conglomerate, a trap, similar in its general appearance[1] to the Dalhousie rock, crops up along the ridge dividing the Gulel from the Tiloga valley. The outcrop is of considerable thickness, and in its S.-W. extension

[1] I have not as yet examined thin slices of it under the microscope.

it dominates the ridge running down to Dihur, in the neighbourhood of which village it either dies out or is cut off by a fault. The outcrop appears to widen in its northerly extension, and it is evidently present in force along the high ridge N. E. of Bhandal, the streams flowing down from which are full of boulders of trap. The western boundary of the trap runs a little to the east of the villages of Tiloga, Baroga, Kalsara, and Chikotra.

Following the road from Dihur to Himgiri, I found that where the road crosses it the outcrop is still of considerable width. It crops out at no great distance from Dihur, and extends to near the village of Dalui. On following a low-level path, near the river, as far as the stream to the north of Banjwar, however, I found that the trap does not extend as far east as this village.

Along the south-western boundary of the trap, the latter is in sharp contact with the limestones of the carbo-triassic series. This is well seen on the road leading from Dihur to Himgiri, where the limestones, which dip about N. N. E., are in great force. Both the trap and the limestones are typically developed, and the latter do not appear to be at all altered at their junction with the trap.

The limestone series is also well seen along the crest of the ridge north of Manjir. It crops out a little south of Nandla, and extends as far as Dhar. The dip, which is variable when the limestones first appear on the crest of the ridge, soon settles down to a N.-E. 5° N. dip. Some of the limestones are pale-blue, some creamy-white, and a few are of a deep dark-blue colour. Some of them weather to a rusty buff. I saw numerous blocks of limestone along this ridge crowded with crinoid stems, but I did not observe any *in situ*.

In connection with the trap above described, a variety occurs, which I have not observed elsewhere in the Himalayas, but which probably represents the porphyritic trap of Kashmir described by Mr. Lydekker. It is a felspar porphyry, an intensely hard rock; so hard that it was with extreme difficulty that I could obtain hand specimens of it. Boulders of it are brought down by the stream from the ridge N. E. of Bhándal, together with boulders of the ordinary variety of the trap. I have not yet seen it *in situ*.

Conclusion.—The observations made this season confirm the conclusion previously arrived at, that we have, in the Dalhousie-Chamba section, a normal sequence of silurian rocks resting on the "central gneiss." The "Blaini" conglomerate (upper-silurian) and the "Simla slates," of the Simla region, are both represented in Dalhousie-Chamba area; the conglomerate cropping out in a continuous line parallel to the granitoid gneiss.

The upper-silurian conglomerate is followed, in the Bhándal-Dihur region, by the carbo-triassic series, resting apparently conformably on it; but if the view taken of the age of the trap in the Dalhousie area in my paper on the geology of that region is sound, the boundary between the two series must really be a faulted one. The thinness of the conglomerates on the south side of the carbo-triassic limestones, as compared with their great development on the northern side of the limestone outcrop, is a fact which, to some extent, favours the fault hypothesis.

In the Bhándal-Dihur area, under consideration, the carbo-triassic limestones are followed by trap, and the latter by the upper-silurian conglomerate and a normal sequence of silurian rocks in inverse order.

In the Dalhousie area, the trap comes in between the carbo-triassic series and the tertiary rocks. In the Bhándal-Dihur area, it comes in between the carbo-triassic series and the upper-silurian conglomerate.

In my paper on the geology of Dalhousie, I adopted the hypothesis that the trap is of upper-silurian or pre-carboniferous age. I see nothing in the facts recorded in this paper inconsistent with that hypothesis. Indeed, I may say that when I formed my views regarding the age of the trap, I had distinctly before my mind's eye the possibility that trap might be found in the Bhándul-Dihur area, where I have since found it. I thought this possible from the fact that the Siul river under Manjir is full of trap boulders.

In both the Dalhousie and the Bhándal-Dihur areas the trap is found in contact with the carbo-triassic series; whilst in the latter section, it is in sharp contact with the upper-silurian conglomerate on the one side, and the carbo-triassic limestones on the other.

The fact that, in the Bhándal-Dihur section, the trap does not occur between the carbo-triassic series and the upper-silurian conglomerate, on both sides of the limestone outcrop, may I think be explained by the hypothesis of a fault between the limestones and the southern outcrop of the conglomerate.

The Bhándal-Dihur section, from the granitoid gneiss, south of Bhándal, to the lower-silurians, north of Bhándal, seems to me to be a crushed synclinal fold, complicated with faulting. That there is a fault somewhere seems self-evident. Whether the trap is of pre-carboniferous or of post-carboniferous age; in either case there must be a fault between it and the upper-silurian conglomerate.

The simplest mode of explaining the section, it seems to me, is to put a fault between the southern boundary of the limestone outcrop and the southern outcrop of the conglomerates; we should then have a normal ascending series of rocks from the "central gneiss" to the upper-silurian conglomerate, and a descending series of rocks from the carbo-traissic limestones to the lower-silurian schists. In short, I believe that we have in this section a crushed synclinal fold, with a fault along its axis, the compression of the folded strata having been great enough to produce a general conformity of dip.

In the Hulh section, I have some grounds for suspecting that the trap occurs between the southern outcrop of the conglomerate and the carbo-triassic limestones; but should this surmise prove correct, the point is immaterial as far as the hypothesis above propounded is concerned.

The observations made this season show that the outcrops of trap are not continuous; but whether this is due to faulting or to thinning out, I am not at present in a position to say. Either supposition seems equally probable.

The discovery of a boulder of granitoid gneiss in the upper-silurian conglomerate of the Bhándal region, taken in connection with the discovery by Mr. Lydekker of similar granitoid gneiss boulders in the silurian slates of the Pángi-Lahoul area, is another indication of the connection between the rocks of the two regions;

and, on the supposition that the granitoid gneiss boulders were derived from the "central gneiss," which Mr. Lydekker apparently does not now doubt[1], the fact supports the conclusion I arrived at for the Simla area, that a hidden unconformity exists between the silurian and the "central gneiss" series. A similar conclusion was drawn by Mr. Lydekker in his fifth paper on the geology of Kashmir.[2]

On the Basalts of Bombay, *by* COLONEL C. A. MCMAHON, F. G. S.

(with two plates).

During my last visit to Bombay, I made a carefully selected collection of typical specimens of the lavas exposed at different parts of the island, and I have since studied thin slices of them under the microscope.

I think it will be worth while to give a brief description of these; partly as the first contribution towards a better knowledge of the Deccan traps, regarding which our petrological information is at present very deficient; and partly because the description of the very typical lavas of Bombay may be useful as a standard with which to compare more doubtful basic igneous rocks in other parts of India.

I arranged the specimens which I am about to describe with sole reference to their colour. They range from iron black through less and less dark shades of grey to a greenish-grey colour.

In specific gravity the specimens vary very little, ranging from 2·80 to 2·85, their average being 2·82. They are all remarkable for the absence of olivine. Augite, plagioclase, and magnetite are present in each slice. All contain a few crystals of sanidine, but it occupies an extremely subordinate position.

No. 1.—*A dark-grey, almost black, compact rock.* Sp. G. 2·82.

M.[3]—This slice consists of a net-work of very small felspar prisms, and minute granules of augite, starred about in a partially devitrified glassy base, with moderately large crystals of felspar and augite sparsely scattered through it. The base is brownish-green, dappled with white, in reflected light, and olive-green in transmitted light. The white opaque material is, I think, leucoxene, a secondary product resulting from the decomposition of ilmenite, though in the particular slice there is no direct evidence of its connection with that mineral.

The felspar prisms, for the most part, present very sharp outlines, and the great majority of them are seen to be triclinic. They contain numerous glass cavities, many of which have fixed bubbles. Some of these glass enclosures are elongated, others are in rounded forms. The presence of such cavities is considered by Dr. Sorby to indicate the true volcanic origin of the rock containing them (Q. J. G. S. XXXVI, 49, 53). In one of the prisms, the glass enclosures have ranged themselves roughly in a zone conforming to the shape of the prism. Other prisms contain portions of the glassy base caught up in them.

[1] Records, XIV. 42. [2] *Ib.*

[3] In this and following papers M stands for microscopic aspect.

Augite crystals are extremely abundant, and most of them are of very minute size. Among the larger crystals twinning is common, and some are well shaped. In transmitted light the augites exhibit a faint tint varying from greenish-yellow to yellowish-brown, but so faint as to be almost white. This is the predominant colour of the augite in all the slices.

The augite and felspar appear, on the whole, to have crystallised at the same time, though some individuals have formed before the others. In fig. 1, plate II, I have given a sketch of a couple of augite crystals of irregular shape, joined together in a manner suggestive of twinning, which have formed round a felspar prism; whilst in fig. 2, plate II, I have depicted a group of triclinic felspar prisms, which have formed upon, and partially enclosed, a cracked augite crystal.

The augite and felspar in this slice are remarkably fresh. This is a characteristic of the augite in all the Bombay slices.

Magnetite is present in some abundance, both in regular shaped crystals and in the skeleton forms described in my paper on the Darang traps. Some titanic iron (ilmenite) appears to be also present.

In fig. 1, plate I, I have given a sketch of a portion of this slice, as seen in the field of the microscope, under a magnifying power of 60 diameters. The outline of the felspar crystals is generally sharp,—an indication I think that the lava was in a very fluid condition. Towards the centre of the field a rather large augite crystal is represented. On three sides the prismatic faces may be traced, though they are not well depicted; whilst the crystal may be seen to be traversed by rather irregular prismatic cleavage lines. Cracks are sometimes of use and furnish indications, in a general way, of the direction of the cleavage. A large crack in the crystal under consideration affords an illustration of this. For some distance it follows the direction of one set of cleavage lines, and then changing its course follows the direction of the second set, which crosses the first at an angle (87° 5′) approximating that of a right angle.

A crack traverses the slice and appears to have been filled up by an exfiltration process; the material it contains being cryptocrystalline.

No. 2.—A compact, dark-grey, almost black rock, closely resembling the last Sp. G. 2·82.

Under the pocket lens it has a somewhat vitreous lustre, and small facets of felspar are to be seen in it here and there.

M.—This slice is so like the last one that it hardly requires a separate description. The glassy base is whitish in reflected, and brown in transmitted light. Here and there it has been altered to a dull olive-green substance, which, when a single nicol only is used, transmits little light. In places it is stained brown-yellow to orange colour,—a result doubtless of the decomposition of magnetite.

Felspar is even more abundant than in the last slice; and here and there crystals of it are of comparatively large size. Glass and stone cavities are common in the felspar, but I discovered no bubbles in them.

Augite is fairly abundant. Its shape is irregular, but twinning is common.

Magnetite is very abundant, both in regular crystals and in skeleton forms in the glassy base. In the latter, as in the case of the augite in the pitchstones of Arran[1], the crystallization of the magnetite has resulted in a sort of halo being formed round the crystals,—the latter having in the act of crystallization drawn the colouring matter out of the base, leaving a comparatively colourless glass in their immediate vicinity.

No. 3.—A dark-grey, almost black, compact rock. Sp. G. 2·83.

M.—This slice consists of a profusion of augite, felspar, and magnetite crystals, scattered about in a glassy base.

The magnetite crystals are of good size, and are fairly well formed. The felspar and augite crystals are of two sizes; in the case of both minerals the majority are of small size (the augites being very minute); whilst here and there are others of comparatively large size. The majority of the felspar prisms are distinctly triclinic. Many of the augites are twinned.

Stellate groups of felspar, similar to those described in my paper on the Darang traps[2], are to be met with in all the Bombay slices. One of them from this specimen is shown in fig. 3, plate II, and another from No. 8 is given in fig. 10, plate II. The latter, which is quite accurately drawn, looks like a cross seen in part profile.

In my paper on the Darang traps I noted how crystals are often cramped at the time of their formation by adjoining crystals. In fig. 4, plate II, I have sketched a twinned augite which has attempted to crystallize in the midst of a perfect barricade of felspar prisms, and its outward symmetry of form has consequently suffered considerably. In such cases, however, though the external shape is deformed, the plane of twinning almost invariably exhibits a rigid straight line, and the internal symmetry, on which the optical properties of the mineral depends, sustains no injury.

In J. D. Danas' Manual of Mineralogy (1873), p. 152, augite crystals are said to be "usually stout and thick, and none have the slender bladed form common with hornblende." In lavas, however, as seen under the microscope, augite crystals sometimes take the form of acicular microliths, and not unfrequently assume the form of elongated prisms. A prism of this character occurs in the slice under consideration, and is represented in fig. 5, plate II.; (*a*) (*d*) is a long prism of augite which has grown up side by side with one of triclinic felspar. From (*c*) to (*d*) the augite is twinned, the twinning plane running with the length of the prism. From (*c*) to (*a*) the prism is made up of a crystal not in optical continuity with either of the twins below it. The augite in the course of its formation has enclosed the ends of small felspar prisms, which may be seen sticking, like parasites, into its side. The adjoining felspar prism appears to have grown tranquilly by the side of the augite up to (*b*), when the supply of felspathic material appears to have been less plentiful than that of the constituents of the augite and magnetite (three crystals of which are indicated at this point), and its

[1] Allport. Geological Magazine, Vol. IX, p. 2.
[2] *Supra*, Vol. XV, p. 155.

symmetry was greatly marred by the intervention of crystals of augite and magnetite (*b*). The ill-shaped felspar at the top (see sketch) is no doubt a portion, or what ought to have been a portion, of the prism seen below. The molecules of felspathic matter did their best, I take it, to keep the alignment of the felspar prism, and they are in optical continuity with it, but the augite and magnetite crystals got in the way, and the shape of the felspar prism was marred.

This, and the previously noted illustrations, will, I think, enable us to understand how the external symmetry, and the regular development of crystals in an igneous rock, are seriously interfered with by the contemporaneous formation of other minerals in close proximity to them, or by the presence and pressure of previously formed crystals.

No. 4.—A dark-grey compact rock. Sp. G. 2·82.

M.—The felspar and augite crystals are set in a glassy base, which is sufficiently abundant to entitle the rock to be classed as a magma basalt. The base is, for the most part, of light vandyke-brown colour, but is here and there altered to a substance olive-green in transmitted light. The base is crowded with microliths of magnetite in its rod-like form; it occurs also in large and rather well-shaped crystals and as a fringe round augite.

Almost all the felspar is visibly triclinic, and radiating groups are common.

Augite is very abundant, and very fresh, but its outward shape is rarely good and never perfect. Twinning is common, and the intersection of the prismatic cleavage lines is sometimes well seen.

In fig. 2, plate I, I have given a representation of a portion of this slice. Some of the felspar crystals therein figured present sharp and characteristic outlines; others again are very irregular. On the right hand of the illustration, two augite crystals are seen embracing two curiously shaped crystals of felspar. To the left also a large block, formed of a congeries of shapeless augite crystals, has more or less enclosed a radiating group of very irregularly shaped masses of felspar.[1] The partial enclosure of felspar by augite is very common in these slices, especially in the one under consideration. This, and the enclosure of augite by felspar noted in connection with slice No. 1, seems to indicate that the lava was at first in a very fluid state, in which free molecular action was possible; but that it cooled with such rapidity that the minerals were unable to disengage themselves from each other, and their crystallization was arrested before the symmetry of their external form was complete. Small peculiarities of structure of this kind are, I think, of value. The volcanic origin of the Bombay basalts being well known, structural characters observed in them may aid us to interpret rocks of more doubtful character in other regions.

Professor Geikie, in his paper on the Carboniferous Volcanic Rocks of the Basin of the Firth of Forth,[2] has described similar instances of felspar prisms

[1] Some of these seem to approach those "*complex fan-shaped brushes*" which Dr. Sorby describes as forming the terminations of felspar prisms in artificially melted rocks, and which he met with in a natural rock from a dyke near Beaumaris. Opening address, Geology Section of the British Association, 1880.

[2] Transactions, Roy. Soc., Edinburgh, Vol. XXIX, p. 437.

"shooting" through crystals of augite, and severing the augite into two parts in such a way that "not uncommonly it might be supposed to have been penetrated across its figure by intrusive prisms of felspar;" an appearance which Professor Geikie attributes to augite having "formed round and enclosed the already completed net-work of triclinic felspar prisms."

These partial enclosures of the one mineral by the other are described as occurring in the rocks which he classes as diabases and dolerites. The latter term he proposes to restrict to intrusive sheets and dykes which consolidated beneath the ground, retaining the word 'basalt' for interbedded augitic lavas which consolidated at the surface.

It is to be noted, however, that a glassy base does not appear to be entirely absent from either Professor Geikie's diabases or dolerites; and although I do not intend to infer from the preceding remarks that the intersection of small or moderate-sized crystals of augite by prisms of felspar, or of felspar prisms by augite, is an exclusive characteristic of rocks which have consolidated at the surface of the earth's crust; or that it would enable us to distinguish the latter from intrusive sheets or dykes; still, it is a structural peculiarity of basic volcanic rocks which is worth noting, and it may help us to distinguish basic lavas from basic plutonic rocks. Acid igneous rocks have characteristic features of their own.

The slice under consideration is of larger grain than any of the preceding ones.

No. 5.—A dark-grey compact rock. Sp. G. 2·83.

M.—This is a very fine-grained rock, and so closely resembles those first described that a detailed account of it is not necessary. The magnetite is well formed. The augite is for the most part very small, and twinning is common in the larger crystals.

At fig. 6, plate II, I have sketched an illustration of the way the formation of minerals went on side by side, in these Bombay basalts, at almost the same time. The illustration represents a crystal of magnetite and two crystals of augite. The growth of the lower augite and that of the magnetite appears to have gone on side by side, and, at first, at very much the same pace. The magnetite then gained on the augite and finally partially surrounded it. The formation of the second augite then began and went on so rapidly that it enclosed a portion of the magnetite in its embrace.

No. 6.—A perfectly compact dark-grey rock with a dull green tint in it. It weathers brown. Sp. G. 2·80.

M.—This is a fine-grained magma basalt. The base consists of a brown glass, here and there converted into a green amorphous substance. Augite crystals are abundant in this slice. Most of them are very minute, and, in polarised light with crossed nicols, they stand out from the black background like stars on a clear night. Some are of fairly large size. Twinning is common, and a few of the augites are well shaped.

Felspar is abundant and is chiefly in small prisms. Most of it gives decided evidence of belonging to the triclinic system.

Magnetite is for the most part well shaped and of good size, but it is also to be seen in elongated stalk-like microliths in the glassy base.

Fig. 7, plate II, is an illustration taken from this slice showing the way minerals, in the process of crystallization, catch up, enclose, and become entangled with other minerals. An augite crystal is there seen to have enclosed several crystals of magnetite, and to have partially surrounded crystals of triclinic felspar; whilst other crystals of magnetite have formed on it.

The microscope enables one to understand how it is that the chemical analysis of minerals often yields such divergent results. Fig. 7, will, I think, suggest the explanation of how this takes place.

No. 7.—A compact greenish-grey rock. Sp. G. 2·85.

M.—The grain is larger than that of the preceding slices. Augite is abundant. Much of the felspar exhibits the twinning peculiar to triclinic felspar, and is in characteristic prisms. Felspar also occurs in large crystals and in shapeless masses, some of which are certainly sanidine.

The glassy base is of green colour. Here and there minute portions of it have been converted into delessite, and the whole of it is more or less changed. The rock is passing into the condition of the Darang traps (*l. c.*). In these slices, however, the glassy base can still be distinctly recognised as such. Very little magnetite is left in the rock.

At fig. 3, plate I, I have given a sketch of a portion of this slice. The very dark portion is the glassy base. The less dark portion is augite, and the white is felspar.

At fig. 9, plate II, I have sketched a group of augite crystals in polarised light under crossed nicols. It is impossible, in simple black and white, to indicate the various colours in which the crystals polarise; but the different shades of black will, perhaps, suffice to show the want of optical continuity between the different members of the group. The two small crystals at the upper left hand are seen to be twinned, the twinning plane being a sharp straight line, and the two halves of each twin polarising in complimentary colours. The others are crystals of different sizes and of very irregular shape. The various crystals of which this and similar groups are composed, began to crystallize, apparently, much about the same time from independent centres, and from want of space interfered with each other's growth and development. One micro-augite is enclosed in a large crystal, whilst another augite contains a gas bubble.

The group appears to have been rapidly formed, for along the upper margin a tongue of the glassy base (*a*) is partially enclosed in it.

I have depicted another characteristic group in fig. 8, plate II, taken from slice No. 10. One augite crystal, at the right hand, is seen to be nearly surrounded by a larger crystal of the same mineral. The shapes of all the members of the group are very irregular, and they have evidently interfered seriously with each other's development. The finishing off of the group has been hurried in its last stages, as along the outer margin a zone of cavities is to be seen,—a not uncommon feature in the augite of volcanic rocks. These cavities, the irregular shapes of the crystals, and the confused association of imperfectly formed augites, are, I think, indications of the rapidity with which the rock cooled.

The large felspar crystals are not at all homogeneous in their internal structure, and they enclose irregular-shaped augite crystals and patches of viridite.

No. 8.—*A greenish compact rock.* Sp. G. 2·4.

M.—This slice very much resembles the last. The glassy base has been converted into a greenish substance which contains in it minute embryonic crystals of epidote. Alteration has been set up in the felspars. Magnetite is not abundant, and is mostly in skeleton forms.

No. 9.—*A greenish-grey compact rock.* Sp. G. 2·85.

M.—In this slice augite is very abundant. The glassy base is still recognisable, but it has passed into an alteration product, olive green in transmitted light, which is in part, at any rate, delessite. A radiating structure is often apparent in it, and all of it is feebly dichroic when the polariser alone is used.

This slice contains a good many sanidine prisms exhibiting the simple twinning of the Carlsbad type, but they are quite subordinate to the plagioclase.

In one case water has clearly gained access to the rock, and a thin undulating ring of quartz has been left behind to mark its passage.

Augite crystals often partially enclose crystals of felspars, and felspars occasionally enclose fragments of the glassy base.

No. 10.—*A grey compact rock.* Sp. G. 2·81.

M.—The glassy base is still to be seen here and there, but in most cases it has been replaced by delessite, and in a few cases by chalcedony. It gives clear evidence of the invasion of water. The latter has often left castellated watermarks behind it, and has partially rounded the margins of the channels through which it flowed, so that in some cases these altered portions of the base have the appearance of amygdules plugging amygdaloidal cavities. I think that the results above described may be accounted for on the supposition that the uncrystallized glassy base yielded more readily to the solvent powers of heated water than the minerals that had crystallized out of it.

It is important to note the tendency, here evidenced, of acid water passing through a rock to excavate *rounded* cavities; the removal of olivine and leucite, and the rounding of the edges of the matrix in which they were buried, might lead to the formation of a pseudo-amygdaloid, and prevent the secondary minerals, substituted for olivine and leucite, being recognised as pseudomorphs of those minerals.

The felspar is more or less altered, but the augite is quite fresh. The slice contains some prisms of sanidine which exhibit characteristic Carlsbad twinning.

No. 11.—*A greenish-grey compact rock.* Sp. G. 2·81

M.—This slice closely resembles the last. The magnetite or titaniferous iron is a good deal decomposed, and much of it has passed into leucoxene. A study of these slices confirms the view taken of the origin of the opaque white material formed in connection with the Darang basalts. The white opacity diffused in a nebulous way through the latter is, I think, due in many cases, not to the decomposition of large regular crystals of ilmenite, but to the minute dendritic forms of iron disseminated through the base.

This rock generally is passing into a stage of alteration like that described in the traps of Darang (*l.c.*)

Conclusion.

I have not detected olivine in any of these slices either fresh or in an altered condition.

Olivine, though a very characteristic mineral, usually present in basalts, does not appear to be universally so abundant as to be invariably visible in every thin slice made for microscopic examination.

Forchhammer states that it does not occur at all in the basaltic rocks of the Faroe Islands;[1] whilst Professor Geikie, in his paper on the microscopic characters of the basalts of the Firth of Forth,[2] notes that it "varies much in quantity;" and though it is "usually discernible in every thin slice," in some basalts it appears only in occasional "rare and small pieces." Zirkel notes (Microscopical Petrography of the Fortieth Parallel, p. 219) that in rocks "closely allied" to the "proper or genuine felspar (i.e., plagioclase) basalts," and which he classes as a sub-division of the basalts, olivine is generally wanting. In some of the Deccan traps from other localities, specimens of which the Superintendent of the Geological Survey of India has kindly allowed me to see, it is very abundant. Olivine may possibly not be altogether absent from the Bombay lavas; but, if present, it must be sparsely disseminated through them.

In view of the absence, or sparseness, of olivine, the question arises whether these rocks should be classed as basalts at all. In mineral composition they approximate closely to the quartzless-augite-andesites, in which olivine is rarely met with.[3]

The specific gravity of andesites ranges from 2·70 to 2·85; whilst the Bombay lavas, judging from the specimens now described, range from 2·80 to 2·85. In view, therefore, of the absence of olivine, a good case might be made out for classing the Bombay rocks with augite-andesites rather than with basalts.

But, on the whole, it will, I think, be better to retain the name by which the Bombay rocks have hitherto been known, and to continue to call them basalts; for I think it will conduce to clearness and simplicity if we restrict the term 'andesite' to the lava form of diorite and retain the words 'basalt' and 'dolerite' for basic augitic lavas. The term 'augite-andesite' seems a suitable one for intermediate forms between the two in which augite and hornblende are both present; and I prefer not to use it for the Bombay rocks because they contain no trace of the latter mineral.

As the Bombay basalts are very typical volcanic rocks, it may be useful, and may aid us to determine more doubtful rocks in other localities, to sum up the indications they afford of being superficial lava streams.

[1] Bischof's Chemical Geology, II, p. 356.
[2] *Loc. cit.*, p. 506.
[3] Rutley's Study of Rocks, p. 236.

The following points, I think, afford evidence of rapid cooling, though some of them are more cogent than others:—

1. The presence of a glassy base.
2. Skeleton, dendritic, and rod-like forms, of magnetite and (?) ilmenite.
3. The presence of glass enclosures, and gas bubbles, in augite and felspar crystals.[1]
4. The abundance of felspar prisms of small size, the longer axis of which usually points in all directions.[2]
5. The abundance of granular[3] and minute crystals of augite.
6. Clusters of irregular-shaped augite crystals.
7. Imperfectly-formed and feathery felspar crystals.[4]
8. The penetration of augite by felspar and of felspar by augite.

EXPLANATION OF PLATES.

PLATE I.

Figs. 1, 2, and 3.—Thin slices of Bombay basalts as seen under the microscope.

PLATE II.

Fig. 1.—Partial enclosure of felspar by augite.
Fig. 2.—Partial enclosure of augite by felspar.
Fig. 3.—Stellate prisms of felspar.
Fig. 4.—A twinned augite and felspar prism.
Fig. 5.—Augite and felspar prisms formed side by side.
Fig. 6.—Augite and magnetite formed at nearly the same time.
Fig. 7.—Augite enclosing magnetite and felspar.
Figs. 8 and 9.—Irregular-shaped clusters of augite crystals.
Fig. 10.—Another stellate form of felspar.

[1] Dr. Sorby, Ann. Address, Q. J. G. S. XXXVI, 53.

[2] Professor Geikie, in the paper already quoted, states that intrusive dolerite "along the line of contact with a sandstone or other granular rock" "becomes exceedingly close-grained," and the felspar prisms "tend to range themselves parallel with the surface of the sandstone."

[3] Professor Geikie, in the paper already quoted, writes of the volcanic rocks of the Firth of Forth:—"There is one distinctive feature between the mode of occurrence of the augite in the 'dolerites and in the interbedded anamesites and basalts which I have found to hold good with 'few exceptions. While in the intrusive sheets the augite occurs either in well-marked crystals or 'in large crystalline irregularly-shaped portions, in the superficial lava-beds it is commonly present 'in abundant small granules and in sparse definite crystals."

[4] See Dr. Sorby's opening address, Geology section of the British Association, 1880.

Fig. 1 × 60

Fig. 2 × 85

Fig. 3 × 85

Reproduced in heliogravure from the original drawings at the Surveyor General's Office, Calcutta
January 1883.

Fig. 1

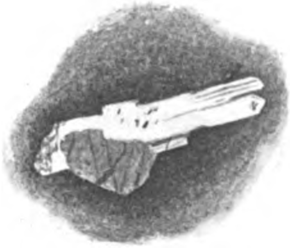

Fig. 2

Fig. 3

Fig. 4

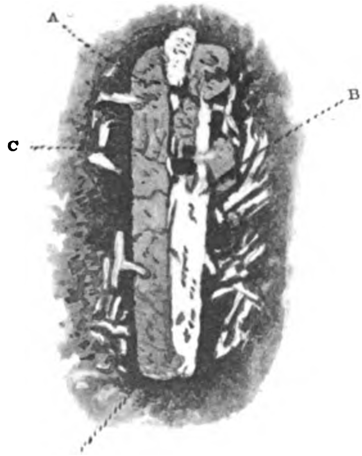

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

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January 24th, 1883.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1883. [May.

Synopsis of the Fossil Vertebrata *of* India, *by* R. Lydekker, B.A., F.G.S., F.Z.S.

Introductory.

In the "Journal of the Asiatic Society of Bengal" for the year 1880 there appeared a paper by the present author, under the title of a "Sketch of the History of the Fossil Vertebrata of India," in which every species of fossil vertebrate animal then discovered in India was recorded, while there was also given a short summary of the labours of those palæontologists who had written on the Indian Fossil Vertebrata. Since the date of publication of that paper a great increase in our knowledge of the subject has been obtained, and it has accordingly been thought advisable to republish the substance of that paper, with such additions and alterations as are necessary to bring it up to the present state of our knowledge. In many instances these alterations have been so extensive as to have made it necessary to totally re-write a great portion of the original paper. It has been thought better to omit the introductory portion, in which the names of the chief workers in this field of enquiry are recorded, as there is no essential alteration to be made regarding them. Some introductory observations on the general relations of the Indian fossil vertebrates have likewise been omitted, as well as all the references. The record of the local distribution of species, and the places where the more remarkable specimens are preserved, form a new feature in this memoir.

The plan of the original paper has been in the main strictly adhered to; this consists in taking each of the classes of the vertebrata and recording their geological distribution, from the oldest to the present time. At the end a systematic synopsis of all the known forms is given, arranged according to their geological distribution; and also an alphabetical list of the species.

Class I.—PISCES.

Carboniferous.—The earliest fishes of which there is any record are known merely by a few specimens of teeth and dorsal spines obtained in the palæozoic rocks of the Salt-range in the Panjáb. The beds from which these remains were obtained are termed the "Productus-Limestone," and are considered to correspond roughly to the carboniferous of Europe. Among these fishes there is a new genus of ganoid described, upon the evidence of a single tooth, under the name of *Sigmodus dubius;* this tooth is of an elongated conical form, much resembling the teeth of certain Saurians. Of the *Cochliodontidæ*, here provisionally referred to the Ganoidei, there are two genera, each represented by a single species, namely, *Pœcilodus paradoxus* and *Psephodus indicus;* the tooth of the former is of the flattened cestraciont type. Of the Elasmobranchii, five genera have been named, some from the evidence of teeth, and others from spines; but, in view of certain modern discoveries, it is not impossible that in some cases distinct genera have been formed from the different remains of the same animal. Of these the new genus *Helodopsis*, allied to the European *Helodus*, has been formed for the reception of two teeth, which have been referred to distinct species under the respective names of *H. elongata* and *H. abbreviata.* A fragmental tooth, too imperfect for specific determination, has been referred to the common European carboniferous genus *Psammodus.* A fourth tooth, under the name of *P. indicus*, is referred to the European genus *Petalorhyncus*, which is very doubtfully separated from *Petalodus.* Of the spines, three specimens are referred to the genus *Xystracanthus*, of the carboniferous of America, under the names of *X. gracilis*, *X. major*, and *X. minor;* the possibility of these specimens belonging to some species of *Helodopsis* is, however, suggested. A fourth spine is referred to a new genus, under the name of *Thaumatacanthus blanfordi.* As far as the evidence of these fishes goes, it is apparent that sharks with crushing teeth were the dominant forms in the Indian carboniferous seas, as well as in those of Europe and America. All the specimens noticed above are in the collection of the Indian Museum.

From the same rocks there have been obtained teeth of two species of the elasmobranch genus *Acrodus*, to one of which the name *A. flemingi* has been applied. Other small teeth have been doubtfully referred to the ganoid genus *Saurichthys*, with the name of *S. (?) indicus.*

Trias-jura.—In the upper portion of the great Gondwána system, probably corresponding as a whole to the trias and jura, remains of fishes have been found in some abundance, the determined forms belonging to freshwater ganoids. In the Maleri group[1] of this system, the fauna of which shows a rhæto-triassic facies, three spines of the genus *Ceratodus* have been determined, and respectively named *C. hislopianus*, *C. hunterianus*, and *C. virapa.* The latter is considered to be closely allied to *C. polymorphus* of the rhætic of Bristol. At the present day the genus inhabits the rivers of Queensland, and in Europe is found fossil from the Keuper to the Jura. The specimens of the Maleri teeth are in the Indian Museum. From the Kota group, sometimes classed with the Maleri group, but showing a more distinctly liassic series of fossils, nine species of ganoids have been determined, belonging to the genera *Dapedius*, *Lepidotus*, and *Tetragonolepis*, all of which occur in the secondary strata of Europe, where they range from the lias to the eocene, *Lepidotus* being especially characteristic of the wealden. The majority of the specimens on which these species are founded are, it is believed, in the collection of the Geological Society, but there are a few in the Indian Museum;

[1] I follow the Director General of the Geological Survey of Great Britain and Ireland in continuing to use the term 'group' as subordinate to the terms 'system' and 'series.'—See Geikie: "Text-Book of Geology," 1882, p. 635.

in many cases they comprise nearly perfect fish. Bones, apparently of fishes, have been obtained from the trias of Tibet, but are too imperfect for determination.

Cretaceous.—A few remains of fishes have been obtained from the middle cretaceous Lameta group, but are not determined, though it has been suggested that some of them may belong to the genus *Sphyrænodus*, of the eocene and miocene of Europe. From the middle and upper cretaceous Trichinopoli series, seventeen species of Elasmobranchi have been described, belonging to the genera *Corax*, *Enchodus*, *Lamna*, *Odontaspis*, *Otodus*, *Oxychina*, *Ptychodus*, and *Sphærodus*, and one ganoid, doubtfully referred to *Pycnodus*; all these genera occur in the cretaceous of Europe, of which period some are characteristic. Two of the Indian species, *viz.*, *Corax pristodontus* and *Ptychodus latissimus*, are common to the cretaceous of Europe. Most of these species are founded on the evidence of teeth, some of which are in the Indian Museum and others in the collection of the Geological Society of London.

Eocene.—From the eocene of the Andaman Islands and Rámri Island on the Arakán coast, there have been obtained two teeth of a large *Diodon*, named *D. foleyi*; from the occurrence of *D. hystrix* off these coasts at the present time, it may be assumed that the genus has lived there since the eocene. Remains of a large species of this genus have been obtained from the miocene of Malta. Undetermined cycloid scales have been obtained from the eocene of Thyetmyo in Burma. From the eocene of the Panjáb there are other undetermined scales, and the dental plate of a species of eagle-ray,—*Myliobatis*,—a genus very common in the eocene of Europe, and widely distributed at the present day. From the neighbourhood of Kohát, in the Panjáb, from strata of eocene or lower miocene age, a single incisor of a sparoid fish, named *Capidotus indicus*, has been obtained. The genus was previously known only from the miocene of Vienna and Silesia, and is allied to the living *Sargus*. All the above specimens of teeth are in the collection of the Indian Museum.

Pliocene.—From the Siwalik series numerous species of fishes have been obtained, though severa lhave not been determined. Among the siluroids, we have a large skull in the Indian Museum (originally referred to a gigantic batrachian) belonging to the living species *Bagarias yarrelli*, of the larger Indian and Burman rivers. The British Museum has the anterior portion of the skull of a siluroid (labelled *Pimelodus*), belonging probably to a smaller species of the same genus; and a smaller but nearly complete skull in the same collection belongs probably to this species. The survival of a pliocene fish to the present day is a fact of much interest. The genus would seem to have been widely distributed in eocene times throughout the East, as a species has been described from the tertiaries of Sumatra under the name of *B. gigas*. The posterior half of the skull of a gigantic siluroid in the British Museum indicates another genus of this group. Palatal teeth of a third form of siluroid, from the Panjáb and Sind, and now in the Indian Museum, probably belong to the genus *Arius*, now inhabiting the rivers of India. Among the elasmobranchi a few teeth indicate a species of Siwalik *Lamna*, while a single tooth in the Indian Museum from Burma belonged to a small species of *Carcharodon* or *Carcharias*. Large squaline vertebræ, now in the Indian Museum, have been obtained from the Siwaliks of Perim Island.

From the tertiaries, or post-tertiaries, of the Káshmír valley a few fish-scales have been obtained.

Class II.—AMPHIBIA.

Trias-jura.—The oldest-known Indian amphibian is represented by a skull and part of the vertebral column, from the Bijori group of the Gondwánas, of a large species. This fine specimen belonged to the Asiatic Society of Bengal, and was sent to England for description about 18 years ago, since which time it has lain unnoticed. It has recently been recovered, and the writer hopes subsequently to give a description of it. The skull is of a triangular shape, and has been referred to *Archegosaurus* and *Labyrinthodon*. In its restricted sense, no skull is known of the latter genus, and it is quite possible that the Indian specimen may belong to *Mastodonsaurus* or to some other genus. Provisionally, it is convenient to refer to it as an *Archegosaurus* (see Note, p. 93).

From the Panchet group of the Gondwánas three genera of slender-jawed labyrinthodonts, allied to those of the European trias, are known. The first of these, *Pachygonia*, has only the one species *P. incurvata*, and is known by the greater part of the mandible, and a fragment of the skull. The marking of the former is like that of *Mastodonsaurus*. The second genus, *Gonioglyptus*, has two species, the smaller known as *G. longirostris* and the larger as *G. huxleyi*; it is considered to be closely allied to *Trematosaurus* of the bunter-sandstone of Germany. The third genus is known only by a single fragment of the mandible, to which the name *Glyptognathus fragilis* has been applied. These three genera are peculiar to India, and all their remains are exhibited in the Indian Museum; the two former belong to the group Euglypta.

From the Mángli beds of the Gondwánas, another peculiar genus of labyrinthodont has been obtained, and is represented by a single skull in the collection of the Geological Society, to which the name *Brachyops laticeps* has been applied. The genus is allied to *Rhinosaurus* from the jurassic of Europe, to *Micropholis* of the trias of Africa, and to *Bothriceps* of the trias of Australia, and with them constitutes the group Brachyopina.

From the Maleri group fragmentary jaws of a species of *Pachygonia*, probably the same as the Panchet form, have been obtained, as well as simple biconcave vertebræ of considerable size, probably belonging to a labyrinthodont; these specimens are in the Indian Museum.

Tertiary.—No amphibian remains have hitherto been obtained between the trias-jura and the tertiaries. In the lower series of the latter at Bombay there occur numerous remains of a small frog, belonging to the genus *Oxyglossus*, now living in China, Siam, and possibly India; the fossil species is extinct, and is known as *O. pusillus*: remains of a larger, but undetermined, frog are also indicated.

Class III.—REPTILIA.

Trias-jura.—The oldest reptiles hitherto found in India belong to the orders Dinosauria and Dicynodontia, and occur near Ráníganj in lower Bengal, in the Panchet group of the Gondwanas, probably of triassic age. The remains of a species of *Dicynodon*, belonging to the sub-genus *Ptychognathus*, are of comparatively common occurrence in the coarse Panchet sandstone, and have been described as *D. orientalis*. Other remains seem to indicate a second and larger species of the genus. This order of reptiles seems to be characteristic of the trias of India, Russia, and Africa, and to have attained its fullest development in the latter country. The remains of the Indian forms all occur over a very small area in one thin seam of the Panchets. The Dinosaur has been named *Ankistrodon indicus*, and is the sole representative of the genus; it is known merely by two minute compressed and trenchant teeth with serrated edges, like those of *Megalosaurus*, implanted in distinct sockets. The above specimens are in the Indian Museum. The Maleri group of the same system has yielded numerous, though much broken, remains of a large crocodilian, constituting the still undescribed genus *Parasuchus*, and bearing the manuscript specific name of *hislopi*, after the late Rev. Mr. Hislop, the discoverer of the vertebrate fossils of the Maleri group. This crocodile belonged to the amphicœlian division of the order, and seems to have been closely allied to *Belodon* and *Stagonolepis* of the trias of Europe, the three genera forming a group characterised by the non-union of the pterygoids behind the palatines. The scutes referred to *Parasuchus* differ from those of living crocodiles by their sculpture consisting of ridges and furrows radiating from a sub-central point, instead of isolated irregular pits. From the Denwá group of the same system a single scale of a gigantic crocodilian, probably belonging to the above genus, has been obtained. The Tiki beds in South Rewá, which are not improbably the equivalent of the Panchet group, have yielded other crocodilian remains, agreeing in the structure of the scales with *Parasuchus*, but distinguished by a totally different form of barioccipital, whence it is inferred that they probably belong to a distinct genus. In addition to the above, the Maleri and South Rewá rocks have yielded remains of a large species of the lacertian genus *Hyperodapedon*, originally described from the English trias. The Indian species, *H. huxleyi*, differs from the European, *H. granti*, by the greater number of the palatal teeth, and the presence of some additional teeth on the outer surface of the mandible; its length has been roughly estimated at 16 feet. The genus is closely allied to the living *Hatteria* of New Zealand, and has been supposed to have an affinity to *Rhynchosaurus* of the trias of Europe. From the Chári group of the jura of Kach there has been obtained a single crocodilian vertebra, not improbably belonging to *Parasuchus;* and from the Umia group of the same, a fragment of the mandible of a *Plesiosaurus*, described as *P. indicus;* the affinities of this form cannot be fully determined from the specimen.

The whole of the remains from the trias-jura, mentioned above, are in the collection of the Indian Museum.

Cretaceous.—From the Trichinopoli group (upper cretaceous), and probably from the Lameta group (middle cretaceous), there have been obtained a few teeth of a species of *Megalosaurus*, a genus whose range in Europe extends from the jurassic to the wealden; the one tooth of the Indian form now forthcoming is in the Indian Museum. From the Lameta series there have also been obtained the remains of another genus of gigantic dinosaur, to which the name *Titano-*

saurus has been assigned. This genus is allied to *Pelorosaurus* of the English wealden, and to *Oetiosaurus* of the jurassic, and was a long-tailed terrestrial form. The genus was represented by two species,—*T. indicus* and *T. blanfordi;* the former characterised by the centre of the caudal vertebræ being compressed, while in the latter they are sub-cylindrical. Numerous vertebræ, chiefly caudal, and a huge femur, nearly 4 feet in length, are preserved in the Indian Museum, and there is a cast of one of the former, belonging to *T. indicus*, in the British Museum. A few bones, in the former collection, indicate a smaller undetermined reptile from the Lametas.

The Chelonia are known in the cretaceous merely by some broken plates, in the collection of the Indian Museum, obtained from the Lametas, from the infra-trappeans of Rájamahendri (Rajamundry), and from the upper cretaceous of Sind.

The Crocodilia of the cretaceous are known only by one amphicœlian species, apparently allied to *Suchosaurus* of the English wealden, of which some vertebræ have been obtained from the upper cretaceous of Sind, and are now in the Indian Museum.

A large species of *Ichthyosaurus*, named *I. indicus*, is known solely by a few vertebræ obtained from the middle cretaceous of Trichinopoli, and now in the Indian Museum; the range of the genus in Europe is from the lias to the chalk.

Eocene.—The only specifically determined eocene reptile has been referred to the genus *Hydraspis*, under the name *H. leithi.* The specimen on which this determination rests is a carapace from the inter-trappeans of Bombay. The genus *Hydraspis* belongs to the *Emydidæ*, and is now confined to tropical America. From the nummulitics of the Panjáb numerous fragmentary remains of crocodilians have been obtained, but in too imperfect condition for determination.

Pliocene[1].—Many of the Siwalik chelonians in the British and Indian Museums are still undescribed, and the following list must, therefore, be considered imperfect. Of the Crocodilia, a species from the Sub-Himalaya and Perim Island has been identified with the living Indian *Crocodilus palustris* (*bombifrons*), remains from Burma and Sind probably belonging to the same species. Of the genus *Gharialis* (*Leptorhynchus*), a species from the Sub-Himalaya, Burma, Sind, and Perim Island is identical with *Gharialis gangeticus* of the Ganges and Jamna. A second species from the Sub-Himalaya, with slender teeth, has been named *G. leptodus;* and a third, of gigantic dimensions, and with shorter and stouter jaws and teeth, *G. crassidens;* the latter has been obtained from the Sub-Himalaya, Burma, and Sind. Remains of the above species are preserved both in the British and Indian Museums.

Of the order Lacertilia only one species of *Varanus* is known, and named *V. sivalensis:* this determination rests on the evidence of the distal extremity of a humerus, from the Sub-Himalaya, in the British Museum. The genus *Varanus*

[1] In this memoir the fossiliferous Siwaliks of Sind (lower Manchhars) are termed earlier pliocene, and those of the Sub-Himalaya and other parts of India higher pliocene,—the possibility of some of the Sind beds being of miocene age being still kept in view. The terms earlier and higher pliocene are intended merely to indicate that the one is older than the other, and not to indicate their correlation with the divisions of the European pliocene.

is now of common occurrence, and has probably existed since the oligocene, as the so-called *Palæovaranus* of the Quercy phosphorites is probably the same.

The Ophidia are known only by some vertebræ from the Panjáb and Sind, belonging to the genus *Python*, and not distinguishable from those of the living Indian *P. molurus;* these specimens are in the Indian Museum. A species of python (*P. cadurcensis*) from the Quercy phosphorites seems to have very closely resembled *P. molurus.*

The Chelonia are well represented, and comprise among other land tortoises the gigantic *Colossochelys atlas* from the Sub-Himalaya and Burma. This form is stated to be mainly distinguished from *Testudo* by the thickening of the episternal portion of the plastron, but it is doubtful if this character is of generic value, and the species should probably be referred to the latter genus. The length of the restored carapace in the British Museum is 12 feet 3 inches, and the entire animal, with the head and tail extended, is considered to have attained the length of 22 feet. In addition to this gigantic animal there is good evidence of the existence of other large tortoises, as the Indian Museum possesses several specimens of the ankylosed episternals of at least two species of large tortoises. These bones are as thick, but not as long, as those of *Colossochelys*, and their extremities are shorter, but more divergent; they probably belonged to species of *Testudo*, about two-thirds the size of *C. atlas*. A broken episternal indicates a third, but smaller species; while a fourth species of about the same size as the last is represented by three episternals in the Indian Museum, which are not bifurcated at their anterior extremities. A single carapace of a small tortoise in the Indian Museum seems also to belong to the genus *Testudo*. Among the hard-shelled emydine tortoises we have a species of *Bellia*, represented by two carapaces in the Indian Museum, which has been named *B. sivalensis*, and is considered to be closely allied to *B. crassicollis*, now inhabiting Tenasserim, Siam, and Sumatra; the genus is only represented by one other living species, *B. nuchalis* of Java. Another carapace in the Indian Museum, also from the Panjáb, seems to indicate a second Siwalik species of the genus. In the British Museum there are two carapaces of Siwalik land tortoises, with three dorsal ridges, which, although differing considerably in size, evidently belong to the same species, and since the smaller cannot be distinguished from the living *Damonia hamiltoni*, inhabiting Lower Bengal, they may be referred to that species; as is frequently the case, however, the fossil form greatly exceeded the living in size. The larger specimen was named *Emys hamiltonoides* in manuscript. An imperfect carapace from the Panjáb, in the collection of the Indian Museum, seems to belong to the genus *Emys*. A single marginal plate, also in the Indian Museum, has been referred, under the name of *Cautleya annuliger*, to a new genus, said to be distinguished from all other emydine tortoises by the cartilaginous, in place of the osseous, union of the marginals with the adjoining plates. Among the Bataguridæ, some carapaces in the British Museum indicate an animal identical with the living *Pangshura* (*Emys*) *tectum*, now inhabiting Lower Bengal; the fossil form attained a larger size than the recent. A large species of *Batagur* has been obtained in some numbers, but is not specifically determined. A carapace of this genus in the Indian Museum, with a ridge on the vertebral plates, very probably belongs to a second species. Remains of a large *Trionyx* are likewise not uncommon, but have not yet been specifically determined. A carapace in the British Museum has been identified with the living *Emyda vittata* (*ceylonensis*) of Central and Southern India and Ceylon, and it is probable that numerous other remains of this genus may be referred to the same species.

Pleistocene.—The reptiles of the pleistocene are still very imperfectly known, but it is probable that they all belong to living Indian species. From both the Jamna and Narbada beds specifically indeterminable remains of crocodiles have been obtained. Two complete specimens of the carapace of *Pangshura tectum* from the Narbada are in the Indian Museum, and serve to connect the living with the Siwalik form, and show that the range of the species once extended over the greater part of India. A portion of the plastron of a *Batagur* from the Narbada has been provisionally referred to *B. dhongoka*, now found in the same river. A fragment of the carapace of a *Trionyx*, from the same deposits, probably belonged to *T. gangeticus*, and it is highly probable that a large chelonian cranium in the British Museum, from the same deposits, should be referred to the same species.

General.—The foregoing notes will show that the fossil reptiles are very few in number, and that many are only known by very fragmentary remains. The known mesozoic forms belong entirely to extinct genera; the one known eocene reptile belongs to a genus still living, but now far removed from India; the pliocene forms (with the exception of the doubtful genus, *Colossochelys*) all belong to modern Indian genera, and frequently to existing species, although their range is now frequently restricted to the more southern parts of India; in the pleistocene it is probable that all the forms belong to existing species, which still inhabit the same districts as their fossil ancestors.

CLASS IV.—AVES.

Pliocene.—Remains of birds have hitherto been found only in the Sub-Himalayan Siwaliks, and in one instance in Sind; their numbers are still very small. Some of these remains are in the British, and the others in the Indian Museum. Among the carinates, a tarso-metatarsus has been considered to belong to a cormorant, and is provisionally referred to the genus *Graculus*. A species of pelican (*Pelecanus cautleyi*), somewhat smaller than the living Indian *P. mitratus*, is indicated by a fragment of the ulna; while another fragment of the same bone has been referred to a second species, under the name of *P. sivalensis*, but there is some doubt whether the generic determination is correct. A gigantic wader has been described, from the evidence of a sternum and tibia, under the name of *Megaloscelornis sivalensis*, and it is possible that the condyles of a humerus from Sind, measuring 2 inches in diameter, may belong to the same genus. A species of adjutant stork, which appears to have had considerable variations in size, has been named *Argala falconeri*. The Ratitæ appear to have been represented by three species, one of which was a true ostrich (*Struthio asiaticus*[1]), and is known by several bones of the leg and foot; and some cervical vertebræ. The second species is an emeu (*Dromæus sivalensis*,) and is indicated

[1] The name *S. palæindicus* occurs in manuscript.

by some toe-bones; while the third, which is not even generically determined, is considered to be a three-toed form, intermediate between the ostrich and the emeu, and is only known by one of the bones of the foot.

CLASS V.—MAMMALIA.

Eocene.—No traces of mammals have yet been detected below the eocene, and there only some very fragmentary bones have been obtained from the Panjáb. The determinable bones consist of the distal portions of the femur and the metatarsus of a perissodactylate animal, allied to, if not identical with, the palæothere and the astragalus of an artiodactylate. The latter was obtained above the nummulitic clays of Fatehjang, and belonged to a (probably) ruminant animal, in which the navicular and cuboid elements of the tarsus were united. These specimens are in the Indian Museum.

Miocene.—The only definitely determined miocene mammal is a rhinoceros from the Gáj beds of Sind, which is apparently a variety of *R. sivalensis*, and has been named *v. gajensis.*

Pliocene.—The primates are known merely by a few fragmentary specimens of upper and lower jaws, with their teeth, and by one bone. The palate of a female, and the upper canine of a male, have been referred to a large anthropoid ape, under the title of *Palæopithecus sivalensis;* the genus seems to be allied to the orang, but is distinguished by the narrower form of the premolars: this specimen is in the Indian Museum. The half of a palate, not improbably belonging to a species of *Semnopithecus*, in the British Museum, has been provisionally named *S. subhimalayanus.* A lower jaw and an astragalus, the former in the British Museum, seem probably to belong to a smaller form of *Semnopithecus*, considered to be distinct from the former species. A species of *Macacus*, larger than *M. rhesus*, is indicated by two fragments of the mandible, in the British Museum; while a second species, smaller than *M. rhesus*, and known as *M. sivalensis*, is represented by two fragments of the maxilla, with teeth, in the Indian Museum.

Among the Carnivora we find a large species of tiger, characterised by its greatly developed sagittal crest, which has accordingly been named *Felis cristata*[1]; this species is represented by three crania (and limb-bones) in the British Museum, to one of which the separate specific name *F. grandicristata* has been applied, but apparently on insufficient grounds. The Indian Museum possesses some limb-bones, and a lower carnassial tooth, which not improbably belong to this species. A smaller species of the genus, about the size of *F. bengalensis*, is indicated by a single ramus of the mandible, in the Indian Museum. The genus *Machairodus* is represented by *M. sivalensis* (*M. falconeri*, Pomel), apparently varying in size from the dimensions of the jaguar to those of the tiger, although it has been proposed to distinguish the larger form under the name of *M. palæindicus.* This species is represented by two broken skulls, and numerous fragments of the jaws in the British Museum, and by the hinder part of a small skull, and part of the mandible in the Indian Museum. The genus *Pseudælurus*, distinguished from *Felis* by the presence of three, or occasionally four,

[1] The manuscript name, *F. palæotigris*, exists.

in place of two lower premolars[1] (although the ante-penultimate premolar is occasionally present as an abnormality in *Felis*), is known by a ramus of the mandible, in the Indian Museum, named *P. sivalensis;* the species was about equal in size to a small leopard. Among the civet-like animals we have a species of *Viverra*, said to be closely allied to the living civet, and represented by two skulls in the British Museum, to which the name *Viverra bakeri* has been applied. *Ictitherium* is represented by *I. sivalense*, of which the two rami of one mandible, a broken ramus, without teeth, of another, and a canine tooth are known, all of which are in the Indian Museum, and came from the Panjáb. The hyænas are represented by *Hyæna sivalensis*, said to present relationship both to the Indian *H. striata* and to the African and European *H. crocuta*, of which there are numerous specimens of the skull and mandible in the British and Indian Museums. It has been proposed to separate some of these specimens under the name of *H. felina*, a so-called species said to be characterised by the absence of the first upper premolar, and by the minute size of the last upper true molar; a large series of specimens shows, however, a great variety in these respects. Remains of a species of *Hyæna* have been described from the pliocene of China, and referred to a distinct species. The dogs are represented by *Canis cautleyi*, and *C. curvipalatus;* the former closely allied to the wolf: portions of the skulls of these species are in the British Museum, and a specifically undetermined palate in the British Museum. The genus *Amphicyon*, distinguished from *Canis* by its plantigrade character and by the presence of an additional upper true molar, is represented by *A. palæindicus*, of which the Indian Museum possesses several specimens of the jaws and teeth from Sind and the Panjáb. The bears are represented by the genera *Ursus* and *Hyænarctos:* of the former there is a skull, without teeth, from the Sub-Himalaya, and a canine from the Irawádi, both in the collection of the Indian Museum. Of the latter there are two species, *H. sivalensis* and *H. palæindicus*. *H. sivalensis* has the molars with quadrangular crowns, and is known by a fine skull, the half of a mandible, and some limb-bones, in the British Museum; and by numerous specimens of the teeth and jaws in the Indian Museum; a single upper molar from the newer pliocene of England much resembles the teeth of this species. *H. palæindicus* is known only by a single maxilla in the Indian Museum, and is distinguished by the triangular form of the crowns of the upper molars, which approach those of *Amphicyon*. Of the subursoid carnivores, the genus *Mellivora* (*Ursitaxus*) is represented by *M. sivalensis*, known by a fragment of the mandible from the Panjáb, in the Indian Museum, and apparently very closely allied to the living Indian species; and the genus *Meles* by a single species, of which there is also only a fragment of the mandible contained in the Indian Museum. Of the otters, *Lutra palæindica* has been named from the evidence of a skull and lower jaw in the British Museum; and a second species seems to be indicated by a lower jaw from the Panjáb, in the Indian Museum. *Enhydriodon*, represented by *E. ferox*, is a genus peculiar to the Siwaliks; the only known specimens are two skulls in the British Museum, a part of the maxilla in the Museum of the Royal College of Surgeons, and a mandible. The genus takes its name from its

[1] Occasionally a tubercular true molar is present, and the genus then approaches *Proailurus*.

affinity to the living sea-otter (*Enhydras*). The living genus inhabits the coasts of the North Pacific during winter, and proceeds up the rivers in summer; but it is probable that its fossil ancestor must have been entirely a river-dwelling form.

The Proboscidia are very abundantly represented, species of all the known genera or sub-genera being present. The most specialised genus, *Euelephas*, is represented by *E. hysudricus*, of which the molars are of less complex structure than those of *E. indicus*. *Loxodon* is represented by *L. planifrons*, remarkable for being the only species of true elephant in which premolars are known to have been developed. The genus or sub-genus *Stegodon*, peculiar to South-Eastern Asia, is represented by four species. Of these the molars of *S. ganesa* and *S. insignis* appear to be indistinguishable from one another; the skull of the former, however, of which there is a magnificent specimen in the British Museum, is distinguished by its enormous tusks; while that of the latter, of which there are numerous specimens, by the peculiarly depressed form of the fronto-parietal region. Molars of either *S. insignis* or of the next species, if not of both, have been obtained from strata of probably pliocene age in Japan. The molars of the third species, *S. bombifrons*, are less complex than those of the preceding; its skull has very prominent frontals; remains of this species have been obtained from the pliocene (?) of China, and described under the name of *S. orientalis*. Of the fourth species, *S. clifti*, the skull is unknown, but the molars are still simpler, the intermediate ones bearing only six ridges each; remains of this species have also been obtained from Burma, Japan, and China, a tooth from the latter country having been named *S. sinensis*. Five species of mastodons are also known, three belonging to the tetra-, and two to the tri-lophodont subdivision of the genus. Of the former, *M. latidens* approaches nearest to the stegodons, and, as it has open valleys, and the intermediate molars occasionally carry five ridges, it affords such a complete transition between *S. clifti* and the other mastodons that it seems highly probable that the generic divisions of the elephants and mastodons should be swept away, and the whole of them included under one large genus. The skull of *M. latidens* is unknown; its remains have been obtained from the Irawádi valley, the Sub-Himalaya, Sind, and Perim Island. *M. perimensis* has the molars rather less regular than the last; there is a fine skull in the British Museum, and its remains have been found in the Panjáb and Perim Island. The third tetra-lophodont species, *M. sivalensis*, has the molars with an "alternate" arrangement of the ridges, and occasionally presenting a tendency to a pentalophodont formula; there is a fine skull in the British Museum, and remains of this species have been obtained only from the Sub-Himalaya. The skulls of the two trilophodont species are unknown, and all their remains, which are from the Panjáb, Sind, and Perim Island, are in the Indian Museum [1]. In the first, *M. falconeri*, the valleys of the molars are open, and the symphysis of the lower jaw is short, and sometimes provided with small cylindrical tusks. In the second, *M. pandionis*, the valleys of the molars are obstructed by outlying columns, and the symphysis of the lower jaw is produced into a long trough-like process, which may or may not be furnished with large compressed tusks. Of the genus *Dinotherium* three species are

[1] This is exclusive of the remains of *M. pandionis* from the pleistocene of Madras.

known: the largest of these, *D. indicum*, rivals in size the European *D. giganteum*; there are several specimens of the teeth and jaws in the Indian Museum, and also in the collection of the Bombay Branch of the Royal Asiatic Society; there is also a cervical vertebra, part of the mandible, and an upper molar in the British Museum; remains of this species have been obtained from the Panjáb and Perim Island. The second species, *D. pentapotamiæ*, is of smaller size, and has been obtained from the Panjáb, Kach, and Sind; numerous specimens of the teeth and jaws are exhibited in the Indian Museum. The last species, *D. sindiense*, is only known by two specimens of a part of the mandible, one from Sind and the other, lacking the crowns of the molars, from the Panjáb; both specimens are in the Indian Museum. The mandible in this species is subcylindrical in cross-section, and thereby approaches the mastodons.

Coming to the Ungulata, we find both the perisso-, and the artio-dactylate sections well represented, though the latter are by far the most numerous. Among the former, we have the rhinoceroses represented by three species of true *Rhinoceros*: the first of these was a unicorn form, apparently very closely allied to the living *R. javanicus* (*sondaicus*), which it resembles in the form of its molars and the mandible. Skulls and teeth of this species are contained both in the British and Indian Museums, and its remains have been obtained from the Sub-Himalaya and Sind. The second species, *R. palæindicus*, does not seem to come very near to any living form; this species was also unicorn, and the mandible had two pairs of incisors; the upper molars are intermediate in structure between those of the living Javan and Indian species. Most of the remains of this form are from the Sub-Himalaya, and are in the British Museum. The third species, *R. platyrhinus*, was of huge size, and furnished with two horns; its molars are of the complex type of *R. indicus*, and its mandible has no incisors like the mandibles of the living African species, and the extinct *R. pachygnathus* of Pikermi. Remains of this species have been obtained only from the Sub-Himalaya, and are nearly all in the British Museum, where there is a nearly complete skull. All the above species have high-crowned (hypsodont) molars. It is possible that certain remains from the Bhúgti hills, now in the hands of the writer, may indicate a new species of the genus, with a mandible resembling that part in the existing African species.

Imperfect molars of a species of *Rhinoceros* have been obtained from the pliocene of China, and described as *R. sinensis*. The hornless rhinoceroses are represented by the gigantic *Acerotherium perimense*[1], of which there are a fine skull and numerous teeth and jaws from the Panjáb, in the Indian Museum, and a magnificent palate and some specimens of the mandible, from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society; the British Museum also possesses a few specimens of teeth and jaws from Perim Island. The genus *Chalicotherium*, formerly classed among the artiodactylates, but now placed by many among the perissodactylates as a link between the rhinoceroses and the palæotheres, is represented by *C. sivalense*,—a species presenting a peculiarly aborted dentition, and hence referred by some to a distinct genus, under the name of *Nestoritherium*; it has been considered to be nearly allied to *Rhinoceros pachygnathus*. This species is of rare occurrence, but is known by an

[1] Syn. *Rhinoceros iravaticus* and *R. planidens*.

associated cranium and mandible, in the Museum of St. Andrew's University; by the upper molars of each maxilla and a mandible in the British Museum, and by a few lower molars in the Indian Museum. The latter specimens are from Sind, and the others from the Sub-Himalaya. Another species has been described from the pliocene of China. It seems doubtful whether the genus *Tapirus* occurs; the symphysis of a mandible from the Irawádi valley has indeed been referred to it, but the determination cannot be considered certain[1]. Fossil remains of the genus have, however, been obtained from the pliocene of China. The genus *Listriodon*, sometimes referred to the pigs, is represented by *L. pentapotamiæ* and *L. theobaldi*, the former being known by several molars, and the latter only by one molar of small size. All these teeth were obtained from the Panjáb, and are in the Indian Museum.

The horses are represented by the genera *Equus* and *Hippotherium* (*Hipparion*); of the former there are two species, *viz.*, *E. sivalensis*, apparently closely allied to the Tibetan kiang (*E. hemionus*), but retaining some ancestral characters, and *E. namadicus*, more nearly allied to the existing horse. Remains of these species have been obtained from the Sub-Himalaya, and one species of the genus from Perim, of which there are three molars in the Museum of Trinity College, Dublin. Of *Hippotherium* there are also two species, *viz.*, *H. antelopinum*, closely allied to the European *H. gracile*, and *H. theobaldi*, distinguished by its superior size, and the form of its upper milk-molars. The former has been obtained from the Sub-Himalaya and Perim Island, and there are numerous remains both in the British and Indian Museums. A fine skull from Perim has been recently sent on loan to the Indian Museum, and is the only known example. The latter has been obtained from the Panjáb, Burma, and Perim Island, and most of its remains are in the Indian Museum; it is not improbable that the range of this species extended to China, where molars belonging to some form of the genus have been obtained. Coming to the artiodactylates, we have among the bunodont pig-like animals two species of *Hippopotamus*, one of which, *H. sivalensis*, was of large size, and furnished with six incisors in either jaw; the other, *H. iravaticus*, is very imperfectly known, but seems to have been of small size. Remains of these species have been obtained from the Sub-Himalaya and the Irawádi valley. A large animal, *Tetraconodon magnum*, is known only by a broken mandible, from the Panjáb, in the Indian Museum, and of which there is a cast in the Museum of the Royal College of Surgeons, and by a figure of the upper dentition. The mandible is remarkable for the enormous size of the premolars, and indicates an animal allied to the European and American tertiary genus *Entelodon* (*Elotherium*), but distinguished by the greater relative size of the premolars, and the more regularly oblong form of the true molars. The true pigs (*Sus*) are represented by three species, the first of which, *S. giganteus*, is distinguished by its enormous size; there is a nearly complete skull, with the mandible attached, and with some of the limb-bones, of this fine species, as well as numerous other remains in the Indian Museum, and a large series of teeth and jaws in the British Museum, all of which have been obtained from the Panjáb and Sub-Himalaya. The second species, *S. hysudricus*, is smaller

[1] Remains of *Listriodon* have been described as *Tapirus*.

than the living wild-boar, and has been obtained from the Panjáb, Sub-Himalaya, Perim Island, and Sind. The last species, *S. punjabiensis*, is of very small dimensions, and is only known by two portions of the mandible from the Panjáb, now in the Indian Museum. *Hippohyus* is a genus peculiar to the Siwaliks, whose molars present a remarkable complex arrangement of the columns, recalling the pattern of the molars of the horse; it appears to have been represented by two species, both from the Sub-Himalaya, and one of which has been named *H. sivalensis*. *Sanitherium* is another genus peculiar to the Siwaliks, and is represented only by *S. schlagintweiti*, of which three fragments of the mandible are known, two being in Germany and the third in the Indian Museum; all three are from the Panjáb and Sub-Himalaya. The European miocene genus *Hyotherium* is represented by the molars of one species from Sind and Perim Island, which has been named *H. sindiense;* these teeth are in the Indian Museum. Of the selenodont pig-like animals, we have, among the group with five columns on the upper molars, two species of *Anthracotherium*, and two of *Hyopotamus*. Of the former, one species, *A. silistrense*, is of small size, and is known by three upper molars, and parts of the mandible; these specimens have been obtained from near Sylhet, the Panjáb, and Sind, and most of them are in the Indian Museum. The second species, *H. hyopotamoides*, is of large size, and is known by an upper molar in the Indian Museum, from the Bhúgti hills, to the north of Sind; some mandibles may also belong to this species. Of *Hyopotamus*, a small species, *H. palæindicus*, is known by several teeth and one lower jaw, from Sind, in the Indian Museum; the molars of this species differ somewhat from those of typical species. The second species, *H. giganteus*, is known by an upper molar, and by some specimens of the mandible from the Bhúgti hills, now in the Indian Museum [1]; the upper tooth much resembles that of *Anthracotherium hyopotamoides*, and with that species forms such a complete transition between the genera *Anthracotherium* and *Hyopotamus* that it seems highly probable that the two should be united. Among the forms characterised by having only four columns on the upper molars, there are four peculiar genera, each of which is known only by a single representative. The best known of these is *Merycopotamus*, represented by *M. dissimilis*, a genus allied to the hyopotamids by the structure of its teeth, and to the hippopotamus by the form of the mandible; this species has been obtained from the Sub-Himalaya and the Irawádi valley, and there are fine series of its remains in both the British and the Indian Museums. A second genus, *Hemimeryx*, is only certainly known by an upper molar of somewhat similar structure to the molars of the last genus; this specimen has been named *H. blanfordi*, and was obtained from Sind; it is now in the Indian Museum. Another upper molar in the same collection, also from Sind, has been named *Sivameryx sindiensis*, and indicates a smaller animal allied to the above. A maxilla with the upper molars, from the Garo hills, presented to the Geological Society, indicates another small animal of the same group, to which the name *Chæromeryx silistrensis* has been applied.

[1] Casts of the teeth of this species and of *A. hyopotamoides* will be found in the British Museum. The names of these, and of other selenodont Suina, are mentioned here for the first time, the memoir in which they are described being still in the press.

A single upper molar from Sind, in the Indian Museum, belongs to the American family *Oreodontidæ*, and has been provisionally referred to the genus *Agriochærus*; it seems to be very close to the American *A. latifrons*.

Among the true ruminants we have the deer family represented by several imperfectly known species, at least one of which had large branching antlers. Of these, *Cervus triplidens* had a large accessory column to the molars, while in *C. simplicidens*, a species as large as *C. kashmirianus*, the accessory column is much smaller. In *C. sivalensis* the molars had very low crowns. The genus of the fourth species, *C. latidens*, is somewhat doubtful. Remains of these species have been obtained from the Panjáb and the Sub-Himalaya, and are numerously represented in the Indian Museum. The genus *Dorcatherium* is represented by the two species *D. majus* and *D. minus*, of which there are teeth in the Indian Museum, obtained from the Panjáb. A single upper molar in the Indian Museum, from the Panjáb, seems to belong to a genus related to *Palæomeryx*, for which the provisional name *Propalæomeryx sivalensis* has been proposed; it probably connects the true deer with the giraffe. The family *Camelopardalidæ*, which is taken to include both the giraffes and the sivatheres, is represented by several genera. In these we have a true giraffe, distinguished as *Camelopardalis sivalensis*, of which there are numerous teeth and a few bones in the British and Indian Museums, from the Sub-Himalaya, the Panjáb, and Perim Island. A species of *Helladotherium*, not distinguishable from *H duvernoyi* of Europe, is represented by a single cranium in the British Museum. Of four genera peculiar to the Siwaliks, the first, *Vishnutherium*, is known by a part of the mandible from Burma, and probably by two upper molars, and some bones from the Panjáb, all of which are in the Indian Museum. It seems to come the nearest of the four to the giraffe, and has been named *V. iravaticum*. The second, *Hydaspitherium*, is known by two species, of which *H. megacephalum* is known by a skull and a large series of teeth and bones, all from the Panjáb, and now in the Indian Museum; it carried a massive common horn-base above the occiput, from which the horns took their origin. The second species, *H. grande*, was larger and is only known by the upper molars and the mandible, all from the Panjáb, and now in the Indian Museum. It is probable that a cervical vertebra from Beluchistan, in the collection of the Geological Society, belongs to one of the above species. The third genus, *Bramatherium*, is represented by *B. perimense*, of which the skull, teeth, mandible, and some of the limb-bones are known; this species carried a pair of horns above the occiput, and a large common horn-base on the frontals. Its remains have been obtained from Perim Island, and the one known skull is in the Museum of the Royal College of Surgeons, the upper molars in the British Museum, two fragments of the mandible in the Indian Museum, and another, with the last true molar, in the Museum of Trinity College, Dublin. The fourth genus is the well-known *Sivatherium* represented by the one species, *S. giganteum*, in which the skull was furnished with two pairs of horns. Remains of this species have been obtained only from the Sub-Himalaya eastward of the Panjáb, and the British Museum possesses a magnificent series of them. There has been much discussion as to the serial position of the foregoing forms, *Helladotherium*, with the giraffe, being classed by some with the stags, while *Sivatherium* and the two preceding genera are classed with the antelopes. The resemblance of the teeth of all these animals is, however, so close that it seems preferable to class them all together in one large family, connecting the deer with the antelopes.

Of the antelopes, the best known is the so-called *Antilope palæindica*, which seems to have been closely allied to the South African genus *Damalis* (Bonte-bok, and Sassaby), and should probably be termed *D. palæindica;* there are two skulls in the Indian and one in the British Museum, all from the Sub-Himalaya. A skull from the same locality, in the Indian Museum, indicates a second species of antelope closely allied to the living Indian *A. cervicapra*, which has been named *A. sivalensis*. A third species, *A. acuticornis*, is indicated by numerous horn-cores from the Panjáb, in the Indian Museum, and was probably a kind of gazelle. A fourth species, *A. patulicornis*, has been named from a pair of horn-cores in the same collection. A species of *Portax* is indicated by numerous teeth and a fore-limb, in the Indian Museum; while other molars in the same collection not improbably belong to the genus *Palæoryx*, of the Pikermi beds. The oxen are represented by numerous species, three of which are here referred to one genus under the name of *Hemibos*, but have also been referred to two genera under the names of *Probubalus* and *Amphibos;* the group is closely allied to, if not identical with, the living Celebes genus *Anoa*, which has been referred to it under the name of *Probubalus celebensis*. The first species of *Hemibos* is named *H. occipitalis*, and varies considerably in the form of its horn-cores, which are sometimes nearly straight and triangular in section, and at others curved and pyriform in section; another variety is hornless. There are fine series of the skulls of this species, both in the British and the Indian Museums, all from the Sub-Himalaya. The second species, *H. antilopinus*, is also known by several skulls from the same districts. The third species *H.* (*Amphibos*) *acuticornis*, is a long-horned form, and is also represented by numerous skulls, from the Sub-Himalaya, in the British and Indian Museums. *Leptobos falconeri* is a fourth form of ox, which was in some cases hornless, of which there are several crania in the British Museum. The genus *Bubalus* is represented by two species; the first of these, *B. platyceros* (*sivalensis*), is known by one cranium in the British and another in the Indian Museum, both from the Sub-Himalaya; the horns were stout and concave superiorly. The second species is *B. palæindicus*, which occurs also in the pleistocene, if, indeed, the topmost beds of the Siwaliks in which it occurs should not be referred to that period; this species is evidently only a race of the living *B. arni*, and is very probably the same as *B. pallasi* from the pleistocene of Danzig. One skull from the Sub-Himalaya, in the Indian Museum, belongs to a species of *Bubalus*, and has been named *B. sivalensis;* it is the earliest form of the genus, and seems to have been allied to the fossil European *B. priscus*. Of the true oxen (*Bos*), three species have been named, *viz.*, *B. acutifrons*, remarkable for its enormous horns and angulated frontals; *B. planifrons*, with shorter horns and flattened frontals, and closely allied to the European *B. primigenius;* and *B. platyrhinus*, only known by the lower half of a skull of which the generic affinities are doubtful. The latter specimen, as well as a skull of each of the preceding species, are in the Indian Museum, and came from the Sub-Himalaya. Species of *Bos* or allied genera are indicated from Perim Island by molars in the Museum of Trinity College, Dublin.

A remarkable hornless skull, of comparatively large size, from the Sub-Himalaya, in the collection of the British Museum, has been described under the name of *Bucapra daviesi;* this skull comes nearest to the skulls of the goats, while the molars are of a bovine type, and, if found separately, would certainly have been referred to some form of oxen. There is evidence of three species of true goats, the first of which, *Capra sivalensis,* is known by two skulls in the British Museum, from the Sub-Himalaya, and is considered to be allied to the jharal of the Nilgherries (*Hemitragus jemlaicus*), and not improbably belongs to the same genus. The second species, *C. perimensis,* is known by a portion of a skull in the Indian Museum from Perim Island, and was probably allied to the living markhoor (*C. falconeri*) of the Himalaya, though the horn-cores do not show a spiral twist. The third species is unnamed, since its horn-cores, of which the Indian Museum possesses numerous specimens from the Panjáb, are so like those of the markhoor that it is difficult to point out characters of specific distinction with the materials available; it is possible that the horns may belong to older individuals of *C. perimensis.* It has been stated that a cranium from the Sub-Himalaya, which is not now forthcoming, belongs to the living Himalayan ibex (*C. sibirica*), butthis determination requires confirmation, although it is highly likely that the specimen may have belonged to an allied species. Another cranium, also lost, has been referred to the genus *Ovis.*

A species of chevrotain has been determined from the evidence of a single upper molar, from the Panjáb, in the Indian Museum, under the name of *Tragulus sivalensis.*

The camels are known by *Camelus sivalensis,* which presents a peculiarity in the structure of its lower molars, connecting it with the llamas (*Auchenia*) of America. Remains of this species have been obtained from the higher beds of the Sub-Himalayan Siwaliks, and are well represented in both the British and Indian Museums.

The remaining orders of the mammalia are only represented by a few species of rodents, and by one edentate. Of the former, a species of rat (*Mus*) is indicated by some incisors from the Sub-Himalaya. A species of bambú-rat (*Rhizomys sivalensis*[1]) has been determined on the evidence of three specimens of the mandible from the Panjáb now in the Indian Museum. A porcupine (*Hystrix sivalensis*) is known by a part of the cranium and the mandible, the former being in the British and the latter in the Indian Museum; one is from the Sub-Himalaya and the other from the Panjáb.

The edentates are known by one species of pangolin, *Manis sindiensis,* named on the evidence of a solitary phalangeal bone from Sind, now in the Indian Museum. The species must have been about four times the size of the living Indian *M. pentedactylus.*

Pleistocene.—Coming to the pleistocene, we find that its mammals are even less well known than those of the pliocene. As the pleistocene ossiferous strata are distributed in patches, very frequently in the valleys of the great rivers, the

[1] Probably the same as *Typhlodon* of Falconer.

remains from the more important of these areas must be treated of separately. The most important areas are parts of Madras and the Deccan; the valleys of the Jamna, Narbada, Pemganga, Krishna (Kistna), and Godávari, with their numerous tributaries, and the plains of Húndes in Tibet. It is also not improbable, as already mentioned, that the topmost strata of the Sub-Himalayan Siwaliks should really be referred to the pleistocene. In many instances, as in the delta of the Ganges, it is difficult, if not impossible, to draw any satisfactory line of distinction between the pleistocene and the prehistoric deposits. The presence in any stratum of the remains of *Hippopotamus*, or other genus not now found living in India, is considered as fair evidence for assigning such deposit to the pleistocene.

From the laterite of Madras palæolithic implements and a human platycnemic tibia have been obtained, and are assigned to the pleistocene.

From the alluvium of the Krishna valley, in the Deccan, a part of the skull and the mandible of a rhinoceros have been obtained and described under the name of *Rhinoceros deccanensis*. This species seems to be more nearly allied to the living African and the pliocene European species than to any living Indian form. Remains of an ox, not improbably *Bos namadicus*, have also been obtained from the same deposits, and, with the last-mentioned specimens, are in the Indian Museum. Certain molars of the pliocene *Mastodon pandionis* from the Deccan, and now in the British Museum, were not improbably derived from the same deposits in the upper part of the Krishna basin.

From the ossiferous gravels of the Narbada palæolithic implements of a rude form have been found associated with mammalian bones. The carnivora are represented by a small species of bear (*Ursus namadicus*), of which there are a maxilla and a tibia in the British, and a canine in the Indian Museum; and a large species of *Felis* is indicated by the distal extremity of a femur in the former collection. Of the Proboscidia, there is *Euelephas namadicus*, characterised by its prominent frontal ridge, and whose molars very closely resemble those of the European *E. antiquus*, from which resemblance it has been thought that the two forms may belong to the same species. The Indian species has also been obtained from Japan. There is one fine skull in the British Museum, and three skulls in the Indian Museum. *Stegodon* is represented by *S. ganesa*, of which there is a fine tusk in the Indian Museum, and very probably by *S. insignis*. The perissodactyles are represented by *Rhinoceros indicus*, of which the Indian Museum has two molars, and by a little-known extinct form to which the name *R. namadicus* has been applied; there is a scapula of this species in the last-named collection. There is also a species of horse, *Equus namadicus*, which seems to be a survivor from the Siwaliks. Among the Artiodactyla two species of hippopotamus were originally described under the names of *Hippopotamus namadicus* and *H. palæindicus*; the former having six, and the latter four, incisors. Specimens in the Indian Museum seem, however, to show that there is a transition in these respects between these two so-called species, and all the remains have accordingly been referred to *H. palæindicus*, which was hexaprotodont in some individuals, and tetraprotodont in others. The pigs seem to have been represented by *Sus giganteus*, another survivor from the Siwaliks. Remains of a deer apparently very close to, if not identical with, the living Indian *Cervus duvaucelli*, have been obtained, and there is some evidence of a second species. Three species of oxen have been described, *viz.*, *Bos namadicus*, a species showing some affinity to the Asiatic genus *Bibos*, of which there is a magnificent skull in the Indian Museum; *Bubalus palæindicus*, also occurring in the topmost Siwaliks, and the ancestor of *B. arni;* and *Leptobos frazeri*, which was sometimes hornless, and is represented by some fine skulls in the British Museum. A species of nilghai, of which there are two broken crania in the same collection, has been named *Portax namadicus;* it is distinguished from the living species, among other characters, by the horns being placed nearer to the orbits. The rodents are only known by some incisors in the Indian Museum, probably belonging to a species of *Mus*.

From the pleistocene of the Jamna valley only four mammals have been specifically determined with any certainty, *viz.*, *Euelephas namadicus*, *Bubalus palæindicus*, *Hippopotamus palæindicus*, and the living *Antilope cervicapra;* the latter being known by a single horn-core in the Indian Museum. In addition to these, remains of a species of *Semnopithecus*, *Sus*, *Portax*, *Equus*, *Mus*, and of a *Rhinoceros* furnished with lower incisors, have also been obtained. A tiger, as large as the existing species, is indicated by a scapho-lunar bone in the Indian Museum; this species was very probably the same as the Narbada form, and may have been *Felis tigris*.

The pleistocene of the Pemganga valley has yielded remains of *Bos namadicus*, a *Portax*, and *Hippopotamus palæindicus*.

The remains from the Godávari deposits have not been satisfactorily determined.

The horizontal lacustrine strata of Húndes in Tibet formerly classed as Siwalik, but which are more probably of pleistocene age, have yielded a small number of mammalian remains. Among these is a tooth referred to a species of *Hyæna*. Bones belonging to some form of horse have also been obtained, among which a cannon-bone in the collection of the Geological Society belongs to a species of *Hippotherium*, a genus elsewhere unknown in the pleistocene. Several of the limb-bones and the fragment of an upper molar of a rhinoceros are also known, but they are too imperfect for specific determination. The other known fossils belong to ruminants, the best preserved of which is the greater portion of the skull of an antelope, provisionally referred to the living Tibetan genus *Pantholops*, under the name of *P. hundesiensis;* this specimen cannot now be found, but is figured in Royle's "Illustrations of the Botany of the Himalaya Mountains." There is also a skull said to belong to some genus of bovine animal; another belonging to a goat resembling the markhoor (*Capra falconeri*); and a palate, in the collection of the Geological Society, doubtfully referred to a sheep (*Ovis*).

It may be added that mammalian remains are stated to have been obtained from a cave in the Karnúl district of Madras; these remains have, however, never been described, and cannot now be found.

Prehistoric.—The prehistoric deposits, as already said, have in many cases not yet been satisfactorily separated from the pleistocene, and the very local occurrence of vertebrate remains in the former renders this point of doubt one not likely to be soon cleared up. Any old alluvial deposit in which bones of only living mammals occur is here provisionally referred to the prehistoric.

Human remains and neolithic implements have been obtained in the alluvium of the plains in many localities, and frequently at considerable distances below the surface; the former are generally very imperfectly preserved and have never been carefully examined. Polished celts are extremely abundant in many places, and particularly in Burma and the Banda district of the North-West Provinces. The prevailing types are elongated forms with oval section, wedges, and the "shouldered" form. Among the mammals specimens of the teeth and jaws of *Macacus rhesus* from the alluvium and turbary of Goalpára, in Assam, and from Madras are exhibited in the Indian Museum, those from the former district being in a highly mineralised condition. Molars of the Indian elephant occur at considerable depths in the alluvium of the plains and of Burma. A last upper molar of *Rhinoceros indicus*, in the Indian Museum, was obtained from the turbary of Madras, and indicates the former extensive range of this species. It may be observed, in passing, that the range of the other species of *Rhinoceros* was probably much more extensive than at present, even in the historic period, because it has been inferred that the species killed by Akbar on the banks of the Indus was *R. javanicus* (*Sondaicus*), this inference being founded on the improbability of its being possible to kill *R. indicus* by means of arrows, with which Akbar's animals were destroyed. *Sus indicus* has also been obtained from the turbaries of Madras and Calcutta. Antlers, horn-cores, and teeth of undetermined species of *Bos* and *Cervus* have been obtained from the alluvium of various districts in the plains, and from raised beaches in Kattiawár; some of the latter deposits being probably in part of pleistocene age.

General.—Of the mammalia as a whole it may be observed that those of the pliocene are characterised by the great number of forms belonging to the orders which include animals of large corporeal bulk. Another noticeable point is the admixture of genera characteristic of modern Africa (*Hippopotamus*, *Camelopardalis*) and other parts of the old world (*Bos*, *Capra*, *Ursus*, *Equus*, etc.); of oligocene, miocene, and pliocene Europe (*Dinotherium*, *Anthracotherium*, *Hippotherium*, etc.) with those now peculiar to Asia (*Euelephas*, *Rhinoceros* [in its restricted sense] etc.). Among orders which have now diminished extensively in numbers in India, the Proboscidia stands pre-eminent, its fourteen Siwalik representatives having now dwindled to one. The perrissodactylate Ungulata have also diminished considerably, the modern forms inhabiting India and the adjacent countries being five and the extinct eleven or twelve. The artiodactylate modification has perhaps suffered a still more serious diminution, especially among the pig-like animals, in which the whole of the selenodont group like *Merycopotamus* and *Hyopotamus* has completely disappeared, while their congener, the hippopotamus, is now confined to Africa, and the Indian wild-boar and the diminutive terai hog (*Porcula*) are the sole representatives now remaining. The ruminants have lost their larger representatives, either entirely (*Sivatherium*) or by transference to Africa (*Camelopardalis*), and some of their smaller forms are considered to be allied to South Indian (*Hemitragus*) or South African form (*Damalis*), while others have always been exclusively Indian (*Portax*). The diminution in numbers of the ruminants cannot be clearly indicated owing to the numbers of small forms now existing, when analogues cannot be determined in the Siwaliks. Similarly, owing to the poverty of the remains of the other orders, and of the almost total absence of the micro-mammalia, comparisons cannot be instituted between the numbers of the recent and fossil species, but enough has been indicated to show that modern India has only the impoverished remains of a once extensive fauna of mighty forms. Regarding the range in space of the Siwalik fauna, it is probable that this was once very extensive, as we find some of the species ranging as far as China and Japan, and it has even been suggested that one species (*Hyænarctos sivalensis*) occurs in the pliocene of England. Representatives of some of the other common Siwalik or Indian genera, although considered to be specifically distinct, have also been obtained from China (*e.g.*, *Chalicotherium*, *Rhinoceros*, *Tapirus*, and *Hyæna*). It may also be observed that the mammals from Sind belong mainly to European oligocene and miocene genera, while those from the Panjáb show a mixture of miocene, pliocene, and existing genera; the two latter prevailing more extensively, as we proceed eastward along the Sub-Himalaya. The high degree of evolution or specialisation of many of the genera is a marked feature, and one strongly confirmative of their pliocene age. Thus, it may be noticed that the rhinoceroses had high-crowned molars, and that in one form the incisors were absent and two horns present; while some of the horses had reduced their digits to one on each limb. The pigs had well-developed tusks, the deer large branching antlers, the oxen wide-spreading horns, and the cats (*Machairodus*) huge trenchant fangs.

In the pleistocene the majority of the larger forms had disappeared, though a few of the extinct genera and species still lingered on. Many of the existing species were already in existence, or were represented by closely allied forms. Palæontological history is, however, still silent as to the origin of some of the larger existing mammals, like the Indian elephant. Some new forms (*e.g.*, *Bos namadicus*), which cannot be directly traced back to pliocene ancestors, seem to have appeared and to have died out again before the prehistoric.

In the latter period all the mammals seem to belong to existing species, although the range in space of some of them was more extensive than at present.

SYSTEMATIC CHRONOLOGICAL LIST OF SPECIES.

A.—ANTHROPOZOIC.

a.—PREHISTORIC.

MAMMALIA .	. PRIMATES .	. Homo (? sapiens, Lin.).
		Macacus rhesus (F. Cuv.).
	PROBOSCIDIA .	. Euelephas indicus, Linné.
	UNGULATA .	. Rhinoceros indicus, Cuvier.
		Sus indicus, Gray.
		Cervus, sp.
		Bos, sp.
REPTILIA .	. CHELONIA .	. Gen. *non det.*

b.—PLEISTOCENE.

MAMMALIA	PRIMATES	Homo, sp.
		Semnopithecus, sp.
		Ursus namadicus, F. & C.
		Hyæna, sp.
		Felis (? tigris, Lin.).
	PROBOSCIDIA	Euelephas namadicus, F. & C.
		Stegodon ganesa, F. & C.
		(?) ——— insignis, F. & C.
		Mastodon pandionis, Fals.
	UNGULATA	Rhinoceros deccanensis, Foote.
		——— indicus, Cuv.
		——— namadicus, F. & C.
		——— sp.
		Equus namadicus, F. & C.
		Hippotherium, sp.
		Sus giganteus, F. & C.
		Cervus (? duvaucelli, Cuv.).
		Bubalus palæindicus, F. & C.
		Bos namadicus, F. & C.
		Leptobos frazeri, Rüt.
		Portax namadicus, Rüt.
		Antilope cervicapra, Pallas.
		Pantholops (?) hundesiensis, Lyd.
		Capra, sp,
		Ovis, (?) sp.
	RODENTIA	Mus, sp.
REPTILIA	CROCODILIA	Crocodilus, (?) sp.
	CHELONIA	Pangshura tectum (Bell).
		Batagur (? dhongoka, Blyth).
		Trionyx (? gangeticus, Cuv.).

B.—THERIOZOIC.

a.—PLIOCENE [1].

MAMMALIA	PRIMATES	Palæopithecus sivalensis, Lyd.
		Macacus sivalensis, Lyd.
		——— sp.
		Semnopithecus (?) sub-himalayanus, Myr.
		——— sp.
	CARNIVORA	Felis cristata, F. & C.
		——— sp.
		Machairodus sivalensis, F. & C.
		Pseudælurus sivalensis, F. & C.
		Ictitherium sivalense, Lyd.
		Viverra bakeri, Bose.
		Hyæna sivalensis, F. & C.
		Canis curvipalatus, Bose.
		——— cautleyi, Bose.
		† Amphicyon palæindicus, Lyd.
		Ursus, sp.

[1] The forms of the earlier pliocene are marked by a cross (†).

MAMMALIA .	. CARNIVORA .	. Hyænarctos sivalensis, F. & C.
		——— palæindicus, Lyd.
		Mellivora sivalensis, F. & C.
		Meles, sp.
		Lutra palæindica, F. & C.
		—— sp.
		Enhydriodon sivalensis, F. & C.
	PROBOSCIDIA .	. Euelephas hysudricus, F. & C.
		Loxodon planifrons, F. & C.
		Stegodon ganesa, F. & C.
		——— insignis, F. & C.
		——— bombifrons, F. & C.
		——— clifti, F. & C.
		† Mastodon latidens, Clift.
		——— sivalensis, F. & C.
		† ——— perimensis, F. & C.
		† ——— pandionis, Falc.
		† ——— falconeri, Lyd.
		† Dinotherium sindiense, Lyd.
		† ——— pentapotamiæ, Falc.
		——— indicum, Falc.
	UNGULATA .	. † Chalicotherium sivalense, F. & C.
		Rhinoceros palæindicus, F. & C.
		——— platyrhinus, F. & C.
		† ——— sivalensis, F. & C.
		† Acerotherium perimense, F. & C.
		Listriodon pentapotamiæ, Falc.
		——— theobaldi, Lyd.
		(?) Tapirus sp.
		Equus sivalensis, F. & C.
		——— namadicus, F. & C.
		Hippotherium antilopinum, F. & C.
		——— theobaldi, Lyd.
		Hippopotamus iravaticus, F. & C.
		——— sivalensis, F. & C.
		Tetraconodon magnum, Falc.
		Sus giganteus, F. & C.
		† — hysudricus, F & C.
		— punjabiensis, Lyd.
		Hippohyus sivalensis, F. & C.
		——— sp.
		Sanitherium schlagintweiti, Myr.
		† Hyotherium sindiense, Lyd.
		† Anthracotherium silistrense (Pent).
		† ——— hyopotamoides, Lyd.
		† Hyopotamus palæindicus, Lyd.
		† ——— giganteus, Lyd.
		Merycopotamus dissimilis, F. & C.
		Chœromeryx silistrensis (Pent).
		† Hemimeryx blanfordi, Lyd.
		† Sivameryx sindiensis, Lyd.
		† Agriochœrus, (?) sp.
		Cervus triplidens, Lyd.
		——— sivalensis, Lyd.

MAMMALIA .	. UNGULATA .	.	Cervus simplicidens, Lyd.
			—— (?) latidens, Lyd.
			Dorcatherium majus, Lyd.
			—— minus, Lyd.
			Propalæomeryx sivalensis, Lyd.
			Camelopardalis sivalensis, F. & C.
			Helladotherium duvernoyi, Wag.
			Vishnutherium iravaticum, Lyd.
			Hydaspitherium grande, Lyd.
			—— megacephalum, Lyd.
			Sivatherium giganteum, F. & C.
			Antilope (? Damalis) palæindica, F. & C.
			—— patulicornis, Lyd.
			—— (? Gazella) porrecticornis, Lyd.
			—— sivalensis, Lyd.
			Palæoryx, (?) sp.
			Portax, sp.
			Hemibos occipitalis, Falc.
			—— acuticornis, Falc.
			—— antilopinus, Falc.
			Leptobos falconeri, Rüt.
			Bubalus platyceros, Lyd.
			—— palæindicus, F. & C.
			Bison sivalensis, Falc.
			Bos acutifrons, Lyd.
			—— planifrons, Lyd.
			—— (?) platyrhinus, Lyd.
			Bucapra daviesi, Rüt.
			Capra (? Hemitragus) sivalensis, Lyd.
			—— perimensis, Lyd.
			—— sp.
			Ovis, (?) sp.
			Tragulus sivalensis, Lyd.
			Camelus sivalensis, F. & C.
	RODENTIA .	.	Mus, sp.
			Rhizomys sivalensis, Lyd.
			Hystrix sivalensis, Lyd.
	EDENTATA .	. †	Manis sindiensis, Lyd.
AVES . .	. CARINATÆ .	.	Graculus, (?) sp.
			Pelecanus cautleyi, Dav.
			—— (?) sivalensis, Dav.
			Megaloscelornis sivalensis, Lyd.
		†	—— (?) sp.
			Argala falconeri, M. Ed.
	RATITÆ . .	.	Struthio asiaticus, M. Ed.
			Dromæus sivalensis, Lyd.
			Gen. *non det.*
REPTILIA .	. CROCODILIA .	.	Crocodilus, palustris, Less.
			Gharialis gangeticus, Gmel.
			—— leptodus, F. & C.
		†	—— crassidens, F. & C.
	LACERTILIA .	.	Varanus sivalensis, Falc.
	OPHIDIA . .	. †	Python (? molurus, Lin.).
	CHELONIA .	.	Colossochelys atlas, F. & C.

REPTILIA .	. CHELONIA . .	Testudo (?) 5, sp.
		Bellia sivalensis, Theo.
		—— sp.
		Damonia hamiltoni, Gray.
		Emys, sp.
		Cantleya annuliger, Theo.
		Pangshura tectum (Bell).
		† Batagur, sp.
		† Trionyx, sp.
		Emyda vittata, Pet.
PISCES . .	. ELASMOBRANCHII .	Carcharias, sp.
		Lamna, sp.
	TELEOSTEI . .	Bagarias yarrelli, Syk.
		Arius, sp.
		Gen. *non. det.*

b.—MIOCENE.

MAMMALIA .	. UNGULATA . .	Rhinoceros sivalensis v. gajensis, Lyd.

c.—EOCENE.

MAMMALIA .	. UNGULATA . .	(?) Palæotherium, sp.
		Artiodactyle, gen. *non det.*
REPTILIA .	. CROCODILIA . .	Gen. *non det.*
	CHELONIA . .	Hydraspis leithi, Carter.
AMPHIBIA .	. ANOURA . . .	Oxyglossus pusillus, Owen.
		———— (?) sp.
PISCES . .	. ELASMOBRANCHII .	Myliobatis, sp.
	TELEOSTEI . .	Diodon foleyi, Lyd.
		Capitodus indicus, Lyd.
		Gen. *non det.*

C.—SAUROZOIC.

a.—CRETACEOUS.

REPTILIA .	. DINOSAURIA . .	Megalosaurus, sp.
		Titanosaurus blanfordi, Lyd.
		———— indicus, Lyd.
		Gen. *non det.*
	CROCODILIA . .	Gen. *non det.*
	CHELONIA . .	Gen. *non det.*
	ICHTHYOSAURIA . .	Ichthyosaurus indicus, Lyd.
PISCES . .	. ELASMOBRANCHII .	Corax incisus, Eg.
		—— pristodontus, Ag.
		Enchodus serratus, Eg.
		Lamna complanata, Eg.
		—— sigmoides, Eg.
		Odontaspis constrictus, Eg.
		———— oxypeion, Eg.
		Otodus basalis, Eg.
		—— divergens, Eg.
		—— marginatus, Eg.
		—— minutus, Eg.
		—— nanus, Eg.
		—— semiplicatus, Eg.

PISCES	ELASMOBRANCHII	Oxyrhina triangularis, Eg.
		——— sp.
		Ptychodus latissimus, Ag.
		Sphyrænodus, (?), sp.
	GANOIDEI	Pycnodus (?), sp.

b.—JURA-TRIAS.

REPTILIA	DINOSAURIA	Ankistrodon indicus, Hux.
	CROCODILIA	Gen. *non det*. (Chari gp.).
		Parasuchus hislopi, Hux. Mss.
		Gen. *non det*. (Rewah.).
	LACERTILIA	Hyperodapedon huxleyi, Lyd.
	DICYNODONTIA	Dicynodon orientalis, Hux.
		——— sp.
	PLESIOSAURIA	Plesiosaurus indicus, Lyd.
AMPHIBIA	LABYRINTHODONTIA	Brachyops laticeps, Owen.
		Goniogiyptus longirostris, Hux.
		——— huxleyi, Lyd.
		Glyptognathus fragilis, Lyd.
		Pachygonia incurvata, Hux.
		Archegosaurus, (?), sp.
		Gen. *non det*.
PISCES	GANOIDEI	Ceratodus[1] hislopianus, Old.
		——— hunterianus, Old.
		——— virapa, Old.
		Dapedius egertoni, Syk.
		Lepidotus breviceps, Eg.
		——— calcaratus, Eg.
		——— deccanensis, Eg.
		——— longiceps, Eg.
		——— pachylepis, Eg.
		Tetragonolepis analis, Eg.
		——— oldhami, Eg.
		——— rugosus, Eg.
		Gen. *non* det.

D.—ICHTHYOZOIC.

CARBONIFEROUS.

PISCES	GANOIDEI	Sigmodus dubius, Waag.
		Pœcilodus paradoxus, Waag.
		Psephodus indicus, Waag.
		Saurichthys indicus (?), De Kon.
	ELASMOBRANCHII	Helodopsis elongata, Waag.
		——— abbreviata, Waag.
		Psammodus, sp.
		Petalorhynchus indicus, Waag.
		Xystracanthus gracilis, Waag.
		——— major, Waag.
		——— giganteus, Waag.
		Thaumatacanthus blanfordi, Waag.
		Acrodus flemingi, De Kon.
		——— sp.

[1] Following Professor Miall ("Monograph of the Sirenoid and Crossopterygian Ganoids," Palæontographical Society, 1878), the order Dipnoi is merged with the Ganoidei.

ALPHABETICAL AND SYNOPTICAL LIST OF SPECIES, ARRANGED IN CLASSES[1].

CLASS I.—PISCES.

Acrodus flemingi, De Kon.	Salt-range	Carboniferous.
——— sp.	"	"
Arius	Panjáb and Sind	Pliocene.
‡ Bagarias yarrelli, Sykes *Pimelodus bagarias*, Syk.	Sub-Himalaya	Higher pliocene.
Capitodus indicus, Lyd.	Panjáb	Eocene.
Carcharias, sp.	Burma	Higher pliocene.
Ceratodus hislopianus, Old.	Maleri	Trias-jura.
——— hunterianus, Old.	"	"
——— virapa, Old.	"	"
Corax incisus, Eg.	Trichinopoli	Cretaceous.
——— pristodontus, Ag.	Trichinopoli and Europe	"
Dapedius egertoni, Syk.	Kota	Trias-jura.
Diodon foleyi, Lyd.	Rámri and Andamans	Eocene.
Enchodus serratus, Eg.	Trichinopoli	Cretaceous.
* Helodopsis abbreviata, Waag.	Salt-range	Carboniferous.
——— elongata, Waag.	"	"
Lamna complanata, Eg.	Trichinopoli	Cretaceous.
——— sigmoides, Eg.	"	"
——— sp.	Burma	Higher pliocene.
Lepidotus breviceps, Eg.	Kota	Trias-jura.
——— calcaratus, Eg.	"	"
——— deccanensis, Eg.	"	"
——— longiceps, Eg.	"	"
——— pachylepis, Eg.	"	"
Myliobatis, sp.	Panjáb	Eocene.
Odontaspis constrictus, Eg.	Trichinopoli	Cretaceous.
——— oxypeion, Eg.	"	"
Otodus basalis, Eg.	"	"
——— divergens, Eg.	"	"
——— marginatus, Eg.	"	"
——— minutus, Eg.	"	"
——— nanus, Eg.	"	"
——— semiplicatus, Eg.	"	"
Oxyrhina triangularis, Eg.	"	"
——— sp.	"	"
Petalorhynchus indicus, Waag.	Salt-range	Carboniferous.
Pœcilodus paradoxus, Waag.	"	"
Psammodus, sp.	"	"
Psephodus indicus, Waag.	"	"
Ptychodus latissimus, Ag.	Trichinopoli and Europe	Cretaceous.
Pycnodus, (?) sp.	Trichinopoli	"
Saurichthys indicus (?), De Kon.	Salt-range	Carboniferous.
* Sigmodus dubius, Waag.	"	"
Sphyrænodus, (?) sp.	Lameta gp.	Cretaceous.

[1] Synonyms (of which only the more important are given) are in italics; living species are indicated by a double cross (‡), and fossil genera peculiar to India or Burma by an asterisk (*).

Tetragonolepis analis, Eg.	Kota	Trias-jura.
———— oldhami, Eg.	„	„
———— rugosus, Eg.	„	„
* Thaumatacanthus blanfordi, Waag.	Salt-range	Carboniferous.
Xystracanthus giganteus, Waag.	„	„
———— gracilis, Waag.	„	„
———— major, Waag.	„	„

CLASS II.—AMPHIBIA.

Archegosaurus, (?) sp.	Bijori gp.	Trias-jura.
* Brachyops laticeps, Owen.	Mangli	„
* Glyptognathus fragilis, Lyd.	Panchet gp.	„
* Gonioglyptus huxleyi, Lyd.	„	„
* ———— longirostris, Hux.	„	„
Oxyglossus pusillus, Owen (*Rana pusilla*, Owen).	Bombay	Eocene.
———— (?) sp.	„	„
* Pachygonia incurvata, Hux.	Panchet gp.	Trias-jura.

CLASS III.—REPTILIA.

* Ankistrodon indicus, Hux.	Panchet gp.	Trias-jura.
‡ Batagur (? dhonkoka, Blyth)	Narbada	Pleistocene.
Bellia sivalensis, Theo.	Panjáb	Higher pliocene.
—— sp.	„	„
* Cautleya annuliger, Theo.	„	„
* Colossochelys atlas, F. & C.	Sub-Himalaya and Burma	„
‡ Crocodilus palustris, Less. (*C. bombifrons*, Gray.)	Sub-Himalaya and (?) Narbada.	Higher pliocene and (?) pleistocene.
‡ Damonia hamiltoni, Gray (*Emys hamiltonoides*, Falc.) (*Damonia hamiltonoides*, Falc.)	Sub-Himalaya	Higher pliocene.
Dicynodon orientalis, Hux. (*Ptychognathus orientalis*, Hux.)	Panchet gp.	Trias-jura.
‡ Emyda vittata, Peters (*E. ceylonensis*, Gray.)	Sub-Himalaya, &c.	Higher pliocene.
Emys, sp.	„	„
‡ Gharialis crassidens, F. & C. (*Crocodilus crassidens*, F. & C.) (*Leptorhynchus crassidens*, F. & C.)	Sub-Himalaya and Sind	Pliocene.
‡ ———— gangeticus, Gmel. (*Leptorhynchus gangeticus*, Gmel.)	Sub-Himalaya, Burma, Sind, and Perim.	„
———— leptodus, F. & C. (*Leptorhynchus leptodus*, F. & C.)	Sub-Himalaya, Burma, Sind, and Perim	„
Hydraspis leithi, Carter (*Testudo leithi*, Carter.)	Bombay	Eocene.
Hyperodapedon huxleyi, Lyd.	Maleri and South Rewá	Trias-jura.
Ichthyosaurus indicus, Lyd.	Trichinopoli	Cretaceous.
Megalosaurus, sp.	Trichinopoli and Lameta gp.	„
‡ Pangshura tectum, Bell (*Emys tectum*, Bell).	Sub-Himalaya and Narbada.	Higher pliocene and pleistocene.

* Parasuchus hislopi, Hux.	Maleri	Trias-jura.
——— (?), sp.	Denwa gp.	„
Plesiosaurus indicus, Lyd.	Umia gp.	Jura.
‡ Python (? molurus, Lin.)	Panjáb and Sind	Pliocene.
Testudo, *sp. var.*	Sub-Himalaya	Higher pliocene.
* Titanosaurus blanfordi, Lyd.	Lameta gp.	Cretaceous.
——— indicus, Lyd.	„	„
‡ Trionyx (? gangeticus, Cuv.)	Narbada	Pleistocene.
——— sp.	Sub-Himalaya	Higher pliocene.
Varanus sivalensis, F. & C.	„	„

CLASS IV.—AVES.

Argala falconeri, M. Ed. (*Leptoptilus falconeri* [M. Ed.])	Sub-Himalaya	Higher pliocene.
Dromœus sivalensis, Lyd.	„	„
Graculus (?), sp.	„	„
Megaloscelornis sivalensis, Lyd.	„	„
Pelecanus cautleyi, Dav.	„	„
——— (?) sivalensis, Dav.	„	„
Struthio asiaticus, M. Ed. (*S. palæindicus*, Falc.)	„	„

CLASS V.—MAMMALIA.

Acerotherium perimense, F. & C. (*Rhinoceros iravaticus*, Lyd.) (——— *perimensis*, F. & C.) (——— *planidens*, Lyd.)	Panjáb, Burma, Perim, and Sind	Pliocene.
Agriochœrus (?)	Sind	Earlier pliocene.
Amphicyon palæindicus, Lyd.	Panjáb and Sind	Pliocene.
Anthracotherium hyopotamoides, Lyd.	Bhúgti hills	Earlier pliocene.
——— silistrense, Pent. (*Chæromeryx silistrensis*, Pent.) (*Rhagatherium ? sindiense*, Lyd.) (*A. punjabiense*, Lyd.)	Sind, Gáro hills, and Panjáb	„
‡ Antilope cervicapra, Pallas (*A. bezoarctica*, Ald.)	Jamna	Pleistocene.
——— palæindica, F. & C. (*Damalis* (?) *palæindica*, F. & C.)	Sub-Himalaya	Higher pliocene.
——— patulicornis, Lyd.	„	„
——— porrecticornis, Lyd. (*Gazella* (?) *porrecticornis*, Lyd.)	„	„
Bison sivalensis, Falc.	„	„
Bos acutifrons, Lyd.	„	„
— namadicus, F. & C.	Narbada, &c.	Pleistocene.
— planifrons, F. & C.	Sub-Himalaya	Higher pliocene.
— platyrhinus, Lyd.	„	„
— (?) sp.	Perim	„
* Bramatherium perimense, Falc. (*Sivatherium*, sp., Owen.)	„	„
Bubalus palæindicus, F. & C.	Sub-Himalaya, Narbada, &c.	Higher pliocene and pleistocene.
——— platyceros, Lyd.[1] (*B. sivalensis*, Rüt.)	Sub-Himalaya	Higher pliocene.

*	Bucapra daviesi, Rüt.	Sub-Himalaya	Higher pliocene.
	Camelopardalis sivalensis, F. & C. (*C. affinis*, F. & C.)	Sub-Himalaya and Perim	„
	Camelus sivalensis, F. & C.	Sub-Himalaya	„
	Canis cautleyi, Bose.	„	„
	—— curvipalatus, Bose.	„	„
	Capra perimensis, Lyd.	Perim	„
	—— sivalensis, Lyd. (*Hemitragus sivalensis*, Lyd.)	Sub-Himalaya	„
	—— sp.	„	„
	—— sp.	Tibet	Pleistocene (?).
‡	Cervus (? duvaucelli, Cuv.)	Narbada	„
	—— (?) latidens, Lyd.	Sub-Himalaya	Higher pliocene.
	—— simplicidens, Lyd.	„	„
	—— sivalensis, Lyd.	„	„
	—— triplidens, Lyd.	„	„
	Chalicotherium sivalense, F. & C. (*Anoplotherium sivalense*, F. & C.) (*Nestoritherium sivalense*, Wag.)	Sub-Himalaya and Sind	Pliocene.
	Chœromeryx silistrensis, Pent. (*Anthracotherium silistrense*, Pent.)	Gáro hills	Higher pliocene.
	Dinotherium indicum, F. & C.	Panjáb and Perim	„
	—— pentapotamiæ, Falc.	Panjáb, Kách, and Sind	Pliocene.
	—— sindiense, Lyd.	„	„
	Dorcatherium majus, Lyd. (*Merycopotamus nanus*, Falc.)	Panjáb	Higher pliocene.
	—— minus, Lyd.	„	„
*	Enhydriodon ferox, F. & C. (*E. sivalensis*, F. & C.) (*Amyxodon*, F. & C.)	Sub-Himalaya	„
	Equus namadicus, F. & C. (*E. palæonus*, F. & C.)	Sub-Himalaya and Narbada	Higher pliocene and pleistocene.
	—— sivalensis, F. & C.	Sub-Himalaya and (?) Perim	Higher pliocene.
‡	Euelephas indicus, Lin. (*Elephas indicus*, Lin.)	Plains and Burma	Prehistoric.
	—— hysudricus, F. & C. (*Elephas hysudricus*, F. & C.)	Sub-Himalaya	Higher pliocene.
	—— namadicus, F. & C.) (*Elephas namadicus*, F. & C.)	Narbada, &c.	Pleistocene.
	Felis cristata, F. & C. (*F. grandicristata*, Bose.) (*F. palæotigris*, F. & C.) (*Uncia cristata*, Cope.)	Sub-Himalaya	Higher pliocene.
	—— sp.	„	„
‡	—— (? tigris, Lin.)	Jamna and Narbada	Pleistocene.
	Helladotherium duvernoyi, Wag.	Sub-Himalaya	Higher pliocene.
*	Hemibos acuticornis, F. & C. (*Amphibos acuticornis*, F. & C.) (*Leptobos acuticornis*, Falc.)	„	„
	—— antilopinus, F. & C.) (*Amphibos antilopinus*, F. & C.) (*Leptobos antilopinus*, Falc.)	„	„

Hemibos occipitalis, Falc.	Sub-Himalaya	Higher pliocene.
(*H. triquetriceros*, F. & C.)		
(*Bos occipitalis*, Falc.)		
(*Leptobos triquetricornis*, Falc.)		
(*Peribos occipitalis*, Lyd.)		
(*Probubalus triquetricornis*, Rüt.)		
* Hemimeryx blanfordi, Lyd.	Sind	Earlier pliocene.
Hippopotamus iravaticus, F. & C.	Sub-Himalaya and	
(*Hexaprotodon iravaticus*, F. & C.)	Burma	Higher pliocene.
———— palæindicus, F. & C.	Narbada, &c.	Pleistocene.
(*Hexaprotodon namadicus*, F. & C.)		
(*Hippopotamus namadicus*, F. & C.)		
(*Tetraprotodon palæindicus*, F. & C.)		
———— sivalensis, F. & C.)	Sub-Himalaya	Higher pliocene.
(*Hexaprotodon sivalensis*, F. & C.)		
* Hippohyus sivalensis, F. & C.	„	„
———— sp.	„	„
Hippotherium antilopinum, F. & C.	Sub-Himalaya and	
(*Equus antilopinus*, F. & C.)	Perim	„
(*H. gracile*, Myr.)		
———— theobaldi, Lyd.	Burma, Perim, and	
(*Sivalhippus theobaldi*, Lyd.)	Sub-Himalaya	„
(*H. gracile*, Myr.)		
———— sp.	Tibet	Pleistocene (?).
* Hydaspitherium grande, Lyd.	Sub-Himalaya	Higher pliocene.
———— megacephalum, Lyd.	„	„
(*H. leptognathus*, Lyd.)		
Hyæna sivalensis, F. & C.	„	„
(*H. felina*, Bose.)		
———— ? sp.	Tibet	Pleistocene (?).
Hyænarctos sivalensis, F. & C.	Sub-Himalaya and	
(*Ursus sivalensis*, F. & C.)	Panjáb	Higher pliocene.
———— palæindicus, Lyd.	Panjáb	„
(? *Dinocyon*.)		
Hyopotamus giganteus, Lyd.	Bhúgti hills	Earlier pliocene.
———— palæindicus, Lyd.	Sind	„
Hyotherium sindiense, Lyd.	„	„
Hystrix sivalensis, Lyd.	Sub-Himalaya	Higher pliocene.
Ictitherium sivalense, Lyd.	Panjáb	„
Leptobos falconeri, Rüt.	Sub-Himalaya	„
———— frazeri, Rüt.	Narbada	Pleistocene.
Listriodon pentapotamiæ, Falc.	Panjáb	Higher pliocene.
(*Tapirus pentapotamiæ*, Falc.)		
———— theobaldi, Lyd.	„	„
Loxodon planifrons, F. & C.	Sub-Himalaya	„
(*Elephas planifrons*, F. & C.)		
‡ Macacus rhesus, F. Cuv.	Plains	Prehistoric.
———— sivalensis, Lyd.	Sub-Himalaya	Higher pliocene.
———— sp.	„	„
Machairodus sivalensis, F. & C.	„	„
(*M. falconeri*, Pomel.)		
(*M. palæindicus*, F. & C.)		
(*Drepanodon sivalensis*, F. & C.)		
Manis sindiensis, Lyd.	Sind	Earlier pliocene.

Mastodon falconeri, Lyd.	Panjáb & Sind	Pliocene.
——— latidens, Clift. (*M. elephantoides*, Clift.)	Sub-Himalaya, Burma, Panjáb, and Sind	"
——— pandionis, Falc.	Sub-Himalaya, Sind, Perim, and Deccan.	Pliocene and pleistocene.
——— perimensis, F. & C.	Sub-Himalaya, Sind, and Perim	Pliocene.
——— sivalensis, F. & C.	Sub-Himalaya	Higher pliocene.
Meles, sp.	Panjáb	"
Mellivora sivalensis, F. & C. (*Ursitaxus sivalensis*, F. & C.)	"	"
* Merycopotamus dissimilis, F. & C. (*M. sivalensis*, F. & C.) (*Hippopotamus dissimilis*, F. & C.)	Sub-Himalaya and Burma	"
Mus, sp.	Sub-Himalaya	Higher pliocene.
—— sp.	Narbada	Pleistocene.
Ovis, (?) sp.	Sub-Himalaya	Higher pliocene.
——, (?) sp.	Tibet	Pleistocene.
• Palæopithecus sivalensis, Lyd.	Panjáb	Higher pliocene.
Palæoryx, (?) sp.	"	"
Palæotherium, (?) sp.	"	Eocene.
Pantholops, (?) hundesiensis, Lyd.	Tibet	Pleistocene (?).
Portax namadicus, Rüt.	Narbada, &c.	"
——— sp.	Panjáb	Higher pliocene.
Propalæomeryx sivalensis, Lyd.	Sub-Himalaya	"
Pseudælurus sivalensis, Lyd.	Panjáb	"
Rhinoceros deccanensis, Foote.	Madras	Pleistocene.
‡ ——— indicus, Cuv.	Madras and Narbada	Prehistoric and Pleistocene.
——— namadicus, F. & C.	Narbada	Pleistocene.
——— palæindicus, F. & C.	Sub-Himalaya	Higher pliocene.
——— sivalensis, F. & C.	Sub-Himalaya and Sind	Pliocene.
——— —— var. gajensis, Lyd.	Sind	U. Miocene.
Rhizomys sivalensis, Lyd. ((?) *Typholodon*, Falc.)	Panjáb	Higher pliocene.
* Sanitherium schlagintweiti, Myr. (*Sus pusillus*, Falc.)	Sub-Himalaya and Panjáb	"
Semnopithecus sub-himalayanus, Myr.	Sub-Himalaya	"
——— sp.	"	"
——— sp.	Jamna	Pleistocene.
Sivameryx sindiensis, Lyd.	Sind	Earlier pliocene.
• Sivatherium giganteum, F. & C.	Sub-Himalaya	Higher pliocene.
Stegodon bombifrons, F. & C. (*S. orientalis*, Owen.) (*Elephas bombifrons*, F. & C.)	Sub-Himalaya and (?) China	"
——— clifti, F. & C. (*S. sinensis*, Owen.) (*Elephas clifti*, F. & C.) (*Mastodon elephantoides*, Clift.)	India, Burmá, China, and Japan	"
——— ganesa, F. & C. (*Elephas ganesa*, F. & C.)	Sub-Himalaya and Narbada.	Higher pliocene and pleistocene.

Stegodon insignis, F. & C. (*Elephas insignis*, F. & C.)	Sub-Himalaya, Japan, China and (?) Narbada.	Higher pliocene and (?) pleistocene.
Sus giganteus, F. & C. (*Hippopotamodon*, Lyd.)	Sub-Himalaya and Narbada.	Higher pliocene and (?) pleistocene.
—— hysudricus, F. & C.	Sub-Himalaya, Sind, and Perim	Pliocene.
‡ —— predicus, Gray. (*S. cristatus*, Wag.)	Madras	Prehistoric.
—— punjabiensis, Lyd.	Sub-Himalaya	Higher pliocene.
Tapirus (?) sp.	Burma	„
* Tetraconodon magnum, Falc.	Sub-Himalaya	„
Tragulus sivalensis, Lyd.	Panjáb	„
Ursus namadicus, F. & C.	Narbada, &c.	Pleistocene.
—— sp.	Sub-Himalaya	Higher pliocene.
* Vishnutherium iravaticum, Lyd.	Burma and (?) Panjáb	„
Viverra bakeri, Bose (*Canis* sp., Baker and Durand.)	Sub-Himalaya	„

Note on the Bijori Labyrinthodont.—*By* R. LYDEKKER, B.A., F.G.S., F.Z.S.

As it is always expedient to correct erroneous determinations as speedily as possible, I have thought it advisable to publish a preliminary note regarding the large labyrinthodont skeleton from the Bijori group of the Gondwánas[1], which has recently come into my custody. Careful 'development' has exposed a considerable portion of the palatal aspect of the skull, which was previously concealed by matrix. As I hope eventually to describe and figure this important and interesting specimen, which has hitherto been considered as probably belonging to *Archegosaurus*, in the "Palæontologia Indica," it will only be very briefly noticed on this occasion.

The skull, which is the only part that need now be mentioned, is triangular in shape, and has a length of about 11, with an extreme breadth of 8, inches. The orbits are oval and placed somewhat posteriorly. The teeth are small, subcylindrical, and regular; there are several larger "tusks" close to the symphysis of the mandible, placed (as in *Mastodonsaurus*, *Labyrinthodon*, and *Pachygonia*) interiorly to the row of small teeth. This character alone shows that the specimen cannot belong to *Archegosaurus*. The structure of the teeth seems to be less complex than in the first three of these genera, but more so than in the last. The skull is greatly produced at its postero-external angles, and has large epiotic cornua, thereby differing from *Mastodonsaurus*. The mandible has apparently no distinct post-articular process, but a well-developed internal articular buttress. The palatine foramina are large and approximated.

Except in the apparent absence of a distinct post-articular process to the mandible, the skull shows decided affinity to the first division of the Euglypta[2]; in that respect, however, it agrees with *Loxomma*, but is distinguished by the

[1] See "Manual," part I, p. 128.
[2] See "British Association Report," 1874, p. 150.

characters of the teeth and orbits. The specimen will almost certainly have to be referred to a new genus.

It may not be out of place to mention that in describing the lower jaw of *Glyptognathus fragilis*, represented in figure 1 of the plate accompanying my last notice of Gondwána labyrinthodonts[1], the specimen, from the presumed absence of a post-articular process, was inferred to belong probably to the Brachiopina. It should have been stated, assuming the correctness of the inference as to the absence of the process, that it probably belonged to the Brachiopina, or some of the subsequent sections of Professor Miall's classification[2].

Note on a skull of Hippotherium antilopinum, *by* R. LYDEKKER, B.A., F.G.S., F.Z.S.

Among a small collection of Siwalik fossils from Perim Island lent by Mr. Theodore Cooke, LL.D., F.G.S., of Poona, and transmitted to me for determination, there is a very fine example of the skull of *Hippotherium antilopinum.* The species was previously unknown from Perim, and this is the first known example of the skull. It shows the complete molar dentition of the left side. and is otherwise fairly perfect: I shall hope to give a further description of it on a future occasion.

The Lodge, Harpenden, Herts.

On the Iron Ores, *and* Subsidiary Materials *for the* Manufacture of Iron, *in the North-Eastern part of the* Jabalpur District; *by* F. R. MALLET, F.G.S., *Geological Survey of India.* (With a map.)

From time immemorial the Jabalpur district has held an important place amongst those centres where the smelting of iron has been carried on in the native method. Plentiful ores, extensive jungles for the supply of charcoal, and proximity to thickly populated alluvial tracts of country, combined to give Jabalpur a commanding position in the old days, before railways had brought the native hearths into an unequal struggle with the blast-furnaces of England. Even now iron is made on what, from the native point of view, must be considered a large scale, numerous furnaces being scattered over the iron-bearing portions of the district.

The advantageous central position of Jabalpur, now that it is in railway communication with the richest parts of the surrounding provinces, is too great to have escaped notice with reference to the manufacture of iron on European principles. As far as was known, ores and flux were to be had in abundance, and the means for distributing the manufactured iron to the surrounding markets was at hand. But the often-experienced difficulty of keeping large furnaces in blast with charcoal, and the absence of any available coal, were a deterrent to any decisive action.

[1] "Records," Vol. XV, p. 27.
[2] "British Association Report." *loc. cit.*

Within the last year or two, however, the discovery of workable coal by Mr. T. W. H. Hughes, in the immediate neighbourhood of the Jabalpur district, has given the question a new aspect. A line of railway from the new coal-field at Umeria to Murwára (Katni), on the East Indian line, has been proposed, and the preliminary surveys already executed.

The question of fuel, then, being in a fair way towards a satisfactory solution, it became important to ascertain whether the generally received opinion as to the abundance and excellence of the Jabalpur ores was fully borne out by fact. I was consequently directed, in the early part of this year, to visit the more important places where iron was known to occur, with a view to forming an opinion as to the extent of the deposits, and the feasibility of working them, and to collect samples for subsequent analysis. The question of flux and other subsidiary materials was also to be looked into. The following paper, then, embodies the results of my work in the field and laboratory.

The iron ores, for purposes of description, may be regarded with reference either to their mineralogical characteristics, their geological distribution, or their topographical position. The accompanying map, the geological work on which is mainly, and indeed, with reference to the area with which we are more immediately concerned, exclusively, due to surveys executed by Mr. C. A. Hacket in 1869-72, shows the distribution of the different series of rocks. It will be seen that between the great spread of Vindhyan sandstones on the north and Deccan trap on the south, both of which formations are almost barren of any metallic wealth, there is a belt, some 30 miles wide, where a very varied and intricately disposed assemblage of rocks occurs. It is just here that the band of iron-bearing transition strata, which stretches eastwards for more than 200 miles through the Son Valley, comes in contact with the thickly populated alluvial belt through which the Narbadda flows westwards for about the same distance. Hence one of the most important advantages which the iron-smelters of Jabalpur have enjoyed. Hematite ores similar to those of Jabalpur are known to occur largely in the wild country to the east; but there are not the same facilities there for disposing of the manufactured product.

The formations just mentioned include—

Alluvium.
Rock laterite.
Deccan trap.
Lameta group.
Upper Gondwána.
Coal measures.
Tálchir group.
Upper Vindhyans.
Lower „
Bijáwar or transition series.
Gneiss.

The Bijáwar series and the rock laterite are those with which we are more immediately concerned now, for it is in them that nearly all the iron ore is contained[1]. By reference to the map, then, one sees at a glance the general lie of the iron-bearing tracts, which are those coloured respectively purple and burnt sienna, although it is only in certain portions of those areas that the ores are found. The Bijáwar ores occur more especially in the Parganas Khumbhi and Gosulpur, while the Pargana Bijerágogarh contains the greater portion of the lateritic ores.

Mineralogically considered, the iron ores are almost exclusively varieties of hematite and limonite (or red and brown hematite), the former being especially characteristic of the Bijáwars, and the latter of the newer formation. They may be classified thus—

BIJÁWAR ORES	1, *Hematite*	Schistose hematite. Micaceous iron. Jasper-hematite[2]. Semi-ochreous hematite. Manganiferous hematite.
	2, *Limonite.*	
LATERITE ORES	1, *Limonite*	Pisolitic limonite, breaking with smooth conchoidal fracture. Pisolitic limonite, breaking with rough uneven fracture. Ordinary laterite, some parts of which contain a high percentage of iron.
	2, *Hematite.*	

Magnetite has been found in small crystals disseminated through the hematite beds of Sehora, but I am not aware of its occurring anywhere in such quantity as to entitle it to be included in the above list as an ore.

BIJÁWAR ORES.

The Bijáwar series has been subdivided by Mr. Hacket thus (in descending order) :—

Chandardíp group.
Lora „
Bhítri „
Majhauli „

It is in the inferior strata of the Lora group (so called from the Lora range east of Sehora) that all the most important existing mines are sunk[3]. "All the iron-workings," says Mr. Hacket. "are situated near the base of the (Lora) group, where the quartz bands[4] are absent, and the rocks consist almost entirely of micaceous iron, or mixed with a few bands of clay. The Jauli mines are so situated, as also those of Mangela, and at Agaria in the Majgaon hills, and also

[1] Some ore also occurs in the Gondwána beds, but it is "very impure and requires much selection and cleaning" and is "very rarely worth working" (J. G. Medlicott, Memoirs, Geological Survey of India, Vol. II, p. 278).

[2] *Vide* p. 100.

[3] Here, and subsequently, in reference to native operations, I use the word 'mine' to express an excavation where ore is extracted, irrespective of its form. Underground workings are rather the exception than the rule, the majority of the excavations being irregular open pits.

[4] *Vide* p. 100.

in the hills west of the 'marble rocks'. This band of rich iron appears to be very constant in the section, but, being softer than the rocks above, is mostly worn away, and covered by the alluvium, or debris from the ridges of the harder rocks; but that the band exists is shown by the pieces of rich iron strewn along the line."[1]

A few workings in the Majhauli hills (near the western edge of the map) are situated in rocks of the Bhítri group, but these are of very secondary importance[1].

Probably the most extensively worked cluster of mines in the district are those situated in the group of low irregular hills south of Sarroli and Majgaon (8 miles south-east of Sehora), and as the iron-bearing strata are exposed there more clearly, and on a larger scale, than in any other localities that I have visited, it will be convenient to take that neighbourhood as a starting point in any detailed descriptions.

Hill ½ mile south of Agaria.

The hill half a mile south of Agaria (4 miles west-south-west of Sarroli) appears to be formed entirely of iron ore. The strata have a low irregular dip towards the south. The highest beds, *i.e.*, those on the south side of the hill, where there are numerous pits, are of evenly laminated micaceous iron, interbanded with occasional argillaceous layers. The rock is so soft that it can be powdered between the fingers, and is simply dug out with ordinary *kodalis*. But the greater portion of the ore, constituting the lower beds, is schistose hematite, which is harder than the micaceous iron, although easily worked on account of its fissile character. Numerous pits have been sunk into it also. There is a thin skin of laterite on the top of the hill, which is, in great part at least, and I believe wholly, due to alteration of the iron-schist *in situ*.

As this hill is about a third of a mile long, flat-topped, and wide, and not far from 100 feet high, the quantity of ore available by open workings, with free drainage, is enormous. As a very rough estimate, the cubic contents of the hill may perhaps be taken at $\frac{600 \times 450 \times 30}{2}$, or about four million cubic yards[2], which is equivalent to about fourteen million tons of ore. Even then if a liberal deduction be made for possible concealed bands of useless rock, the remaining figures will represent an immense amount of ore.

A sample of schistose hematite from the northern side of the hill yielded on analysis—

Ferric oxide	97·54	= Iron 68·28
Phosphoric acid	·12	
Sulphuric acid	trace	
Sulphur	traces	
Loss on ignition[3]	·89	
Ignited insoluble residue	1·21	
Alumina and undetermined	·24	
	100·00	

[1] MSS. report, 1870-71.

[2] The product of the dimensions of the hill is divided by 2 to allow for the slopes and irregularities.

[3] This and the other ores analysed were air dried. The loss on ignition, therefore, includes hygroscopic moisture, as well as, in the case of the hydrous ores, chemically combined water.

Ridge at Agaria.

In the low ridge which runs westward from Agaria a band of hematite schist, several yards thick, is visible along the crest. Elsewhere the rock is obscured by talus, &c. Except, however, near the base of the southern slope, where pieces of ferruginous sandstone are strewn, the *debris* on the ridge is entirely of hematite schist, so that considerably more ore may exist than is actually seen. The ridge is perhaps 40 to 50 feet high, and comparatively wide, with gentle slopes. Even if the hematite band is not thicker than the exposed strata, a large amount of ore is available in the ridge. The dip, as seen about half a mile west of the village, is to the south at 40°—50°.

Hills south-east of Agaria.

In the hills south-east of Agaria I observed runs of ore in two or three places, but nothing of much importance. At the western end of the Jhíti ridge some limonite schist is seen, dipping S. 20° E. at 40°, but no good section is exposed. This, as well as other Bijáwar limonite ores, which are of rather unfrequent occurrence, may possibly be due to hydration of hematitic strata near the surface. At the southern base of the hillock just west of Kurumukur, jaspery quartz schist interbanded with micaceous iron is seen. The hillock is capped by laterite, and similar rock is to be seen in some of the hills to the north-east of the same village. These hills are low and featureless, with little or no other rock visible. It is not at all improbable, however, that the laterite is due to superficial alteration of iron ore, and that there is a considerable, perhaps a large, quantity of the latter in the hills in question.

Sarroli.

There are two low hillocks close to Sarroli, one three-quarters of a mile somewhat south of west, and the other a mile south-south-west from the town. The former of these is composed of schistose hematite and micaceous iron, the beds of which have an irregular strike, corresponding on whole with the direction of the hill, and an uncertain dip at high angles. There is a skin of laterite in places due, I have no doubt, to superficial alteration of the ore.

The northern part of the other hill is also composed of iron ore, which has an irregular dip, apparently towards the south as a whole. The southern part of the hill is formed of hornstone. The lower beds of ore, *i.e.*, those in the most northern part of the hill, are of hard micaceous iron passing into schistose hematite, while the upper strata are of soft, crumbly, finely laminated micaceous iron, with some interbanded argillaceous layers. It will be observed that the section here is similar to that in the hill half a mile south of Agaria—soft crumbly ore above and harder beds beneath—and I do not think there can be much doubt that the strata in the two localities belong to the same horizon. There are two rather large excavations in the upper beds; that to the south-east is known as the Sarroli mine, and that to the north-west as the Partábpur mine (from a village close by which is not marked on the map).

As a rough estimate of the amount of ore available by open workings, with free drainage, in the Sarroli hills, the cubic contents of the northern may perhaps be taken at $\frac{500 \times 150 \times 13}{2}$, or about 500,000 cubic yards, and that of the iron-bearing part of the southern at $\frac{300 \times 300 \times 17}{2}$, or about the same amount. This is equivalent to about 1,700,000 tons of ore in each hill, or say three and a half million tons in both together. In this estimate, as in that for the hill south of Agaria, no account is taken of the ore which could be raised from open workings beneath the level of the surrounding country. From such workings an immense amount of ore could be obtained.

A sample of the crumbly micaceous iron from the Partábpur mine, taken as it was being loaded on to buffaloes for transmission to the neighbouring furnaces, yielded—

Ferric oxide	92·21	= Iron 64·55
Phosphoric acid	·07	
Sulphuric acid	trace	
Sulphur	trace	
Loss on ignition	1·86	
Ignited insoluble residue	4·50	
Lime, alumina and undetermined	1·36	
	100·00	

The harder ore from the north end of hill gave—

Ferric oxide	97·16	= Iron 68·02
Loss on ignition	1·30	
Ignited insoluble residue	·89	
Undetermined [1]	·65	
	100·00	

Jauli.

The largest iron mine in the district is that near Jauli, somewhat less than a mile south-east of the village (3 miles south-east of Sarroli). The ore is a semi-ochreous hematite, in which a slightly schistose structure is often apparent. Hematite with metallic lustre also occurs, but is quite subordinate to the more ochrey kind. The ore is interbanded with quartzose layers, which in some places greatly exceed the ferruginous part of the rock. In other places they are comparatively rare, and in the best ore they are still less common. These layers vary from a fraction of an inch to several inches in thickness. The beds are vertical, the strike, where best seen, being N. 40° E. A rough measurement showed the beds exposed to have a thickness of about 150 feet, but in estimating the thickness of ore, a deduction must be made as an allowance for the quartzose portion just alluded to.

The ore has been very largely worked, the mine being nearly 100 yards long by 50 yards broad, and perhaps 50 feet deep. I was informed by Mr. Olpherts' agent in charge of the mine, that it is not flooded in the rains; it is a sort of deep trench (the length of which coincides with the strike of the rock) in which water would accumulate if it did not soak away subterraneously, or evaporate, quicker than it entered. The surrounding country is an undulating one, and without actual levelling it would be impossible to say to what extent free drainage could be depended on for more extensive operations.

It is from picked ore from this mine that Mr. W. G. Olpherts' 'metallic paint' is made, by grinding to an impalpable powder.

[1] In this, and subsequent analyses, in which phosphorus and sulphur are not given separately, any present is included in the undetermined portion of the ore.

Some distance, perhaps a quarter of a mile, to the north-east of the above mine, there is an old abandoned one. The ore exposed is not as rich as that in the mine now worked, and naturally so, as previous to abandonment all the best ore exposed would be removed. The beds dip E. 30° S. at 60°, the strike therefore being nearly the same as in the newer mine. Mr. Hacket considered the ore in both mines to belong to the same band, and one can scarcely doubt that such is the fact; but the ore is so soft that it makes no show at the surface, and hence cannot be traced along the outcrop. If the band is continuous, however, for even a quarter of a mile only, with anything like the thickness it has in the present mine, a very large amount of ore is hidden beneath the surface.

An average sample of the Jauli ore, taken as it came, and including the inter-banded quartz, yielded on analysis—

Ferric oxide	75·69	= Iron 52·98.
Phosphoric acid	·10	
Sulphuric acid	traces.	
Sulphur	traces.	
Loss on ignition	1·59	
Ignited insoluble residue	22·32	
Manganese oxide, lime and undetermined	·30	
	100·00	

By the aid of some picking, however, a much purer ore can be obtained. A sample assayed by Mr. A. Tween gave 97·86 per cent. of ferric oxide = 68·50 of iron, and some of Mr. Olpherts' paint gave 97·10.

Ores of the Sarroli hills bedded, not fault, rock.

Before leaving the ores of this neighbourhood, I ought to mention that the hematite of Jauli and Agaria, as well as of the hills close to Sarroli, is most distinctly a bedded rock, having generally (except at Jauli, where it is less strong marked) a highly schistose character. Locally indeed the rock is crushed and recemented, and this crushing may have taken place along lines of faulting (probably merely local slips). But except in such very limited sense the ore is most certainly not a fault rock. The point is one of practical importance with reference to the probable persistency of the ore, and is alluded to as the reverse has been previously stated[1].

Lora Hills.

The most prominent rock in the Lora range (east of Sehora) is a ferruginous siliceous schist, composed of alternating layers of micaceous iron and quartz, which is usually of a red jaspery type. The layers are of irregular thickness, varying from a small fraction of an inch to an inch and upwards. For want of a better name, and to avoid circumlocution in referring to it, this rock may perhaps be called jasper-hematite schist. If it were marked as an iron ore, the Lora range (as well as many other lines of hill) should be streaked with gold from end to end. But a large proportion of the rock contains too great an amount of silica to allow of its being smelted with advantage, more especially when ores practically free from silica are to be obtained in abundance. Only those places, therefore, are marked with gold in which I have myself seen good workable ore.

[1] Memoirs, Geol. Surv. of India, Vol. II, p. 278.

North of Mangola.

At the termination of the range north of Mangola a band of jasper-hematite is exposed *in situ* along the crest. Lower down the slopes there is a talus of the same rock, amongst which pieces of micaceous iron 2 or 3 inches thick, or more, and free from siliceous layers, are not uncommon. But the beds are not exposed sufficiently for one to form an opinion as to whether there is any considerable quantity of ore.

Gogra and Danwai.

The hill half a mile north of Gogra is formed mainly of jasper-hematite. Near the base of southern slope there are a number of shallow ore pits[1], but they are only in talus, not in the rock *in situ*. The miners seek for the small bits of ore which can be used at once in the furnaces, and leave the large lumps, which would require the labour of breaking up. The ore is a manganiferous micaceous hematite, containing a varying proportion of interbanded jaspery quartz. It is a siliceous ore, although not very highly so. As the manganiferous band is entirely concealed beneath the talus, no estimate can be made of its thickness. Judging, however, from the large amount of *debris*, it seems probable that the thickness is considerable. As the loose ore must either lie directly over that *in situ*, or else have come down hill, and as the pits extend 20 or 30 feet (vertically) from the base of the hill, probably a large amount of ore is obtainable by dry open workings, whether these be through a deep mass of talus or into solid rock.

The proportion of manganese varies much, as can be seen from the outward appearance of the ore. In some specimens of the micaceous iron, the presence of manganese is scarcely apparent to the eye; in others, the ore shows by its dark colour that it contains a large amount, and in the highly manganiferous portions psilomelane occurs in irregular segregations. A carefully chosen average sample, made up of a large number of small pieces taken from different pits, yielded—

Ferric oxide	66·33	= Iron 46·43
{ Manganese (with traces of cobalt)	12·26	
{ Oxygen	6·83	
Phosphoric acid	·27	
Sulphuric acid	·03	
Sulphur	trace.	
Ignited insoluble residue	9·55	
Lime, alumina, water and undetermined	4·76	
	100·00	

The manganese exists, in large part at least, in the form of psilomelane, occurring in irregular segregations, or more minutely disseminated through the rock.

The Gogra miners told me (and Mr. Hacket mentions the same thing) that the ore from these pits produces a hard steely iron, used for making edged-tools, &c., while that from the mines in the Sarroli neighbourhood yields a soft iron, used largely for '*karrais*' (shallow basins for making *chupatis* in, &c.). The difference is no doubt to be attributed to the manganese in the former.

[1] Those to the west belong to the village Gogra, and those to the east to Danwai.

Kuthola.

The ridge running eastward from Kuthola (1 mile south-east of Sehora) is formed mainly of jasper-hematite. At the gap where the railway passes, the strata dip at a high angle towards the south. In the low hill just west of the railway station (Sehora road), the beds in which seem to be higher in the section, as the rocks actually lie, than those just mentioned, manganiferous hematite schist, with psilomelane, is visible. The rock is more earthy and impure-looking than that at Gosulpur, which will be described presently, and contains a considerable amount of interbanded jasper and quartz. No great thickness is exposed, but the outcrop is of some importance, as indicating the position of the manganiferous band.

Where the Deccan road passes the end of the ridge, jasper-hematite with hornstone is visible *in situ*, and pieces of psilomelane, &c., are scattered about.

Gosulpur.

On the northern slope of the hillock, about 300 yards N. 15° W. from the Dák Bungalow at Gosulpur, a strong band of manganiferous micaceous iron outcrops. In a little nalla at the foot of the hill the following section is exposed :—

	Feet.
Clay-slate, seen about	50
Somewhat ferruginous quartz schist	5
Obscured	20
Manganiferous micaceous iron	15 ?
" quartz schist	5
" micaceous iron, seen	35

The total thickness of ore actually seen being about 50 feet. The section is given in descending order, as the rocks lie, the dip being about 60° to N. 30° W.

The hillock just mentioned forms the eastern extremity of a low scarp, running from Gosulpur to W. 30° S. The scarp is capped by several yards of rock laterite, but lower down the slope (which faces to N. 30° W.) the mangano-ferruginous band outcrops in several places. It is fairly seen at intervals for about a third of a mile, and reveals its presence more obscurely, by occasional small outcrops, and by loose fragments, for at least a quarter of a mile more. As in the first third of a mile the outcrop is well above the plain (averaging perhaps 30 feet or so), there is, unless the band thins out considerably immediately westward of Gosulpur, which is not likely, some hundreds of thousands of tons to be had by dry open workings, and probably some millions by going deep enough.

The appearance of the rock shows (as at Gogra) that the proportion of manganese is very variable. The greater portion of it, at least, exists in the form of psilomelane, occurring partly as linings to small cavities in the rock, and in irregular segregations and masses, some of which contain some cubic feet of mineral. I am somewhat inclined to think that the psilomelane is most abundant where the schist has crushed and re-cemented, psilomelane being the cementing material. A sample of the more manganiferous part of the schist afforded 18·02 per cent. of manganese (with a little cobalt), while the psilomelane gave 83·20 per cent. of available peroxide.

Reviewing the above details, it will be seen that manganiferous micaceous hematite has been found in several places along the southern side of the Lora range. One can scarcely feel much doubt as to there being a continuous band in that position. It is highly probable that the Gosulpur ore belongs to the same horizon, but whether it is a direct continuation of the same outcrop or not is more doubtful. The strata in the Lora range have a general dip towards the south-south-east at high angles, while the beds at Gosulpur dip N. 30° W. at about 60°. This may be a mere local feature, or it may indicate that the Lora and Gosulpur outcrops are on opposite sides of a synclinal flexure.

There does not appear to be any reason why the Gosulpur and Lora manganiferous ore should not form a suitable material for the manufacture of spiegeleisen. Although part of the manganese occurs in distinct segregations, a large proportion of it is minutely disseminated through the ore.

On the slope of the hillock at Gosulpur above mentioned, a little below the outcrop of the manganiferous ore, there is a band of limonite not less than 15 feet thick. It can be traced westwards for about the same distance as the other ore, to which it runs parallel. Some parts are very massive, the rock lying about in large blocks; others present a schistose appearance. At the time I took this to be a bedded Bijáwar rock, but I am not prepared to assert positively that it is so. Whether it be or not, a considerable quantity of ore (containing, however, a rather high percentage of phosphorus) is to be obtained from it. It yielded on analysis—

Ferric oxide	81·57	= Iron 57·10
Phosphoric acid	1·69	
Sulphuric acid	0·00	
Sulphur	traces [1]	
Loss on ignition	10·91	
Ignited insoluble residue	4·08	
Lime, alumina and undetermined	1·75	
	100·00	

LATERITIC ORES.

The pisolitic ores occur on a horizon near the base of the lateritic strata. "The bottom beds (of the group) consist of a coarse ferruginous sandstone, formed of rounded bits of quartz, sometimes as large as a pea, embedded in a hard ferruginous paste. Above this there are some beds of fine ferruginous earthy sandstone, containing badly preserved leaf-impressions. Resting upon these in some sections, there are several feet of a rich oolitic iron ore, covered by red, white, and purple clays, with bands of a coarse ferruginous sandstone interbedded, the whole capped by the ordinary rock laterite."[2]

There are two main varieties of pisolitic ore, one of which breaks with a smooth conchoidal fracture and shining surface; the other with a rough uneven fracture and dull lustreless surface. In the former the hardness and tenacity of the spherules, and of the cement in which they are embedded, are about equal, so that fracture takes indifferently through both parts of the rock. The difference of fracture in the other variety is due partly to the cement, and also the spherules,

[1] ·003.
[2] C. A. Hacket, MSS. report, 1871-72.

breaking with a dull uneven surface; partly to some of the spherules being dragged out of their sockets unbroken, so that the surface of the rock shows a number of roundel prominences and depressions. The conchoidal-fractured limonite is hard and brittle, the other much softer, and sometimes quite friable.

The spherules of the former vary in size from that of large peas downwards, so that the rock passes into oolitic limonite. Intimately associated with it in many sections is a highly ferruginous sandstone, which, when looked at under the lens, is seen to be composed of minute grains of quartz with an abundant limonitic cement. Sometimes the rock is free from spherules of limonite; more frequently such are scattered through it more or less abundantly. Thus it passes into the rich pisolitic ore in which grains of quartz are sometimes visible between the spherules, though more frequently the cement is, like the spherules themselves, purely limonitic. The sandstone and pisolitic ore are often found in juxta-position, with a sharp line of division between the two.

An immense number of small pits, most of which are now abandoned, are scattered over the lateritic area. The majority of those I visited are in the neighbourhood of Bijori (7 miles east-south-east from Murwâra) and in the Kanhwâra hills.

Bijori.

There is a quarry a quarter of a mile S. 15° W. from Bijori from which Mr. W. G. Olpherts obtained some of the ore smelted in his experimental works at Murwâra. The section at one end comprises—

	Ft.	In.
a. Surface soil	1	0
b. Lateritic *debris*	1	6
d. Pisolitic limonite with conchoidal fracture	0	11
e. Ochreous, somewhat pisolitic, limonite with rough fracture	0	4
f, g. Semi-ochreous red oxide of iron, in onion-like nodules several inches in diameter	0	8
h. Lithomargic clay	0	7
i. Soft friable sandstone, seen	0	7

One hundred feet to the east, at the other end of the quarry, the section is as follows—

	Ft.	In.
a. Surface soil	1	0
b. Lateritic *debris*	1	0
c. Soft pisolitic limonite with rough fracture	3	4
d. Pisolitic limonite with conchoidal fracture	0	10
e. Ochreous, somewhat pisolitic, limonite with rough fracture	0	5
f. Pisolitic limonite with conchoidal fracture	0	4
g. Ochreous, somewhat pisolitic, limonite with rough fracture	0	5
h. Lithomargic clay, seen	0	10

In comparing the above two sections it will be observed that the band of semi-ochreous red oxide of iron in the first corresponds to $f + g$ in the second, or to one or other of them, the other having died out. In either case there is a change in mineral character laterally, which change may be either original or secondary. The absence of *c* in the first section is merely due to denudation.

About a mile south of Bijori there is another quarry, which has been worked by Mr. Olpherts. The section at the eastern end comprises—

	Ft.	In.
a. Surface soil	1	0
b. Disintegrated laterite, or lateritic *debris*	2	8
c. Disintegrated laterite with one or two layers of highly ferruginous sandstone, and thin seams of pisolitic limonite with conchoidal fracture	0	9
d. Pisolitic limonite with conchoidal fracture	0	3 to 4
e. Soft pisolitic limonite with rough fracture	1	9
f. Pisolitic limonite with conchoidal fracture	0	½
g. Soft pisolitic limonite with rough fracture	1	10
h. Limonite, with conchoidal fracture; pisolitic in the upper part, passing into oolitic lower down	0	11
i. Laterite, seen	1	2

At the other end of the quarry, 22 feet to the west, the band *h* is represented by—

		Ft.	In.
h.	Pisolitic limonite with conchoidal fracture	0	5
	Soft pisolitic limonite with rough fracture	0	4
	Oolitic limonite with conchoidal fracture	0	5½

The middle 4-inch band, therefore, dies out in a very short distance. In the western part of the quarry, also, the band *d* is represented by a layer, about equally thick, of compact brittle limonite. It is further noticeable in this section that ordinary laterite underlies the pisolitic ore.

An average sample from the band *h* gave on analysis—

Ferric oxide	81·20	= Iron 56·84
Phosphoric acid	1·41	
Sulphuric acid	trace.	
Sulphur	trace.	
Loss on ignition	13·42	
Ignited insoluble residue	1·29	
Alumina, lime and undetermined	2·68	
	100·00	

On the north side of the village 3 feet 4 inches of soft pisolitic limonite, with rough fracture, is exposed, with the base not seen. This afforded—

Ferric oxide	71·72	= Iron 50·20
Loss on ignition	14·68	
Ignited insoluble residue	7·94	
Undetermined (alumina & lime in part)	5·66	
	100·00	

In an old pit half a mile east of Bijori 2 feet of ore of the same kind is exposed.

There are a number of abandoned pits about 300 yards north of the village, in one of which the following section was measured:—

	Ft.	In.
Surface soil	1	6
Soft pisolitic limonite with rough fracture	1	5
Pisolitic limonite with conchoidal fracture	0	1
Soft pisolitic limonite with rough fracture	0	7
Ochreous pisolitic limonite with rough fracture	0	3

	Ft.	In.
Pisolitic limonite with conchoidal fracture; the amount of cement between the spherules increasing in amount downwards until the rock passes into highly ferruginous sandstone	0	7 to 8
Soft pisolitic limonite with rough fracture	0	6
Friable ferruginous sandstone with some thin irregular hard layers, seen	1	6

Majhgaon.

About half a mile south-west of Majhgaon, some ferruginous beds are very imperfectly seen in a nalla.

	Ft.	In.
Pisolitic limonite with conchoidal fracture, not less than	1	6?
Arenaceous semi-ochreous hematite, in beds of irregular thickness, seen	4	0

The lower beds are considerably contorted on a small scale.

On the south-west side of the village, in an old pit, about 2 feet of oolitic limonite, mostly of the soft variety, underlies some 4 feet of lateritic *debris*. The base of the ore is not visible.

Bhadora.

Three quarters of a mile south-west of Bhadora there is a group of old pits, in the largest of which the following section was measured :—

	Ft.	In.
Surface soil, &c.	3	0
Bed of earthy limonite, with faint plant impressions	0	10
Lithomargic clay	3	0
Oolitic limonite, softer and less highly ferruginous than that below	2	0
Oolitic limonite, rather soft and breaking with rough fracture, seen	1	0

Summarizing the preceding sections, we find the thicknesses of ore actually seen, to be as follows :—

	Pisolitic limonite with conchoidal fracture.	Pisolitic limonite with rough fracture.	Non-pisolitic limonite.	Hematitic ore.	TOTAL.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
½ mile S. 15° W. from Bijori	1 2	4 2	...	...	5 4
1 mile south of Bijori	1 3	3 7	...	...	4 10
North side of Bijori	...	3 4	...	...	3 4
½ mile east of Bijori	...	2 0	...	...	2 0
300 yards north of Bijori	0 8	2 9	...	...	3 5
½ mile south-west of Majhgaon	1 6?	...	...	4 0	5 6?
South-west side of Majhgaon	...	2 0	...	...	2 0
¾ mile south-west of Bhadora	...	3 0	0 10	...	3 10

In the sections which are best seen there is about 5 feet of ore. In the others either a portion of the ore has been denuded away from the top, or the lowest beds are not visible.

With reference to the important question whether the iron-bearing strata are continuous throughout the area over which the pits above noticed are scattered, it would be perhaps rash to express an unqualified opinion. The strata are most obscurely seen, being rarely visible except in the old pits, and seldom in them even except by clearing out the rubbish, by which they are more or less choked up. But I am certainly strongly inclined to believe that the ore will be found to occur continuously at the same horizon, although the details of the section may vary in different localities. Some of the sections given above show slight differences within a few yards even, but those in which the rocks are best seen agree in there being a foot or so of limonite with conchoidal fracture, covered by a thicker band of the softer kind of ore.

The map scarcely indicates the form of the ground correctly. There is low ground, occupied by alluvium, on the borders of the streams, sloping gently upward to more elevated ground, where the surface rock is laterite, rather than definite hills and valleys. The ore beds generally occur near the foot of the lateritic slope, a little above the level of the alluvium. They have probably, therefore, been denuded away from some, at least, of the alluvial hollows. But these hollows occupy a far less area than the lateritic ground. In the latter I believe the ore will be found continuously; at or close to the surface in the lower ground, and obtainable by open workings, but in the more elevated tracts probably beneath such a depth of overburden as to necessitate shallow mines. The amount of ore must be very large. A continuous bed of even one yard only would contain more than eight million tons to a square mile.

About a mile north of Emelia there are two quarries about 100 yards apart.

Emelia.

That to the north was worked last year, and a considerable heap of ore was stacked at the time of my visit. The section includes—

	Ft.	In.
Surface soil	0	2
Highly ferruginous sandstone	1	8
Disintegrated ordinary laterite	1	8
Pisolitic iron ore, seen	4	0

The floor of the quarry is on the ore, so that the total thickness of the latter is not apparent. The strata dip about N. N. W. at 5°. The ore is somewhat different to any that I have seen elsewhere. It consists of spherules of limonite (having an onion-like structure, and ranging up to an inch, or even more, in diameter, but usually not exceeding half an inch) which are embedded in a semi-ochreous cement consisting mainly of brown, but partly of red, oxide of iron. Most of the spherules on the surfaces of fracture remain unbroken, being torn out of their sockets on one side.

In the other quarry the same beds are seen less fully.

	Ft.	In.
Surface soil	0	9
Highly ferruginous sandstone	1	0
Disintegrated ordinary laterite	0	5
Pisolitic iron ore, seen	1	3

The ore is similar to that in the first quarry, except that the cement contains more red oxide. Dip north-west at 5°.

The ore in these quarries being on rising ground, and, where it is now exposed at least, close to the surface, is favourably situated for open workings. An average sample from the first-mentioned gave—

Ferric oxide	77·81	= Iron 54·47
Manganese (calculated as Mn_2O_3). with traces of cobalt	1·54	
Phosphoric acid	·82	
Sulphuric acid	traces.	
Sulphur	traces.	
Loss on ignition	13·20	
Ignited insoluble residue	3·27	
Alumina, lime and undetermined	3·36	
	100·00	

Jhijri.

On the rising ground about a mile west-south-west of Jhijri several shallow pits have been sunk, but they are now abandoned. Lumps of ore are freely scattered about over the surface, and here and there a thin bed is visible *in situ*. The thickest I saw included 10 inches of pisolitic limonite with conchoidal fracture.

Kailwára.

At the base of an outlying hillock of laterite, about half a mile north-west of Kailwára, there is a band of ore, similar to that near Jhijri, which has a thickness of not less than 20 inches.

Murwára.

In a nalla, close to Mr. Olpherts' paint mill on the Katni, a mass of somewhat earthy limonite, mixed with red oxide, appears from beneath the alluvium for a distance of about 20 yards. It has an apparent schistose structure and is unlike any lateritic ore that I am acquainted with. On the other hand, it is very improbable that the Bijáwar rocks should appear at the surface, which they could only do by very peculiar faulting, so that I feel uncertain as to the relations of the ore. It afforded—

Ferric oxide	75·23	= Iron 52·66
Loss on ignition	9·02	
Ignited insoluble residue	11·08	
Undetermined (alumina and lime in part)	4·67	
	100·00	

Kanhwára hills.

The Kanhwára hills (6 miles north-east of Murwára) form a level plateau bounded by a sharply defined escarpment. The surface rock on top is ordinary laterite, while bands of rich iron ore outcrop along the face of the slope.

Pisolitic limonite, in great part of the kind with conchoidal fracture, forms a strong band at the top of the escarpment a quarter of a mile W. 20° N. of Pilongi. There is little or no overburden on it.

At the foot of the ghát, half a mile N. 20° W. of Piprehta, a bed of similar ore not *less* than 2 feet thick is visible.

Not far from the top of the scarp above Piprehta there is a strong band of the same kind of ore. There appears to be another lower down, but the section is obscurely seen.

On the slope of the projecting spur, a quarter of a mile south-east of Piprehta, there are some old pits. In one of them the following section was measured :—

	Ft.	In.
Pisolitic limonite, mainly of the kind with conchoidal fracture, in part somewhat ochreous, seen	2	10
Coarse ferruginous sandstone	1	6
Compact, or slightly ochreous, limonite	0	2
Do. red oxide of iron	0	3
Lithomargic clay, seen	1	6

there being 3 feet 3 inches of ore, with the top of the main band missing through denudation. The ore is 15 feet (vertically) below the top of the hill, which is about 70 yards to the north—

A sample from the main seam yielded on analysis:—

Ferric oxide	82·18	= Iron 57·52
Phosphoric acid	·76	
Sulphuric acid	trace	
Sulphur	traces	
Loss on ignition	13·89	
Ignited insoluble residue	1·57	
Alumina, lime and undetermined	1·60	
	100·00	

It will be noticed that this, as well as the other lateritic ores analysed, contains a much higher percentage of phosphorus than the hematites. In the latter the phosphoric acid ranges from ·10 to ·27 per cent.; in the former from ·76 to 1·41 per cent.

At the foot of the hill, below the pits just mentioned, there is a strong band of oolitic and pisolitic limonite with conchoidal fracture.

To the north-west of Kamtarra (a village 1 mile south of Mohári) there are some old pits 25 feet above the foot of the escarpment, which is 70 feet high. The ore is pisolitic limonite with conchoidal fracture, and is not *less* than 12 inches thick. There seems to be more than one band of ore besides that in the pits, but the section is very obscure. Large quantities of loose ore are strewn on the hill-side at different levels.

Just west of Mohári the hill is capped, with no overburden, by 2 feet 4 inches of oolitic limonite with conchoidal fracture. There are some old pits here, and others about half way down the hill.

In the nalla just north of Mohári there is—

	Ft.	In.
Oolitic limonite with conchoidal fracture, seen	0	9
Slightly arenaceous limonite, in thinnish beds containing plant impressions	0	9
Ferruginous sandstone, seen	1	6

Near the bottom of the ghát, half a mile north-west of Mohári, there is a band of pisolitic limonite with conchoidal fracture, seemingly about 2 feet thick. Higher up there is another strong band of similar ore.

On the slope above Kanhwára 2 feet 6 inches of same kind of ore, but somewhat ochreous in part, outcrops in one place.

About half a mile south of Kanhwára the surface rock, at some little distance from the foot of the escarpment, is pisolitic limonite with conchoidal fracture.

On comparing the above sections it will be seen that there is one band of ore near the top of the escarpment, another at the foot of it, and a third in an intermediate position. The thicknesses, in as far as I was able to ascertain them, were—

	Top seam.	*Middle seam.*	*Bottom seam.*
¼ Mile W. 20° N. of Pilongi	Strong band	...	...
¼ „ N. 20° W. of Piprehta	...	...	Not less than 2 feet.
Piprehta	Strong band	?	...
¼ Mile south-east of Piprehta	Not less than 3 feet 3 inches.	...	Strong band.
North-west of Kamtarra	...	Not less than 1 foot.	...
West of Mohári	Not less than 2 feet 4 inches.	?	...
North of Mohári	...	...	Not less than 1 foot 6 inches.
North-west of Mohári	...	Strong band	2 feet ?
Kanhwára	...	2 feet 6 inches	...
South of Kanhwára	...	...	?

It is, I think, tolerably safe to estimate the average thicknesses of the seams at—

	Ft.	In.
Top seam	2	6
Middle seam	2	0
Bottom seam	2	0

The area of the plateau west of Mohári being about two and a half square miles, there would be in the—

Top seam	19 million tons of ore.
Middle seam	15 „ „
Bottom seam	15 „ „

A large amount of ore from the top seam is available by open workings with free drainage in places where, as in some of the localities noticed above, it occurs at the very top of the escarpment with little or no overburden. A considerable quantity could also be got from the bottom seam, in the same way, in places where it extends into the plain at the foot of the slope. The great mass of ore from the two lower seams, however, and some probably from the top one, could only be obtained by mining. But mining in horizontal strata at such insignificant depths would be of the simplest kind, an immense quantity of ore being within reach by adits driven in from the face of the escarpment.

In the above estimate no account has been taken of the Kanhwára hills east of Mohári, where there can be little doubt ore exists in equal abundance.

Ordinary laterite as ore.

A considerable proportion of the ordinary laterite contains a high percentage of iron, and in countries less favoured than that under discussion would be looked on as a valuable ore. As a case in point, I may mention the hillock near Kailwára previously alluded to. It is about 40 feet high, and formed of rock laterite of a common type. A carefully chosen average sample yielded—

Ferric oxide	63·27	= Iron 44·29
Loss on ignition	10·48	
Ignited insoluble residue	19·36	
Undetermined (mainly alumina and lime)	6·89	
	100·00	

Scope of notes.

I ought not to conclude these notes on the iron ores of Jabalpur without saying that they do not profess to give an account of every locality in which such mineral resources are to be found. Iron is, indeed, well known to occur in places which I have not visited—at Gangai, for instance, near the marble rocks, and the Majhauli hills, west of Sehora. Such ores, however, are, from their position, obviously out of count in connection with the Umeria coal. In the localities I have described, there is a practically unlimited supply of high-class brown, red, and manganiferous ores, none of which are more than a few miles distant from the railway. So much being ascertained, it would be useless, at any rate until the question of working the ores takes a more definite form than at present, to spend time in the examination of the more remote and less important localities.

FLUXES.

Lower Vindhyan limestone.

The most important member of the Lower Vindhyan series, and that possessing the greatest constancy in the section, is a band of limestone some hundreds of feet in thickness. Constituting, as it does, nearly the highest subdivision of the series, and generally dipping towards the north at moderate angles, it occupies the lower portion of the Kymore escarpment (beneath the sandstones of the upper series), or a belt of country, of varying width, immediately to the south. In this position it extends from near Sasserám to Bijerághogarh, a distance of some 200 miles. In the neighbourhood of the latter town the outcrop is exceptionally wide, covering a breadth of more than 3 miles. A little west of Bijerághogarh, however, the alluvium begins to encroach, the limestone outcrop rapidly narrows, and near the village of Kachgaon finally disappears beneath the more recent deposits[1]. But it is practically certain that, although concealed, the limestone forms a continuous fringe, bordering the Upper Vindhyan rocks, from Kachgaon towards the south-west, and then eastwards again to Murwára. In the latter position there are numerous quarries sunk through the alluvium.

These excavations are in a line running north and south from just south of the town to the base of Murwára Hill Station. With one exception they appear to be all very nearly on one strike. The depth of overburden in the different

[1] The narrow band, colored blue on the map, to the westward of Kachgaon, is of shale, which occupies a position between the limestone and the Upper Vindhyan rocks above.

quarries varies from 10 to 25 feet, except in the most southern of the line, where it is less than 5. It consists of clay, with Lower Vindhyan shales and inferior shaly limestone, which overlie the band that is worked. The latter consists of grey limestone in beds of rather small thickness, averaging say 2 to 5 inches. A carefully chosen average sample gave—

Carbonate of lime	94·65
„ of magnesia (by diff.)	2·98
„ of iron	·58
Phosphoric acid	traces
Sulphuric acid	0·00
Sulphur	traces[1]
Ignited insoluble residue	1·79
	100·00

—a result which shows the stone to be eminently suitable as a flux.

The band of superior limestone (above and below which is inferior stone) is only some 10 feet thick, and as it dips (towards the west) at 15°—20°, it cannot be followed towards the deep for any distance, the overburden even at the outcrop being excessive. The amount of stone therefore obtainable from the present quarries is limited. The outcrop of the whole band of limestone, however (which, as I have said, is some hundreds of feet thick in the Son Valley), probably extends for a considerable distance eastwards of the quarries beneath the laterite and alluvium, and many other beds of good stone are probably concealed in that position. (There is indeed one excavation, some 130 yards east of the others, which has struck limestone, but of an inferior kind.) It is very doubtful, however, whether the more recent deposits are not too thick to allow of such being worked, even if found. A well in Mr. Olpherts' compound, a few hundred yards east of the line of quarries, was sunk through 90 feet of clay without striking rock.

In the event, then, of iron works on a large scale being started at Murwára, I think it is not impossible that, sooner or later, the supply of limestone on the spot will fail. In this case search should be made a little south of where the railway passes through the Kymore hills (west of Ponchi). It is quite possible that the limestone is to be found there beneath a less depth of overburden than at Murwára, and a few shallow wells would be sufficient to settle whether it is or not. If not, perhaps the best plan would be to construct a tramway from Murwára to the limestone area west of Bijerághoghar, or to the latter town itself. Limestone is to be had there in unlimited quantity at the surface of the ground. The tramway, therefore, besides serving to bring in iron ore from the rich deposits of the Kanhwára hills, and flux for smelting purposes, could supply lime-works on any required scale with stone, probably at a cheaper rate than it can be had now at Murwára, as the expense of removing such a mass of overburden would be avoided. As the Murwára[2] lime is now exported as far even as Calcutta, a market would doubtless be found for a large supply, if deliverable at a sufficiently low rate. A certain amount of passenger and ordinary goods traffic would also, no doubt, be obtainable for such a tramway as a feeder of the East Indian Rail-

[1] ·004.
[2] Or Katni. Murwára is the name of the town, Katni that of the adjoining railway station.

way. As the country is nearly level, with only one stream of any size to cross, there would be no difficulty in construction.

There is an unlimited supply of limestone to be obtained from the lameta beds.

Lameta limestone.

Besides the fact, however, that these rocks do not approach the railway anywhere north of Jabalpur, the stone is markedly inferior to that of Murwára. An average sample, taken from several heaps collected for burning near Jabalpur, contained 21·38 per cent. of residue insoluble in hydrochloric acid, the remainder being carbonate of lime, with trifling quantities of magnesia and iron.

Aluminous laterite.

A pisolitic variety of laterite, containing, besides iron, a large proportion of alumina, occurs abundantly in the hills south of Murwára. If an aluminous flux should be required for smelting some of the hematite ores, the rock in question might perhaps be found useful.

DOLOMITE.

The occurrence of manganiferous iron ore, available for the production of spiegeleisen, would probably lead to Bessemer steel-making being included in any scheme for utilising the Jabalpur ores. If the basic process were adopted, dolomite for lining the converters would be required. The rock occurs in great abundance in the district, and, although very unequal in quality, can be obtained, by a little selection, of great purity.

Marble rocks.

The well-known 'marble rocks,' which are situated about 2 miles from Mirganj station on the Great Indian Peninsular Railway (11 miles from Jabalpur and 68 from Murwára), are dolomitic throughout. The rock has a saccharine texture, and is mainly of a pure white colour, although here and there it has a grey, yellow, or pink tinge. The bedding, as a rule, is not very thick, and in places it is quite thin, the rock verging towards a dolomitic schist. The greater portion of the dolomite contains disseminated crystals of tremolite, and very often irregular strangulated layers of quartz parallel to the bedding. But rock free from visible impurity is to be obtained without any difficulty. A sample of such, of a pure white colour, and obtained from different spots, yielded—

Carbonate of lime	55·48
„ „ magnesia (by diff.)	43·55
„ „ iron	·36
Ignited insoluble residue	·61
	100·00

This is a very close approximation to normal dolomite, which contains 54·35 and 45·65 per cent. of carbonate of lime and magnesia respectively.

Near Sleemanabad.

Dolomite of a somewhat less pure variety also occurs largely in the neighbourhood of Sleemanabad. It is mostly grey, with occasional cherty and quartzose bands, but rock free from visible impurity can easily be got by selection. A sample taken from the side of the railway between Dharoli and Deori (2 miles from Sleemanabad station and 20 from Murwára) gave—

Carbonate of lime	52·45
„ „ magnesia (by diff.)	38·22
„ „ iron	2·76
Ignited insoluble residue	6·57
	100·00

The same band of rock is also found close to the Sleemanabad station.

FIRECLAY.

Jabalpur.

Firebricks have been made in the Jabalpur jail from clay obtained from the Upper Gondwána beds, in the neighbourhood of Jackson's hotel. Last year I made some trial of their infusibility on a small scale. Three sharp-edged fragments, together with three similar fragments of a Scotch firebrick, from Kilmarnock, were placed in a covered crucible, and exposed for an hour to a dazzling white heat in a Fletcher's injector gas furnace. After cooling it was found that the edges of none of the fragments showed even incipient signs of fusion. The fragments of both bricks had acquired a slight glaze on the parts forming portions of the original surfaces, and when broken were found to have become extremely hard (so as to resist the point of a knife), somewhat porous, and the fracture semi-vitreous looking. The Jabalpur brick, before heating, had a smoother fracture than the Scotch one, and was much softer and more easily broken. After heating, however, both seemed to be equally hard.

Amdari.

Bábu Hira Lál, of the Geological Survey, recently forwarded some clay, similar in appearance to that from which the Jabalpur bricks were made, which he found in the Upper Gondwána strata in the hill west of Amdari, a village 14 miles south-west of Chandia. He states that the clay occurs in considerable quantity. It is a white indurated kind, breaking with a semi-conchoidal fracture when dry. When powered moderately finely[1], it yielded a highly plastic mass with water. From this small bricks with sharp square edges were made, measuring $1\frac{1}{2}'' + \frac{1}{2}'' + \frac{1}{4}''$. Similar bricks were made from fireclay from Glenboig and Garnkirk (Scotland) and from Ráníganj. One of each was enclosed in a covered crucible, with one end resting on the bottom, and the other touching the side. After exposure for an hour to a dazzling white heat in an injector furnace[2], the edges of the Amdari brick were only slightly rounded, but the brick had softened sufficiently to allow it to bend somewhat, until partially supported by the side of the crucible. It had not contracted in a marked degree. The Glenboig and Garnkirk bricks remained with perfectly sharp edges and contracted very slightly; the former showed no trace of bending, while the latter was bent in a very slight degree. The Ráníganj brick had the edges completely rounded, and was reduced to a semi-fused condition.

[1] Sifted through a sieve of 38 holes to the linear inch.

[2] The temperature was sufficiently high to soften the cover of a crucible from the Battersea works, and allow it to sagg downwards.

Some of the powdered Amdari clay was subsequently washed by suspension in water, dried, repowdered and sifted, and made into bricks of the same kind, which were similarly heated. The edges were very slightly rounded, and the bricks bent somewhat from their own weight, but decidedly less than that made from unwashed clay.

Although the clay, then, showed itself to be inferior to Scotch clay, good fire-bricks could probably be made from it, especially if washed. Similar clay is doubtless to be found elsewhere in the Upper Gondwána area, and one may expect the coal measures of Umeria to contain fireclays like those of Ráníganj and other coal fields.

MURWÁRA AS A SITE FOR IRON-WORKS.

In the preceding remarks I have more than once alluded to Murwára as a site for future iron-works. The advantages of the position are not far to seek. The two primary conditions in selecting a site are firstly, that there shall be an ample supply of water, and secondly, that the spot shall be on the line of railway. Now, between Gosulpur, in the neighbourhood of the most important hematite and manganiferous deposits, and Umeria, *viâ* Murwára, the East Indian Railway and the projected line to Umeria only cross three streams of any size, namely, the Heran, south of Sehora; the Katni, at Murwára; and the Máhanaddi, near Chandia. The first of these is obviously too far away from the coal-field. The Máhanaddi is within a comparatively short distance of the coal, which forms the heaviest individual item of haulage, but not only would the ore and flux have to be taken from near, or beyond, Murwára to the Máhanaddi, but all the iron produced would have to be carried from the Máhanaddi to Murwára. Roughly speaking, there would be the haulage of ore + flux + iron *versus* the haulage of coal[1].

Murwára, as will have been seen, occupies a central position with reference to the different mineral products required. It is actually on limestone, and within less than 15 miles of an unlimited supply of the same mineral to the north-east. It is in the immediate neighbourhood of the lateritic brown ores, and about equally distant from the Umeria coal-field to the south-east, and the hematite and manganiferous ores to the south-west, while dolomite is to be had within 20 miles by railway. The Katni, which flows past Murwára, is a stream with a drainage area of 230 square miles above the town, and there is an abundant supply of water throughout the year[2].

[1] If the new line were continued to Belaspur a certain quantity of iron would find its way to the south-east, but the amount would probably be a small proportion of the total made.

[2] It appears from data kindly supplied to me by Mr. V. Pont, Resident Engineer of the East Indian Railway at Jabalpur, that in April last year, when the stream would be almost at its lowest, there was a flow of 996 cubic feet per minute.

A magnificent sheet of water could be formed by throwing a dam across the gorge, through which the Katni flows just west of Murwára, and a sufficient head of water perhaps obtained to work heavy machinery; to ascertain the exact fall obtainable would require actual levelling. The reservoir, however, could unfortunately only be made at the expense of submerging a large area of cultivated land.

On Lateritic *and other* Manganese Ore *occurring at* Gosulpur, Jabalpur District, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

In a previous volume of the Records[1] some account is given of the manganese ore at Gosulpur, which was visited by the Superintendent of the Geological Survey in 1879. The sections then available for examination were very poor indeed, but, judging from which could be seen, Mr. Medlicott thought that a large supply of the ore could probably be depended on. The following year a shaft was sunk with a view of testing the richness of the deposit. When this had reached a depth of 20 feet, the engineer in charge reported "that all trace of the ore was lost at a depth of 9 feet from the surface, at which depth a yellow subsoil, resembling ochre, was entered; that about $1\frac{1}{2}$ cubic feet of ore were obtained, and even this small quantity of rather an inferior quality; that in consequence I recommended and discontinued operations." As this discouraging result was at variance with the hope previously entertained of a considerable supply, I was directed to take the opportunity, while in the neighbourhood recently, of visiting the locality and seeing how the discrepancy was to be explained.

The shaft is dug on the site of the pre-existing holes examined by Mr. Medlicott, from which the ore had been extracted for use in glass-making at Murwára and elsewhere. The section comprises—

	Feet.
a. Laterite	4 to 5.
b. Manganese ore	2 „ $2\frac{1}{2}$.
c. Laterite containing some nodules of manganese ore, about	6
d. Distintegrated quartz schist dipping at a high angle (to bottom of shaft)	7

The manganese ore *b*, which, as mentioned in the previous notice[2], is pyrolusite mixed with some psilomelane, occurs in the form of irregular spongy nodules varying in size from a fraction of an inch to several inches diameter, and averaging perhaps half an inch to 1 or 2 inches. These seem to constitute an irregular layer, which is 2 feet thick, or rather more, at the shaft. It is exposed in two or three other places within a length of 20 feet. The level varies somewhat even in this short distance, and, as pointed out by Mr Medlicott, the ore found in the village well, 120 yards to the east, is at a lower level than that at the shaft. This difference is, I think, to be ascribed to the laterite (including the ore) having been deposited on an irregularly denuded floor of Bijáwar rocks.

There is little or no laterite of the ordinary (ferruginous) type included in the manganese stratum, and the separation between this stratum and the laterite above is tolerably well defined; that between the manganese and the laterite below is not so well marked, the laterite containing occasional nodules of pyrolusite through it. The laterite above and below the ore looks somewhat like the detrital variety, but experience elsewhere has led me to believe that the rock laterite[3] has a tendency to disintegrate into a mass of irregular nodular fragments, which bear

[1] Vol. XII, p. 99.

[2] *Ibid*, p. 100.

[3] By 'rock laterite' I mean the first form of laterite mentioned on page 117. The term is no doubt open to criticism, but is convenient aud serves to avoid circumlocution.

a very close resemblance to the detrital form. Taking into account that no distinctly foreign matter is visible in the rock in question; that undoubted rock laterite occurs close by; and that the manganese ore is pyrolusite, not psilomelane (a point to which I shall allude again), I do not think there can be any reasonable doubt that the laterite, inclusive of the ore, is rock laterite, not detrital. Such is the view which Mr. Medlicott also took: "This laterite is of the older type; at least in the exposed sections I could not detect any palpable *debris*, which generally characterises the secondary or detrital laterite. It is therefore presumable that the lumps of ore are in rate, and that the manganese is an integral component of the laterite in this position."[1]

With reference to the original source from which the manganese was derived, it is I think scarcely open to doubt that it is to be sought in the strong band of manganiferous micaceous iron which outcrops along the southern side of the Lora range and again at Gosalpur[2]. But, as I said in the preceding paper, the manganese in this ore occurs mainly, if not entirely, in the form of psilomelane, while the manganese of the laterite is mainly pyrolusite. The latter, therefore, cannot be the result of mere mechanical degradation and transport, unless it be supposed that the nodules in which the ore occurs are pebbles, originally of one mineral which has subsequently been changed into another. This mode of origin is rendered very unlikely by the absence of any other recognisable debris in the manganese stratum.

If the latter be not a mechanical deposit, it must be a chemical one. Carbonate of manganese being, like carbonate of iron, soluble in water holding carbonic acid in solution, the former metal is capable of being leached out and re-deposited in the same, or nearly the same, way as the latter[3]. During the deposition of the main stratum of manganese ore, the water appears to have held little but manganous carbonate in solution, while at the time the laterite below was formed, ferrous carbonate was the chief substance dissolved, but with some manganous salt, the manganese subsequently separating itself into nodules by segregatory action. Specimens may be obtained consisting in part of ordinary laterite, and partly of manganese oxide.

The occurrence of this manganese laterite, interbedded with ordinary ferruginous laterite, furnishes, I think, strong evidence in favour of the view as to the origin of the latter which I have advocated in a former paper[4], namely, that laterite is (in as far as the iron is concerned) a chemical deposit due to the leaching out and redeposition of iron through the agency of decaying vegetation and the carbonic acid produced by its decomposition. I of course am speaking of the first only of the three forms of laterite which I believe are now generally recognised, *viz*:—

1st.—Laterite due to deposition, and excluding the *3rd* form.

2nd.—Laterite due to the alteration of other rocks *in situ*[5].

[1] Vol. XII, page 99.
[2] Page 102.
[3] *Vide* Vol. XIV, page 145.
[4] *Ibid*, page 139.
[5] Some examples of this form are noticed in the preceding paper, pages 97, 98.

3rd.—Detrital laterite due to the denudation and redeposition of the *1st* or *2nd* form.

With reference to the amount of manganese ore obtainable, it is not easy to form any decided opinion. I think, however, that there is a fair chance of the layer being somewhat extensive, although very likely subject to much irregularity in level and the amount of overburden covering it, and perhaps in thickness also. When there is a demand for the mineral, the bed might be followed from the present diggings, and the superincumbent laterit utilised for road metal on the Deccan road which passes close by.

It will have been seen that the reason why so little ore was obtained from the shaft was that the latter passes through the manganese stratum into quartz schist below it. The shaft, indeed, merely exposed the thickness of the bed, but proved nothing as to its lateral extension.

In the preceding paper I have pointed out that a considerable quantity of psilomelane occurs with the manganiferous micaceous iron at Gosulpur. If the latter were worked in connection with iron-making, the psilomelane would be raised at the same time, and available as an ore of manganese. On assay it yielded 83·20 per cent. of available peroxide, or about the same amount as the lateritic pyrolusite. From both sources combined it may be reasonably hoped that a considerable supply of ore will be procurable when there is a demand for it.

Further notes on the Umaria Coal-field (*South Rewah Gondwana Basin*), *by* THEO. W. H. HUGHES, A.R.S.M., F.G.S., *Geological Survey of India.*

In my notes of last year on the Umaria coal-field were embodied the general results inferable from the evidence afforded by the preliminary experiments carried out under the management of the Rewah State: that coaly matter occurred in abundance; that it lay at a shallow depth from the surface over a proved area of $1\frac{1}{2}$ square miles; that it thickened to the deep; that the gradient was low and advantageous for working; and that the quality of the coal at the outcrop was encouraging.

The promise was a fair one, and from the exceptionally commanding geographical position of the field it required small advocacy to show that if the expectations based on the introductory enquiries were confirmed, a splendid reserve of coal had been established. I am happy to say that Captain Barr, the Political Agent of Rewah, has keenly appreciated the exigencies of the case, and his further sanction has been obtained for carrying out such trials as shall set at rest any apprehensions that prudence may give rise to.

I confess that I have little or no misgiving as to the worth of the Umaria and the adjacent Johilla fields, and I have belief enough in my opinion to give it expression. But I admit the necessity of verification; and, in view of the important issues dependent upon the true practical estimate of these fields, I strongly commend the course that had been suggested of reducing to its narrowest limits the margin of uncertainty regarding the nature, quality, and permanency of their seams.

To achieve this object it was determined that the coal should be approached under the ordinary conditions of approved mining. There were two plans open for adoption, either to drive an incline from the outcrop, or to sink a shaft to the seam. The second method was preferred, as being in every sense more workman-like, and as affording more scope for efficiently dealing with an influx of water; and on the 11th March 1883, a pit of 10 feet internal diameter was commenced under the charge of Mr. Thomas Forster, M.E.

Shaft determined upon.

The position of the pit is near No. 8 bore-hole, where Mr. Stewart struck coal at 93 feet from the surface and recorded the thickness of the seam as 10 feet. I had a strong wish to go further to the deep towards No. 9 bore-hole, but I was deterred by the dread of water, and the possibly heavy outlay that would have to be incurred for pumping machinery.

Position of pit. Record of No. 8 bore-hole.

In an untried field it is always impossible to gauge the water difficulty, and I selected the spot for the trial shaft where I anticipated the least amount of inconvenience on this score. The choice has been up to the present justified by the results, for though the shaft is 40 feet deep one workman occasionally bailing suffices to keep it dry. Should the pleasant expectation that this fact gives rise to be strengthened by further experience, I would certainly recommend another pit near No. 9 bore-hole being put down. In the future development of the field, it would act as a ventilation channel; and in the initiatory stage it would yield another point where the quality of the coal might be judged.

Water.

According to the journals of last year, two seams measuring respectively 10 feet and 6 feet were passed through in No. 9 boring, and I remember that the coal brought up in the sludger was very clean and bright. The section of the hole is as follows:—

No. 9 bore-hole.

No. 9 bore-hole—

1.	Black surface soil	1′ 0″
2.	Brown sandy soil	7′ 0″
3.	Brown sandstone	9′ 0″
4.	Red sandstone	30′ 0″
5.	Carbonaceous shaly sandstone	3′ 0″
6.	Carbonaceous sandstone	13′ 0″
7.	*Coal*	*2′ 0″*
8.	Carbonaceous shale	1′ 0″
9.	Carbonaceous shaly sandstone	3′ 0″
10.	*Coal*	*10′ 0″*
11.	Carbonaceous shaly sandstone	3′ 0″
12.	Carbonaceous shale	1′ 0″
13.	*Coal*	*2′ 0″*
14.	Carabonaceous shale	1′ 0″
15.	*Coal*	*6′ 0″*
	TOTAL	92′ 0″

As the trial shaft has not yet reached coal, I have not much to comment upon; but I would explain that a more favourable record of labour could have been shown had local skilled artizans been available, and had not vexatious delays occurred in procuring and transporting the mining plant, and in gathering together the necessary building materials. It has also been a misfortune that Mr. Forster was continuously indisposed, and that his illness at one time was so aggravated that he had to go to Jabalpur for European medical advice. Notwithstanding all these drawbacks, very fair progress has been made; and compared with the experience during the early days in the Wardha Valley coal-field, there is considerable room for congratulation.

The main operations are those in connection with the shaft and the workings that will be extended from it; but in order to gain some immediate information respecting the seam, and at the same time win a little coal for night fires, smiths fires, limestone burning and brick burning, a narrow 6-feet incline was driven down to the deep from the quarry made last year. It has been advanced a distance of 20 yards. Throughout that length the seam retains nearly the thickness that it has at the outcrop, and for comparison I give the sections that are seen at the extreme ends of the incline.

Incline 6' wide.

		Outcrop (1882).	Heading (1883).
(*a*)	Coal hard	6"	10"
(*b*)	Stony band	1"	1½"
(*c*)	Coal bright	6"	7"
(*d*)	" hard	7"	6"
(*e*)	" bright	6"	6"
(*f*)	" hard	4"	1½"
(*g*)	Stone band	2"	½"
(*h*)	Coal hard	2' 0"	2' 0"
		4' 8"	4' 8½"

Mr. Forster says that the coal works easily, and that there is a thin band of soft shale under the bottom of the seam which will facilitate pricking, and so reduce very materially the amount of waste. The roof is an excellent one, and not a single stick of timber has been required to support it. This is a most favourable feature in the estimation of the seam, for when a roof is bad the expenditure under the heading of timber forms a considerable item. With respect to the quality, the bottom 2 feet and the bright coals are excellent; but the hard band lettered (*d*), and which varies in thickness, would have to be picked out, as it clinkers very easily. The addition to the cost of getting the coal that this picking would entail might be set down at quarter of an anna a ton.

Mr. Forster's opinion of the seam.

The operations are not sufficiently advanced yet to yield facts on which to base conclusive inferences; but I may venture to say that the aspect of affairs up to the present is *not* discouraging.

The amount so far expended on the works and establishment is Rs. 8,000, and a further sum of Rs. 10,000 has been allowed for the completion of the enquiry, including the raising of 500 tons of coal.

Expenditure.

At a small additional cost the Johilla valley seams can be tested, as the necessary machinery and other plant will be at hand, and trained men will be available. I would strongly urge that these seams be not overlooked, and a less elaborate method of procedure to that adopted in the Umaria field may be followed.

Johilla seams.

A period of six or seven months ought to be quite time enough in which to carry out the plans now in hand, and by the end of the next working season, I trust we shall be able to give practical answers to all practical questions.

UMARIA,
23*rd May* 1882.

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Donors.

Coal from Kywaising, Henzada, Burma.

THE CHIEF COMMISSIONER, BURMA.

Auriferous quartz from various localities in the Nilgiri district, Madras.

R. BROUGH SMYTH.

Tinstone from Mt. Bischof, Tasmania.

W. G. OLPHERTS.

Heulandite from Dumbartonshire, and two concretions from the Permian limestone of Sunderland.

DR. G. WATT.

Red hematite, micaceous iron, and limonite from the Jabalpur district, with a bloom of iron smelted from each ore; also pyrolusite from Gosulpur.

W. G. OLPHERTS.

A slab of Bhanrer sandstone with dendritic markings, from near Satna, E. I. R.

G. PEDDIE.

Opal in a ferruginous matrix, from Queensland.

G. NEVILL.

ADDITIONS TO THE LIBRARY.

FROM 1ST JANUARY TO 31ST MARCH 1883.

Titles of Books. *Donors.*

ABICH HERRMANN.—Geologische Forschungen in den Kaukasischen Ländern. Theil II, with Atlas (1882), 4to. & fol., Wien.

BRONN'S.—Klassen und Ordnungen des Thier-Reichs.
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THE UNITED STATES GEOLOGICAL SURVEY.

April 16th, 1883.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1883. [August.

On the microscopic structure of some Dalhousie rocks—By Colonel C. A. McMahon, F.G.S. (With two plates.)[1]

The gneissose granite.

In order to avoid repetition it will be convenient to describe the following sample specimens of the Dalhousie granitic rocks together. An account of their macroscopical and lithological aspect has already been given in my paper on the geology of Dalhousie (*supra* Vol. XV, p. 34).

Specimens described.

No. 1. Porphyritic gneissose granite. Bakrota Upper Mall, Dalhousie.
„ 2. Ditto from the same locality.
„ 3. Fine-grained granite from the summit of Dainkund.
„ 4. Granite from the same locality.
„ 5. Another specimen from the same locality.
„ 6. Gneissose granite on the road from the church to the brewery, south-west side of the Dalhousie ridge.
„ 7. Porphyritic variety on the same road.
„ 8. Another porphyritic specimen from the same locality.
„ 9. Gneissose granite on the road from the church to the water-works, south-east side of the Dalhousie ridge.
„ 10. Another specimen from the same locality.
„ 11. Fine-grained granite near Chil on the Dalhousie and Chamba lower road.
„ 12. White granite on the same road about two-thirds of the way to Chil.
„ 13. Prophyritic variety with very fine-grained matrix, having a superficial resemblance to a felspar porphyry. Between Dalhousie and Chil, on lower road to Chamba.
„ 14. A light-coloured gneissose granite from the same locality.
„ 15. Gneissose granite in actual contact with the slates on the road to Bakloh (above the slate quarries), Dalhousie.

[1] It is due to Colonel McMahon to state that this paper has been in my hands since the 15th March, and was in type for the May number of the Records, but had to be deferred on account of delay in obtaining the heliogravure copper-plates. This was particularly unfortunate when there is so much discussion going on regarding gneissose granite.—H. B. Medlicott.

All the above specimens are rich in quartz, and, as is usually the case in granites, this mineral polarises with great brilliancy. The polysynthetic structure is extremely prominent, and is very characteristic of the quartz of these rocks.

Dr. Sorby[1] states that "the quartz of *thin foliated* gneiss and mica schist differs from that of granite in having a far less simple optic structure;" * * * "instead of the larger portions of quartz being made up of a few comparatively large crystals, they are frequently composed of very many closely dove-tailed together, as if formed *in situ*." On the following page he goes on to state: "I have been unable to detect anything that would serve to distinguish the quartz of *thick foliated* schists from that of true granite."

An attempt has been made at fig. 1, plate I, to depict the appearance of the quartz, as seen in slice No. I, in polarised light. The quartz is seen to be composed of a number of large crystals and of congeries of microscopic grains suggestive of the roe of a fish. The small grains polarise as brilliantly as the large ones, and they add greatly to the beauty of the slices under the polariscope.

The fish-roe grains for the most part divide large grains of quartz from each other, forming a brilliant setting to them; sometimes this setting is thick, as in my illustration, but at others it is limited to a single line of crystals. Cracks in felspars filled up with these micro-crystals are common, and occasionally irregular branches meander into the interior of large crystals of quartz.

Some specimens of granite collected by me on the Grimsel pass, Switzerland, contain exactly similar fish-roe grains intermixed with larger grains of quartz.

On the whole I do not see sufficient grounds for regarding this polysynthetic structure as affording evidence of the original clastic origin of the Dalhousie rocks. This structure, as seen in these rocks, seems to me rather to suggest that the large grains were the result of slow cooling; whilst the fish-roe micro-grains appear to indicate either a comparatively rapid ending of the process, or conditions of strain towards its termination.

The quartz in all the specimens contain liquid cavities with movable bubbles. They exist in prodigious numbers in some specimens, whilst in others they are sparse; in most, however, they are abundant. Air, or gas, cavities are also present.

There are apparently some stone cavities. These appear to have either deposited a second mineral on cooling, or to have caught up opacite or other similar substance in the act of crystallization. Some of them appear to contain fixed bubbles. These enclosures, however, are so exceedingly minute that they cannot be satisfactorily determined with the highest powers applicable. Some microliths contain internal cavities, running with the length of the microliths for a portion of their length, which undoubtedly indicate shrinkage on cooling.

All the specimens, without exception, contain more or less triclinic felspar. In some it is rather abundant; in others sparse. It appears from its optical characters to be oligoclase.

Eight out of the 15 slices contain typical microcline, and in some of them it is abundant.

[1] Anniversary Address, Q. J. G. S., XXXVI, 48.

Zirkel at pp. 45, 47, of his Microscopical Petrology of the 40th Parallel, describes the occurrence of a fibrous orthoclase in granite. A similar felspar is very abundant in these rocks. It occurs in all but three of the specimens, the slices in which it is not present, namely, Nos. 3, 12, and 14, being those in which typical microcline is also absent. In every slice in which typical microcline occurs, the fibrous felspar is present. It also occurs in three slices in which the typical mineral is absent. The fibrous appearance is only observable in polarised light, and the felspar in which it occurs seems to me to be a form of microcline. In some an incipient cross hatching can be made out; whilst in one, at least, it is distinctly visible in parts of the fibrous structure.

Orthoclase is present in all the slices, though, if the fibrous felspar be included under the head of microcline, the latter mineral is more abundant than orthoclase. The triclinic felspar (oligoclase) is very subordinate to the orthoclase and microcline taken together.

Much of the felspar is very opaque and has a white glistening appearance in reflected light owing to the presence in it of a multitude of extremely minute gas or air cavities. Liquid cavities with movable bubbles also occur here and there in the felspar.

Some of the felspars are studded with numerous microliths of silvery mica, which occasionally, in polarised light, impart to the portion of the slice in the field of the microscope the appearance of graphic granite. Zirkel, in his work on the rocks of the 40th Parallel (p. 46), notes the occurrence of a similar structure in the granites of Nevada.

Many of the orthoclases and microclines contain the usual intergrowths of plagioclase and occasionally grains of quartz. Some of the microcline exhibits a tendency to inter-laminated structure resembling that of perthite, only it is finer grained and less pronounced. The intergrowth of felspar alluded to is quite distinct from the ordinary twinned structure.

All the specimens contain muscovite, and in all but three biotite is present. The muscovite polarises in delicate but brilliant colours, and some of it is twinned. Some of this mica contains inclusions in the line of basal cleavage of a substance that is absolutely opaque, and black, in transmitted light, and shines with a bright silvery lustre in reflected light.

Muscovite is present in all these slices, not only in good-sized plates and packets, but in a form for which I propose the name of crypto-crystalline mica. In this form no definite crystals can be made out, the leaflets, under polarised light, fade and melt into each other and exhibit no definite shape; whilst no signs of cleavage or lamination are visible.

In transmitted light the crypto-crystalline mica varies from a pale buff to a pale grey colour, and has a superficial resemblance to the base of some felsites and rhyolites. In a specimen in my collection, labelled "Banded felsite, Glencoe" (I did not myself collect the hand specimen from which the slice was made), I find a precisely similar structure present, along with quartz, and the ordinary felsitic base of felstones.

The felsitic matrix of felstones is believed to be an intimate mixture of quartz and orthoclase; and I suspect, from the appearance of some of my specimens, that the crypto-crystalline structure of the mica now described may be due to an admixture of quartz with the mica.

The crypto-crystalline mica passes imperceptibly into a condition that would require, strictly speaking, the use of the term micro-crystalline, but in the following pages I purpose calling it all crypto-crystalline mica.

This crypto-crystalline mica is present in all the slices. It traverses them in ropy masses; sometimes it is extremely attenuated and drawn out into thin strings; at other times it widens out into comparatively broad expanses. It frequently encloses, or leads up to, crystals of muscovite, and of quartz, and more rarely embraces other minerals. It meanders through some large crystals of felspar; whilst isolated patches of it are caught up in other felspar crystals. In both these last cases it represents, I apprehend, the residuum left after the separation of the constituents of the felspar.

All the slices contain magnetite grains and garnets, but in some of them both the garnets and the magnetite grains are very minute.

Six of the slices, namely, Nos. 3, 4, 7, 11, 12, and 13, contain schorl. It is in a rather fragmentary condition, and is much cracked, the cracks being filled with quartz. In some cases the fragments appear to have floated some little distance from each other.

No. 15, a specimen of the gneissose granite in actual contact with the slates above the slate quarries, is a very interesting and instructive slice, for it exhibits in a typical way what appear to me to be decided indications of fluxion structure consequent on traction. Both the biotite and the crypto-crystalline mica are drawn out into long strings in the direction of the flow. This structure is not confined to the larger bands, which can be discerned with the aid of a pocket lens, but even the microliths of muscovite in the quartz are seen, under the microscope, to point in the same direction, and to be drawn out into long trains or strings.

Even more characteristic are the gas cavities. Some of these are themselves elongated and drawn out in the direction of the flow, and they are arranged in lines pointing in the same direction. Some of the gas cavities have deposited granular matter on cooling.

There are also stone cavities, the longer axes of which point in the direction of the flow.

This slice seems to me to exhibit, as far as a granite can do so, as decided fluxion structure as that to be seen in rhyolites and obsidians.

An attempt, to give an idea of the appearance of this slice under the microscope, has been made at fig. 2, plate II, where the bands of crypto-crystalline mica and biotite are represented drawn out into strings.

The quartz, though hyaline in transmitted light, is seen between crossed nicols to consist almost entirely of the fish-roe grains, previously described, drawn out into lines in the direction of the flow. Possibly this structure may depend on strain.

A pseudo fluxion structure is doubtless to be seen in many gneissic rocks, but that above described can alone be attributed, I think, to the action of traction in a rock in motion reduced to a plastic condition by heat.

Another piece of evidence in favour of the conclusion that the fluxion structure observable in the slice under consideration is due to traction, is to be found in the crumpled appearance of some of biotites. I have sketched one in this slice at fig. 4, plate II; a single crystal, one-half of which has been folded over and bent back flat upon the other half. This biotite must, I apprehend, have been crumpled up and folded over on itself after crystallization, but whilst the folia were still in a somewhat pliable condition. I cannot conceive of a contortion of the basal cleavage lines, to the extent represented in the sketch, being produced in any other way. A moderate curvature of the basal cleavage lines is not an uncommon feature in the mica of some rocks, and I can readily understand how this may have been produced, even in the case of mica formed in clastic rocks by an epigenital process; for such mica, formed *in situ* in the spaces between the fragments of clastic origin, might often be cramped at the time of formation, and its symmetry interfered with, from want of space for its perfect development; but I do not think a mica could, from this cause, be completely doubled up in the manner represented in the illustration.

The basal cleavage lines of the mica enclosed in the long ropy strings of crypto-crystalline mica are usually at a slight angle to the direction of the flow, as represented at fig. 5, plate II, the direction of the flow being east and west. The outer edge of these biotites is usually covered with dark fluffy matter.

The foliation of the slaty portion of No. 15 is parallel to the line of fluxion in the granite.

Rocks next the gneissose granite.

Considering how important a thorough knowledge of the Dalhousie rocks is in determining questions of local geology, I propose to give a brief separate description of each of the remaining slices.

No. 16.—Junction of an intrusive vein, 3 or 4 yards wide, and the slate into which it is intruded, close to the main mass of the gneissose granite on the road to Mamul, Dalhousie. The actual junction of the two rocks is seen both in the hand specimen and in the slice.

M.—This slice shows the junction of the two rocks perfectly. The granitic rock possesses the characteristics of some of those already described, being distinctly gneissoid, whilst foliation has been set up in the slate. The structure of the slate corresponds closely to No. 19, described further on.

The slate contains numerous crystals of schorl which do not extend into the granitic rock; whilst the latter contains many small garnets, a mineral not visible in the slate.

There are several points of difference to be noticed between the silvery mica of the granitic rock and that of the slate. The silvery mica of the granite is pure looking; is in large leaflets; its basal cleavage is very perfect; and the cleavage lines are close together; whilst twinning is not uncommon. The silvery mica in the slate, on the other hand, contains numerous inclusions indicating an imperfect separation between the several constituents of the slate; it is in small leaflets; its basal cleavage is imperfect; and the cleavage lines are sparse; whilst there are no indications of twinning.

The granitic rock gives several indications of fluxion structure. The crypto-crystalline mica forms long curving streams in the ground mass, meandering about as an Indian river in its sandy bed during the dry months. In some places these streams approach each other and join; at others they make wide sweeps and diverge considerably. The curves are sometimes gentle, but at others they are rather sharp and have a wide radius. Sometimes the streams are broad; at others they are split up into innumerable narrow meandering rivulets. The dark mica also forms ropy-looking masses drawn out in the line of flow.

An attempt to represent the general appearance of a portion of this slice has been made at fig. 1, plate II; whilst at fig. 2, plate I (*a*), an illustration is given of the crumpling of the silvery mica as seen in this slice.

In some cases the twinning planes of the plagioclase are bent out of the perpendicular. I have occasionally seen instances of this in lavas, though it is of rather rare occurrence; and it seems to indicate conditions of strain subsequent to the crystallization of the felspar before the mineral had become perfectly rigid on cooling.

Zirkel, at p. 28 of his work already quoted, mentions the presence of fluid cavities in the quartz enclosed in garnets; but the garnets themselves, in this slice, contain numerous fluid cavities with movable bubbles. The quartz of the granite itself contains fluid cavities about the same size as those in the garnets.

No. 17.—Argillaceous schist in actual contact with a thick vein of granitic rock within 3 or 4 yards of the main mass of the gneissose granite. Same locality as the last. It is an indurated rock with minute flecks of mica visible here and there.

M.—In transmitted light the ground mass appears to be homogeneous and colourless, but thin and minute flakes of a green mica are thickly disseminated through it. Patches of opaque ferriferous material are dappled about over the field; whilst the slice is here and there stained with ferruginous material, and dots of yellow and red ferrite are occasionally to be seen. Flakes of colourless mica are sparsely scattered about, and there are numerous small fragments of a bluish-brown tourmaline. Between crossed nicols the slice presents a dark base relieved by numerous patches of semi-luminous material presenting highly irregular outlines, and bright flecks of mica.

The slice contains some air bubbles, but no liquid cavities. Some of the schorl shows that this mineral has been subjected to heat, and that the air or liquid enclosures which they contained expanded and forced a way to the surface of the mineral before its complete consolidation. An illustration of this, taken from this slice, is given at fig. 7, plate II.

No. 18.—Argillaceous schist in actual contact with the main body of the gneissose granite. From the same locality.

M.—This slice closely resembles the last. There is comparatively little schorl, and it is in very minute prisms. The slice contains numerous dots of magnetite.

No. 19.—An argillaceous schist in contact with a granitic vein, 3 or 4 yards wide, close to the main body of the gneissose granite. From the same locality. This is a more distinctly foliated rock than the preceding two specimens.

M.—The ground-mass consists of quartz in minute grains. Inter-laminated with this are strings of a fibrous dark-green mica and strings of the crypto-crystalline mica which I have shown to be a characteristic of the gneissose granite. Muscovite is also very abundant in the slice, whilst crystals of schorl, many of them being very minute, are present in great numbers. It is of the type and colour of that found in the gneissose granite, and for the most part it lies in a zone corresponding to the plane of foliation, the crystals lying more or less at right angles to that plane. The schorl contains numerous enclosures and some empty cavities, the contents of which have apparently forced their way through the mineral to the surface in the manner already described. The slice contains grains of magnetite, opacite, and ferrite, and some minute crystals of garnet; also one crystal of triclinic felspar. There are no liquid cavities.

No. 20.—Slate from the quarry near the gneissose granite on the Mamul Road, Dalhousie.

M.—Under the microscope this is seen to be distinctly foliated; quartz, in minute granules, alternating with a fibrous green mica that is but feebly dichroic. Some very minute and imperfectly formed prisms of tourmaline are scattered through the slice.

Light flocculent clouds of nebulous matter, opaque in transmitted, and yellowish-white in reflected light, are also abundant. A sketch of a portion of this slice is given at fig. 3, plate I.

No. 21.—A spotted schist within a few yards of the gneissose granite, Potrain Hill, Dalhousie. Viewed macroscopically this has a distinctly foliated aspect, and specks of muscovite are visible here and there.

M.—The ground mass consists of quartz in small granules of very varied and irregular shapes, interspersed with crypto-crystalline mica that meanders about in all directions.

In this ground-mass are embedded numerous crystals of muscovite, and of a dark well-laminated mica, brown in transmitted light. Some of the latter contain grains of quartz and of magnetite. Magnetite and rounded grains of opacite are rather abundant in this slice, which also contains numerous prisms and fragmentary pieces of schorl, of the same type as that in the gneissose granite. There are also numerous micro-crystals of garnet. There are no liquid cavities.

At fig. 3, plate II, I have given a representation of a portion of this slice, showing the way in which the crypto-crystalline mica and the hyaline quartz are intermixed. The dark portions, in the illustration are intended to represent the former, and the uncoloured portions the quartz.

No. 22.—A similar rock a little further away from the gneissose granite, on the same road. It is of more spotted appearance and granular texture than the last, having lost, in the hand specimen, all traces of foliation.

M.—This slice closely resembles the last and requires no separate description. The crypto-crystalline mica is very abundant. Some of the grains of magnetite are of good size.

No. 23.—A fine-grained silicious schist in contact with the gneissose granite on the cart-road, between the Mall and the Bull's Head Hotel, Sananotala.

M.—This is a distinctly foliated rock, and the description given of slice No. 19 exactly applies to this one. No liquid cavities are present.

No. 24.—A crystalline granular rock a few yards below No. 23, on the same road.

M.—This exactly resembles No. 22, and is evidently the same rock. The quartz contains no liquid cavities. Small rounded fragments of the crypto-crystalline mica are included in the quartz; whilst grains of quartz are included in all the other minerals.

In many cases small colourless microliths are attached to rounded grains of opacite in a way to suggest, at first sight, that the opacite had on cooling given off a gas that had intruded into the adjoining matrix. Illustrations of these combinations are given at fig. 6, plate II (see upper and left-hand figures). A careful study of these groups, however, showed that they are simply due to the accidental conjunction of two different minerals. Such forms as that depicted on the right hand of this figure seem to show this conclusively. The occurrence of these conjunctions, however, is so common that it seems to indicate that the rock was reduced to a sufficiently viscid and plastic condition, to allow of microliths moving by molecular attraction some little distance, at any rate, towards each other. The whole appearance of the slice, and the small rounded dots of crypto-crystalline mica included in the quartz, all point in the same direction, and indicate a viscid condition. The slice, I may add, contains numerous small rounded cavities that are probably due to shrinkage on cooling.

No. 23.—Another fine-grained silicious schist a few yards further down on the same road.

M.—This presents much the same features as the last slice. The schorl is not so abundant, and for the most part is in small prisms. The dark mica is arranged more in strings, and the crypto-crystalline mica is relatively more abundant than the quartz. In this slice it is micro-crystalline rather than crypto-crystalline.

Nos. 26 & 27.—Other speckled varieties of the crystalline granular rock a few yards further down on the same road. They contain ma grains of iron-pyrites. Sp. G. 2, 74.

M.—The description given of Nos. 22 and 24 applies equally to these specimens. Schorl is abundant.

The peculiarity of these slices is that they contain a considerable amount of zircon, in irregularly shaped granules, intimately intermixed with grains of quartz. Much of the zircon is distinctly dichroic, changing from a white, or faint bluish-white, to a delicate tint of light red. It does not exhibit colours in polarised light owing to its strong double refraction.

This is the first time that I have met with zircon *in situ* in Himalayan rocks, but a sample of the gold-bearing sands of the Sutlej river, sent me by a friend, is full of well-formed crystals of this mineral.

The quartz contains what appear to be stone cavities with fixed bubbles, whilst others have either caught up and enclosed opacite when in a plastic condition or have deposited it on cooling.

Rocks between the gneissose granite and the first outcrop of gneiss.

The cart-road, from near its junction with the Mall, between Thera and Potrain, to near the Bull's Head Hotel, Sanánotála, runs a little below the junction of the gneissose granite and the schistose rocks. Near the Bull's Head Hotel, on the neck of the Sanánotála spur, the gneissose granite re-appears, having been brought down, apparently, by the flexion of the strata. The schistose rocks between the gneissose granite on the Mall and the outcrop on the cart-road, near the Bull's Head Hotel, have been described in the preceding pages. The rocks, now to be described, are a descending series which crop out on the cart-road between the gneissose granite, near the Bull's Head Hotel, and the mica schists at Banikhet.

No. 28.—A silicious schistose rock in contact with a vein of granitic rock cutting through the schists. Viewed macroscopically two sets of lines may be made out with a pocket lens on the cut and wetted face of the hand specimen, and in the thin slice; the lines cutting each other at an angle of about 40°.

M.—Viewed under the microscope one set of lines is seen to be due to partial foliation; that is to say, to be due to the development of a tendency on the part of the dark mica to segregate in more or less parallel lines. It is noticeable, however, that the laminæ of the mica are arranged parallel to the *second set of lines*, and not to the lines of dark mica. The mica has segregated into lines, but each flake of mica in the line is arranged with its longest axis at an angle of about 40° to its own line.

The second set of lines alluded to are due to the occurrence of lenticular masses of crypto-crystalline mica, the lines of which, though discontinuous, preserve a pretty constant course in one direction. Another point noticed is that these lines of crypto-crystalline mica contain rather numerous microliths of tourmaline, the prisms of which point, as the microliths in rhyolite and similar rocks, in the direction of the flow.

These facts appear to me to indicate that the rock was subjected to two different processes of contact metamorphism; one process—due to heat—resulting in foliation; whilst the second process was probably the injection of matter from the granitic rock, possibly in a gaseous or liquid condition, along lines that followed the original direction of lamination or of cleavage.

This observation, which was very unexpected, seems to have an important bearing on the point at issue. If the crypto-crystalline mica in the schistose rocks adjoining the gneissose granite is not a product of the original constituents of those rocks but has been derived from the granite, the existence of the crypto-crystalline mica in the gneissose granite affords no evidence of the metamorphic origin of the latter or of its affinity with the schists.

The general appearance of this slice is closely similar to those of the slates in contact with the gneissose granite already described. The ground-mass consists of granular quartz. A dark green fibrous mica is very abundant, but muscovite is comparatively sparse. Schorl, as usual, is present. There are no liquid cavities. Ferrite is abundant.

No. 29.—A silicious schist adjoining the gneissose granite.

M.—This is only a variety of the spotted schists already described, as for instance Nos. 21 and 22. The crypto-crystalline mica is rather abundant and swells out into large lake-like expansions. I have observed a few stone cavities in this slice, one with a fixed bubble, and two with deposits in them.

Nos. 30, 31, and 32.—Very fine-grained schists, in descending order.

M.—These may be described together. Under the microscope they approximately resemble the slaty rock, No. 17. The ground mass consists of micro-granular quartz, in which a yellowish-green scaly mica is so abundantly disseminated as to nearly pervade the whole mass. In No. 31 it has segregated into spotty masses in which it varies in colour, in transmitted light, from a green to a rich greenish-orange colour. Some of the mica is fibrous, and is, I think, paragonite. The slices contain grains of magnetite and ferrite, and slice No. 31 contains, apparently, a little hæmatite. All contain the opaque whitish mineral described under No. 20 and micro-prisms of tourmaline. The magnetite is most abundant.

Nos. 33 and 34.—Earthy looking schistose rocks. No. 34 has a strong earthy smell, even without breathing on it.

M.—These exactly resemble 30—32 and need no separate description. No. 33 contains two minute garnets. In 34 magnetite in micro-grains is abundant. In both micro-prisms of tourmaline are plentiful.

Section below No. 4 Barrack, Ballun.

No. 35.—A fine-grained schistose rock approaching the slaty type. With a pocket lens it is seen to have a fine micaceous glaze on the splitting surface.

M.—Under the microscope the rock is seen to be made up of a mesh-work of fine fibres, or microliths, of mica, in a quartz base. Larger crystals of mica are dotted about in it here and there, and stringy agglomerations of the fibrous mica. The mica is decidedly dichroic, and each of the microliths polarises rather brilliantly. I think the species is probably paragonite.

The slice contains grains of ferrite, and I think very minute grains of magnetite; also the flocculent opaque matter previously described. In this slice its colour varies from yellowish to reddish. It is, I think, a product of the alteration of magnetite.

No. 36.—A very fine-grained, pale bluish-grey, micaceous schist. The micaceous element is much more prominent in this hand specimen than in the last.

M.—This rock is so similar to the last that a further description is unnecessary.

No. 37.—A very fine-grained silicious rock approaching the slate type.

M.—This rock is of the same type as the last two, and consists of a fibrous mica, probably paragonite, disseminated through a quartz base. It contains a long irregular-shaped, lake-like space filled with hyaline quartz that has evidently been formed *in situ*, the prisms of mica projecting into it along its outer edges. It contains some gas enclosures and a few, very few, liquid enclosures with bubbles.

No. 38.—A buff coloured, very fine-grained, friable schistose rock.

M.—The structure and material are seen to be the same as the last. The mica is of yellowish-green in transmitted light, and it evinces a tendency to segregation, forming spots of darker colour than the ground-mass. There are some good-sized bits of ferrite.

No. 39.—A pale greenish-grey argillaceous schist.

M.—In both 37 and 39 the lines of original lamination can be distinctly traced on the cut surface with a pocket lens. In this rock (No. 39) they have suffered some contortion. The lines of incipient foliation are at a high angle to the lines of lamination in all three specimens. The microscope shows that No. 39 is composed of the same constituents as the last few described. The slice contains some micro-prisms of tourmaline.

No. 40.—A very fine-grained micaceous schistose rock.

M.—This consists of a quartz base in which a yellowish-green scaly mica is profusely disseminated. It is doubtless of the same species as the preceding. The slice is dotted over with countless cubes and octahedrons of magnetite.

No. 41.—Blue micaceous slate above Surkhi-galli.

M.—This consists of an intimate admixture of quartz in micro-grains and a green mica in minute scales. An immense profusion of magnetite grains are dotted over the field, mostly in elongated irregular forms, the longer axes of which are turned in the same direction. There are numerous micro-prisms of tourmaline and very minute crystals of sphene, which require high powers to detect. In many cases the sphene and magnetite have adhered together.

No. 42.—A pale blue slate similar to the last.

M.—This is apparently a very similar rock to No. 41; but the micaceous element is more fibrous and colourless.

No. 43.—A pale french-grey coloured argillaceous schist from the same locality.

M.—An exactly similar rock to No. 41 except that the magnetite is absent and a little ferrite has taken its place. The micro-prisms of tourmaline and sphene are abundant. I observed a liquid cavity in the mica.

No. 44.—A fine-grained friable whitish mica schist.

M.—This consists principally of minute scales of a yellowish-green mica and some minutely granular quartz. There are numerous air bubbles. I have not detected any tourmaline. Minute crystals of sphene are abundant. Magnetite and ferrite are also present.

No. 45.—A white wafery schist with a silky gloss on the cleavage surfaces.

M.—A very similar rock to the last, only the scaly mica is very colourless. The grains of magnetite and ferrite are very sparse. Micro-crystals of tourmaline and sphene as in the last. There are a few minute garnets.

No. 46. A light-grey, fine-grained silicious schist.

M.—The appearance of this rock under the microscope is very different from those described from No. 30 downwards. Its affinities are with the spotted schists Nos. 19 and 23, the latter of which it much resembles. It may be described as a micro-gneiss, and it consists of lenticular grains (eyes) of quartz and triclinic felspar set in crypto-crystalline mica which flows in ropy masses round them. The quartz very largely predominates over the felspar; indeed, the latter is sparse. Large flakes of muscovite are present, but no biotite. There are some good-sized pieces of schorl of the type present in the granitic rocks-also a few rounded grains of what appears to be sphene. I have not been able to detect any liquid cavities even with the use of very high powers.

No. 47.—Paragonite slate (?)—An extremely fine-grained, french-grey coloured mica schist of slaty appearance.

M.—This has, unfortunately, been sliced so thickly that little can be made out, but it does not appear to differ in any essential particular from No. 41. Pounded fragments examined under the microscope confirm this impression and show that the rock is principally composed of an almost colourless mica in scales and fibres, and countless elongated granules of magnetite. The mica appears to be paragonite. There are as usual microscopic prisms of tourmaline.

No. 48.—The pearly mica schist of Banikhet.

M.—This is closely similar to No. 44. It is principally composed of a scaly mica, varying in colour from white to pale green, with ferruginous yellow stains in spots here and there. There is an admixture of quartz in a finely granular condition. The beautiful pearly opalescence of the thin slice, seen in reflected light without the aid of a lens, appears to be due to the presence of myriads of air or gas bubbles with which this rock is crowded. There are countless elongated grains of magnetite; the usual micro-prisms of tourmaline are also present; also micro-crystals of sphene.

Conclusion.

The general conclusions at which I have arrived from the detailed study of the Dalhousie rocks are as follows:—Fifteen specimens of the gneissose granite from various parts of the Dalhousie ridge, exhibiting some typical varieties of structure when examined macroscopically, are seen, when examined with the aid of the microscope, to be mere varieties of the same rock. No essential difference of any kind can be detected between them. All of them contain orthoclase microcline, plagioclase, quartz, muscovite, magnetite, garnets, and liquid cavities containing movable bubbles. Six of the specimens contain schorl in some abundance, and all but three of the thin slices contain biotite. In all the quartz exhibits a polysynthetic structure very prominently, whilst all contain crypto-crystalline mica.

Some of the slices give unmistakable indications of having been reduced by hydro-thermal agencies to a plastic condition, and exhibit true fluxion structure. It is also important to note that the specimens which exhibit these characteristics most prominently are those which show, when viewed macroscopically, a pseudo-foliation, and have consequently a gneissose aspect.

The rocks are not true granites, but it does not follow from this fact that they are necessarily of metamorphic origin. Between the deep-seated roots of volcanos and the lavas that have actually flowed out at the surface of the earth's crust, there must of course be many gradations. The presence of the crypto-crystalline mica in the Dalhousie gneissose granite, that is to say, the presence of an imperfectly crystallised residuum, seems to indicate their affinity with the felspar porphyries. Indeed specimen No. 13 approximates in its macroscopical appearance very closely to a felspar porphyry.

Allport, in his paper "On the Metamorphic Rocks surrounding the Lands'-end

Mass of Granite," Q. J. G. S., XXXII, 407, shows that the mineralogical changes produced in clay slates by the intrusion of a mass of granite are chiefly the development in them of some of the minerals which constitute its own mass; that is to say, quartz, tourmaline, and three kinds of mica; occasionally tremolite, magnetite ("and andalusile ?"), and in some localities felspar. The structural changes produced in clay slates by contact metamorphism, according to Allport, are " (*a*), foliation more or less perfect, with every gradation from nearly straight parallel lines to the most complicated contortions; and (*b*), concretionary, showing a decided tendency to segregation of both quartz and mica, the result being a spotted schist."

A precisely similar influence appears to have been exercised by the gneissose granite on the slates in contact with it at Dalhousie. As to structure, we have seen that foliation has been produced and "spotted schists" have been formed; whilst schorl, garnet, dark mica, muscovite, and magnetite have been introduced or created out of the constituents of the slate.

As regards mineralogical changes, Allport noticed in the rocks described by him in the paper just quoted, that the strata near the granite were "far more highly silicated than those at a distance from it," and he expressed the opinion that "there can be no doubt that much of the quartz has been derived directly from the intruded rock."

In the case of the rocks under consideration, a study of slice No. 28 led me to the conclusion that the crypto-crystalline mica seen in the schists in contact with the granitoid rock, is due to the injection of matter from the granitic rock into the schists in a gaseous or liquid condition.

Two other points are to be noted: *first*, that though the gneissose granite is rich in felspar, only one small crystal of this mineral was found in the numerous slices of rocks in contact with the gneissose granite examined under the microscope; *secondly*, that though liquid cavities are most abundant in the quartz of the gneissose granite, they are entirely absent from the schists immediately in contact with it, and are almost entirely absent from the schistose rocks below them.

Professor A. Geikie, in a critique on a paper by Père Renard, of the Royal Museum, Brussels, on the crystalline schists of the French and Belgian Ardennes (Nature, December 7, 1882) which came to hand after I had finished my examination of the slices now described, comments on the absence of fluid cavities in the quartz of the Ardennes schists as follows:—"In subjecting to microscopic examination thin slices of some of these altered rocks, M. Renard noticed that the quartz granules, presumably of clastic origin, have lost the liquid inclusions so generally found in the quartz granules of old sedimentary strata. This fact (already observed by Sorby in the case of sandstone invaded by dolerite) seems to indicate that the sand-grains have not escaped the influence of the changes which have so profoundly affected the other constituents of the former sediment."

Dr. Sorby notices this effect of contact metamorphism in his Anniversary Address (Q. J. G. S., XXXVI, 1882):— "One point of interest is," he writes, "that although the grains of sand contain many cavities which no doubt, as usual, originally contained water, they have all lost it, as though it had been expelled by the heat of the igneous rock, in the same manner as it is easily expelled from unaltered quartz by a high artificial temperature."

That the absence of liquid cavities, in the schistose rocks in contact with the gneissose granite, is due to heat, is rendered highly probable by the fact noted in the foregoing papers (see notes on slices 17 and 19) that pieces of schorl retain internal evidence that the contents of enclosures in this mineral had expanded by heat and forced their way to the surface.

We have already seen that whilst the granitic rocks abound in felspar, the altered slates in contact with them have not developed that mineral. I have also given my reasons for believing that the gneissose granite was reduced by *hydro-thermal* action (evidenced by the great abundance of its liquid cavities) to a plastic condition; and that portions which present a decided gneissose aspect exhibit true fluxion structure.

We have also seen that the schists in contact with the gneissose granite exhibit the peculiarities usually developed in rocks by contact metamorphism; that is to say, minerals present in the granitic rock, schorl, biotite, muscovite, garnet, magnetite, and crypto-crystalline mica have been developed in them near their point of contact; whilst the water, which was presumably present in the quartz of the clastic rock, has been driven off by heat. These facts, it seems to me, render it improbable that the features presented by the Dalhousie rocks are the result of selective metamorphism applied to a conformable series of sedimentary rocks.

The slaty and schistose rocks between the gneissose granite and the outer band of gneiss, though very varied in macroscopic aspect, present little variation under the microscope. They consist of an admixture of quartz and mica. The quartz contains no liquid cavities. One exception to this only was noted in the case of clear quartz plugging what may have been a pre-existing cavity, and which was probably filled with foreign material from intrusive granitic masses in its vicinity.

The quartz in all the slices described has lost all trace of its original clastic origin, and the mica has certainly been formed *in situ*. The change in the shape and appearance of the quartz grains has doubtless been due to after-growth in the manner pointed out by Dr. Sorby (Ann. Address, Q. J. G. S. XXXVI, 62).

The mica is of a different species from the micas present in the gneissose granite, and much of it appears to be paragonite. Some of the lower beds, as for instance No. 47, are, I think, entitled to the name of paragonite slates.

The general character of the schists may be said to be more silicious towards the gneissose granite and more micaceous towards the first outcrop of gneiss.

As the outer band of gneiss is neared, sphene makes its appearance in micro wedges and crystals, and is rather abundant. Garnets are rare. On the other hand, zircon is present in the spotted schists next the gneissose granite, and garnets are not uncommon.

Very minute prisms of tourmaline, of bluish colour in transmitted light, are present more or less throughout the schistose beds; but schorl, of the type found in the gneissose granite, is confined to the rocks in immediate contact with it.

Schorl also re-appears in No. 46, but the whole aspect of that rock is suggestive of the near proximity and the contact action of granitic rocks.

The metamorphism of the slate series, as a whole, does not seem to require the aid of great heat to explain it, for the action of moderately heated water is sufficient to account for the formation of the hydro-micas, the minute prisms of tourmaline, and the addition of quartz to the pre-existing grains of that mineral. The gneissose granite on the other hand has undoubtedly been fused, whilst its action on the slaty series in immediate junction with it has been analogous to the contact action of eruptive granite.

In conclusion, whilst I am not able to affirm as the result of my investigations up to date, that any of the axial gneiss of the Dhuladhár range is true gneiss, I find that it presents the characteristics of an igneous rock. It has been in a fused condition; it shows fluxion structure; it invades the rocks immediately in contact with it; its structure and composition is uniform over wide areas; and it expands suddenly along the line of strike from a width of 250 feet to a width of 6½ miles. The facts, at present known, point to the conclusion that the gneissose granite is an intrusive rock and has been squeezed up through a faulted flexure along an axis of maximum strain.

In my paper on the Geology of Dalhousie (*Supra*, Vol. XV, p. 44) I wrote—"The granitoid gneiss is highly porphyritic, and is undistinguishable from, and doubtless is identical with, the 'central gneiss.'" As a result of the subsequent microscopical study of the Dalhousie rocks, I have dropped the term "granitoid gneiss" in my present paper, and have substituted gneissose granite for it; and it is for consideration whether the term "central gneiss," introduced by the lamented Dr. Stoliczka, and since used to denote the "granitoid gneiss" of the North-West Himalayas, should not be discontinued in future.

The terms "central gneiss" and "granitoid gneiss" insensibly suggest cambrian and pre-cambrian times; and their use is apt to create a prejudice in the mind of the student both as to the origin and the age of the rock, for the tendency of petrological inquiry in the present day is to predicate a great geological age for crystalline rocks in which the granitic structure is due to regional metamorphism. But if the conclusions at which I have arrived in this paper are sound, it follows that the gneissose granite of the Dhula Dhár is of eruptive origin, and instead of being an archæan, cambrian, or "converted" silurian rock, it is in reality of tertiary age, and was brought into its present position in the course of the throes that gave birth to the Himalayas.

I do not intend to draw the inference that all the granitoid, and still less that all the gneissose rocks of the North-West Himalayas are of eruptive origin,—that would be too sweeping a generalisation to make from the facts at present ascertained,—but I think the most natural conclusion to draw from the evidence before us, taken as a whole, is that the "central gneiss" and "granitoid gneiss" of Dalhousie is really an eruptive rock; that is to say, whether it has travelled a short distance, only, from its seat of extreme metamorphism, or whether it was more or less directly connected with volcanic or plutonic action, it was in actual motion in a fused or plastic condition and occupies now the position of an intruder in the silurian series. I think the balance of evidence is against the supposition that it was reduced into a fused condition *in situ*.

DESCRIPTION OF PLATES.

PLATE I.

Fig. 1. Gneissose granite, Dalhousie. This sketch, taken from slice No. 1, is intended to show the polysynthetic structure of portions of the quartz.

" 2. A portion of slice No. 16, taken from a granite vein intruded into slate, Dalhousie; (*a*) shows the crumpling of mica due to traction. See also fig. 1, plate II.

" 3. A portion of slice No. 20. Slate from the quarry near the gneissose granite, Dalhousie.

PLATE II.

Fig. 1. A portion of slice No. 16, taken from a granite vein intruded into slate. See also fig. 2, plate I.

" 2. A portion of slice No. 15; gneissose granite in contact with slate, above the slate quarries, Dalhousie. This sketch represents the mode in which the crypto-crystalline mica and biotite are drawn out into strings.

" 3. A portion of slice No. 21; spotted schist within a few yards of the gneissose granite; Dalhousie. The sketch shows the way the crypto-crystalline mica and hyaline quartz are intermixed.

" 4. Sketch of a biotite crumpled up by traction, taken from slice No. 15, gneissose granite in actual contact with slate.

" 5. Showing a common mode of occurrence of mica in connection with the ropy strings of crypto-crystalline mica.

" 6. Showing the mode in which grains of opacite and microliths of an undetermined mineral adhere together.

" 7. A crystal of schorl taken from slice 17, showing that air or liquid enclosures originally contained in it had subsequently expanded from heat and forced their way to the surface of the mineral before its final consolidation.

Fig. 1 × 60

Fig. 2 × 60

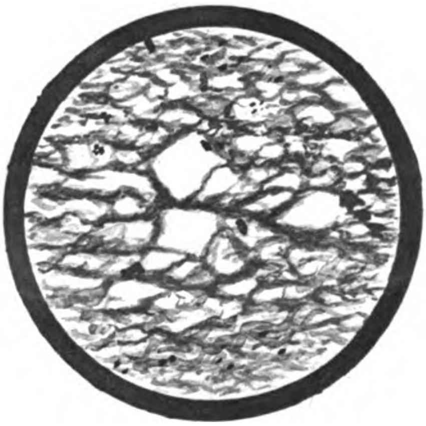


Fig. 3 × 60

Reproduced in heliogravure from the original drawings at the Surveyor General's Office, Calcutta
May, 1883

Fig: 1×30

Fig. 4

Fig. 5

Fig. 2×30

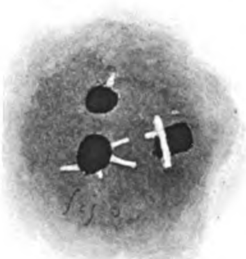


Fig. 6

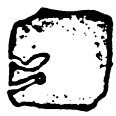


Fig. 7

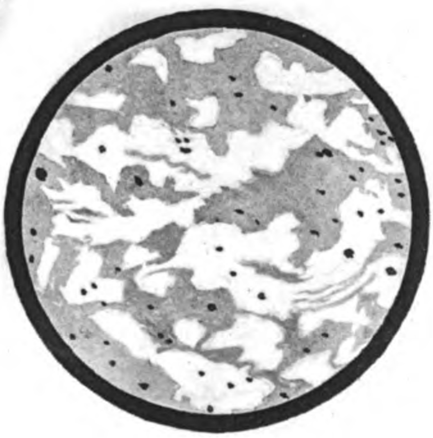


Fig. 3×100

Reproduced in helio-gravure from the original drawings at the Surveyor General's Office Calcutta.
May, [illegible]

On the **lavas** *of* **Aden**—*By* **COLONEL C. A. MCMAHON, F.G.S.**—*(With a plate.)*

A BRIEF account of the extinct volcano of Aden is given by Mr. F. R. Mallet, F.G.S., in his paper "On the Geological structure of the country near Aden, with reference to the practicability of sinking Artesian Wells." Vol. VII, Memoirs, Geological Survey of India.

The following description of the lavas found at Aden is taken from Mr. Mallet's paper: "The varieties of rock met with are very numerous; there are perfectly compact lavas of brown, grey, and dark-green tints, sometimes containing crystals of augite and not unfrequently those of sanidine, and there are rocks exhibiting every degree of vesicularity until we arrive at lavas resembling a coarse sponge and passing into scoriæ. The vesicles again are in some specimens globular, and in others flat and drawn out. In some places the lava is quite schistose, and might if seen *per se* be easily mistaken for a metamorphic rock. Such lava is sometimes vesicular, but by no means always so, at least not to the naked eye. Volcanic breccias are also met with, as near the main pass where fragments of dark-green lava are imbedded in a reddish matrix. Tufas are also present, but apparently to a limited extent. Some specimens of tufa shown me by Captain Mander, the Executive Engineer, were made up principally of fragments of pumice, from which it would appear that pumice must be amongst the volcanic products, though I am not aware of any locality in which it is found *in situ*. Obsidian is to be met with occasionally in thin seams."

I have not met with any detailed account of the micro-petrology of the Aden lavas, but the following passing allusions to them may be quoted here. Mr. Frank Rutley, F.G.S., in his Study of Rocks, p. 152, 2nd edition, writes as follows: "A globular condition of silica has been lately described by Michael Lévy as occurring in the euritic porphyries of Les Settons, and similar globular conditions of silica have been observed and noticed by M. Vélain in a quartz trachyte from Aden. The former author regards this condition as intermediate between the crystallized and the colloid forms of silica."

Professor A. Daubrée, in his paper on zeolitic and silicious incrustations (Q. J. G. S., XXXIV, 73), states that silicious infiltrations are found in many volcanic rocks of the "trachydoleritic class," and refers to Aden as one of his examples.

The above are the only references to the Aden rocks that I have yet met with, and the following account of some of the lavas to be found at that place may not be without interest. As I have never been able to remain at Aden for more than a few hours, my examination of the extinct crater has only been a cursory one. The specimens from the vicinity of the tanks were collected by me, but the others were collected for me by a resident Engineer through the kindness of a friend. I proceed to describe the specimens in detail.

Basalts.

No. 1.—A grey compact lava. With the aid of a pocket lens, crystals of felspar and numerous dots of a greenish-yellow amorphous mineral are visible here and there. The locality in Aden from which this specimen was obtained is unknown. Sp. G. 2·78. The rock is magnetic and under the blowpipe fuses to a black bead.

M.—The base consists of a devitrified glass in which dendritic and rod-like forms of magnetite are abundant. Magnetite is also present in regular crystallographic forms.

In this base countless prisms of felspar are starred about; whilst large porphyritic crystals of that mineral are visible here and there. The porphyritic crystals are all plagioclase with the exception of one medium-sized prism which is orthoclase. Many of the minute prisms are visibly triclinic and the others are presumably so. The porphyritic felspars contain numerous enclosures of the base.

There are several augite crystals in the slice, but they are not very fresh. Part of the magnetite has been converted into hæmatite or göthite, imparting a reddish tinge to the slice, when viewed in reflected light.

The greenish-yellow amorphous mineral, alluded to above, is probably a secondary product of the decomposition of olivine, but none of the unaltered mineral is to be detected.

This rock is evidently an ordinary basalt.

No. 2.—A very dark-grey lava from Station Flagstaff Hill. It is highly vesicular, the area of the vesicles in the thin slice being nearly equal to the substance of the lava itself, but they are too minute to be seen by the unaided eye.

The rock is decidedly magnetic and fuses readily to a black bead. It seems to be a favourite rock for building purposes, and it is said to take the chisel well.

M.—The ground-mass is perfectly opaque except at the edges of the vesicular spaces and at the ends of felspar crystals, where it is seen to be made up of microscopic globulites and grains of crystalline matter. Some of this globulitic granular matter appears to be augite.

The ground-mass contains numerous crystallites and small crystals of felspar, several of which are distinctly triclinic. They contain many enclosures of the base, and some are mere skeleton crystals. Some of the larger felspars enclose prisms of apatite.

Several augites are visible in the ground-mass.

This specimen is also, I think, a basalt.

No. 3.—A very dark-grey finely vesicular lava closely resembling the last. The rock is magnetic and it fuses under the blowpipe to a black bead. From Ras Baraldu.

M.—This so closely resembles the last that a separate description is not necessary. The vesicles are not so uniformly distributed as in the last specimen and merge into elongated confluent cavities. The thin slice in reflected light has a warm brown tint. The ground-mass is not so absolutely opaque as the last specimen. In the larger felspars the enclosures of the base are so abundant as to give them quite a skeleton appearance. A fragment of augite is present in the ground-mass.

This is said to be a good building-stone and to take the chisel well.

No. 4.—A dull red highly vesicular lava. It powerfully affects the magnet, and it fuses under the blowpipe to a very dark mass that adheres to the magnet. Locality from which obtained unknown.

M.—The ground-mass is quite opaque.

Andesites.

No. 5.—A slaggy-looking lava with crystals of felspar visible here and there. Some vesicular cavities contain a zeolite which also forms incrustations on the surface. The specimen was obtained near the Station Point Cemetery. Sp. G. 2·64. The determination of the specific gravity may be a little under the mark, as there are a few vesicular cavities. The specimen is powerfully magnetic, and it fuses at the edges.

M.—The ground-mass is nearly opaque and consists of multitudes of grains of magnetite disseminated through a base of flocculent matter, probably a product of devitrification rather than of decomposition. None of the magnetite exhibits regular crystallographic forms, and part of it has been converted into hæmatite or göthite. The latter imparts a reddish and pseudo-felspathic appearance to much of the base when viewed macroscopically.

The ground-mass contains numerous micro-prisms of felspar, whilst felspars of large size are porphyritically embedded in it. The latter are nearly all visibly triclinic, and contain very numerous enclosures of the base, and buff coloured amorphous masses, that probably represent decomposed augites. Augites are not unfrequently caught up in large felspar crystals, as is the case, also, in slice No. 1. The felspar contains gas cavities and enclosures of ferrite.

No. 6.—A dark-grey vesicular lava from the vicinity of Station Point Cemetery. The hand specimen resembles the mudstone matrix of a conglomerate from which the pebbles have been extracted, the vesicular spaces having very smooth and regular surfaces as if they had enclosed hard substances. Sp. G. 2·61. The hand specimen is strongly magnetic and fuses easily under the blowpipe to a black bead which adheres to the magnet.

M.—A striking feature in this slice is the presence of numerous crystals of a red mineral which I have not been able to satisfactorily identify. It occurs in six and four-sided prisms, and in irregular shapes, and in fragment-like pieces. Some are in long and thin prisms, others in rather massive lumps. In transmitted light it is of rich orange red colour—yellowish orange when thin—deeper red when thick. When the polariser alone is revolved it absorbs light distinctly, but does not change colour. It very frequently contains enclosures of felspar, and in one instance the latter has conformed to the shape of the prism. These enclosures seem to indicate that the mineral is an original constituent of the rock and not a secondary product. The cleavage is irregular. The angle of the prism varies very much; some being nearly right angles, others being very obtuse. The average of the measurements of 17 prisms come to 103° 52′. In a few, not included in this average, adjacent faces intersected at an angle of 135°. The variation in the angle seems due to the mineral itself and not to oblique slicing.

Extinction coincides with the length of the prism and with the diagonal of the prismatic angles seen in cross section.

Between crossed nicols the mineral changes from dark to its natural colour in this slice, but in No. 16 it changes from dark to a rich crimson colour.

The prevalence of four-sided prisms is against the mineral being rubellite, or an allied species of tourmaline; its orange colour and transparency shuts out the idea of its being hæmatite, whilst the extinction shows that it is not a monoclinic pyroxene. In some respects it would do for brookite and the angles would agree fairly well with the Arkansas variety of that mineral, but I do not feel satisfied that it is brookite.

Can it be an ortho-rhombic pyroxene? the presence of which mineral in augite-andesites has recently been determined by Cross, Rosenbusch, and Teal. Its colour is not favourable to this supposition. Altogether the mineral is rather a puzzle to me at present.

The base of the rock under consideration consists of a slightly devitrified glass, of pale yellowish colour, in which are disseminated a micro-crystalline mixture of felspar, magnetite, and granular hornblende or augite. It is not dichroic and from the angle of extinction in some pieces of prismatic form I think it is augite.

Besides the micro-prisms of felspar, scattered in great abundance through the base, felspars in larger prisms are porphyritically imbedded in the ground-mass. They are nearly all visibly triclinic, as are some of the very small ones.

Considering the low specific gravity of the last two specimens, I think they must be classed as andesites. They are evidently transitional forms between the basalts and the trachytes of the Aden volcano.

Trachytes.

No. 7.—A grey compact lava with minute crystals of sanidine visible here and there. From the vicinity of the tanks. Sp. G. 2·66. The hand specimen is magnetic, but not strongly so. Under the blowpipe it fuses to a dark bead.

M.—The ground-mass consists of an intimate mixture of minute felspar prisms and irregular-shaped pieces of felspar: countless patches or granules of hornblende, and grains of magnetite and ferrite. In this are porphyritically imbedded large crystals of felspar; plagioclase and sanidine being almost equally abundant. Two of the latter present penetration twins, the others are twinned on the Carlsbad type.

The sanidine contains numerous enclosures of the ground-mass, and also stone or glass enclosures that have deposited mineral matter on cooling. Two of these are depicted at figs. 7 and 8.

The margin of many, and occasionally the whole of the sanidines in this, and in most of the slices about to be described, have a curious dusty appearance. Under high powers these felspars are seen to be full of imperfectly defined contorted fibrous particles of a doubly refracting mineral, and the dusty appearance seems to be due to the irregular intergrowth of either quartz, or another species of felspar. These enclosures do not interfere with twinning, and the latter shows that the mineral is sanidine and not nepheline.

In a portion of the slice the hornblende and magnetite are arranged in dendritic combinations.

The hornblende exhibits dichroism very strongly. One set of cleavage lines are occasionally to be seen, and the angle of extinction is characteristic of hornblende.

The slice contains a piece of the red mineral described under No. 6.

No. 8.—A grey compact rock with numerous crystals of sanidine imbedded in it. From the vicinity of the tanks. Sp. G. 2·63. The hand specimen is distinctly magnetic; under the blowpipe it fuses at the edges and adheres to the magnet.

M.—This specimen is more felspathic than the last, and the base in transmitted light is clearer. It consists of a micro-crystalline admixture of felspar, in which very numerous patches of a yellowish-green hornblende, and grains of magnetite, are freely scattered about. There are also a good many patches of hæmatite, or göthite, most of which are directly connected with magnetite grains.

There are two sizes of felspar crystals porphyritically imbedded in the ground-mass, namely, medium-sized and very large sized. Nearly the whole of the felspar of all sizes is orthoclase, but there are a few prisms of plagioclase. The larger prisms contain numerous rod-like belonites, some of which are fractured, which are doubtless imperfectly formed apatite crystals. In some cases opacite, or granular magnetite, has formed on these belonites, and sketches of three of them are given at figs. 11, 12, and 13. These combinations are particularly worth noting, because exactly similar forms are common in the gneissose granite of the North-West Himalayas, and in both cases they seem to afford evidence of the rocks which contain them having been reduced to a fused or plastic condition.

In fig. 13 the magnetite is seen to have formed on the belonite after the consolidation of the latter, and to have completely embraced it. In fig. 12 the magnetite has partially encircled the larger mineral in its arms, whilst in fig. 11 it has consolidated along its edge. In fig. 11 a cavity, running with the length of the belonite, is seen depicted at (*a*). It is probably due to shrinkage on cooling.

It is interesting to find bodies, such as those described, common to acid lavas and the gneissose granite of the Himalayas.

The felspars contain thousands of air or gas cavities.

An isotropic mineral is to be seen here and there; one of the crystals presents a six-sided outline—the sides being equal—whilst the others are in more rounded forms. It is doubtless garnet.

No. 9.—A grey compact rock, somewhat mottled in appearance, with minute prisms of felspar visible here and there. The specimen was obtained near the tanks. Sp. G. 2·60. The rock attracts the magnet, and it fuses under the blowpipe to a dark bead.

M.—The ground-mass is dark owing to the abundance of magnetite; in other respects it does not differ from that of the slices of trachyte previously described. Amongst the large porphyritic crystals plagioclase preponderates over the sanidine, but the smaller crystals all belong to the latter species. Some of the triclinic felspar is in the form of long thin prisms.

The larger felspars contain numerous enclosures of the ground-mass. In some they are so abundant as to give the prisms a somewhat skeleton appearance.

Microliths and stone enclosures are abundant, whilst a zonal growth is visible in some of the sanidines.

There is one good-sized, rounded crystal and an irregular-shaped piece of augite, whilst numerous patches of hornblende are scattered throughout the ground-mass. The rounded augite encloses a minute crystal of hornblende. The latter mineral presents irregular shapes, but in one case the cross cleavage lines are fairly well developed.

The slice contains a garnet. Much of the magnetite has passed into hæmatite, or göthite, whilst an apparently hydrated species of iron oxide often stains the matrix round the magnetite grains.

The trachyte in this specimen appears to be approaching the andesites, and is on the border line between the two.

A sketch of a portion of this slice is given at fig. 2 ; a group of felspar crystals, round which much magnetite has collected, occupies the centre of the illustration. The felspars are seen to have caught up numerous fragments of the ground mass which are alligned in general correspondence with the cleavage planes of the enclosing felspars.

No. 10.—A compact light grey coloured rock with minute crystals of sanidine visible here and there. This was obtained near the tanks. Sp. G. 2·48. The hand specimen contains, caught up in the compact rock, several fragments of pumicious lava in which vesicular cavities are numerous. This seems sufficient to account for the abnormally low specific gravity, as the air caught up in the vesicular cavities of the pumicious fragments would be sufficient to vitiate the result. The hand specimen is magnetic, but it is almost infusible under the blowpipe.

M.—This seems to be quite a typical trachyte. The ground-mass appears to be made up of an aggregation of felspar microliths. In this are imbedded medium and large sized felspar crystals. Amongst the two latter sanidine is abundant and is in very typical forms. The slice contains very little plagioclase, and the felspar micro-prisms of the base are either undifferentiated or are orthoclase.

Hornblende occurs in patches throughout the ground mass, though it is not so abundant as in some of the slices previously described. There are one or two fragmentary looking pieces of augite. In transmitted light it is of a greenish-brown, or brownish-green, but of so pale a tint as to be almost colourless. It is not dichroic, and in extinction and other characteristics it agrees with augite. The outer edge is a good deal corroded, but internally it is perfectly fresh. Some of the hornblende is much corroded and altered. It is of yellowish-green colour, and most of it is decidedly dichroic.

The ground-mass contains numerous grains of magnetite. Hæmatite or göthite is present here and there, and has penetrated cracks in the sanidine ; it also occurs in patches in the latter. Some apatite is also present.

A long cavity in the slice is stopped with calcite, which is here and there crystallized in characteristic forms. The calcite encloses some minute prisms of epidote. A zeolite appears to be also present.

Quartz trachytes.

No. II.—A grey compact rock with minute crystals of sanidine visible here and there. Part of it is of dark grey, and part a very light grey colour; and when examined with the aid of a pocket lens, it has the appearance of two magmas imperfectly mixed together. The specimen was obtained near the tanks. Sp. G. 2·60. The rock is strongly magnetic. The dark portions fuse, under the blowpipe, to a dark magnetic bead, but the light portions fuse at the edges only to a transparent colourless glass.

M.—This is a very beautiful specimen in the field of the microscope. The ground-mass in transmitted light is, in parts, very clear and transparent, and in other parts, representing the dark portions previously alluded to, the magnetite and hornblende are crowded together, so as to almost cover an area equal to that occupied by the felspar. In the clearer portions of the ground-mass the magnetite and hornblende are in larger and in more perfectly crystallized grains. In the dark portions much of the hornblende is in an embryonic condition, being shapeless aggregations of minute granules, the optical characters of which are indistinct.

From the microscopic examination of this slice, I am disposed to think that the mottled character of the rock is due to segregation.

There are numerous large crystals of sanidine scattered through the ground-mass besides others of medium size. Plagioclase is sparse. The large felspar crystals contain numerous enclosures of hornblende and a profusion of stone enclosures. The curious dusty appearance seen along the border of sanidines, described under No. 7, is very prominent in those of this slice.

Patches of hæmatite or göthite are visible here and there, and some of it is distinctly traceable to the alteration of magnetite; whilst large grains of the latter have also stained the matrix for some distance round them with a yellowish doubly refractive substance.

The slice contains a garnet and a little apatite. Here and there patches of hornblende very much resemble leaflets of mica, but I do not think any of them are really that mineral, as they are of exactly the same tint as the undoubted hornblende contained in the slice, and no trace of cleavage is visible in any of the flakes alluded to. The slice, however, contains a thin string of crypto-crystalline mica meandering about in it, similar to that described in my paper on the gneissose granite of Dalhousie. This additional link connecting acid volcanic rocks with the gneissose granites of the North-West Himalayas is most interesting.

Free quartz is to be seen here and there in the ground-mass. It is evidently a residuum, and, like the quartz of granite, it is moulded on to the other minerals.

The slice also contains another specimen of the red mineral described under No. 6.

No. 12.—A pale grey compact rock with crystals of sanidine porphyritic in it, from the vicinity of the tanks. Sp. G. 2·57. The hand specimen is magnetic. Under the blowpipe portions fuse to a magnetic bead, whilst other portions are but slightly acted on.

M.—This specimen so closely resembles the last described that only a few additional remarks are needed. Plagioclase is subordinate to the orthoclase. Magnetite is plentiful and is in well-shaped grains. Hæmatite is also abundant and for the most part assumes dendritic forms, and is but feebly translucent.

Hornblende is very abundant, being present in both the ground-mass and in the felspar crystals; and some of the crystals present well-shaped six-sided prismatic sections.

Apatite is extremely abundant in the ground-mass, and the rock, when examined chemically, gives the phosphoric acid re-action with molybdate of ammonia very decidedly.

The slice contains two shapeless garnets.

Glass and stone cavities are very abundant in the felspar crystals, and are, for the most part, of types similar to figs. 4 and 5. Figs. 9, 10, and 16 are taken from this slice.

As in the last specimen, free quartz is present in the ground mass.

No. 13.—A mottled grey compact lava with felspar facets visible here and there. It was obtained near the tanks. Sp. G. 2·56. It is magnetic, and its behaviour under the blowpipe is as in Nos. 11 and 12.

M.—This specimen is so similar to the last that a detailed description is unnecessary. The ground-mass is not as clear as the two last slices; but the felspar crystals, on the other hand, do not contain hornblende, and they are much more free from enclosures generally.

Apatite is very sparse, and there are no garnets. Hæmatite is not so abundant, and it is not in dendritic forms.

The slice contains an augite with a deep dark border.

Numerous glass or stone enclosures are to be observed in the sanidine, illustrations of which are given at figs. 4 and 5. In some the matter deposited on cooling appears to be partly mineral and partly gaseous, as in figs. 6, 9, and 16; that is to say, a gas appears to have first separated from the glass, on the consolidation of the latter, and then on cooling to have deposited mineral matter previously held in suspension.

Numerous gas or air bubbles are present in the ground-mass.

Free quartz is present as in the last two specimens.

Fluxion structure is observable in a portion of the ground-mass, where the microliths of felspar are seen to flow round a large crystal.

A sketch of a portion of this slice is given at fig 1. It is not possible on the scale at which it is drawn to attempt to depict the microliths of the ground-mass.

No. 14.—A light grey compact rock with sharply defined patches of a dark lava visible here and there imparting a brecciated appearance to the hand specimen. This lava occurs near the tanks. Sp. G. 2·48. The rock attracts the magnet, but fragments of it are infusible before the blowpipe. Facets of felspar are visible in the dark and light portions alike.

M.—The ground-mass is clear owing to the comparative sparseness of magnetite. There are only two or three small pieces of hornblende present in the slice.

There is no plagioclase, but sanidine is very abundant, and, as usual, is present in very large, in medium, and in minute crystals.

Quartz is abundant and is a much more prominent feature in the ground-mass than in any of the specimens previously described. Over about half the total area of the slice, the quartz is intimately intermixed with the felspar of the ground-mass, and in polarised light the combination of the two present a curious sieve-like appearance, the quartz constituting the meshes. Here and there free quartz forms larger masses having an irregular ramifying external outline. Minute crystals of sanidine are frequently imbedded in the free quartz.

There are a few small garnets, whilst magnetite, ferrite, and hæmatite or göthite are present as usual.

No. 15.—A greenish-grey vesicular lava from behind the post office. The greater part of Steamer Point Church is said to be built of this rock. From a builder's point of view, it is said to weather badly. The hand specimen is feebly magnetic; and under the blowpipe it becomes glassy on the surface, but does not fuse to a bead.

M.—I have examined four slices of this interesting lava. The ground-mass is micro-aphanitic, and is composed of minute prisms of felspar radiating in all directions. Grains of quartz are visible here and there in the ground-mass, but they are most abundant along the margins of the vesicular cavities when they exhibit rounded and hexagonal outlines. It is I think, tridymite.

The quartz contains numerous liquid cavities with enclosed bubbles, a fair proportion of which are movable. The size of the bubbles, relative to that of the cavities containing them, varies so much that no reliable calculation can be based on the proportion between the two. One of the quartz grains contains glass enclosures that have deposited mineral matter on cooling, and one of them has several fixed bubbles. The ground-mass contains many air or gas bubbles.

There are no porphyritic crystals of felspar.

Hornblende is very abundant; most of it is in acicular prisms of irregular outline, and rather pale green colour, resembling the hornblende of the Wolf rock (phonolite) of Cornwall; but there are larger stumpy prisms, here and there, of bluish to dark green colour in transmitted light, that have sharp outlines, give good six-sided sections and occasionally exhibit cross prismatic cleavage lines. It is decidedly dichroic changing from brown to bluish-brown; but under crossed nicols the absorption is so powerful that the colours exhibited are very feeble.

No. 16.—A light grey vesicular lava from Flag Staff Hill. Sanidine and quartz are to be observed here and there. It is slightly magnetic and fuses at the edges. Numerous round silicious granules with rough surfaces are visible in the vesicular cavities; they are dull and somewhat opalescent-looking, and have none of the liquid lustre of vitreous quartz. Most of them are globular, but some are flattened and present hexagonal outlines and are seen to have a yellowish nucleus. They are infusible under the blowpipe, and hydrochloric acid takes no notice of them.

M.—Under the microscope these spherulitic bodies are seen not to be exclusively confined to the edges of the vesicular cavities, but to occur occasionally in the ground-mass itself. Their central portions are, in transmitted light, of buff colour, and are feebly translucent, but the outer portions are transparent. Most of the globular bodies have rounded outlines, but others are flattened at the poles and present a hexagonal prism in section. Those which occur along the edges of vesicular cavities are segments of circles, the yellow nucleus being truncated and abutting directly on the edge of the ground-mass. Under crossed nicols the transparent portion is seen to have a distinctly radiated structure, and in some a dark cross is visible. They polarise in simple black and white and never exhibit colours. In some, the rough exterior surface, alluded to in my remarks on the macroscopic aspect of the rock, appears to result from minute prisms, or minute plates of tridymite projecting from the outer surface. In both cases the angles of adjoining faces are approximately 120°.

These globular bodies seen in section resemble the spherulites of rhyolites, dacites, and acid vitreous rocks, and were those found in the ground mass, seen by themselves they would undoubtedly be taken for ordinary spherulites; but the way they stand out from the surface of the vesicular cavities, their occasional hexagonal outline, and the fact that the yellow globular nuclei of those which line the vesicular cavities ar usually bisected by the bounding surface of the ground-mass, and are not continued into it, shows that they differ from ordinary spherulites. They have evidently been formed, in the great majority of cases, either by the exudition of silica from the base into the vesicular cavities, or have been deposited in these cavities through the agency of steam or water; and are not, like ordinary spherulites, the product of the devitrification of the glassy base.

I presume that these globules are identical with those noticed by M. Vélain (see *ante*). Their behaviour under crossed nicols is not, however, similar to M. Michael Lévy's description of the globular silica occurring in the euritic porphyries of Les Settons.

It is not quite clear what Michael Lévy means by a "condition *intermediate* between the crystallized and the colloid forms of silica." It seems to me that the globular silica of the Aden lavas is only a variety of hyalite, and that its peculiarities are principally due to an intergrowth, or rather to a successive formation of hyalite and tridymite. The nuclei are probably formed of common opal.

The ground-mass of the rock under consideration is micro-aphanitic, and consists, as in many of the previous specimens, of light clear portions and dark portions, as though two magmas had imperfectly mixed together.

Some large porphyritic crystals of felspar are triclinic. Some of the felspars contain large enclosures of the ground mass which have not entirely separated from the main mass; whilst the dusty appearance described in the previous pages is very prominent in the felspars of this slice. In some cases it makes them resemble nepheline, but the angle of extinction and the twinning of the sanidine and plagioclase (for the dusty appearance is seen in both classes of felspars) usually prevent any mistake in their identification.

The ground-mass contains granules of greenish hornblende, whilst minute four and six-sided well-shaped prisms of a brownish hornblende project from the ground-mass into the vesicular cavities The prism of one measured exactly 124°, 30.[1]

Apatite is present, also magnetite and hæmatite or göthite. There are also several large and small crystals of the orange red mineral, previously described. Between crossed nicols it changes from a rich crimson colour to dark.

Several of the vesicular cavities are stopped with calcite.

No. 17.—A greenish-grey fine-grained but highly vesicular lava, from the vicinity of the Station Point Cemetery. It is distinctly magnetic and fuses at the edges under the blowpipe. The siliceous globules are abundant.

M.—This is more uniformly vesicular than the last specimen, and the vesicular spaces occupy a considerable area relative to the ground-mass; consequently very large crytals of felspar are wanting and medium-sized ones are comparatively rare. In other respects this specimen closely resembles the last.

There are siliceous globules, as in the last, but tridymite is also abundant and occurs on the edges of the vesicular cavities. An overlapping of the plates is an almost constant feature in the tridymite of this and other slices. The vesicular cavities are occasionally plugged with a fibrous zeolite.

The red mineral is absent and the brown hornblende, of the last specimen, is extremely sparse. Green hornblende in acicular prisms is very abundant.

Trachytic Pitchstones.

No. 18.—A compact brick-red lava with facets of felspar visible here and there. From the vicinity of the Station Point Cemetery. Sp. G. 2·40. The rock is magnetic and fuses, but not very readily, to a white blebby mass full of air bubbles.

M.—The ground-mass is of such microscopic fineness that it requires powers of over 100 diameters to make it out. It consists of a matted mass of felspar microliths and fine granular matter. In this are scattered felspar crystals of various sizes, some hornblende and large magnetite grains. None of the felspars give evidence of being triclinic. The large felspar crystals contain numerous enclosures of the base. The slice contains countless crystallites of felspar that closely resemble those described in my paper on the basalts of Bombay,[2] having either frayed ends, or being mere skeletons enclosing the granular matter of the ground-mass.

Hyalites are to be seen in a few vesicular cavities; their outlines are semicircular.

This vitreous lava may, I think, be described as a devitrified trachytic pitchstone. A sketch of a portion of this slice is given at fig 3.

No. 19.—A reddish compact rock from the vicinity of the Station Point Cemetery. Sp. G. 2·38. This looks more like a rotten schist than a lava. Though not visibly porous or vesicular, yet when plunged into water it gives off a stream of minute air bubbles that lasts for some hours. It is not magnetic. Under the blowpipe it fuses with difficulty and becomes frothy.

M.—The ground-mass consists of micro-crystals of felspar interspersed with

[1] Rutley's Study of Rocks, p. 152, 2nd Ed. [2] Records, Vol. XVI., p. 42.

micro-grains of quartz, and an amorphous opaque red ferrite. It is of much larger grain than the last specimen.

All the porphyritic crystals of felspar are sanidine. They contain stone and glass enclosures. One of the latter is depicted at fig. 14, and is seen to contain three fixed bubbles and three crystals. Fig. 15 represents a cavity within a glass enclosure; the outer glass enclosure containing a large fixed bubble and a small crystal. The inner cavity appears to contain a minute bubble. Enclosures that have deposited dusty matter on cooling; and glass enclosures, each of which contains a large fixed bubble, are not uncommon. The slice contains no hornblende.

This lava seems to be intermediate between a quartz-trachyte and a pitchstone, but must, I think, be classed as a devitrified trachytic pitchstone.

Pumice.

No. 20.—A light grey pumice obtained in the vicinity of the Station Point Church.

M.—The vesicular cavities are filled with calcite, a zeolite, and I think some aragonite.

The pumicious part consists of a glass containing millions of air bubbles; some of these are round, whilst others are elongated, and are drawn out in the direction of the flow.

Conclusion.

Though I cannot suppose that my collection of the lavas of Aden afford complete examples of all the varieties to be obtained in the neighbourhood of that extinct volcano, still it is sufficient to show that the now silent craters, in the days of their activity, poured out basic, intermediate, and acid lavas. We have presented to us inside the main crater of Aden an unbroken succession of lavas, from acid pitchstones, on the one hand, to basaltic rocks on the other. Pitchstones shade into quartz-trachytes; quartz-trachytes into trachytes; whilst the latter pass into andesites, and through them, into basalts. On the whole, the acid rocks seem to have predominated.

Many of the lavas described in these pages have a mottled, and even a brecciated appearance, and it is difficult to say positively whether this is due to segregation, or to an imperfect blending of basic and acid magmas.

It would be interesting to know the order of succession in which the basic, intermediate, and acid lavas appeared; but on this point I have no information.

The specific gravity of each class of lava is low. I did not attempt to determine the specific gravity of the vesicular specimens, and though it is possible that hidden vesicles may, to some extent, have vitiated the determination of the specific gravity of some of those examined, yet, on the whole, I am disposed to attribute the low averages to the predominance of the acid element in the Aden lavas.

The following averages were obtained:—

Basalt	Sp. G.	2·78
Andesite	„	2·62
Trachyte	„	2·58
Quartz-Trachyte	„	2·55
Pitchstone	„	2·39

The pitchstones yield a somewhat abnormally high specific gravity, indicating their connection with the quartz-trachytes; but all the others, noted above, though within the minimum limits, are below the normal *average* specific gravity usually given for each class of rock in our text books.

The ground-mass of the intermediate and acid lavas, described in these pages, is micro-aphanitic; in no instance is it micro-felsitic. There are, except in the extremely vesicular specimens, and in the pitchstones, always three generations of felspar; micro-crystals in the ground mass, and medium and large-sized porphyritic crystals.

In the basalts and andesites the felspar is, almost without exception, plagioclase. Amongst the trachytes, those on the border line of the andesites, as No. 9, contain more porphyritic crystals of plagioclase than of sanidine; whilst those that approach the quartz-trachytes contain scarcely any plagioclase.

In intermediate varieties, as Nos. 8 and 10, the porphyritic crystals of triclinic and monoclinic felspar are pretty equal in number. In the quartz-trachytes, themselves, plagioclase is either wanting or is subordinate to the sanidine; whilst in the pitchstones plagioclase is wholly absent.

Augite is prominent in the basaltic lavas, but only stray crystals of it are present in the other lavas, namely, in Nos. 6, 9, 10, and 13.

Hornblende is abundant in the trachytes and in most of the quartz-trachytes; whilst it is sparse or wanting in the pitchstones.

Magnetite is present in all except No. 20, and every specimen, except Nos. 19 (pitchstone) and 20 (pumice), distinctly attracts the magnetic needle; some of them acting powerfully on it.

Hematite or göthite is found in all the specimens except the pumice; whilst apatite is commonly present, sparsely in some, but abundantly in others.

An isotropic mineral which I doubt not is garnet is to be seen in several slices, namely, in Nos. 8, 9, 12, and 14.

There is nothing in the appearance of the mineral to lead me to suppose that it is hauyne, a mineral frequently mentioned in connection with trachytes. Zirkel, in his Microscopic Petrology of the Fortieth Parallel, notes the occurrence of garnet in rhyolites and trachytes; and seeing that this mineral so commonly occurs in granite and syenite, its presence in the lava form of those rocks is hardly surprising.

Mica is conspicuous by its absence; but there is, however, a notable exception in slice No. 11 (quartz-trachyte), in which a thin string of crypto-crystalline mica, similar to that which takes so prominent a place in the gneissose granites of the North-West Himalayas,[1] is seen meandering through the slice. This link between acid volcanic and acid plutonic rocks seems to afford an indirect confirmation of the correctness of the conclusion regarding the affinities of the gneissose granite arrived at on other grounds.

Stone and glass enclosures are common in the felspars; also cases of magnetite forming upon and embracing microliths in a way that indicates a viscid, or

[1] Records, Volume XVI, p. 129.

fused, condition, and consequent freedom of molecular action,—facts which also form interesting points of contact with the gneissose granite of the Himalayas.

The general absence of fluid cavities is generally considered characteristic of the quartz of lavas, as compared with that of granite; but exceptions to this rule do not appear to be altogether uncommon. Dr. Sorby notes one in his Ann. Address, Q. J. G. S XIV. p. 84; another instance will be given in my forthcoming paper on the Traps of Dalhousie; whilst yet another will be found in this paper in my description of slice No. 15.

EXPLANATION OF THE ILLUSTRATIONS.

Fig. 1.—A quartz-trachyte, slice No. 13. The central felspar is imperfectly formed, and contains enclosures of the ground-mass.

Fig. 2.—A trachyte, slice No. 9; with a group of felspar crystals, in the centre of the field, round which magnetite and ferrite have collected. The felspars enclose portions of the ground-mass alligned in general correspondence with the direction of cleavage.

Fig. 3.—A devitrified trachytic pitchstone, slice No. 18.

Figs. 4 & 5.—Stone enclosures, slice No. 13.

Fig. 6.—Enclosures in felspar of slice No. 13. The matter deposited is partly mineral and partly gaseous.

Figs. 7 & 8.—Stone and glass enclosures that have deposited mineral matter on cooling.

Fig. 9.—A glass cavity taken from slice No. 12 which contains an enclosure of gas.

Fig. 10.—A stone enclosure, slice No. 12.

Figs. 11, 12, & 13.—Magnetite and opacite forming on belonites.

Fig. 14.—Glass enclosure, slice No. 19, containing crystals and fixed bubbles.

Fig. 15.—A glass cavity containing an inner enclosure, slice No. 19.

Fig. 16.—An enclosure taken from No. 12, which has deposited mineral matter and also contains gas.

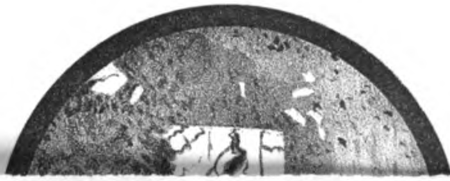
Note on the Probable Occurrence *of* Siwalik Strata *in* China *and* Japan. *By* R. Lydekker, B.A., F.G.S., F.Z.S.

I have lately received from Herr L. v. Loczy, of the Royal Geological Survey of Hungary, a letter in which I am informed that during a recent expedition to China he observed extensive tertiary formations on the Upper Hwangho (Hoang-ho) river, in which he collected fresh-water shells and numerous bones of Proboscidia and Rodentia[1] (*sic*). In Western Kansu[2] he acquired from a native dispensary other large fossil bones, and the lower molar of an elephant which he considered very similar to the teeth of the Siwalik *Stegodon clifti;* this molar

[1] ? Ruminantia.

[2] A province on the Upper Hwangho, due north of Burma.

Mc Mahon: Aden lavas.



CORRIGENDA *and* ADDENDA *to* "SYNOPSIS *of the* FOSSIL VERTEBRATA *of* INDIA." *Supra, pp. 61—94.*

N. B.—It is to be regretted that Mr. Lydekker could not correct the proof sheets of his paper. Most of these corrections are such as only the author could make.—H. B. M.

Page 62, 86. The *Cochliodontidæ* (*Poecilodus* and *Psephodus*) should be referred to the *Ganoidei*.

„ 63, line 8 from top, for *Oxychina* read *Oxyrhina:* the genus *Sphærodus* should be referred to the *Ganoidei*.

„ 65 „ 21 „ bottom, for *barioccipital* read *basioccipital.*

„ 66 „ 4 „ top, „ *centre* read *centra.*

„ 69 „ 14 „ bottom, before *British Museum*, add *Royal College of Surgeons and.*

„ 70 „ 3 „ „ for *two* read *three:* in the following line *dele* '*and a mandible.*'

„ 71 „ 1 „ top. „ *Enhydras* read *Enhydris.*

„ 72, note, for *irvaticus* read *iravaticus.*

„ 74, line 19 from top, for *H. hyopotamoides* read *A. hyopotamoides.*

„ 76 „ 11 „ „ „ *acuticornis* read *porrecticornis.*

„ 77 „ 10 „ „ „ *Nilgherries* read *Himalaya.*

„ 80 „ 2 „ bottom, *dele* '*south.*'

„ 81 „ 3 „ top, for *when* read *whose.*

„ 85 „ 1 „ bottom, for *Eg.* read *Münst:* also on p. 87, line 12 from bottom.

„ 86 „ 4 „ top, before *Sphyrænodus* add *Teleostei.*

„ „ „ 5 „ „ below *Pycnodus*, add *Sphærodus rugulosus*, Eg.: this should also be inserted in the alphabetical list.

„ 88 „ 20 „ „ for *dhonkoka* read *dhongoka.*

„ 92 „ 17 „ bottom, for *Typholodon* read *Typhlodon.*

„ „ „ 8 „ top, „ *predicus* read *indicus.*

Fig 3 × ..

J. Schaumburg, Lith.

Printed at Geol Survey Office

is described as being brown and highly mineralized, and apparently in very similar condition to the Siwalik fossils.

I am promised an opportunity of examining a cast of the molar, but the description given leaves little doubt that the strata whence the fossil was obtained correspond to the Siwaliks. It will be remembered that Professor Owen has described [1] the milk-molar of a *Stegodon*, said to have been obtained from "marly beds near Shanghai," which he referred to a new species under the name of *S. sinensis*, but which I have seen [2] no reason to separate from the Siwalik *S. clifti*. The mineralization of this specimen (now in the British Museum) is precisely similar to that of the Siwalik fossils, and leads me to conclude that the beds from which it was obtained, together with the Hwangho beds, almost certainly correspond, at least in part, to the Siwaliks. The geographical position of the Hwangho beds, due north of Burma, lends a strong support to this conclusion, as it is well known that the Siwaliks of that country, whence Crawfurd's original specimens were brought, extend far up the valley of the Irawadi, and thus are only separated by Yunan and Sechuen from the Kansu district.

In the same paper Professor Owen also described various other Chinese fossil mammals, belonging to the genera *Chalicotherium*, *Rhinoceros*, *Tapirus*, *Stegodon*, and *Hyæna*, and said to have been obtained from a cave in the province of Sechuen (Sze-chuen), or between Kansu and Yunan and Burma. The mineralization of these specimens is much less complete than that of the Shanghai and Siwalik fossils, but the difference in the manner of the entombment of the specimens is probably quite sufficient to account for this. The genera are all characteristic of the Siwaliks, and although Professor Owen has assigned all the specimens to distinct species, yet it has appeared to me [3] to be highly probable that the *Stegodon* is the same as one of the Siwalik forms; while work on which I am now engaged leads to the conclusion that the Sechuen hyæna is identical with, or very closely allied to, one of the Siwalik hyænas. Whether or no the species be the same, it appears to be most probable that the Sechuen mammals belong to the same period as those of the Siwaliks, and connect those of Burma with those of Kansu.

Turning to Japan, it may be observed that in 1881 Dr. Edmund Naumann figured and described [4] various remains of fossil elephants from that country, which he referred to the following species, *viz.*, *Stegodon clifti*, *S. insignis*, *Elephas namadicus*, and *E. primigenius*; the two first being Siwalik species, the second (or the allied *S. ganesa*) also ranging up into the Narbada beds, and the third being characteristic of the latter. These fossils indicate pretty conclusively that representatives of the mammaliferous beds of India, which probably correspond both to the Siwaliks and the Narbadas, exist in Japan, and are probably the continuation of the Chinese deposits.

[1] "Quar. Jour. Geol. Soc," Vol. XXVI, p 417.

[2] "Palæontologia Indica." Ser. X, Vol. I, "Siwalik and Narbada Proboscidia."

[3] *Ibid.*

[4] "Ueber japanische Elephanten der Vorzeit." 'Paläontographica,' Vol. XXVIII, pt. 1, pls. I—'II.

Since the publication of Dr. Naumann's memoir, another paper on the same subject has appeared by Herr D. Brauns,[1] which is certainly a very remarkable paper indeed. In that paper it is first of all attempted to prove that the Siwaliks are entirely of miocene, and the Narbadas of pliocene age, while the Japanese (and presumably the Chinese) mammaliferous deposits are all referred to the pleistocene. Now it is not my intention on the present occasion to go again into the question of the age of the Siwaliks and Narbadas, but there are two points in relation to Herr Brauns' treatment of this question, to which it is almost impossible to omit referring. It happens to be inconvenient to his line of argument that any of the Siwalik species should occur in the overlying Narbadas, and therefore, when such is stated to take place he adopts the very easy, but scarcely scientific, method of doubting the evidence. Thus in the case of the occurrence of *Stegodon insignis* (or the allied *S. ganesa*) in the Narbadas, it is stated[2] that the two specimens of broken teeth figured in the "Fauna Antiqua Sivalensis[3]" from those deposits are not sufficiently perfect for determination, and therefore that *S. insignis* does not exist in the Narbadas. Even if those specimens are insufficient evidence, if the author had but taken the trouble to refer to page 117 of the first volume of the "Palæontological Memoirs," he would have seen a very perfect specimen of the lower jaw of *S. insignis* (No. 1) from the Narbada described by Dr. Falconer; this specimen, which is now in the Indian Museum, where there are others from the same beds, leaves not the slightest doubt that *Stegodon insignis* (or *S. ganesa*, which, as far as teeth are concerned, is the same) occurs in the Narbadas. From this may be gathered the value of the following dogmatic statement of Herr Brauns, *viz.*,—

Elephas namadicus	solely pliocene,
Stegodon insignis	„ miocene.
„ clifti	„ „

In the case of the occurrence of the Narbada *Bubalus palæindicus* in the topmost Siwaliks, it is argued that the specimens are not properly determined. It happens, however, that they are unquestionably the same as the Narbada species. I have not figured them because there are so many other specimens of more importance. Similarly doubt is thrown upon the authenticity of the stone implements from the Narbadas. If this sort of reasoning be allowed, of course anything can be proved.

Leaving now the Narbadas and Siwaliks which Herr Brauns has proved to his own satisfaction are respectively pliocene and miocene and contain no species in common, attention may be re-directed to the Japanese fossils. Considering, as Herr Brauns does, that the beds from which these fossils were obtained are entirely pleistocene, and therefore altogether newer than the Siwaliks and the Narbadas, it would never do that any of the fossils from them should

[1] "Ueber japanische diluviale Säugethiere," Zeits. d. Deutsch. Geol. Gesell., 1883, pp. 1—83.

[2] *Ibid*, p. 9.

[3] Pl. 56, figs. 10, 11.

be the same as those of either of the latter. Accordingly the fossils described and figured by Dr. Naumann are re-named as follows, *viz.*—

Elephas meridionalis, Nesti, = *Stegodon insignis*, Naumann, pls. 3-5.
Elephas antiquus, Falc. = *Elephas namadicus*, Naumann, pls. 6-7.
Stegodon sinensis, Owen = *Stegodon clifti*, Naumann pls. 1-2.

Now there is not the slightest shadow of a doubt that the specimens figured by Dr. Naumann under the name of *S. insignis* are true Stegodons, and belong either to the Siwalik *Stegodon insignis* or *S. bombifrons;* they have nothing whatever to do with a *Loxodon* like *E. meridionalis*. The molars of *E. antiquus*[1] and *E. namadicus* are so alike that it is difficult or impossible to distinguish them, and there is therefore at least a probability that Dr. Naumann's determination may be correct. The specimen figured by Dr. Naumann as *Stegodon clifti* is a typical specimen of the last lower molar of that species, like many in the Indian Museum. I can see not the slightest reason why this tooth should be associated with the Shanghai milk-molar of the so-called *Stegodon sinensis* and so separated specifically from *S. clifti* of the Siwaliks.

There accordingly seems not the slightest doubt but that Dr. Naumann is perfectly correct in referring two of the fossil Japanese elephants to Indian Siwalik species; while it is not impossible that a third is a Narbada form; a fourth species is, however, referred to the European and North American *Elephas primigenius*, and to this Herr Brauns adds the European *Bison priscus*, Bojanus.

These determinations lead to the conclusion that the mammaliferous beds of Japan in all probability correspond both with the Siwaliks and Narbadas of India (which may there be in normal sequence), with the former of which they are connected by the Shanghai, Kansu, Sechuen, and Burmese deposits; and that they also contain an admixture of European palæarctic forms, which have probably reached Japan through northern America. In place of the fauna of the Japanese beds being distinct from that of the mammaliferous beds of India and affording any argument for the latter being pliocene and miocene in place of pleistocene and pliocene, all the evidence points very strongly to the equivalency of the two, and to the confirmation of the latter view of their age.

The Lodge, Harpenden, Herts.

Note on the Occurrence of Mastodon angustidens *in* India. *By* R. LYDEKKER, B.A. *&c., &c.*

Several specimens of the "intermediate molars" of a trilophodont mastodon collected by Mr. W. T. Blanford in the lower Manchhars (Siwaliks) of the Dera Bhugti country (Eastern Baluchistan), are absolutely indistinguishable from the corresponding teeth in the British Museum of *Mastodon angustidens*, Cuvier, of the upper miocene of Europe.

The occurrence of a European species of mastodon on the extreme western

[1] I am indebted to Herr Brauns for pointing out that in "Siwalik and Narbada Proboscidia" I have inadvertently given the age of *Elephas antiquus* as pliocene instead of pleistocene.

limits of India is a fact of great importance, indicating that we may look for a commingling of the faunas of the Siwaliks, and of the European upper miocene and lower pliocene in Persia and Asia Minor.

These important and interesting specimens will be figured in the "Palæontologia Indica" at no very distant date.

Notes on a Traverse between Almora *and* Mussooree *made in October 1882 by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

The following notes were made on a rapid tour between Almora and Mussooree during the month of October last; they cannot of course pretend to be a detailed description, but are of some interest in view of the question of the continuity of the Himalayan rocks in the Almora and Simla regions.

At Almora the rocks are gneiss and schists of various descriptions, lying nearly horizontal on the east of the Kosi, but on the ascent to Bainskhet the dip increases to 45°, the direction being N. 10° E., a dip which continues steady in direction, though varying in amount, till the Gagas is reached. Here the road runs over alluvium for a couple of miles, but rock again shows up on the hill called Buridunga; it is a porphyritic gneiss, similar in structure to the central gneiss. As the road runs near the northern boundary of this exposure cutting across it in several places, it is seen to be fairly straight and presumably a fault, the schists in contact with the gneiss dipping south-south-east; at Dwarahat, where the road cuts across the exposure here not a mile broad, the dip of the foliation of the gneiss has bent round to south-west and, though I was not able to trace the gneiss further to the north-west, I have no doubt that it does extend along the ridge since in the streams flowing down to the Khurrogadh blocks of it are not of infrequent occurrence.

Along the road between Dwarahat and Ganain the only exposure of slates seen was below Naugaon on the south-west side of the valley where they dipped W. 30° S., while near Ganain the dip was south-west.

On the eastern side of this valley, the ridge is capped by limestone (krol), which, apparently forming the peak of Dunagiri, descends further north, at the village of Damtola, almost to the bottom of the valley, and is seen to extend northwards from Ganain as far as the eye can reach, being confined to the eastern side of the valley with the exception of two patches capping the spurs above Bushbira and Naugaon respectively. As is generally the case, no dip was accurately determinable in the limestones, but they evidently dip somewhere about north-west.

Beyond Ganain, where the road leaves the alluvium, slates come in with a dip to W. 10° N. and on the ascent become more and more schistose; the dip at the same time becoming flatter, till near Jaurasi the porphyritic gneiss again comes in with almost horizontal foliation; this is not improbably a continuation of the Dwarahat exposure.

The gneiss continues to near Bongdhar, the only interruption being below the Makroli hill, where a narrow strip of black crush rock is let down by faulting. Near Bongdhar the slates come in again, at first with a N. 50° E dip at 45°, but this soon bends round to the normal N. 10° E. dip, the schistose slates continuing beyond this with a dip varying between N. 10° E. and N. 30° E.; at the bridge over the Nyar a thin band of porphyritic gneiss, probably here merely a more metamorphosed band among the schists, is exposed; opposite Gwalkura quartzites overlie the slates and continue to the bridge between Chifalghat and Pauri. On the crest of the ridge crossed on the road to Pauri quartzose rocks come in again, while beyond this the slates are much disturbed, but keep a pretty steady E. 10° N. and W. 11° S. strike.

Beyond Srinagar there is not much of interest to note; the quartzites show up on the ridge below Maniknath which is itself capped by limestone, but for the most part the rocks are of a recognisable infra-krol type.

Beyond Tiri, where the road runs along the Mussooree ridge infra-krols, quartzites, limestone (krol) and in one place the Blaini are seen, but the structure, as is the case everywhere on the outer ridge, is far too complicated to be unravelled by a simple traverse along the strike of the rocks.

I have reserved for separate notice the alluvial deposits, of which I shall now mention the more important.

Between Bainskhet and Dwarahat near the village of Kapalna the road runs along the surface of an old lake deposit, of which a narrow strip has been left uneroded, the streams on either side having cut deep into the deposits; in both the other valleys crossed before reaching the Gagas traces of extensive deposits are seen but forming a mere skin on the rocks below, having been almost entirely removed by the streams. At Kapalna the gradual raising of the deposits has given the drainage an easier escape over a saddle in the watershed into the next valley to the west; hence the lower part of the deposit has been exposed to the erosion of its own drainage only, while in the other valleys the streams flowing down from the hills to the north have almost entirely washed away the alluvium.

In the Gagas valley there is another alluvial deposit, which, having come mostly from the hills to the west, has by its slope forced the river to the eastern margin of the plain, where it has now cut for itself a new channel in the solid rock of about 60 feet in depth.

This deposit extends up the Pokhy valley, and some of the drainage of its western extremity flows into the Chundas. Here again there has evidently been a diversion of the drainage, due to the gradual raising of the surface of the alluvium to the level of one of the saddles in the original watershed.

Near Dwarahat there is another broad expanse of lacustrine deposits situated at the head of the Baiaru river. These deposits which, be they lacustrine or no, are at any rate formed in true rock basins situated at the very heads of the drainage areas, and rising almost to the level of the watershed have never, so far as I am aware, been adequately explained. They are by no means of merely occasional occurrence, but are scattered throughout these hills; one very good example being at the head of the Blaini river near Solan on the Simla road.

The three rivers which meet at Ganain have all broad alluvial bottoms, part being close down to the present level of the streams, the rest forming a terrace raised some 30 to 60 feet, but the low level ground seems to be merely due to the erosion of the stream, and not to a more recent deposition.

Near Ganain is a very interesting lake known as the Turag Tal; it is situated at the head of one of the streams flowing down to Gunain. In the valley of this stream an alluvial flat extends right up to the foot of the barrier, which is most clearly a landslip, for not only is the gap in the hill from which it has descended most evident, but the only other possible explanation, *viz.*, a moraine, is at once barred by the absence of any other rock but limestone in the barrier which is composed entirely of fragments and not of rock *in situ*. Above the barrier is a broad alluvial surface, the lower end of which is covered by water probably not of any very great depth. The level of this alluvium is about 200 feet above that in the valley below the barrier which itself rises 50 feet above the upper alluvium; the total depth of the landslip is therefore 250 feet, and the time that has elapsed since its fall has been that required for the formation of alluvium 200 feet in thickness.

Near the head of the Binan river there is a small deposit of alluvium as also at Chopryon and Kandura near Powri.

At Srinuggar and Tiri there are extensive terraces covered with a thin coating of river gravel, but in the main merely carved out of the solid rock.

The above-mentioned alluvial deposits are all in true rock basins, but only the three first mentioned, *viz.*, those near Kapalna, in the Gagas, and at Dwarahat, seem, from their uniformity and fineness of texture, to be of lacustrine origin.

Though there was never much doubt as to the propriety of correlating the rocks on the Almora section with those of the Simla region, such shadow of it as there was may be held to be now dispelled, for in the region crossed between Almora and Mussooree the rocks are seen to become gradually less metamorphic, and the distinctions of the sub-divisions but obscurely seen near Almora become more and more marked till the rocks assume the normal character which they are found to maintain from Mussooree to the north-west.

Note on the Cretaceous coal-measures *at* Borsora *in the* Khasia Hills, *near* Laour *in* Sylhet, *by* TOM D. LA TOUCHE, B.A., *Geological Survey of India.*

I have visited and examined a section of the coal-bearing rocks situated at the foot of the Khasia Hills to the north of the district of Laour.

Position of the section.

The section examined occurs in a ravine, at the mouth of which stands the Garo village of Borsora, about 5 miles west of the point where the Panatibh or Jadukhata river leaves the hills. At the edge of the plains on either side of this village nummulitic limestone is exposed dipping to south-south-east or towards the plains at an angle of 38°.* On proceeding up the ravine along a path on the west side of the stream no sections of rock *in situ* are seen, but the path is covered with blocks of

* From this a large amount of stone has been quarried by Messrs. Inglis & Co.

a coarseish yellow and brown sandstone. The path rises for about half a mile until the mouth of a small steep ravine on the west is reached, in the sides of which the coal seams are exposed.

Description of the section.

At the junction of the two ravines carbonaceous shale is seen in the bed of the stream dipping to south-south-east at an angle of 12°. Upon this rests a seam of good coal 3 feet 10 inches thick extending for about 20 yards along the side of the ravine. This is overlaid by 5 feet of shaly sandstone, upon which rests a second seam of coal 3 feet 4 inches thick. This seam has been disturbed by several small faults or slips, and parts of it have been denuded to some extent before the deposition of the overlying sandstone, so that its thickness is not so constant as that of the lower seam. Proceeding up the ravine about 60 feet of fine yellow sandstones are passed over, and a third seam of coal is met with, cropping out on both sides of the ravine. The thickness of this seam could not be determined exactly, as a small landslip has occurred in the rocks above, and has partly covered it, but it is at least 4 feet thick, though not quite free from shaly partings. Above this the ground is covered for 50 or 60 feet with the debris from the slip above mentioned, consisting of fine yellow sandstones and shales with many fragments of coal, and above this again, at the top of the section, is a fourth seam, of shaly coal, 2 feet thick. In the whole section therefore of about 150 feet there are about 12 feet of good coal, distributed in three seams as shown below, in descending order:—

		Ft.	*Ins.*
Shaly coal	about	2	0
Fine yellow sandstone and shale	„	60	0
Coal seam, No. 3	„	4	0
Fine yellow sandstone	„	60	0
Coal seam, No. 2	„	3	4
Shaly sandstone	„	5	0
Coal seam, No. 1	„	3	10
Carbonaceous shale, thickness unknown.			
TOTAL	„	138	2

Quality of the coal.

The coal of seams Nos. 1 and 3 is much disintegrated by exposure, so that it is difficult to get good specimens for analysis, but it appears to be a very good coal, with a bright fracture and black colour, containing numerous specks and nests of a kind of fossil resin. This resinous substance, which is characteristic of the coals of this region occurring in cretaceous rocks, together with the position of the seams below the nummulitic limestone, shows that the coal is of the same age as that of the Garo hills and the small basin at Maobelarkar, and is therefore distinct from the coal of Cherra Poonjee, which occurs above the limestones. The coal of seam No. 2 is more compact and browner in colour, and is traversed in all directions by small joints.

It also contains specks of the fossil resin. Samples assayed in the Survey laboratory by Sub-Assistant Hira Lal gave the following satisfactory results:—

	Seam.	
	No. 1.	*No. 2.*
Moisture	5·84	3·02
Other volatile matter	35·16	39·58
Fixed carbon	50·40	50·80
Ash	8·60	6·60
	100 00	100·00

No. 1 does not cake; ash pale red.
No. 2 cakes; ash red.

Probable extent of the field.

The section examined is very similar in some respects to one described by Captain H. H. Godwin-Austen (Jour. As. Soc. Bengal, Vol. XXXVIII, Pt. II, No. 1, 1869) as occurring on a small tributary of the Umblay near the village of Nongkerasi, about 10 miles to the north-west of Borsora; but to determine whether the coal-measures are continuous between these points would require a more detailed examination of the district than I was able to make. The only means of getting sections in such a country is to follow up the hill streams in which fragments of coal are found to the outcrop of the seam, and at this season (June) these streams are liable to sudden floods and become quite impassable. If it should be found that the coal does extend between these points, its amount must be very large.

Position of the seams as regards extraction of the coal.

The outcrop near Borsora is very favourably situated for being worked. It is not more than half a mile within the hills and at a low elevation above the plain. The coal rises from the outcrops so that mines or quarries could be easily drained. The foot of the hills is only 1 mile from the Patlai river, a branch of the Jadukhata, and during the rains boats can come up to within a few hundred yards of the hills.

Even now great numbers go close to the spot during the rains to carry away limestone from the numerous quarries between Borsora and Lakma.

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July 18th, 1883.

RECORDS

OF THE

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Part 4.] 1883. [November.

Palæontological Notes from the Daltonganj *and* Hutar coalfields *in Chota Nagpur, by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

THE above two coalfields were surveyed by Messrs. Hughes[1] and V. Ball[2] respectively, but no fossils were known from either of them. It was, however, of interest to ascertain whether fossils occurred there and of what character they were, as it was quite to be expected that some portion of the coal beds in one or the other might be of the age of the Karharbári beds. I was consequently last winter deputed to visit these coal-fields and to examine them for fossils. The results were satisfactory enough, as not only were fossils met with in good numbers, but they were also sufficiently clear to allow of some of the horizons being fixed with much probability.

The Daltonganj coalfield.

This coalfield is situated about 50 miles west of Hazáribágh, and is traversed by the Koel and Amánat rivers. The rocks represented in the coal-field are the Talchirs and the coal-measures. These were hitherto assigned to the Barákar group of the Damuda subdivision of the Gondwána system. The examination of the fossils, however, showed that these coal beds of the Daltonganj field most probably are of the age of the Karharbári beds.

The various outcrops in this field are described in Mr. Hughes' report; I visited most of them with the view of examining them for fossils.

Outcrops at Singra.

At the junction of the Koel and Amánat rivers, about 5 miles north of Daltonganj, near Singra, where mining is carried on to some extent, there is a good exposure of the coal-bearing rocks, consisting of sandstones and sandy shales, with three outcrops of coal seams.

The base of the section close to the river surface consists of a series of sandy micaceous grey shales, which are on the whole unfossiliferous; but very

[1] Mem. G. S. I., Vol. VIII, Pl. 2.
[2] *Ibid*, Vol. XV, Pl. 1.

nearly at the base there is a stratum in which some leaf impressions occur; they are not very distinct, though the following can be recognised:—

Gangamopteris cyclopteroides var. *attenuata.*
Glossopteris communis, Feistm; large leaves.
„ *indica*, Schimp.

The stratum immediately above this bed contains root-like impressions traversing the rock in various directions; in some cases they appeared to me to be of *Vertebraria*. Above this bed is the coal outcrop, representing the first seam of the series.

Above this follows a series of sandstones and shales, without any trace of fossils, underlying the second seam. Above this seam there follows a series of grey sandy shales, with a band of hard and light grey shale.

The third seam, which now follows, is not exposed in this section on the river, but a little further to the south. In a soft fine shale, of grey colour with reddish tints, above this seam the following fossils were found:—

Vertebraria indica, Royle.
Nöggerathia hislopi, Bunb. (Feistm.); numerous.
Samaropsis parvula, Heer.
Seeds, may be of the foregoing species.

These fossils, though not very numerous or quite decisive, yet show an ensemble like those from the third Karharbári seam or from the Mohpáni coal seams, both of which, there is little doubt, belong to the Karharbári beds.

This Karharbári character of the fossils is, however, more distinctly expressed in some other outcrops to the north of Singra.

Outcrops at Rajhera.

There is no mining carried on at present at this place, though there are traces of old workings; there is, however, no want of outcrops, one of which yielded a good number of fossils.

In a nala to the south of Rajhera there are at first sandstones like those above the first seam at Singra. Lower down below the sandstones there is an outcrop of grey sandy micaceous shales, about 5 feet thick; in about the middle of these shales, and I think representing the coal outcrop, is a band of a darker shale, which breaks irregularly, with somewhat a sphæroidal structure. I think this outcrop represents the first seam of Singra.

The above-mentioned dark shale band is full of leaf impressions, which are in most cases very well preserved, and amongst which the following species could be recognised:—

Glossopteris communis, Feistm.; very large leaves with a thick midrib and very close and narrow meshes.

Glossopteris indica, Schimp.

„ *decipiens*, Feistm.; one specimen like the species from the Karharbári coalfield.

Gangamopteris cyclopteroides, Feistm. The true original form like in the Talchirs and Karharbáris; in various states of preservation, but also showing distinctly the basal portion.

Gangamopteris var. *subauriculata*; one nice specimen, with doubled up margin.
" var. *attenuata*.

Samaropsis, comp. *parvula*, Heer; just like some from the Karharbári beds.
Voltzia—a branchlet of a coniferous plant, belongs I think to this genus.

There are some other shale outcrops east of Rajhera, which, however, did not yield many distinct fossils, though the rock in which they occurred, a sandy shale of greenish-brownish colour with reddish tints, resembles one in the Mohpáni coalfield containing fossils of the Karharbári type. The only fossils in the present instance were: *Glossopteris communis*, Feistm., and *Equisetaceous* stems.

A comparison of the fossils named above with those from other coalfields will show that they bear the character of those known from the Karharbári beds, and there is little doubt that the coal seams of the Daltonganj coalfield, at least those where fossils were found (at Singra and Rajhera), are of the age of the Karharbári beds, which circumstance would perhaps add not a little to the importance of the coalfield.

The Hutar coalfield.

From this coalfield, which is situated on the Koel river to the south of the Daltonganj field, and which was surveyed by Mr. Ball, I have also brought a few fossils. I visited first the outcrops on the northern margin, south of the village Nowadih. Here the coal-bearing rocks are in contact with the Talchirs. Following a nala which joins the Supuhi river close to where the road from Daltonganj crosses the former, at first several outcrops are found between massive sandstones with a south-west dip; in these no fossils were found. Further on, close to the junction of the coal-bearing rocks with the Talchirs, there are other outcrops of strongly carbonaceous shales, quite close to the Talchirs, in which the following fossils were found:—

Gangamopteris cyclopteroides, Feistm.
" var. *attenuata*.

These carbonaceous shales pass without break into strata which belong to the Talchirs, and are conformable with the former; the rock is, however, not of the usual kind, being still somewhat carbonaceous shale, although undoubtedly already in the Talchirs; here also some fossils were found:—

Equisetaceous stems.
Gangamopteris cyclopteroides, Feistm.; typical form.
" var. *subauriculata*.

If we consider now these latter as belonging to the Talchirs, then the carbonaceous outcrops in close proximity to them are perhaps either of the same age, or else represent the Karharbári beds, while the higher outcrops would have to be considered as representing the Barákar group. This is the only locality where these relations could be recognised.

Further to east, at the village Hutar, there are again some outcrops, also apparently in conformity with the Talchirs; some fragments of fossils were found, but insufficient to determine the horizon; I should, however, feel inclined to consider them as Barákars.

Somewhat better fossils were met with near the east end of the field, north of Saidope. At the confluence of the Dauri and Ghorsam streams there is a great display of beds. At the bottom of the section close to the river surface is coal, over it lies coaly shale, then grey sandy shales, above which follow sandstones of yellowish and reddish colours.

The fossils occurred in the black coaly shale above the coal, and the following could be recognised:—

Equisetaceous stems; very numerous.
Glossopteris indica, Schimp.
„ *damudica*, Feistm.
Coniferous branch like *Voltzia.*

To judge from these fossils, the outcrops can be considered as belonging with great probability to the Barákars, and the same appears to be the case with the other outcrops in the field, so that only on the northern margin of the field would the fossils allow of a more varied grouping of the beds.

Some of the fossils gathered on this occasion from the Daltonganj and Hutar coalfields will be figured in the Palæontologia Indica, together with some others collected on a previous journey in the Aurunga and Káranpura coal-fields.

On the altered basalts *of the* Dalhousie *region in the* North-Western Himalayas, *by* COLONEL C. A. MCMAHON, F.G.S.—(*With two plates*).

In my paper on the Geology of Dalhousie, I have already described the mode of occurrence of the rocks of the volcanic series in the Dalhousie area, and it only remains to note their petrological characteristics as seen in thin slices under the microscope.

Specimens from the Bagrár ridge.

No. 1.—A dull green amygdaloidal rock weathering to a light brown colour. Sp. G. 2·85. The amygdules are of small size and are composed of scolecite, delessite, and a red zeolite. A little iron pyrites is to be seen here and there.

M.—This slice closely resembles an undescribed specimen of the Darang traps. Augite is abundant, and is in irregular-shaped elongated pieces; none of it is fresh, and the felspar is also considerably kaolinised. Viridite is abundant, and the slice contains epidote in a granular form. Scolecite not only fills amygdules, but has replaced much of the original material in their vicinity.

No. 2.—A greyish-green amygdaloidal rock weathering to a light brown. Sp. G. 2·86. The amygdaloidal cavities are filled with quartz and scolecite, and specks of iron pyrites are to be seen here and there in the rock.

M.—The amygdules are composed of scolecite, quartz, and viridite, the latter containing many crystals of epidote. Cracks in the rock and in the amygdules are filled with viridite and a yellow substance resembling epidote. The viridite is of the serpentinous variety.

The augite is altered almost past recognition, but it can be doubtfully made out here and there with the aid of polarised light. The small felspar prisms are still to be traced, but all signs of twinning have disappeared, and the felspars have been so eaten into, and replaced by the green alteration-product, that their outline is irregular. The whole rock is permeated through and through with this green product of alteration, and all the outlines of the original minerals have become confused and hazy. No trace of magnetite remains.

The quartz which occurs in the centre of an amygdule surrounded by scolecite has a dusty appearance, which on the application of high powers (× 300 to 500) is seen to be caused by a multitude of extremely minute liquid cavities, many of which have movable bubbles. The liquid in some of the cavities is red coloured. The quartz appears to have formed after the scolecite which lines the amygdaloidal cavities, as it conforms itself to the outward form of the scolecite crystals.

No. 3.—A grey-green compact rock. Sp. G. 2·81.

M.—This is quite a typical lava. The base which forms a prominent object in the field of the microscope is considerable in amount in proportion to the imbedded crystals, and probably constitutes more than one-half of the whole. It is greenish-white in reflected, and something between a brown and an olive green in transmitted, light. It is not at all dichroic, and it does not polarise between crossed nicols, but changes from dark to its natural colour, much light, however, being absorbed. Under high powers it is resolved into very minute granular matter. This base is evidently a partially devitrified glass and represents the residuum left uncrystallized owing to the rapid cooling of the rock.

In this base, besides the larger crystals to be described further on, minute crystals of felspar, often acicular in shape, are scattered about, which are I think very characteristic of a rapidly cooled lava. Some of them have enclosed portions of the base, as in fig. 7, plate II, whilst others are in skeleton or incomplete forms similar to those depicted at figs. 1, 3, 4, 5, and 6, which are given as samples only, the shape of these minute crystals being very varied.[1]

In this base, besides the minute crystals just described, comparatively large ones of felspar and augite are arranged in clusters and groups.

In my paper on the basalts of Bombay I described the penetration of felspar by augite and of augite by felspar as a structural peculiarity very characteristic of volcanic rocks. This structure is more than usually prominent in this slice; indeed a large proportion of the augite and felspar crystals are interlaced and intermixed in a way that is very striking, and is often very complex. It would seem as if the first formed crystals floating about in the fluid base before they attained any size were drawn together by mutual molecular attraction, and that

[1] Figs. 5, 7, and 10 closely resemble some of the figures depicted in fig. 4, plate XI, Zirkel's Microscopic Petrology of the 40th parallel. Zirkel considers the forms shown in fig. 3, plate XI of his work above quoted as "probably a felspathic crystalline product of devitrification." Unfortunately "devitrification," as at present used by microscopists, is a very ambiguous term; thus Mr. F. Rutley, in a paper published in the Q. J. G. S. XXXVI, 407, writes of a rock described therein: "In the first case, it may be regarded as an obsidian devitrified *at its birth*; in the second, as an obsidian devitrified *in its old age*." Does Zirkel mean that the skeleton crystals he describes are congenital or epigenital? If the latter, I think he has missed the point of the matter. I think these imperfect forms are the result of rapid cooling and correspond to the skeleton crystals of slags.

the growth of the crystals then went on side by side so rapidly that they embraced and interlaced each other in the act of crystallization.

At fig. 1, plate I, the sketch of a portion of this slice, magnified 30 diameters, is intended to give a general impression of its appearance in the field of the microscope, and the way the imbedded crystals of augite and felspar group themselves together in the base—one long band of the associated minerals forming a sort of festoon across the centre of the field.

At fig. 2 of this plate I have given a sketch of another portion of the same slice, magnified 60 diameters. The singular way the augite has embraced the felspar prisms is shown in the sketch. The feathery kind of termination of some of the felspars reminds me of those shown at fig. 2, plate I, of the illustrations to my paper on the Bombay basalts, and suggests the feathery terminations, described by Dr. Sorby, of the felspar of slags.

Other illustrations of the intergrowth of augite and felspar are given at figs. 2, 8, 9, and 11, plate II.

In a previous paper I quoted a passage from Dr. Geikie on the Volcanic rocks of the basin of the Firth of Forth, showing how felspar prisms "shoot" through crystals of augite as though they were "intrusive." Such figures, as the extraordinary ones represented at figs. 9 and 11, plate II, certainly imitate "intrusion" in a remarkable way, and at first sight suggest the idea that the felspar must have filled cracks in the augite crystals at a period subsequent to the genesis of the augite; but, I think these singular appearances are simply due to the fact that the crystallization of both the felspar and augite proceeded rapidly at the same time, and that the supply of material for the formation of the two minerals fluctuated. It will be observed, moreover, in fig. 2, plate I, and in figs. 2 and 9 of plate II, that the felspar is attenuated in the centre of the augite and expands rapidly at the edges. I have observed this to be a general rule, and have seen many cases of it much more striking than those in the illustrations to which attention is directed; and I think this peculiarity shows that the augite did not crystallize around previously formed felspar prisms, but that the crystallization of the two minerals proceeded simultaneously, and that the supply of felspathic material was, for a time, cut off by the vigour with which the molecules of augitic matter came together.

In fig. 2, plate I, and figs. 1, 2, 3, and 9 of plate II, I have attempted to illustrate a tendency observable in felspar crystals to fray out at their ends, or rather to throw off long hair-like prisms or appendages. This peculiarity is another indication, I think, of rapid cooling, showing that as crystallization proceeded, the supply of material was cut off by the loss of perfect freedom of molecular motion consequent on cooling; hence these crystals were unable to assume a perfect crystallographic form.

I dwell upon these details at some length, because they are not without interest in themselves, and because it is chiefly by noticing characteristic structural peculiarities that we are able to distinguish between basic volcanic and basic plutonic rocks.

All the augite in this slice is of irregular shape; a few crystals only are twinned.

If we except the minute crystals just described, and those caught up in augite, the felspar crystals seen in this slice are as a rule well shaped, though many, even of these, are frayed out at one end; that is to say, they have thrown out one or more long and slender terminal prisms indicating that their crystallization, though deliberate at first, was ultimately brought to a sudden and rapid termination.

Here and there the felspar exhibits the multiple twinning of triclinic felspar; a few sanidine prisms exhibit single twinning; but in most of the crystals all trace of twinning is absent. The substance of the prisms has been much invaded by greenish granular matter similar to that seen in the base, and it is difficult to say whether it was caught up in the act of crystallization or whether it is the result of subsequent alteration.

The slice contains no magnetite, and some of the felspar is sanidine. There are a few fields of viridite in the slice.

No. 4.—A greenish-grey compact rock weathering to a light brown colour. Sp. G. 2·84.

M.—This slice exhibits the usual arrangement of felspar and augite scattered about in a devitrified glassy base. Some of the felspar is seen to be triclinic, but in the majority of cases, owing to kaolinisation, the twinning is no longer to be traced. I think, however, from a consideration of the azimuth at which extinction occurs, that some of the felspars are probably sanidine.

This slice contains numerous instances of the enclosure of the glassy base by felspar in the act of crystallization, similar to those already described. An illustration of one of these is given at fig. 10. In some instances these enclosures run the whole length of the prism and maintain a uniform thickness throughout. Another illustration of one of these enclosures is given at fig. 12, plate II.[1] In this case the magma enclosed has thinned away towards the centre of the prism, being thick at both ends. It is not a case of two prisms in close conjunction as one might suppose from the illustration, but of one prism with the glassy base caught up in it.

The augite in this rock is much altered. The slice contains several cracks, filled with quartz, which die out within the slice itself—cracks formed I presume on cooling.

No. 5.—A greenish-grey compact rock, brown and rotten at the edges. Sp. G. 2·69.

This rock occurs on the margin of the outcrop where the trap first appears.

M.—The whole ground mass has been converted into viridite in which the felspar crystals are starred about.

Here and there the triclinic character of the latter can be made out, but their internal structure has been a good deal altered into granular matter. Scattered through the slice are granules of a dichroic yellowish mineral which appears to be epidote. Its shape is irregular and its internal structure is micro-granular. No augite is visible.

[1] This crystal somewhat resembles one of the crystallites in pearlite depicted at fig. 20, plate I, Zirkel's Microscopic Petrology of the 40th parallel.

Descent from Dhalog to Sandára on the Ravi.

No. 6.—A greenish-grey compact rock weathering brown. Sp. G. 2·80. This rock occurs where the trap first crops out.

M.—One of the first objects that strikes one on looking at this slice is the abundance of the light brown glassy base which is partially devitrified into fine-grained granular matter. In this base crystals of felspar and augite are scattered about. Very little magnetite or ilmenite is to be seen, but there is much leucoxene, the product of the decomposition of the latter.

Much of the felspar is seen to be triclinic, but some of it is sanidine, and probably both are equally abundant. The felspar is considerably decomposed by the invasion of viridite, and part of it is coloured red by the presence of fine granular matter in it which is too minute to be determined.

Augite is abundant in irregular shaped prisms, and much of it is twinned. It is not in a fresh condition, but its alteration is not in an advanced stage.

Water has percolated freely through the rock, and meandering lake-like spaces, plugged with scolecite and viridite, are to be seen here and there. Flakes of mica are scattered through the viridite.

The penetration of augite by felspar prisms, which are more attenuated in the middle of the augite than towards the margin of the latter, similar to those previously described, is very frequent.

No. 7.—A greenish-grey compact rock, somewhat mottled in appearance. Sp. G. 2·84.

M.—This slice in its general aspect very closely resembles No. 3, except that the felspar prisms and augite crystals are better formed and are of more regular shape.

The felspar is almost completely kaolinised, and all trace of twinning has consequently been obliterated. Nearly all the augite is partially altered. No unchanged magnetite is discernible in this slice or in No. 3. A portion of this slice is depicted at fig. 3, plate I.

No. 8.—A greenish-grey compact rock with streaks of epidote in it. Sp. G. 2·87.

M.—Epidote, associated with quartz, forms large veins running through the rock and takes up the greater part of the slice; whilst smaller veins of epidote alone, and of quartz alone, traverse it in other directions. The general mass is likewise much penetrated by epidote. The epidote is in a minutely granular condition, though well shaped microscopic crystals are to be seen in abundance along the edges of veins.

The rock itself consists of the usual felspar crystals starred about in a devitrified glassy base. All the felspar crystals are greatly altered and invaded by granular matter. No unaltered augite remains, and nothing distinctly recognisable as augite. Rod-like and dendritic forms of magnetite are abundant in the base.

No. 9.—A greenish-grey compact rock. Sp. G. 2·76.

M.—Augite is abundant and is in rather massive, irregular shaped prisms. The slice contains, however, one long slim augite. Twinning is not common. All the augite is more or less browned as the result of partial alteration.

The felspar is in well-shaped prisms of moderately large size. It is much kaolinised, and the twinning can only be made out here and there. The slice apparently contains both plagioclase and sanidine.

Amygdules of viridite (delessite ?) and scolecite are prominent, and flakes of mica are to be seen in both. All the ilmenite has been converted into leucoxene.

Trap from the Ravi section between Simliu and Kairi.

No. 10.—A mottled greenish-grey compact rock. Sp. G. 2·78.

M.—Augite is abundant in this slice, but it is all more or less altered and converted here and there into a serpentinous product.

The felspar is greatly kaolinised. A serpentinous variety of viridite is abundant and contains some crystals of epidote.

Here and there the original glassy base, now partially devitrified, is still to be made out.

No. 11.—A mottled greenish-grey compact rock. Sp. G. 2·86.

M.—This slice is very similar to the last, but the augite is still more altered.

An irregular vein filled with epidote meanders through the slice. The triclinic character of some of the felspar can still be discerned, but the rest is completely kaolinised.

No. 12.—A pale greenish-grey, perfectly compact rock with a vitreous aspect. Sp. G. 2·84.

M.—The slice consists of a devitrified glassy base in which numerous crystallites of felspar are starred about. The base is composed of micro-granular matter of grey colour with a faint greenish tinge in it. Diffused through this are patches of minutely granular matter, of irregular outline, that polarises between crossed nicols. It is probably imperfectly formed epidote and may possibly represent pre-existing augite.

The slice is traversed by numerous veins filled with crypto-crystalline and apparently felspathic material crowded with countless, colourless, hair-like microliths. These veins were apparently filled by an exfiltration process during the cooling of the rock.

Below the Staging Bungalow Mámul to the west.

No. 13.—A mottled compact rock varying from green to purple. Sp. G. 2·73. B.B : fuses to a black magnetic bead.

M.—This slice consists of a glass, partially devitrified and exhibiting flow structure, containing a large amount of ferruginous, minutely granular material, arranged in flocculent masses. Much of it is peroxidised, and this imparts a red appearance to the slice in reflected light. In this base are scattered minute and irregular shaped prisms of felspar which exhibit no twinning. A comparatively large one has the multiple twinning of a triclinic felspar. Here and there patches of leucoxene are to be seen, but no augite.

The slice contains a few shapeless grains of a dichroic and minutely granular mineral which appears to be epidote.

No. 14.—A greenish-grey compact rock. Sp. G. 2·86. B.B : fuses easily to a dark bead.

M.—This slice consists of a devitrified glassy base in which imperfectly formed crystals of felspar are scattered about. It very much resembles No. 12.

Conclusion.

All the above specimens give abundant evidence of having been lavas erupted at the surface of the earth's crust. No existing volcano could yield a more typical lava than No. 4.

The Dalhousie traps appear, on the whole, to belong to the basic type. No. 5 may possibly belong to the intermediate series, but No. 13 was evidently a highly glassy rock, approximating to a basalt glass, and No. 5 may have belonged to this class also.

Augite is abundant in all the other specimens except in Nos. 12 and 14 (in which it is wanting); and their specific gravity ranges from 2·76 to 2·87; their average being 2·83. The specific gravity of Nos. 12 and 14 is 2·84 and 2·86. All the specimens described in this paper, except No. 5, clearly belong to the basic class.

Sanidine is present in most of the specimens, but it plays a subordinate part. The presence of a small amount of sanidine, even in true basalts, is not specially remarkable.[1]

Considering the extent to which alteration has proceeded, the absence of olivine was only to be expected, for it is one of the first of the basaltic minerals to decay, and it may have furnished the materials for the formation of some of the secondary minerals so abundant in these rocks. On the whole, I think, the Dalhousie traps may be classed as altered basalts.

The next question which arises is whether the microscopical examination of these rocks throws any light upon their geological age.

The idea that basalts are tertiary rocks has long since been exploded, and it is now known that they may be of any age. Moreover, those who formerly held that basalts are of tertiary age would probably have classed the rocks now described as melaphyres. I discard the name melaphyre myself, because its use is apt to be misleading, inasmuch as altered plutonic rocks are sometimes included under that term.

All the specimens examined show that the Dalhousie traps are greatly altered. In none is the augite fresh; whilst in some it is altered almost past recognition.

The felspar is, as a rule, more or less kaolinised; whilst throughout the slices secondary products are abundant.

The extent to which alteration has proceeded in these rocks is in my opinion a good argument in favour of their being of considerable geological age.

The alteration exhibited appears, from the aspect of the rocks under the microscope, to have been the result of either the slow percolation of water or of hydro-thermal agencies. This alteration is not a mere local peculiarity, but appears to prevail throughout these rocks and to extend over a large area.

Considerable time must surely have been required for the production of the uniform changes to be seen in these dense traps. In the absence of evidence to

[1] See Zirkel's Microscopic Petrology of the 40th Parallel, pp. 216-229.

Fig. 1 × 30

Fig. 2 × 60

Fig. 3 × [illegible]

Reproduced in heliogravure from the original drawings at the Surveyor General's Office, Calcutta.
October, 18[illegible]

the contrary, I think we may safely conclude that the extent of alteration affords, in a rough way, a measure of the age of these rocks.

The basalts of Bombay are believed to be of upper cretaceous or lower tertiary age; and if we compare the extent to which alteration has proceeded in the two rocks,—both being basic lavas of much the same character—I think it is logical to infer, unless and until evidence to prove the contrary can be adduced, that the traps of the Dalhousie area are considerably older than the basalts of Bombay. The result of their examination under the microscope is therefore to support the conclusion, as to the age of the traps described in this paper, arrived at on other grounds in my paper on the geology of Dalhousie.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Altered basalt. Dalhousie. Slice No. 3. Sketch intended to give a general idea of the way the augite and felspar crystals are interlaced and grouped together in clusters.

Fig. 2. Another portion of the same slice showing the feathery terminations of some of the felspar crystals and the intergrowth of augite and felspar consequent on the simultaneous crystallization of these minerals.

Fig. 3. Altered basalt. Dalhousie. Slice No. 7. Crystals of felspar and augite are seen scattered about in a partially devitrified glassy base.

PLATE II.

Fig. 1. An incomplete or skeleton form of felspar crystal. Slice No. 3. The result of rapid solidification.

Fig. 2. Intergrowth of augite and felspar, the result of rapid cooling. Slice No. 3.

Fig. 3. Another skeleton form of felspar crystal. Slice No. 3.

Fig. 4. Ditto.

Fig. 5. Ditto.

Fig. 6. Ditto.

Fig. 7. Skeleton crystal of felspar which has, owing to rapid cooling, enclosed a portion of the base. Slice No. 3.

Fig. 8. Intergrowth of augite and felspar. Slice No. 3.

Fig. 9. Ditto.

Fig. 10. Enclosure of the base by a skeleton crystal of felspar. Slice No. 4.

Fig. 11. Intergrowth of augite and felspar. Slice No. 3.

Fig. 12. Enclosure of glassy base by skeleton crystal of felspar. Slice No. 4.

On the microscopic structure *of some* sub-Himalayan rocks *of tertiary age, by* COLONEL C. A. MCMAHON, F.G.S.

No. 1.—A fine-grained sandstone of the Sirmur series, containing a fossil leaf, found by Mr. Medlicott south-east of Chune, on the Ravi. The following note on this specimen is taken from the Records of the Survey of India, Vol. IX, p. 52:—"In this very crushed, probably inverted, outcrop I found a characteristic sample of the Kasauli plant bed, the only occurrence of it known west of the Sutlej."

M.—The grains of quartz in this slice are nearly all angular, and only a few here and there are subangular.

Grains of granular limestone are numerous, and one fragment of felspar is present. Leaves of biotite (?) and muscovite are to be seen here and there, and are evidently original constituents of the rock and were deposited along with the sand. The leaves of mica are bent round and conform to the external shape of the grains between which they are jammed. The sand of our Panjab rivers is full of fragments of mica.

The slice contains some green dichroic grains that may have resulted from the degradation of trap. It also contains fragments of garnet and of schorl.

The interstitial mud has been converted into a crypto-crystalline material.

I have only detected liquid cavities, with movable bubbles, in one grain of quartz. The bubbles are extremely small ones.

Specimens of fine-grained sandstones from Bhond.[1]

No. 2.—This specimen closely resembles the last described. It contains fragments of schorl, muscovite, and green mica. Grains of calcite are present, but they are not so abundant as in the last. There are some micro-garnets and a little hæmatite. I have observed no liquid cavities in the quartz.

No. 3.—The same as the last. The slice contains four minute fragments of plagioclase. Calcite is sparce, and the quartz contains no liquid cavities with bubbles.

No. 4.—This specimen is very similar to the preceding ones. It contains more calcite than the last and more argillaceous material. It contains neither schorl nor garnet, but liquid cavities with movable bubbles are present in the quartz.

No. 5.—The grains of quartz are in angular fragments closely dovetailed together. The interstitial mud which occurs in patches is dark between crossed nicols showing doubly refracting fibres scattered about in it, apparently of felspathic material.

The slice contains some grains of schorl and fragments of green mica and muscovite. Some of the grains of quartz contain liquid cavities with movable bubbles.

In this, and one of the previous slices, a quartz grain contains a microlith with an internal shrinkage cavity,—a circumstance that indicates an igneous

[1] Records XVI, p. 35.

origin and shows that the grain of quartz was derived from the waste of granite or similar rock.

No. 6.—This slice consists of fragments of quartz and a muddy cement converted into a crypto-crystalline material; it contains fragments of schorl, muscovite, green mica, calcite, and one of garnet. There are patches of chloritic material here and there.

Some of the quartz grains contain liquid cavities with movable bubbles.

Red clays—Bhond.

No. 7.—This consists of angular pieces of quartz and fine fragments of muscovite imbedded in very fine red mud. Patches of hæmatite are present here and there.

No. 8.—Much the same as the last specimen. There is less mud and more fine-grained siliceous material and more white and green mica. The slice is of somewhat variegated colour owing to the presence of dark and clear irregularly defined bands.

In one of the quartz grains I detected liquid cavities with small movable bubbles.

No. 9.—Much the same as No. 7. Muscovite is more sparse, and I have not detected any liquid cavities in it.

Kasauli sandstones.

No. 10.—This slice consists of angular fragments of quartz and patches of consolidated mud; it contains pieces of schorl, leaves of silvery and of a yellowish-green mica; also a piece of triclinic felspar; a few small garnets and a fragment of a larger one.

Some of the quartz grains contain movable bubbles, but they are small and sparce. One grain of quartz contains a microlith of hornblende, in which are numerous grains of opacite and several enclosures with fixed bubbles in them. Another quartz grain is full of transparent hair-like belonites. This specimen contains no calcite.

No. 11.—This slice greatly resembles the last. It contains muscovite, a reddish-brown mica, schorl, numerous large pieces of garnet, a little granular calcite, a fragment of epidote and fragments of a carbonaceous slaty rock. The muscovite is in good-sized leaves.

Some of the grains of quartz exhibit a polysynthetic structure, whilst others contain microliths of muscovite similar to those so characteristic of the gneissose granite of the North-West Himalayas. There are some fragments of crypto-crystalline mica (another characteristic of the gneissose granite) and a grain of fibrous felspar (a form of microcline,—see Records XVI, 131).

There is a small fragment of triclinic felspar and, I think, of decomposed orthoclase.

Some of the quartz contains liquid cavities with movable bubbles.

Bakloh sandstones.

Nos. 12 and 13.—These slices consist of angular and sub-angular grains of quartz set in mud. The quartz is not very clear or pellucid, being here and there.

milky and opaque; and some of the grains exhibit a polysynthetic structure. The earthy portion is stained yellow with oxide of iron, and here and there brown dots appear which are probably limonite.

No calcite or mica is present, but there are a few small fragments of a dichroic mineral that may be schorl.

No. 12 contains cavities with bubbles, but not movable ones.

No. 14.—This rock so closely resembles the Kasauli sandstone that a separate description is unnecessary. Schorl, a small garnet, and a little felspar are present in the slice. The quartz contains liquid cavities with movable bubbles and stone cavities with fixed bubbles and mineral deposits. Muscovite is sparce.

Dagshái sandstones.

The specimens described below were taken from the side of the Simla cart road facing Dagshái.

Nos. 15, 16, and 17.—These are seen under the microscope to be composed of fragments of quartz and of slaty rocks, some of which appear to be carbonaceous. Fragments of well crystallised calcite and of schorl are also present. Each slice contains a few pieces of triclinic felspar, one of which includes microliths of muscovite. Leaves of muscovite and a yellowish-green mica are abundant.

One of the grains of quartz has crypto-crystalline mica attached to and penetrating it. It has all the appearance of being a fragment of the gneissose granite. There are also separate fragments of the crypto-crystalline mica. Some of the quartz grains are polysynthetic.

A few small garnets are present, and liquid cavities with movable bubbles are abundant in the quartz.

Siwalik series (Nahan beds ?), Naini Tál road.

Nos. 18, 19, and 20.—These consist of angular pieces of quartz, bits of slate, and a little mud, the quartz predominating. Leaves of muscovite and a greenish mica and fragments of schorl are present in the slice. Some of the quartz grains contain microliths of muscovite similar to those contained in the gneissose granite. Some of the quartz is milky and opaque, and none of it is particularly hyaline.

Liquid cavities are numerous in the quartz, but those with bubbles are comparatively sparce.

Nahan sandstone—Nalagarh.

No. 21.—This slice consists of angular and sub-angular grains of quartz, quartzite, slate, limestone, schistose rocks, and kaolinised felspar, cemented together with mud. Some of the slate appears to be carbonaceous.

A good many of the grains of quartz are of polysynthetic structure similar to the fish-roe grains of the gneissose granite. The slice contains a fragment of triclinic felspar and a few of the foliated variety of microcline. Much of the quartz is milky and opaque; muscovite is present and also a few fragments of schorl.

Liquid cavities with movable bubbles are numerous in the quartz; also air cavities.

Nahan sandstone—Mailog.

Nos. 22 and 23.—These specimens are composed of angular grains of quartz imbedded in fine mud of greenish colour. The slices contain fragments of schorl and the quartz liquid cavities with movable bubbles.

Siwalik (?) sandstone. Dhár.

The undoubtedly Siwalik sandstone of the outermost range is too friable to admit of slicing, but except in induration it seems lithologically identical with the Dhar rock.

No. 24.—This slice very much resembles No. 21 in its general appearance under the microscope and in the nature of its contents. Both contain fragments of red quartzite, green schists containing magnetite that remind me much of hornblendic beds near Shiel, in the Jubal State, beyond Simla; and fragments of a rock that looks like a decomposed amygdaloid. No. 24 differs from No. 21 in containing fragments of a pink garnet, flesh-coloured in transmitted light. Muscovite is present in large leaves in No. 21, but in No. 24 no mica is present, except in the form of microliths in the quartz. No. 24, moreover, does not contain any "fish-roe" quartz.

Both rocks under the microscope are generally so similar, that if they do not represent the same beds, at any rate, some of the rocks that were exposed and in process of erosion when the Nalagarh beds were laid down must have been in process of erosion when the Dhar beds were deposited.

The slice under description (24) contains a doubly refracting mineral that appears to be schorl.

The garnets are full of air cavities; whilst liquid cavities with large movable bubbles are abundant in the quartz.

Conclusion.

A microscopic examination of the fine-grained earthy sandstone containing a a fossil leaf found by Mr. Medlicott in the Sirmur horizon on the Ravi, and of the beds trans-Ravi at Bhond, and of some of the beds under Bakloh (in which fossil leaves have also been found); and a comparison of these rocks with a thin slice of a typical Kasauli bed leave no doubt in my mind that the Kasauli leaf beds continue into the Dalhousie area.[1] Their position, in the Dalhousie region, appears to be near, but not on, the northern boundary of the outcrop of the Sirmur series.

The Kasauli leaf beds, in which name I include all those alluded to in the last paragraph, are composed of very fine-grained angular fragments of quartz, grains of calcite or granular limestone, fragments of carbonaceous slaty rocks, and consolidated mud. Leaves of muscovite and of a greenish mica—evidently original constituents of deposition—are squeezed between the grains of quartz;

[1] I have some very perfect fossil leaves imbedded in an exactly similar rock found by Mr. C. J. Rodgers at Dharmsala and given me by that gentleman.

whilst either minutely triturated fragments of mica are mixed up with the mud, or a portion of the latter has been converted into that mineral. The former explanation seems the more probable one.

Taking the specimens of the Sirmur series described in the preceding pages as a whole, they appear to have had their origin in the subaerial waste of the carbo-triassic limestones, infra-carboniferous slates, granitic rocks, and probably to a small extent of traps. The evidence afforded by the Sirmur sandstones on the latter point, however, is feeble.

A prominent feature in most of the slices is well crystallized or granular limestone, in fragments that have all the appearance of having been deposited with the other constituents of the rock. They are all isolated fragments; there are no veins or connecting links between them, and nothing to support the supposition that they have been formed by an epigenital process after the consolidation of the sandstone. I can only regard these as fragments of limestones, and I think the inference a natural one that the carbo-triassic series was exposed at the surface and was suffering denudation when these tertiary sandstones were formed. We know on other evidence that in the Simla area these limestones were deeply eroded by subaerial agencies[1] in pre-tertiary times.

The presence in these sandstones of fragments of carbonaceous slaty rocks that would answer well for the infra-Krol series also supports this view.

But infra-Krol and Krol rocks were evidently not the only ones that were suffering denudation in the Himalayan area when the Sirmur series were laid down. The presence of schorl, of a type characteristic of granitic rocks; of fragments of garnet, a mineral very abundant in such rocks in the North-West Himalayas; of muscovite and a dark green mica; of triclinic felspar, and of the fibrous variety of microcline, taken in connection with the character of the quartz grains, indicates, I think, clearly enough, that granitic rocks were also exposed at the surface and were suffering denudation when the sandstones were formed.

The schorl and muscovite I should say undoubtedly came from granitic rocks; the former is of the type characteristic of such rocks, and does not resemble the tourmaline found in the silurian sandstones of the Dalhousie area.

Garnets might of course be derived from a variety of rocks, but at the same time it must not be forgotten that this mineral is abundantly present in the granites and gneissose granites of the Himalayas.

But the character of the quartz is the most important point in connection with the subject under consideration. Liquid cavities with movable bubbles are abundant in many grains; in quite as large a proportion of grains as one could reasonably expect on the supposition that they were derived from Himalayan granitic rocks. Then we have grains containing microliths with shrinkage cavities in them, exactly similar to those found in our Himalayan granites; and in No. 10 we have a hornblende microlith containing several enclosures with fixed bubbles in them; whilst in No. 14 we find quartz grains containing stone cavities with fixed bubbles, and mineral matter either deposited by the mineral material of the "stone enclosure" on cooling, or caught up by it in the act of consolidation. All the above are eminently characteristic of granitic

[1] Manual, pp. 533, 569.

rocks and could be matched, over and over again, in the granites and gneissose granites of the Himalayas.

Other points to be noted are that some of the quartz grains exhibit a poly-synthetic structure, and that both quartz and felspar contain microliths of muscovite; whilst Nos. 15—17 contain fragments of crypto-crystalline mica, and a quartz grain penetrated by crypto-crystalline mica. The study of the granites and gneissose granites of Dalhousie and the Satlej valley, under the microscope, has shown that polysynthetic quartz, microliths of muscovite in quartz and felspar, and crypto-crystalline mica are very characteristic of these rocks.

On the whole, then, I cannot doubt that much of the material of the Sirmur sandstones were derived from the waste of granitic rocks.

The comparative paucity of felspar may I think be explained by the fact that this mineral is not so hard as quartz, schorl, or garnet, and consequently must have suffered more than these minerals from trituration. It is moreover very liable to decomposition, and doubtless it was the felspar that suffered most in the passage of granitic detritus down the Himalayan streams and rivers, and supplied a considerable proportion of the constituents of the mud that forms the binding material of the sandstones. The felspar suffered more than the lime-stones, because, I presume, it had to travel further, and came from the axial ridges of the Himalayas, whilst the limestones were nearer home.

Mica is soft, but is very indestructible; and its very lightness and buoyancy in water doubtless preserved it from injury by the way.

Another question remains, namely, were the granitic materials derived directly from granitic rocks, or were they first deposited in ancient clastic rocks and supplied to the Sirmur sandstones on the breaking up of those rocks?

I do not think the latter supposition a probable one. The schorl and garnets are very fresh, and had they lain for long geological periods in ancient clastic rocks before they found a resting place in the Sirmur sandstones, I think they would have shown considerable signs of alteration or have been transmuted into other minerals that result from their degradation.

Assuming then that the granitic materials were directly derived from granitic rocks, the important question arises, were they derived from rocks now visible or from some others?

It does not seem probable that any granitic rocks can have been exposed in the Sirmur sandstone age other than those now visible. It is conceivable that some old intrusive sheets may have been removed by erosion, but they must have left their roots behind in any case.

That rocks of very similar appearance to the gneissose granites described in a previous paper, and which I regarded as of tertiary age, must have been exposed in silurian times, is clear, for the upper-silurian conglomerate contains boulders of granitoid gneiss. Samples of these boulders have not as yet been subjected to a critical examination in the laboratory, and it would be premature to express any decided opinion regarding the character of this granitoid rock; but whatever it may turn out to be, there seems to be no reason why we should suppose that granitic intrusions into the Himalayan area took place during one period only, or that they were limited to the special Himalayan disturbances of post-eocene times.

If these eruptions began in pre-tertiary or early tertiary times, the fact that gneissose granite had come to the surface and was suffering erosion when the Sirmur series were deposited presents no difficulty.

That the gneissose granite was already exposed when the Siwalik conglomerates were laid down, does not admit of a reasonable doubt, for the conglomerates are full of boulders of a rock undistinguishable from it; and the Siwalik conglomerates afford internal evidence of being derived from local sources.

In my paper on the microscopic structure of the Dalhousie gneissose granite (*supra*, p. 143) I spoke of this rock as of probably tertiary age and said that it was probably "brought into its present position in the course of the throes that gave birth to the Himalayas." Whilst I adhere to that statement, I desire to point out that it is not necessary for us to assign a late period in the tertiary age for the invasion of silurian beds by a hypogene rock of this character; or indeed to pin ourselves down to the tertiary period at all. The facts disclosed in this paper would harmonise better with the supposition that the eruption of the gneissose granite took place at a somewhat earlier date than that usually assigned to the beginning of the last series of special Himalayan disturbances.

It has been shown in the Manual of the Geology of India (pp. 525, 569-570) that the disturbing action proceeded with great slowness; that the Himalayan river gorges in Siwalik times were the same as now; that the sea was probably excluded from the sub-Himalayan region from early tertiary times; that elevation preceded compression; and "before any special contorting action had set in, the general condition of sub-Himalayan deposition had been established by a general (continental) elevation of the Himalayan area."

The Krol (carbo-triassic) rocks in the Simla area were deeply denuded by subaerial agencies (Manual, pp. 533-569) before the eocene nummulitics were laid down, and the Sabathu beds are "very variable in thickness suggesting a limit of deposition to the north-east." In other words, the Krol area in the Simla region was above water and formed dry land in pre-tertiary times; and if so, it seems only reasonable to suppose that the central axis of the Himalayas, if not throughout its whole length, had also, in part, at any rate, risen from the sea and formed more or less elevated land in pre-tertiary times, and so we find it stated in the Manual, page 571, that "a considerable Himalayan elevation occurred in pre-tertiary and early tertiary times."

The process of elevation doubtless was a slow and gradual one and extended over a lengthened period; but the "continental elevation" of the Himalayan area during a pre-tertiary period is just as likely to have been accompanied with hypogene granitic invasion of deep-seated rocks below the surface, as the subsequent period of special disturbances which took place during the tertiary period.

Whilst therefore I hold that the invasion of silurian rocks by gneissose granite was connected with the elevation and formation of the Himalayas, and think it probable that, in the Dalhousie area, the eruption of the gneissose-granite took place at the close of the eocene, or early in the miocene period; at the same time, I do not see that we need necessarily associate the eruption of all the gneissose granite of the North-West Himalayas, or indeed any of it, with the latest phase of the special disturbances which began in post-eocene times.

Note on the Geology of Jaunsar *and the* Lower Himalayas, *by* R. D. OLDHAM, *Geological Survey of India.* (With a map.)

1. The last season's work in the Himalayas having shown that the series as adopted ever since the publication of Mr. Medlicott's Memoir on the Lower Himalayas [1] requires some modification and extension to make it applicable to portions of the Lower Himalayas lying outside of the Simla section, it has been thought advisable to publish a short note showing the results of the resumed survey as far as it has gone; but while confining myself as far as possible to what may be said to be definitely proved, it will be impossible to steer clear of other points still doubtful, and these, which I shall distinguish to the best of my ability, must be taken with every necessary reservation.

2. One of the chief difficulties when starting work in Jaunsar, a district chosen chiefly on account of the fact that large scale maps were obtainable, lay in the fact that, with the exception of a great limestone series reasonably identified with the Krol, no representative of any of the sub-divisions established on the Simla section was to be recognised.

3. The oldest formation here, which I shall provisionally call the Chakrata series, consists of grey slates and quartzites, underlaid by a band of limestone generally some 300 or 400 feet thick, which is again underlaid by a great series of slates and quartzites marked by the prevalence of red and mottled beds. The principal exposures of the limestone lie in a zone running about east and west, and passing immediately to the south of the station of Chakrata; to the north of this zone the hills are formed of the underlying red Chakrata slates and quartzites, while to the south the upper grey slates are exposed, notwithstanding the prevailing northerly dip of the beds. This is but part of the great Himalayan puzzle, that newer beds almost always seem to dip under older, that faults are generally reversed, and that the dip of the beds in their neighbourhood is precisely the reverse of what would be expected on *à priori* grounds. The total thickness of these beds is indeterminable, partly on account of their intense disturbance, and partly from the fact that neither their base nor summit has been seen, but it must amount to many thousands of feet.

4. In northern Jaunsar there is another exposure of the same beds intersected by a great fault which, first appearing from underneath the Deoban limestone near the village of Konain, runs north-westwards to Mudhaul, on the west of the Tons, and which I shall refer to as the Konain-Mudhaul fault.

5. To the east of this fault there is exposed a great thickness of grey slates and quartzites, over which comes a band of blue limestone 300 to 400 feet thick, and over this white and coloured quartzites with interbedded red and grey slates; and near Kanda, what appear to be contemporaneous, but may be intrusive, beds of trap, overlaid by greenish slates, which last are covered unconformably by the Deoban limestone. Among the quartzites there is, near Kanda, a band of coarse quartzite conglomerate about 8 feet in thickness, which has been marked

[1] Mem. G. S. I., Vol. III, pt. 2.

on the map illustrating Colonel McMahon's paper[1] as Blaini; but the associated beds and the absence of the characteristic limestone seem to render this impossible.

6. To the west of the fault the section as seen on the ascent from Anu[2] to Bana is first white quartzites with interbedded green and grey slates, overlaid by green and grey slates without quartzites and these again are capped at Chajar (Chilar) by a small patch of blue limestone, which can hardly be anything but the same that is exposed near Kanda, and which I correlate with the Chakrata bed. The only other thing it could well be is the Deoban, but though on the upthrow side of the Konain-Mudhaul fault so far as it affects the Deoban limestone, it is at a lower elevation than the base of the latter as exposed above Banu on the eastern or downthrow side.

7. Here, whether the limestone band be identified with the Chakrata bed or no, there seems to be an inversion on one side or other of the fault, probably to the east, and it is evident that the fault must have a throw sufficient to bring the same bed on either side of the fold to about the same level; it is at present impossible to say for certain which is the up and which is the down throw side, nor to determine, even approximately, the throw of the fault, but it must certainly be measured by thousands of feet.

8. In several parts of Jaunsar volcanic beds are exposed in the Chakrata series; to the east of Chakrata, in the valleys of the Kutnu and Mord gadhs (stream), there are several beds of volcanic breccia and ash lying both above and below a thick band of blue limestone identifiable with great probability as the Chakrata band; near Lauri the same limestone again crops out and is once more associated with the volcanic beds, which are also seen in the valley of the Gamgadh.

9. In the Tons below Anu there are exposures of a brown ferruginous and dolomitic limestone, passing into crystalline ankerite in places, which I have conjecturally correlated, notwithstanding its lithological difference, with the Chakrata limestone. The volcanic beds associated with it are here far more extensively developed than I have seen elsewhere in Jaunsar and I consider that the peculiar nature of the rock is due to a contemporaneous admixture of volcanic detritus, a supposition which is supported by the facts that the southernmost of the exposures as it is traced eastwards becomes less and less ferruginous, till near its disappearance it is in parts a blue limestone little if at all more impure than the normal Chakrata limestone, and that on the western side of the Tons valley above Anu there is an exposure of presumably the same band which, while being in parts a bluish-grey limestone, is also in parts extremely ferruginous. The facts just mentioned seem to point to a centre of volcanic energy shortly to the west or south-west of the confluence of the Binalgadh with the Tons, while the volcanic beds of eastern Jaunsar were very possibly derived from a vent in what is now Tiri-Garhwal.

[1] Rec. G. S., Vol. X., 204. [This outcrop was mapped by me, not by Colonel McMahon; I only crossed the ground once, when marching with Dr. Oldham from Mussooree to Simla in 1860.—H. B. M.]

[2] Misprinted *Dnu* in the map.

10. This zone of volcanic beds promises to be a horizon of great value in tracing out the geology of the Lower Himalayas, and it may not be out of place to indicate the probability of their being contemporaneous with the silurian volcanic rocks of Kashmir and the North-West Himalayas. At the same time I must point out that it is not absolutely certain that they are of the same age as the Chakrata limestone; for although the limestone with which they are associated occurs in a similar position to, and is most probably the same as, the Chakrata bed, yet it must not be forgotten that in the typical area no associated volcanic beds were seen.

11. Overlying the Chakrata series comes a great thickness of limestones and dolomites so similar to the Krol series as to be almost certainly contemporaneous with it, but which, as its relation to the underlying beds is very different to what has been described on the Simla section, I shall provisionally call the Deoban limestone. Lithologically it consists of a great thickness of bluish-grey bedded limestones, some of the beds, as on the ascent to Deoban from Chakrata, containing many nodules of chert; others which are generally mephitic have a peculiar pisolitic structure, being composed of small round black nodules cemented by a white calcareous matrix: a peculiar structure seen in some of the beds makes them resemble an accumulation of some closely-chambered shells imbedded in a matrix of calcareous mud, and so organic looking that it is difficult to believe that they are not obscured fossils. A very considerable proportion of the beds is in some of the sections dolomitic, varying from a slightly magnesian limestone to a pure pale-grey crystalline dolomite. Interstratified with these calcareous beds is a varying proportion of slaty beds, occasionally coloured, but as a rule grey.

12. This series is quite unconformable to the underlying Chakrata beds, as is proved by its unconformably overlapping or overstepping their eroded edges. This is very well seen near Konain, where the Deoban lies on the Chakrata limestone while as the boundary is traced to the west it is seen to rest successively on a (locally) descending series of slates; the unconformity is further indicated by the way in which the limestone rests, above Kanda, on the eroded edges of the presumably inverted Chakratas, and by the fact that the Konain-Mudhaul fault which, as above explained, has a throw of some thousands of feet in the older rocks, has, where it cuts the Deoban limestone, a throw of a few hundreds at most, this being due to a later movement along the original fracture; it would serve no useful purpose to describe every junction of the two series, as the same facts are everywhere to be seen.

13. It is evident that this is very different to what has been described on the Simla section,[1] and there are but three possible explanations—1*st*, that the Deoban and Krol limestones are not contemporaneous; 2*nd*, that the junction on the Simla section is only apparently and locally conformable; 3*rd*, that the Chakrata series is older than the Simla slates and underlies them unconformably. The first supposition may, I think, be dismissed; the second I regard as very probable, the very sudden variations in the thickness of the Krol quartzite pointing to a

[1] H. B. Medlicott: Mem. G. S. I., Vol. III., *passim*, and Manual, pp. 594-609.

possible unconformity between it and the Krol limestone; the third is also possible; but if the volcanic beds of Jaunsar are really of upper-silurian age, there is hardly room for the whole of the sequence between these upper-silurians and the (at latest) triassic Krol limestone. At present sufficient facts are not at my disposal to enable me to say which of the latter two hypotheses may prove correct, but the question depends very much on the nature and amount of the disturbance of the Chakratas anterior to the deposition of the Deoban limestone. The inversion at Kanda may have been a purely local feature, the Chakratas having been elsewhere comparatively undisturbed at the time of deposition of the Deobans—in that case the second supposition may be correct, and the Chakrata beds either representatives of, or forming part of a conformable sequence in, the rocks below the Krol; but if it should ultimately prove to be merely part of a widespread disturbance, the third hypothesis alone remains possible.

14. Above the Deoban limestone comes a series of beds mostly conglomeratic, first identified by me in the neighbourhood of the Mandhali forest bungalow, after which I propose to call them, at any rate provisionally. They consist of conglomerates mostly with a slaty matrix through which pebbles of quartzite slate or limestone are scattered, though some and in southern Jaunsar the majority of the beds are not conglomeratic at all, others are coloured slates not unlike indurated Sirmurs, and others again are calcareous; of the latter, some are fine-grained limestones, others, though this I have only seen near to Mandhali, are limestone conglomerates cemented by a limestone matrix. The presence of these pebbles derived from the underlying Deoban limestone is sufficient to stamp the beds containing them as unconformable to it. In southern Jaunsar, in addition to the limestone conglomerate with slaty matrix, which is not found in every exposure, the characteristic rock is a quartz grit containing fragments of indurated red slate derived from the lower Chakrata beds.

15. The facies of the Mandhalis is essentially littoral, or shallow water, as is testified to by their coarseness of grain, while the conglomerates with a slaty matrix, so similar to those of Blaini age, could not have been formed except through the agency of floating ice; but it is not a little remarkable that, notwithstanding their evidently shallow water origin, there is hardly an exposure which does not exhibit one or more beds of pure limestone: this association of littoral beds with limestone is well seen on the cart road to the north of Kalsi; where a thick band of limestone is bounded on both sides by coarse-grained quartz grits.

16. Outside of Jaunsar I have detected these same beds, to the east in great force near Naini Tal and Bhim Tal, and to the west, in the Giri valley, I saw in 1881 some conglomerates, which at the time puzzled me not a little, but which I cannot now hesitate to refer to Mandhali age.

17. As regards the homotaxy of the Mandhalis, they are later than the Deoban, and are evidently of earlier date than the main disturbance of the Himalayan rocks; so much so that in the limestone area of northern Jaunsar, the small patches that have been left owe their preservation entirely to having been caught up in the folds and faultings of the limestone, and in this way preserved from denudation. They consequently occupy a position analogous to that of the Sirmurs to the northwest, and at first one would be inclined to correlate them

with the last-named rocks and assign to them an early tertiary age. However, the fact that nummulitics of normal type are to be found near Rikhi Khes in Garhwal[1] taken in conjunction with the extent of the Mandhalis, is against this supposition, which, too, it is impossible to reconcile with the finding of characteristic Mandhalis in the Giri valley, within a few miles of the boundary of the Sirmurs, in which no similar rock is to be seen. They must therefore be of pre-tertiary age, for there is no room in the sequence for them to come after the Sirmurs.

18. Above the Mandhalis are two series of rocks, of which, as they occupy totally distinct areas, it is impossible to say which is the older. Of these one is the Nahan; but as it occupies a very small area in the extreme south of Jaunsar, and as it presents no peculiarities, it may be dismissed without further notice.

19. The other series merits attention, as it presents an unsolved and apparently unsolveable problem. In north-eastern Jaunsar, occupying a considerable tract of country is a series of fine-grained glassy quartzites with interbedded schists, some of the beds containing granules of blue quartz, which in the Tons descend to the level of the river, but southwards merely cap the ridges; they lie almost undisturbed and nearly horizontal on the eroded edges of the intensely disturbed older rocks, and are evidently far newer than any of the other formations in Northern Jaunsar, or Bawar as it is locally called; yet, though so much newer and so much less disturbed, the rocks are far more metamorphosed than those of the older series, the siliceous beds being everywhere converted into glassy quartzites, and the argillaceous bands being, in Bawar, uniformly schistose, while across the Tons, in Garhwal, they occasionally become almost gneissose. I propose to call this the Bawar series.

20. As the Bawars are evidently of much later date than the main disturbance of the rocks, which in the Simla section has been shown to be of post-eocene date, they would seem to be referable to a middle or upper tertiary age; but it is difficult to suppose that rocks so metamorphosed can be contemporaneous with the soft sandstones of the lower or the loose shingles of the upper Siwaliks, and besides there are very strong reasons for believing that even in Nahan times the Himalayas existed as an elevated tract subject to denudation; nor is there any similarity between the Bawar and Nahan rocks even where the latter have been metamorphosed by igneous intrusions. It is however possible that these Bawars may be of lacustrine origin and contemporaneous with the Nahans,—a supposition supported to some extent by the extremely small development of the Nahans at the debouchure of the Tons and Jamna rivers, and by the fact that the Bawars so fine grained to the south of the Tons become near their summit, in Garhwal, coarsely conglomeratic. When more information has been collected, these difficulties may doubtless be cleared up, but the improbability of ever finding any fossils in these rocks is a serious hindrance.

21. The glacial epoch has left its traces in Jaunsar, though I know of no traces of actual glaciers to the east of the Tons. Above Kistur there are what might at first sight be taken for terminal moraines, but a more detailed examination

[1] Mem. G. S. I., III, pt. 2. p. 90; and Manual, p. 535.

banishes the idea; the only deposits that can be referred to this epoch are the high-level gravels to be seen in most of the valleys but most distinctly in that of the Seligadh where, as can be seen from the Chakrata and Mussoorie road, they form broad gently-sloping terraces on the valley sides; the slope of the surface is more rapid than that of the present bed of the stream, being over 800 feet above the latter at Makhata while near the junction with the Jumna the difference in level does not exceed 100 feet; in the small lateral valleys the slope rapidly increases, so that sometimes the gravel deposits run almost up to the crest of the water-shed. These gravels have been formed since the Seli valley was cut down to its present depth, as is shown by their extending in places right down to the present level of the stream; they could not have been formed under existing circumstances, for apart from the angularity of the fragments of which they are composed and the slope of their surface the peculiar parabaloidal curve of the surface up the lateral valleys is totally different to what is now being formed anywhere in the lower-Himalayas, but could only have originated when the balance of disintegration and precipitation was very different to what is now the case; disintegration must then have been so rapid that the streams could not dispose of the debris which was shed from the hill slopes, the valley was consequently filled by a deposit whose surface had a comparatively gentle slope in the main valley where the volume of the stream was greater, while in the lateral valleys, where the amount of debris was comparatively greater, the slope increased till it reached the angle of repose. It is needless to expatiate on the fact that this increased disintegration can under the circumstances only be attributed to a more rigorous climate, frost being the great disintegrator in these latitudes.

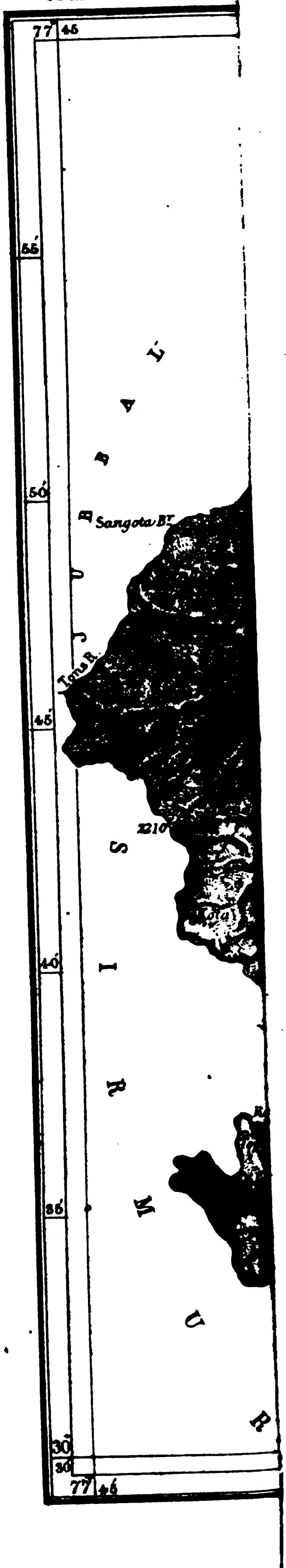
Notes on a Traverse through the Eastern Khasia, Jaintia, *and* North Cachar Hills *by* TOM. D. LATOUCHE, B.A., *Geological Survey of India.*

The object of my season's work was to search for coal and iron within reach of the proposed line of railway from Silchar to the Brahmaputra valley through the North Cachar hills. From what was already known of the ground (Mem. G. S., Vol. IV., pt. 3, 1865) there seemed to be little or no prospect of success, and so it has turned out.

Arriving at Cherra Poonjee about the middle of December, I spent a few days in examining the area mapped by Mr. Medlicott in 1871 (Mem. G. S., Vol. VII., p. 151) so as to familiarise myself with the rocks in it. I then marched across the Jaintia hills to the North Cachar hills, visiting the coal-field of Lakadong on the way.

1. *Lailangkot to Jawai.*—Leaving the village of Lailangkot, which is situated on the boundary of the Shillong series and the granite area of Molim, by the old road to Jawai, Shillong quartzites and granite are passed over alternately for the first 5 miles, there being three exposures of granite extending across the road to the south-west, and probably connected with the main area to the north. The quartzites are vertical, or dip at very high angles with a general strike from

Oldham:



north-east to south-west. The last exposure of granite is about 1 mile to the south-west of Rableng hill. This hill consists of Shillong rocks, which extend without a break to the Mantedu at Jawai, the strike being generally between north and north-east but bending round to east-north-east between the Mangat (the boundary of the Jaintia hills) and the Mantedu. In this direction also the rocks become more schistose, several beds of fine-grained hornblende schist occurring in the valley of the Umthungpha, about 1 mile above its junction with the Mantedu. At the top of the hill to the east of the Mangat, near the village of Simunting, is a small outlier of cretaceous rocks.

Beneath the village of Jawai the schists and quartzites are capped by patches of cretaceous conglomerates, forming low hills in and about the villages; the bedding in these is horizontal.

2. *Jawai to Lakadong.*—Turning south from Jawai along the Jaintiapur road, Shillong rocks extend to the summit of the hill south of the Mantedu, where they are capped by fine cretaceous sandstones forming low scarped hills on either side of the road. Near the 5th milestone from Jawai the border of a small area of granite is passed on the right-hand side of the road, extending to the south-west. The road then runs round the south flank of a hill of cretaceous sandstones to the Mankajai, in the valley of which a broad dyke of trap occurs. This is a coarsely crystalline, dark-coloured rock with a rather metallic lustre and weathering red, and is entirely composed of augite and titaniferous iron. Cretaceous sandstone again appears in the scarp to the south of this valley, coarse at the base and becoming finer towards the top. These rocks continue to and beyond Jarain, forming an undulating plateau with slight inclination to the south.

Coal at Jarain.

At Jarain coal occurs in these rocks, and has been worked to a small extent to supply the dâk bungalows here and at Jawai. A seam crops out on both sides of a gully close to a small bridge on the road to the south-east of the village, and is about 3 feet thick, overlaid by about 12 feet of hard, fine-grained sandstone. It has the usual characteristics of the cretaceous coal of these hills. Another outcrop occurs at about 1½ miles to the north-east of the village and 1 mile from the road, in a small stream running into the Um Pliang, a tributary of the Mantedu. The seam is well exposed, the stream flowing over it in a low fall. It is 3 feet 6 inches thick, with fine-grained sandstone above and below. This coal contains a good deal of pyrites in small nests, and at the base of the seam the rock is covered with a net-work of this mineral, so that the coal would be of very little value.

Turning off to the south-east from the Jaintiapur road in the direction of Lakadong, the path passes by Amlittshor village over the plateau of cretaceous rocks deeply indented on either side by tributaries of the Mantedu until the gorge of this river is reached. This gorge is here about 1,000 feet deep.[1] The cretaceous rocks extend on both sides of the gorge to about 300 feet from the top

[1] Unfortunately my aneroid was out of order, so that I was unable to measure exactly the depth of the gorges crossed in this part of the hills.

and rest directly upon metamorphic rocks, which extend on both sides to the bottom. These rocks are similar to the metamorphics found on the north slope of the hills.

From the top on the opposite side an undulating plateau of cretaceous rocks extends for about 4 miles to the village of Shushen, which is situated on the edge of the gorge of the Lauriang, about 3 miles above its junction with the Mantedu. Cretaceous rocks extend to a few hundred feet from the top on this gorge also, resting on metamorphics, and appear at the same level on the opposite side beneath the village of Batao. These rocks extend to the hill on which Lakadong stands, about half way up which nummulitic limestone occurs, overlaid by sandstone with coal.

Lakadong coal.

The coal workings here appear to be in much the same state now as at the time of Dr. Oldham's visit in 1853 (Sel. Rec. Ben. Govt., No. XIII., p. 45), as since then very little coal has been extracted. The different holes have been driven into the coal as far as is possible without having to support the roof with timber, and the expense of this, together with the increased cost of labour and of carriage to the plains, in 30 years, would probably prevent the coal being worked with profit at the present time. The headman of the village told me that 500 maunds had been extracted last year, and sent down to the plains, but he could not tell me what the cost of extraction and carriage was.

3. *Lakadong to Nokhara.*—To the north of Lakadong on the path to Umrasiang cretaceous rocks forming low scarped hills extend to the gorge of the Saichampa, about half way down which metamorphic rocks appear and a similar section is seen on the opposite bank. The lowest cretaceous beds here are ferruginous sandy clays. Close to Umrasiang village I observed a circular pit, with perpendicular sides in the sandstones, 50 or 60 feet deep, and as many in diameter, probably due to the washing away of the clays beneath through a fissure and the consequent falling in of the sandstones above. The cretaceous rocks continue to a hill about 2 miles east of Umrasiang, near the top of which nummulitic limestone forms a steep scarp to the north. This hill is flat-topped, consisting of sandstones similar to those at Lakadong, but without any traces of coal till near the village of Nokhara, where there is a seam 1 foot thick resting on carbonaceous shale, but of no great extent. To the south the ground falls gradually to the edge of the streams running into the Lubah, where limestone again appears. In many places near Nokhara I noticed large funnel-shaped hollows, 30 or 40 feet deep, caused by underground denudation of the limestone.

4. *Nokhara to Kampat.*—Proceeding to the north from Nokhara on the path to Satunga after descending the limestone scarps to the north, a small outlier of limestone is passed near the village of Umluper. To the north of this the plateau is much more broken than to the west as far as the Laterkap river, in the gorge of which metamorphic rocks occur again. Near the village of Nongtoma (not marked on the map, but about 2 miles to the south of the Laterkap) I passed a funnel-shaped hollow similar to those at Nokhara, but could not find any limestone below it. To the north of the Laterkap cretaceous

rocks extend without a break to Satunga, where they contain a seam of coal.

Coal at Satunga.

Its outcrop is seen at the head of a small ravine to the north of the village. A vertical section, in descending order, is as follows:—

	Ft.	In.
Sandstone and shale, about	20	
Coal	1	9
Shale, carbonaceous at top, less so towards the bottom	5	
	26	9

The hill side slopes rapidly upwards from the top of the section.

Two outliers of nummulitic limestone occur a short distance to the west of Satunga. To the east the ground slopes downwards for about 4 miles to the village of Kampat, which lies at the foot of a well-defined ridge running north and south. The lower 300 feet of this are nummulitic limestone, with a slight dip to the east, resting on a wavy surface of cretaceous rocks, and extending to north and south as far as one can see.

This is capped by upper tertiary sandstones resting on the limestones, and extending to the top of the ridge 500 feet above Kampat. These rocks, though they occupy the same position with regard to the limestone as the coal-bearing rocks of Lakadong and Nokhara, do not contain any traces of that mineral, nor is it found further to the east. They are fine-grained, highly ferruginous sandstones, the lower beds containing numerous grains of pisolitic iron ore. The sandstones rest conformably on the limestone, though in places there are local unconformities, due to underground denudation of the limestone. According to Colonel Godwin-Austen these rocks contain numerous minute fossils. From the top the ridge is seen to bend round to the north-east, striking for the Kopili. A vertical section of the ridge is as follows, in descending order:—

		Ft.	Ft.
Upper tertiary.	Fine-grained ferruginous sandstones, with a little pisolitic iron ore near the base, about		200
Nummulitic limestone.	Massive limestone, becoming shaly and earthy towards the top, about	70	
	Massive limestone, shaly and earthy at top	160	
	Thin bedded earthy limestone	70	
			300
			500

On the eastern side of the ridge limestone is met with again at about 230 feet from the base, and continues to the level of the valley in which Nonklir stands. This is a flat, alluvial plain about 2 miles broad at this part. From the top of the ridge the limestone is seen to form a fringe at the base of the hills surrounding the valley, extending to the south as far as the base of Jakorsing hill, the boundary between the limestone and upper tertiaries being easily traced, as the former is covered with thick tree jungle while the sandstones above are nearly bare of trees and covered with grass.

The limestone visible at the base of the ridge to the east of Nongkli is reduced to 130 feet in thickness, and is succeeded by upper tertiary sandstones and shales rising to 550 feet above the valley. In the next valley to the east limestone does not appear, nor is it again found anywhere to the east.

5. *Kampat to the Hot Springs on the Kopili.*—Following the limestone to the north from Kampat, it is found to occupy nearly the whole of the space between the Kharkor and Kopili rivers, cretaceous rocks forming a fringe at the base of the limestone scarp. It is capped by upper tertiary sandstones beneath the village of Pala, which is situated on a spur of Pomlana 3,754 feet above sea level. To the west of the Kharkor are numerous scarped outliers of limestone, the largest overlooking a level plain of cretaceous rocks to the north of Muncha river. This plain extends to the foot of a lofty ridge of metamorphic rocks (on which the village of Khaushinong stands) running north-east to the Kopili. The metamorphics cross the Kopili about 1 mile north of the hot springs and form the ridge running east and west, called Khandong hill. The Kopili forms a succession of very fine falls and rapids over these rocks.

The nummulitic limestone crosses the Kopili to the north of Umkerpong, and bends round to the east parallel with the metamorphics of Khandong hill. It extends to the east as far as the flanks of Phulong hill, but it does not appear in the valley of the Diyong still further to the east.

The valley between it and the metamorphics is occupied by cretaceous rocks, except at the hot springs, where a small area of limestones has been let down by faults among the cretaceous beds.

6. *The hot springs.*—The following notice of the hot springs is given in Dr. Oldham's catalogue of the thermal springs of India (M. G. S., Vol. XIX, pt. 2, p. 54):

"KOPILI.—Latitude 25° 31′; Longitude 92° 40′; Temperature 122°.

"On the right bank of the Kopili, three days' journey from Silchar, one and a half day's journey from Jawai. The water is not saline but only hot. Official Returns.—Captain (now Lieutenant-Colonel) Godwin-Austen, however, speaking of the spring in a private letter, says it is strongly saline."

The distances given above are not quite accurate as the spring is at least seven days' journey from Silchar and two from Jawai. There are three springs lying in transverse gullies on either side of a stream running west into the Kopili, and about 100 yards from the latter. Of these the one to the south is considerably larger than the other two. Its temperature I found to be 128°. The water had not the slightest saline taste, or indeed a taste of any kind, rather resembling distilled water. The temperature of the two small springs to the north was 130°, and this water also was perfectly tasteless. All these springs lie on the faulted boundary between the cretaceous and nummulitic rocks. The stones over which the water runs are covered with a very thin white deposit, probably calcareous. That this deposit is not thicker, is probably due to the fact that the Kopili during the rains rises several feet above the level of the springs, and so washes it away.

7. *Upper Tertiaries of the North Cachar Hills.*—Beyond the limestone ridge to the south-east of the hot springs upper tertiary rocks extend in an unbroken mass to the Barail range above Asalu. As far as the police outpost of Gunjong

these rocks are horizontal, or nearly so, consisting of fine-grained sandstones and shales. It is in the valley of the Mahur, to the east of Gunjong, that the change from the generally undisturbed condition of the newer rocks on the Shillong plateau takes place, the upper tertiary rocks to the east being everywhere greatly disturbed. The transition does not take place so abruptly as on the southern edge of the plateau, where the newer rocks are bent down suddenly in a uniclinal curve into the area of disturbance; but it is well marked, the rocks at Gunjong having a slight inclination to the east, while in the Mahur valley they are sharply contorted and at Quilong on the opposite side are nearly vertical. The boundary between the disturbed and undisturbed sweeps round to the west, along the Jatinga and Lubah valleys, until it coincides with the east and west strike of the edge of the Shillong plateau.

In these beds, in the Mahur valley, I found a few insignificant strings of coal, but no where did I come across any workable quantity.

Quilong limestone.

Before leaving Calcutta in November I had heard that there were considerable deposits of limestone near the outpost of Quilong, and while there I went in search of them. They are situated on a small stream running into the Langting, to the north-east of Quilong, and about 1,500 feet below it. The rocks here are shales dipping at 20° to north-north-west, and the stream has deposited a bed of calcareous tufa on the upturned edges of the shales. This limestone is from 1 to 2 feet thick where thickest, and is of small extent. A small quantity was burnt on the spot several years ago when the outpost at Asalu was being built, and the remains of it, which are still used to supply Quilong and Gunjong with whitewash, are to be seen in the jungle close by. Similar deposits also occur in the valleys near Gunjong, but none has been burnt there.

Iron.

The natives on the northern border of these hills informed me that in former times they used to extract iron from a highly ferruginous drift which is found in most of the hill streams. But the manufacture of it has entirely died out, and at Walsalai a large Kuki village to the east of the Dirjung, I found them making implements with iron brought from Calcutta.

The iron ore deposits are very scattered, and would probably not repay systematic working.

On Native Lead *from* Maulmain, *and* Chromite *from the* Andaman Islands; by F. R. MALLET, *Deputy Superintendent, Geological Survey of India.*

Native lead.—Amongst a number of ores from the neighbourhood of Maulmain, in Burma, lately sent to the Geological Survey Office by Mr. G. H. Law, is one of a somewhat unusual character. It is a carbonate of lead, breaking with a rather largely facetted crystalline fracture, and having a bright red colour due, apparently, to an intimate admixture of minium. The mineral contains small cavities lined by minute white crystals of ordinary cerussite, and some of the cavities are partly filled with metallic lead. The above-mentioned substance has the appearance of a natural product, but the precaution was taken of writing to Mr. Law on this point, and in reply he states that it is "natural and not artificial." As native lead is a mineral of rare occurrence, its discovery in a new locality is worth putting on record.

Red carbonate of lead similar to the above, except that the native metal has not been observed in association with it, has been found also in the Hazáribágh district of Chutia Nágpur.[1]

Chromite.—During the present month a block of ore was to be sent to the Geological Survey Office, for examination, from the Officiating Chief Commissioner of the Andaman and Nicobar Islands. Mr. M. V. Portman, Extra Assistant Superintendent, who visited the place where it was found, writes: "About 100 yards south of the village of Chuckergaon, on the bank of a small stream, was a mass of ore about 9 inches thick and 4 feet long. It was lying on the surface of the ground. On removing it, and digging round and underneath it, the rock appeared to be a coarse sandstone strongly impregnated with iron. No more ore was found on this spot, though it again appears in two places further down the valley in some considerable quantity, several hundredweight having been brought in. On examination of the rocks within a radius of 300 yards, I found granular and highly crystalline limestone, intersected by views of calcspar in some instances 4 inches thick, diorite, porphyritic trap, and coarse ferruginous sandstone." Chuckergaon, the village mentioned, appears to be close to Port Blair.

The ore proved on examination to be chromite. As this mineral is usually found in serpentine, and serpentine is known to occur in the neighbourhood of Port Blair, there is a strong probability that the Andamanese chromite is no exception to the general rule. "Serpentine and gabbro are found largely developed south of Port Blair and on Rutland Island, and are doubtless intrusive. A "micro-crystalline syenite" was noticed in one locality by Mr. Kurz; it is doubtless a form of the dioritic rock found locally associated with the serpentine in Pegu.[2]" It will have been remarked that Mr. Portman observed diorite, &c., close to the place where the chromite was found.

As chrome iron ore (chromite), of average quality, is worth about £10 a ton in England, the Port Blair mineral, if obtainable in considerable quantities, is well worth attention.

Notice of a Fiery Eruption *from one of the* Mud Volcanoes *of* Cheduba Island, Arakán.

The following correspondence respecting an eruption from one of the Cheduba mud volcanoes is published in continuation of similar records[3]:—

F. R. MALLET.

From Captain F. D. RAIKES, *Deputy Commissioner, Kyouk Phyoo, to the Commissioner of Arakán, Akyab, dated Kyouk Phyoo, 2nd May 1883.*

I have the honour to forward a free translation of a letter received from the Myooke of Cheduba, in which he reports that the volcano in the Minbyin Circle of his Township gave

[1] Records, G. S. I., Vol. VII. p. 35.
[2] W. T. Blanford, Manual of the Geology of India, part 2, p. 733.
[3] *Supra*, Vol. XI, p. 188; XII, 70; XIII, 206; XIV, 196; XV, 141.

out flames on the 23rd March last. The Myooke's report is dated 23rd April, and was received here yesterday. I am about to start for Cheduba, and should anything new regarding the volcano be ascertained, a further report on the subject will be submitted.

From MOUNG TSAU OO, *Myooke of Cheduba, to the Deputy Commissioner, Kyouk Phyoo.*

I beg to report that having been informed that there was an eruption of the volcano in the Minbyin Circle of this Township on the 23rd March last, I sent the following questions to Moung Wine, Yazawoot Gonug of Minbyin, for answer. His answers are given against each question :—

Question.	*Answer.*
1. Did the eruption burst out violently? ...	The eruption was sudden and violent, gradually subsiding.
2. Was it gradual? ...	
3. To what height did the flames rise? ...	About 900 feet (*sic*).
4. What was the circumference of the flame?	About 450 feet.
5. How long did the eruption last? ...	About 9 minutes.
6. Did the flames give out any smell? ...	Yes, that of earth oil.
7. Was there much smoke? ...	Little smoke in comparison with the flame.
8. Was mud alone thrown out? ...	Mud and gravel, no other mineral.

NOTICE.

Irrigation from wells in the North-Western Provinces and Oudh, by CAPTAIN J. CLIBBORN, B.S.C., *Executive Engineer, on Special Duty, Department of Agriculture and Commerce, N.-W. P. and Oudh.* In the Professional Papers on Indian Engineering, 3rd series, Vol. I, p. 103, Roorkee, 1883.

1. In all the visible and measurable elements of the investigation undertaken by Captain Clibborn, the method adopted seems to have been thorough, and the results obtained must be of great and permanent practical service. By the adoption of a unit of work, with values determined by careful experiment, he has reduced to comparable form a chaos of information upon the subject in hand with reference to the depths and capacities of wells and the processes of 'lift' in use. He has moreover applied his method over an immense field of observation, extending right across the Gangetic plains from the terai on the north to the Vindhyan scarp on the south, and some 250 miles broad between Agra and Fyzabad. The sound facts thus accumulated must indeed be accepted as a main contribution to the question in view; but there are considerations of fundamental rather than of collateral importance regarding the distribution and the supply of water available, upon which much light might have been expected from such a course of observation, and upon which the remarks offered by Captain Clibborn are not only defective but misleading; because, no doubt, the facts concerned are not quite visible or measurable. This branch of the subject has come within the cognizance of the Geological Survey, so that some notice of the matter is here called for.

2. The question of artesian sources in the plains of India has been discussed at some length in these Records (Vol. XIV, page 223, *et seq.*), and the probability

of their occurrence asserted. In the paper under notice, Captain Clibborn professes to show that artesian action is quite incompatible with the strata of the Doab. It is necessary to quote two paragraphs to make the position clear:—

"22. Leaving out of the question for the present wells which receive a supply from percolation, we will consider the case of what are usually termed spring (*bom*) wells, which should be sunk so as to have the end or lower ring firmly imbedded in the *mota* (layer of clay), thereby (if a masonry well) shutting out from direct entry all water overlying it. Now the generally adopted theory regarding the use of the mota for water supply is that it acts as an artesian basin, and that the supply entering the well through an orifice which is bored in the clay is a veritable spring, caused by the pressure of water from the collecting area of the basin.

"23. The facts which are alleged to support this theory are *first*, that until the mota is reached, the water-supply is easily exhausted. This is contradicted by experience. *Secondly*, that when the hole is bored into the mota a copious supply enters the well, often causing danger to the workmen if they do not escape quickly, and sometimes rising above the mouth. But the artesian theory pre-supposes the comparative continuity of the mota, which is at variance with the universal testimony of cultivators, and the facts alleged are easily explained on other grounds, *vide* paras. 26—30. It will also be shown that artesian action is quite incompatible with the strata of the Doab."

3. This last sentence is a general proposition, and would properly be taken to include the whole formation concerned. We are by no means sure that Captain Clibborn does not intend it in this sense, for the strata at greater depths are no doubt of the same pattern as those exposed; but as the facts immediately quoted (paras. 24-25) regarding the contour of the sub-soil water (although they are somewhat irrelative to the immediate question) can only refer to the ground above the level of the rivers, and as no direct allusion is made to deeper artesian springs, we may restrict the discussion to the narrower issue; and upon this it is not difficult to show that Captain Clibborn does not seem to understand the needful conditions of evidence or of argument. We are by no means concerned to prove that the *bom*-wells are artesian; only, if the facts asserted of them are correct, they are essentially of that nature.

4. The first fact refuted by Captain Clibborn, in his paragraph 23 just quoted, may be said to be irrelative; but even upon the theory he himself adopts it is not easy to see how experience can contradict that a deeper well, tapping a larger segment of the same water basin, is less easily exhausted than a shallower one. For the 'alleged fact' of the water rising above the surface Captain Clibborn would have done well to introduce the plain contradiction argument, as it would be impossible to explain it otherwise than as artesian; and we need hardly say that no attempt is made to do so. For the remaining and essential point, that water does rise from below the clay, Captain Clibborn adopts a double course, to vitiate the opposite view and to offer a simpler explanation; but in both lines of argument he begs the point at issue.

5. It may well be true that the clay band is not everywhere continuous; but it is altogether too dry a statement to say that the artesian theory pre-supposes this continuity, though such an impression would readily be conveyed by the ordinary text-book exposition of artesian conditions, dealing with strongly-marked examples. Partial artesian action is always possible when percolation along the planes of bedding is much more easy than across them, and this seems to be a general

character of stratification independently of any visible impervious beds. In anticipation of objections such as this, when the proposal for artesian borings in Upper India were first brought forward (in 1867), instances were quoted showing the compatibility of artesian springs with great irregularities (want of continuity) of the deposits (Selections, Government of India, Home Department, No. CLXXVIII, p. 48. 1881.) This condition then, as framed by Captain Clibborn, is artificial.

6. The first item in the housewife's receipt for hare soup, beginning with the injunction to catch your hare, is of equal importance in discussion—to fix your fact before beginning to talk about it. When the *bom*-wells were quoted as an apparent instance of partial artesian action, it was assumed that the engineer who described the phenomenon was aware of the fact that if a tube with a diaphragm over the end be depressed into water the fluid will rise to the same level inside when the diaphragm is pierced; also, that in bringing the fact of the well to notice he was satisfied it was not an instance of this familiar experience, that in fact the waters above and below the clay did not stand at the same level, and were distinct, of which indeed he did give strong independent evidence in the wholly different nature of the water above and below the clay, and this is really the essential question at issue—whether or not the two water strata are distinct. It appears however that Captain Clibborn has an equally implicit conviction on the other side, for he decides the point with a simple assertion (paragraph 27), "the head is the difference of level between the water inside and outside the well;" and he seems to think that the only evidence needed on this score is to show how the water would perform the passage, the fact of free communication between the water tables having been assumed. This is the 'explanation on other grounds,' for which we were referred to paragraphs 26—30. It is introduced as 'a theory, advanced by Mr. J. S. Beresford, Executive Engineer, Irrigation Department,' and consists of an exposition, with the aid of numerous diagrams, how when sand is forced up with the water from below through a hole in the bed of clay, a hollow must be formed in the place vacated by the sand, and further how in passing from the upper to the lower stratum the water will obey the laws of mechanics. It is all quite beautiful in its simplicity, not excepting the omission of the one thing needful, even as a blank assertion, that the natural water levels of the two strata are constantly one and the same. Upon this crucial point (which would have set the whole matter at rest) one would think Captain Clibborn might have picked up some information during his extensive exploration, either by direct observation (not a very difficult matter), or 'from the universal testimony of the cultivators;' without it his 'theory' is all in the air.

7. This question of the artesian character of the bom-wells is a trivial matter in itself, having little or no bearing upon the existence of deep artesian springs, and it would hardly have deserved notice here but that the essential feature of it—the independence of the water tables—is of much practical importance on several counts, and has received notice in these pages (Vol. XIII, p. 273) in connection with the reh scourge. In that discussion, in which the Irrigation Department is deeply implicated, the more or less complete and permanent sepa-

ration over very large areas of the parasitic water (as the French call it) of the sub-soil and the deeper ground water, has passed without challenge as an admitted fact, presumably on the experience of the engineers and the universal testimony of the cultivators; and one might have thought that the investigation of the range of such conditions would have been an express object of Captain Clibborn's researches. It is clear that this fact (if it be one) of the lower water being sweet, while the upper is saline, would afford an independent and sufficient proof of the separation of the water tables and of the so far artesian nature of any rise of water from below the clay; but it is not included in the facts bearing on this point noticed by Captain Clibborn, though it certainly has been alleged in that connection. This might be an oversight; but it is not intelligible how such a fact (or statement, if it be not a fact) can have escaped prominent mention in connection with the investigation under notice, which included extensive tracts of reh land; yet it is not even alluded to. Can Captain Clibborn have found it out to be a popular delusion? His explanation of the bom-well performance would certainly imply that it is not a fact.

8. That the notion of the extensive occurrence of an impure sub-soil water permanently separated by clay beds from the ground water is not quite exploded, may be gathered from an excellent Report on Reh Swamp and Drainage, by Mr. E. E. Oliver, in the same number of the Professional Papers, where quotation is made (p. 9) of a description of such conditions in connection with reh land. The same is described from actual observation over a large part of the Doab in an early notice of the *bom*-wells in the 'Correspondence relating to the deterioration of lands' (Selections, Government of India, P. W. D., No. XLII, 1864, p. 94).

9. Having mentioned Mr. Oliver's paper, we may venture to notice what might be thought a slight confusion in the presentation of the theoretical aspect of the question, in Sections IV, *Chemical composition and analysis*, and V, *Physical theories advanced;* and confusion on this side is at the bottom of most practical mistakes, leading often to incalculable waste of effort and of money. It is rather under the latter of the above sections that one would look for an account of the origin of reh, yet the only explicit statement on this most important point appears casually in the opening sentence of Section IV, and the hints given of it in Section V are extremely obscure. The simple performance which results in a crop of reh scarcely deserves to be condemned under that much abused word 'theory,' it is so obvious when witnessed. Though unacquainted with the word 'capillarity,' any cultivator probably has a sound proximate notion of the reh crop, how it is connected with poisonous sub-soil water which the sun sucks up leaving the reh on the surface; he knows well too that the bad water would not be there if it could get away, and what prevents it. So far General Strachey's 'physical theory,' which Mr. Oliver quotes with approbation, could not well help being 'lucid'; but it professed to be "quite sufficient to account for the whole thing" (Selections, *l.c.* p. 57), and as such it is probably the most hazy thing General Strachey ever wrote. Even the few sentences quoted by Mr. Oliver are rendered mischievous by the false conception they imply regarding the origin (or no origin) of the reh—that these salts are in the soil and

have been there always, having come with the silt from the mountains. He even goes out of his way to make the question occult by the interference of segregation, as in the production of flints in the chalk, saying "so too it seems highly probable that from some physical cause the sulphate of soda, &c., have accumulated in certain places on the alluvial deposits of Upper India." Yet this was written in 1864.

10. In conclusion we may point out a slight misconception where Mr. Oliver notices (p. 10) an apparent contradiction or qualification of opinion as expressed in the following quotations from Mr. Medlicott's reports—"As far as the facts before me are a guide, I am inclined to the opinion that the canal water is *the chief* source of the salt. I am now speaking of the lands newly affected" (1862); and "that the reh scourge existed widely before the canals were thought of, and *this reh constitutes immensely the greater part of what has now to be dealt with*" (1878). In the first place, the two statements pointedly refer to different ground, new and old reh land; but even if they referred to the same area the statements are not logically comparable and might have been written consecutively at either period without discrepancy, for they explicitly refer to different things, one to the stock of reh in hand, the other to the source of reh. A man might surely have little cash in his pockets though having a large income, or *vice versâ*. As a general statement, however, the first one was somewhat misleading, although in some land the possible sources of fresh reh would certainly be less than in the irrigation water. The exaggeration of the partial statement was provoked by the dogma then universally accepted that the canal water acted solely as a vehicle.

H. B. MEDLICOTT.

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