RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XVIII.

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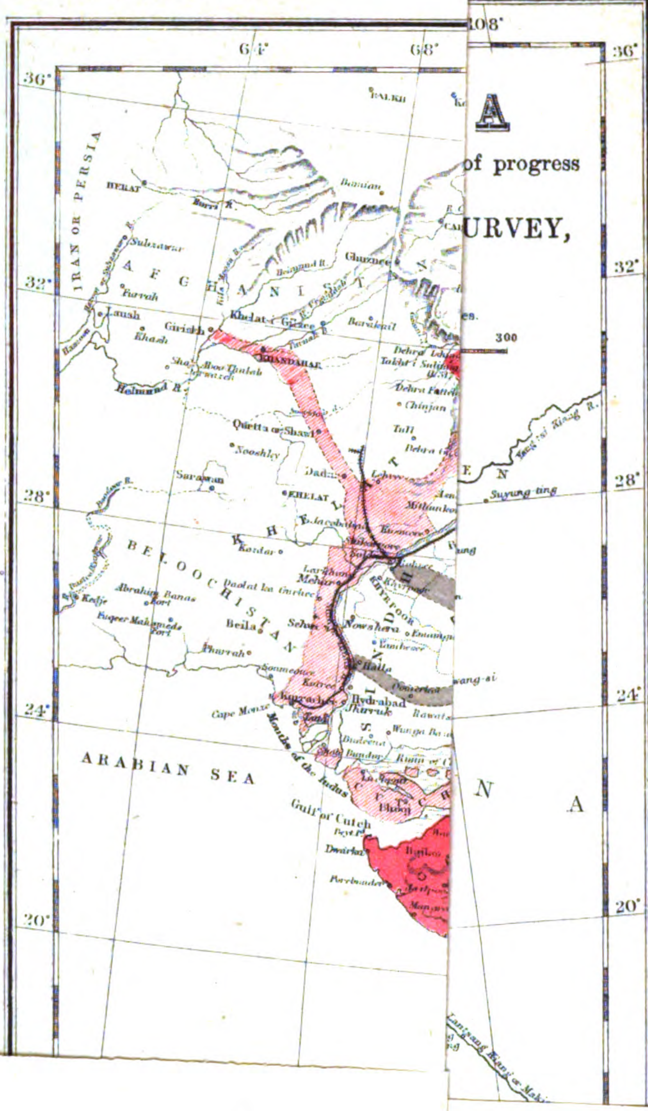
ERRATUM.

Page 32, line 3 of Analysis, for *alumina and magnesia* read *alumina and oxide of manganese.*

Annual Report 1884. ords, Vol. XVIII.



RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1885. **[February.**

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1884.

Billa Surgam Caves: *Mr. Foote.*

The Peninsula area.—In Southern India Mr. Foote began the season's work in continuation of the cave exploration in the Karnul District, but in the middle of it he was called upon to undertake an exploration for coal along an intended line of railway between Hyderabad and the Kistna. Fortunately we were able to secure the services of his son, Lieutenant H. B. Foote, R.A., who had been for some time helping his father as an amateur cave-hunter. An interesting preliminary account of the result is published in the last number of the Records. It is on the whole encouraging; a large number of bones have been secured, some of animals that do not now inhabit this region, some human remains and articles of human manufacture, the latter at the considerable depth of 16 feet, but nothing to show that the caves had ever been used as dwellings or as a place of sepulture. Arrangements have been sanctioned for carrying on the work during the present season, after which a close examination of the whole collections should determine whether the search is worth continuing.

Fruitless search for coal in Hyderabad.

The country between Bezváda and the Singareni coal-field, and from the latter to Hyderabad, where Mr. Foote was sent to look for coal, proved, as we expected, to be all of gneissic rocks. The only reward for his labour was the discovery of a strong lode of rich iron ore close to the Singareni coal-field. An account of the traverse is published in the current number of the Records.

Chhattisgarh coal-fields: *Dr. King.*

As stated in last year's report, Dr. King took up work in the series of coal-fields on the north-east confines of Chhattisgarh, especially with a view to exploration for coal near the line of the projected Nagpur-Bengal Railway. The results of his survey are published in the Records (XVII, part 3). It would be impossible to give any further opinion on the measures until some trial borings have been made; they are now being sunk under Dr. King's direction.

THE REWAH COAL-FIELDS: *Mr. Hughes.*

The promises made in last year's report regarding the Rewah coal-fields have been most successfully accomplished. The shafts put down on the coal in the Umaria field under Mr. Hughes' direction have fully satisfied his expectations, and energetic steps are now being taken under Mr. Hughes' management to establish an extensive colliery there; and a branch railway from Katni on the Jabalpur line is under construction. Mr. Hughes' whole service (since 1862) has been spent on the Gondwana rocks, and it is most pleasing and appropriate that so fruitful a practical result should be in a very special manner due to his sagacity and perseverance. During last season Mr. Hughes also managed to complete the examination of the southern coal-fields of the Rewah Gondwána basin. The total area of exposed coal measures is no less than 1,800 square miles. The descriptive memoir with maps is now in the press.

Mr. Jones joined Mr. Hughes in January. He has this season been deputed to survey the Pench coal-field on the south side of the Sátpura basin.

Sub-Assistant Hira Lál gave satisfactory aid to Mr. Hughes in his survey operations. He has now been transferred to Dr. King.

LOWER VINDHYANS, CHHATTISGARH: *Mr. Bose.*

In the past season Mr. Bose took up new ground, in the basin of the upper Máhánadi. He covered a large area, but I regret to say the result is exceedingly unsatisfactory. For his work in Nimár there was an excellent sketch survey by Mr. Blanford to start with, and the rocks presented no structural complications; Mr. Bose has moreover such facility in expressing himself and in setting up a description that there was little or no room for the detection of error from a perusal of his report, beyond such general defect of scientific insight as I have noticed in the Preface to Mr. Fedden's Kattywar report (Memoirs, XXI, part 2). In Chhattisgarh, Mr. Bose had to break ground for himself; and although this is by no means complicated, his attempt even to understand the problem of the rocks is extremely feeble; his map is no more than a lithological index; there is a total absence of critical observation. In discussing the question of the employment of natives on the Geological Survey of India, I have had frequent occasions to point out that our work is essentially scientific research and does not admit of being done by rule, with little or no understanding; and that if not within measurable range of modern scientific standards it is worthless; on the other hand I mentioned the fact that as yet no single instance had occurred of a native showing himself capable of original scientific work, the conclusion being that the Geological Survey was about the only branch of the public service in which natives could not as yet reasonably find employment. I fear that Mr. Bose is no exception to this rule, although he has had the advantage of the best teaching in the scientific schools of England. It is quite a Darwinian puzzle.

Sub-Assistant Kishen Singh mapped a considerable area of Vindhyan rocks south of Búndi in Rájputána, but it would be impossible to make out a presentable description of the country from his notes.

OUTER HIMALAYA: *Mr. Oldham.*

The extra-Peninsula area.—Mr. Oldham has sent in full progress reports of last season's work in the Himalayan region, embracing a section from the plains to the base of the main range. In the Sub-Himalayan zone the following interesting points have been fixed: the re-discovery of one of Colonel Cautley's most important localities for fossils, at the entrance to the Kalawala Pass (Records, 1884, p. 78); the detection of an unconformity in the upper Siwalik strata east of the Ganges (Records, 1884, p. 161), which later in the season he traced in the range west of the Ganges; but chiefly there has to be noticed a judgment upon the 'main boundary,' that of the old rocks at the inner edge of the tertiary zone. This has been a very burning question, as may be seen by reference to Mr. Theobald's paper on the Siwaliks (Records, XIV, p. 105); but since the correction by Mr. Oldham in 1881 of a certain "key section" near Náhan (Records, XIV, p. 173) the particular view taken by me of the main boundary has lost its chief support, and the view now offered cannot be forcibly contested. The point is discussed with reference to the section in the Nún stream under Mussooree. In the original description of that section in 1864 (Memoirs, III, 2, p. 128) it is left very much an open question whether all the rocks there are not Siwaliks, as Mr. Theobald (*l.c.*) subsequently asserted them to be, and as Mr. Oldham now re-affirms. As regards the main boundary, the 'key' aforesaid made it a very plausible supposition that this feature was an original contact, albeit much disguised by subsequent compression and faulting, whereas Mr. Oldham, by showing inversion of the inner rocks at the boundary, and other fair arguments, makes out the boundary to be a faulted synclinal flexure; though it does not appear that he supposes the original limit of the Siwalik rocks to have been far north of the actual boundary, so that the change of view is not so great as it might seem. When the feature was first discussed the choice seemed to lie between the view then taken and sheer faulting (including under this term the reversed faulting along oblique plains of fracture in the axes of folded flexures); Mr. Oldham also rejects the reversed fault, in its plain form, on account of the absence of the crushing that presumably must occur, and adopts "the supposition of a faulted synclinal flexure in which the disturbance of the original relations has taken place mainly by the older rocks being pushed up over the newer, according to Professor Heim's theory, rather than by an actual shifting of the opposite faces of a fissure." The distinction, in words, is not obvious; and it is very difficult to imagine the process, seeing that the rocks on either side of the dividing plain retain their respective structures; but somehow such contacts *are* brought about with little or none of the grinding action that would seem inevitable. Another very interesting point is the discovery of an outlier of Siwalik sandstone resting on crumpled slates in a low hill north-east of Dehra. With the single exception of a case noticed by Mr. Mallet in the Bhután Duárs (Memoirs, XI, p. 44) it is the only observation of a base-rock within the true Sub-Himalayan zone. The absence of any older tertiary beds here is particularly interesting, as almost necessarily implying their extensive upheaval and removal before the Siwalik period.

Among the vastly more complex rocks of the higher hills the changes introduced are more extensive. The series of formations described in Jaunsár (Records

XVI, p. 193) is somewhat altered and greatly amplified, and brought into relation with those of the Simla region. The following is Mr. Oldham's summary of conclusions :—

1.—That the Simla and Jaunsár sections are not related to each other, but that except for some possible exposures of the Krol in Jaunsár the rocks on either have no representative on the other.

2.—That the Simla section does not represent a conformable sequence, but that between the infra-Krol and the Blaini there are interposed (elsewhere) at least two formations, and two unconformable breaks.

3.—That the Deoban and Krol limestones are not the same, but that the former is much older than the latter.

4.—That the Mandháli series is older than the infra-Krol (but newer than the Deoban).

5.—That the Deoban limestone is newer than the Blaini.

6.—That the Blaini is newer than the lower-Chakráta.

7.—That the series which last year were provisionally and doubtfully grouped together as Lower and Upper Chakrátas must be separated as belonging to different formations.

8.—That the Báwars are but a special form of the basement beds of the infra-Krol.

9.—That the Panjál conglomerate occurs in this region, and it is *not* the representative of the Blaini.

It would be unreasonable to expect that all these announcements should be immutable; Mr. Oldham is certainly right in attempting free-hand tentative groupings, and all are based upon local evidence of variable validity.

Those acquainted with it will be glad to see that the primitive series of the Simla section is not much interfered with at home. The Krol limestone, Krol quartzite, and infra-Krol carbonaceous shales still remain the highest groups of the lower Himalayan rock series; and the several groups (Báwar, Mandháli, and Deoban) separating them from their constant neighbour of the Blaini stream are not said to occur here. The discovery of a second conglomerate will greatly reduce the duties of the hitherto seemingly ubiquitous Blaini; and a second strong limestone band to take the place of the Krol in certain places, as in the Sháli mountain north of Simla, is distinctly a relief. Mr. Oldham gives ample stratigraphical observation to confirm Colonel McMahon's petrological arguments that the 'central gneiss' of the Chor and some other places is truly a granite; still I find a 'central gneiss' at the base of the new table of formations; and this too is satisfactory; it would be almost preternatural that such an immense file of geological records should have no archæan foundation. It is lamentable to have to record that still not even the ghost of a fossil has been seen in these rocks.

I have given Mr. Oldham's results somewhat at length, because they may not be immediately published in original, the exigencies of our Indian service having made it desirable to depute him for the current field season to the Andamans with the Topographical Survey party, for which special arrangements have been made, and such an opportunity might not occur again in our time. Mr. Oldham's experience in Manipur (Memoirs, Vol. XIX) at the starting point of this region of disturbance, may give him some clue to the correlation of the rocks in those island outliers.

Mr. Middlemiss joined Mr. Oldham in January; he has this year been started on independent work in Garhwal.

Colonel McMahon.

Colonel McMahon has now completed his elaborate microscopical studies of a large series of Himalayan rocks, proving among other interesting results the eruptive character of certain pseudo-gneissic rocks of the Dhuladhár, the Chor, and other localities. Mr. Oldham's recent determination of the undoubtedly intrusive relations of this rock in the Chor is a satisfactory conclusion of this enquiry. Colonel McMahon's description (Vol. XVII, p. 104) of the extreme metamorphism, amounting to proximate fusion, of the quartzites of the ridge at Delhi, is an interesting indication upon the history of the Arvali rocks.

HIMALAYAN MOUNTAIN SYSTEM: *Lt.-Col. Godwin-Austen.*

In connection with Himalayan geology it is not out of place to notice a study of the mountain system of the Himalaya presented in Colonel Godwin-Austen's address as President of Geographical Section of the British Association Meeting of 1883, supplemented by a map and sections with notes published by the Royal Geographical Society (Proceedings, 1883, p. 610). If the views given had been mere geographical delineations they would not have called for attention, as being suitable to the audiences addressed; but the essay is a laudable attempt to forestall time by introducing to topographers rational conceptions of mountain structure, and thus geology is necessarily introduced. Unfortunately, however, the author is not himself quite emancipated from the ideas he would subvert. These may be indicated as a mistaken conception of unity based upon an unnatural assumption of continuity. Of this kind is the extension of the extinct axes of the Himalayan range into connection with the gneissic mass of Afghanistan. The confusion is the same as it would be to ignore the separate members of a compound organism; there may be homology, but the forced continuity leaves out of count conspicuous and essential structural characters. Again, to make the Pir Panjál and the Dhuladhár continuous with the Chor mountain of the Simla region, is about the same as it would be to confound the tail of a vertebrate animal with its limbs. These errors have been pointed out before (Records, XV, p. 6).

THE CENTRAL HIMALAYA: *Mr. Griesbach.*

In last year's report I mentioned the completion of Mr. Griesbach's rapid survey of the Hundes region, and that his observations there had been connected with those of Stoliczka in Spiti. I had then to explain the postponement of any fuller notice of the work owing to Mr. Griesbach's urgent deputation to accompany the expedition to the Takht-i-Sulemán. Subsequently to this, while making some connecting observations on the North-West Frontier, he was taken seriously ill at Kohát, in consequence of which it was necessary that he should spend the hot season in the hills, and while at Simla, he managed to get appointed to accompany the Afghan Boundary Commission. Had I been in India, I should probably have succeeded in having some other officer deputed for this duty. No doubt the best use that can be made of Mr. Griesbach is for the superficial kind of work that is alone possible in those expeditions, and his admirable skill in drawing is a special qualification for such work, nevertheless the further postponement of the account of his Himalayan observations, begun in 1879, should have been avoided. His maps were fully prepared before he left, and are now being reproduced for publication; a large number of illustrations are also ready, but the descriptive text has not yet been sent in, and it cannot be fitly prepared away from sources of reference.

THE TAKHT-I-SULEMÁN.

The details of Mr. Griesbach's observations in the Sulemán hills have recently been published (Volume XVII, part 4). They give fresh illustration of Mr. Blanford's remarks regarding the great variability of the cretaceous and eocene deposits of that region. As regards the newer formations two unexpected points are noteworthy. The object of Mr. Blanford's last exploration on that frontier had been to connect the tertiary series of Sind, which he had so carefully worked out, with the tertiary series of the Sub-Himalayan region; and although an actual tie with previous work to the north was not effected, it was thought, as stated in my last annual report (Vol. XVII, page 7) that the main object had been attained, for in the northern part of his ground, on the flanks of the Sulemán, Mr. Blanford found established a section that fairly represented that known to the north—the marine eocenes surmounted by the neogene Nari and Siwalik groups, believed to be fresh-water deposits, and all in apparent conformable sequence, the two marine groups, lower Nari and Gáj of Sind, having disappeared (Memoirs XX, page 159, *et seq.*). This conclusion is however apparently upset by Mr. Griesbach's observations in the intervening ground to the north: a sandstone full of marine fossils is confidently identified (*l. c.*, page 189) with Mr. Blanford's upper Nari sandstone, and the upper tertiaries are only represented by the Siwalik conglomerates resting in total unconformity on the lower tertiary marine beds. It is very unsatisfactory that Mr. Griesbach does not himself notice these discrepancies, as is usual in such cases to give some sign that he was aware of their importance; he had a proof copy of Mr. Blanford's report with him in the field.

THE ANDAMANS: *Mr. Mallet.*

Some ores, especially a chromite, received from the Andamans, and the accounts sent with them, made it desirable to have a professional opinion upon the deposits. Mr. Mallet was deputed for this purpose, and the result of his examination is published in the Records (XVII, part 2). The block from which the specimen of chromite had been taken could not be traced to any mass *in situ;* and as this mineral in minute crystalline grains was found disseminated in the serpentinous rock of the neighbourhood, it may be presumed that the large block was only a local segregation. An opportunity occurred for Mr. Mallet to visit Barren Island and Narcondam. His account of these interesting volcanic sites is now ready for press.

AKA HILLS AND LANGRIN COAL-FIELD. *Mr. LaTouche.*

Early in the season Mr. LaTouche accompanied the expedition into the Aka Hills, north of Tezpur, in Assam. The dense vegetation prevented any observation of the rocks except in the stream courses. The section was found to correspond with that observed in the Daphla Hills to the east by Colonel Godwin-Austen, and as described by Mr. Mallet in the Bhután Duárs to the west. Inside the tertiary zone there is a belt of carboniferous Damuda strata, bordering the schistose rocks of the higher hills. Here, too, the coal is so crushed as to be unserviceable. There was some little delay in the preparation of a map; it will be published shortly with Mr. LaTouche's notes. Later in the season Mr. La-Touche examined the Langrin coal-field on the south-west edge of the Garo Hills. His report with a map is published in the Records (XVII, part 3). This field offers an abundant supply of very fair coal easily accessible on the very borders of the plain of Sylhet.

THE HOMOTAXIS OF INDIAN FORMATIONS; *Mr. W. T. Blanford.*

A very instructive discussion of geological homotaxis is given by Mr. W. T. Blanford in his address as President to the Geological Section of the British Association in its last meeting at Montreal. It is mainly illustrated from Indian geology, and is so important a contribution to this subject that it has been reprinted in the current number of the Records. Numerous instances are given of the discrepancies that occur in the correlations of rocks as based upon their terrestrial fauna and flora, or upon a marine fauna, the latter giving much more comparable results. The former of course maintain all their special interest, but it is very necessary to know upon which kind of evidence the correlation of any strata had been based. Mr. Blanford would somewhat modify the significance of the term homotaxis as introduced by Professor Huxley in 1862. That was, to give expression to the following statement:—"For anything that geology or palæontology is able to show to the contrary, a Devonian fauna and flora in the British Islands may have been contemporaneous with Silurian life in North America, and with a Carboniferous fauna and flora in Africa."[1] These terms of course included the marine fauna; but while granting such conditions to be possible for a terrestrial fauna or flora, Mr. Blanford considers that the marine fauna would give a much nearer approximation to synchrony. He says:—"It appears to me that at the present day the difference between the land faunas of different parts of the world is so vastly greater than that between marine faunas that if both were fossilised, whilst there would be but little difficulty in recognising different marine deposits as of like age from their organic remains, terrestrial and fresh-water beds would in all probability be referred to widely differing epochs, and that some would be more probably classed with those of a past period than with others of the present time."

Mr. Oldham.

The same subject of homotaxis is discussed by Mr. Oldham in the Journal of the Asiatic Society of Bengal for 1884 (Part II, p. 187). He illustrates from our Indian palæontological researches the highly discrepant results of correlations in time from fossil evidence, specially the palæobotanical, and the insuperable failure of any approach to determination of synchrony among distant formations. This is introductory to an attempt to establish synchronous relations of distant formations through the evidence of periods of glaciation, the ground chosen being the same, as containing well-known boulder deposits, the Talchirs of India, the Hawksbury beds of Australia,

[1] Quar. Jour., Geol. Soc., Vol. XVIII, p. xlvi.

and the Karoo boulder bed of South Africa. Such a distribution of presumably synchronous glaciation, Mr. Oldham suggests, "points towards the conclusion that in early secondary times the crust of the earth did not occupy the same position with respect to the axis of rotation as it does now." The contention is well supported by arguments needed to account for the distribution of the cognate terrestrial fossil fauna and flora of the regions in question. Some years ago a suggestion was made to use the last glacial period as a geological chronometer to fix the age of the Indian post-tertiary deposits; and then too the proposal was elicited by a flagrant abuse of the homotaxis method of correlation, losing sight of the actual in the relative (*supra*, Vol. VII, p. 97, note).

Publications.—Two Memoirs were published during the year—Mr. Bose's on the Lower Narbada Valley between Nimáwar and Káwant, and Mr. Fedden's on Káthiáwár, each with a map of the country described. They form parts 1 and 2 of Volume XXI. The work was contemporaneously noticed in previous annual reports, and some general remarks on both will be found in the preface to the part 2, part 1 having been fully printed off before I returned from leave.

The Records for the year contain numerous articles of interest, several of which have been referred to above.

In the Palæontologia Indica, five parts of series X, the Indian Tertiary and Post-Tertiary Vertebrata, by Mr. Lydekker, were published during the year. They form a very worthy addition to this most valuable part of our publications. For the general advancement of geological science, palæontological researches are certainly the most interesting and important, and at present they are inadequately provided for in the allotment of our resources. It would be impossible for one palæontologist to overtake all the work on our undescribed collections of fossils, even if one man could do justice to so wide a range of studies. I hope to be able to effect a temporary diversion of some funds to bring up arrears of work in this branch of our business.

In continuation of his work on the fossils of the Salt-Range, Dr. Waagen furnished last year two parts (Nos. 3 and 4) of the Brachiopoda of the Productus-Limestone. They exhibit the same exhaustive study as heretofore. To the superficial criticism of some naturalists, Dr. Waagen might seem to lay himself open on the score of minute specific distinctions, but he abundantly justifies his method on biological and palæontological grounds. No doubt, as he says himself, more abundant material may lead to the modification of his grouping, but there is a strong presumption that the principle will hold good. However one might be satisfied for purely biological results to exhibit the links of variation in a few developmental sequences of species and genera, geological history will require the process to be applied throughout. Dr. Waagen gives numerous instances in which those slightly distinguishable forms are characteristic of different stratigraphical horizons. His final discussion of the fauna of the Productus-Limestone should form an interesting chapter on the vexed question of homotaxis.

A large fasciculus of Series XIV, with eighteen admirably-executed plates, was issued early in the year. For this series, descriptive of the tertiary and upper-cretaceous fossils of Sind, taken up four years ago, we are so far indebted to the generous labours of Professor Martin Duncan, latterly aided by Mr. Percy Sladen.

It is the beginning of what must one day become the most extensive part of the Palæontologia, that dealing with the tertiary marine fauna, and the most interesting as more fully bearing upon the living fauna of the Indian seas.

Museum.—As specified in the Records for May, several contributions of ores, rocks, and other geological specimens were obtained from the International Exhibition held in Calcutta early in this year. The principal presentations were from the Minister for Mines, New South Wales; the Minister for Mines, Victoria; and the Tasmanian Commissioner. Some of these were in return for Indian geological specimens previously sent to Australian Museums by the Survey, and for the rest a proper return was made on the occasion.

Library.—The additions to the library were 1,608 volumes or parts of volumes, 742 by purchase and 866 by donation or exchange. The printing of the Catalogue was just completed within the year, for which accomplishment I have again to express obligation to the conscientious industry of our librarian, Mr. W. R. Bion, for thoroughly checking the entries and correcting the proofs. Excepting books received after passing the sheets of the Catalogue for press, the following figures represent a rough inventory of our library at this date: total volumes, 13,205; of which 9,236 come under the heading of Serials, including the publications of Societies, as well as Magazines and official reports; of the remaining 3,969, 1,015 are marked in the Catalogue as pamphlets.

Personnel.—Dr. Feistmantel was absent throughout the year. Mr. Hacket returned from furlough on the 18th of November and resumed his field work in Rájputána. Mr. Medlicott was absent on special leave for six months, during which time Dr. King acted as Superintendent of the Survey. Mr. Mallet took six months' furlough from May to October, during which time Mr. Fedden officiated as Curator of the Museum.

H. B. MEDLICOTT,
Superintendent, Geological Survey of India.

CALCUTTA,
The 20th January 1885.

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 1884.

AMSTERDAM.—Netherlands Colonial Department.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
,, Director of Instruction.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Science.
BOLOGNA.—Academy of Sciences.
BOMBAY.—Bombay Branch, Royal Asiatic Society.
BOSTON.—American Academy of Arts and Sciences.
,, Society of Natural History.
BRISBANE.—Royal Society of Queensland.

BRISTOL.—Bristol Museum.
„ Bristol Naturalists' Society.
BRUSSELS.—Geological Society of Belgium.
„ Royal Geographical Society of Belgium.
„ Royal Malacological Society.
„ Royal Natural History Museum of Belgium.
BUDAPEST.—Royal Geological Institute, Hungary.
BUENOS AIRES.—National Academy of Sciences.
BUFFALO.—Society of Natural Sciences.
CALCUTTA.—Agricultural and Horticultural Society.
„ Asiatic Society of Bengal.
„ Meteorological Department, Government of India.
„ Survey of India.
CAMBRIDGE.—Philosophical Society.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CASSEL.—Society of Natural History.
CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
„ Norwegische Comm. der Europäischen Gradmessung.
„ Royal University of Norway.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey of India.
DRESDEN.—Isis Society.
EDINBURGH.—Royal Scottish Society of Arts.
GLASGOW.—Geological Society.
„ Glasgow University.
„ Philosophical Society.
GÖTTINGEN.—Royal Society.
HALLE.—Leopoldino Academy.
„ Natural History Society.
HOBART TOWN.—Royal Society of Tasmania.
KÖNIGSBURG.—Physikalisch-ökonomische Gesellschaft.
LAUSANNE.—Vaudois Society of Natural Science.
LIVERPOOL.—Geological Society.
„ Literary and Philosophical Society.
LONDON.—Geological Society.
„ Iron and Steel Institute.
„ Journal of Science.
„ Linnean Society.
„ Royal Asiatic Society of Great Britain and Ireland.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoological Society.
MADISON.—Superintendent, Public Property.

MADRAS.—Meteorological Department.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
„ Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water Supply, Victoria.
„ Geological Survey of Victoria.
„ Royal Society of Victoria.
MILAN.—Italian Society of Natural Science.
MONTREAL.—Geological and Natural History Survey of Canada.
„ Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—American Journal of Science.
PARIS.—Geological Society of France.
„ Mining Department.
PENZANCE.—Royal Geological Society of Cornwall.
PERTH.—Commissioner of Crown Lands.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
PISA.—Society of Natural Sciences, Tuscany.
ROME.—Camera dei Deputati.
„ R. Accademia dei Lincei.
„ Royal Geological Commission of Italy.
ROORKEE.—Thomason College of Civil Engineering.
SACRAMENTO.—California State Mining Bureau.
ST. PETERSBURG.—Geological Commission of the Russian Empire.
„ Imperial Academy of Sciences.
SALEM, MASS.—American Association for the Advancement of Science.
„ Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—North China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
SPRINGFIELD.—Geological Survey of Illinois.
„ Illinois State Museum of Natural History.
STOCKHOLM.—Geological Survey of Sweden.
STRASBURG.—Royal University Library.
SYDNEY.—Australian Museum.
„ Department of Mines, New South Wales.
„ Royal Society of New South Wales.
TOKIO.—Seismological Society of Japan.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.

VIENNA.—Imperial Academy of Sciences.
„ Imperial Geological Institute.
WASHINGTON.—Philosophical Society.
„ Smithsonian Institute.
„ United States Geological Survey.
WELLINGTON.—Colonian Museum.
„ Geological Survey of New Zealand.
„ New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.

The Secretary of State for India.

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

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

The Commissioner of Northern India Salt Revenue.

The Resident at Hyderabad.

The Comptroller of Indian Treasuries.

The Superintendent of Government Printing, India.

The Superintendent of the Government Central Museum, Madras.

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

Notes on the Country *between the* Singareni Coal-field *and the* Kistna River *by* R. BRUCE FOOTE, F.G.S., *Deputy Superintendent, Geological Survey of India.* (With a map).

The immediate opening up of the Singareni coal-field having been under consideration by the Government of India, I was deputed to examine the unsurveyed country in the valley of the Munièru (Moonyair) river in the hope of finding further outliers of the Barakar rocks, the Indian carboniferous series, between the Singareni coal-field and Bezwada, as the existence of other coal-fields might greatly influence the selection of the line of country to be traversed by the railway to connect the Singareni coal-field with Bezwada, the central point in the great canal system connecting the whole of the Godavari and Kistna deltas with Madras, and the terminus of the new Bellary-Kistna State Railway.

Limits of area here reported on.

The limits of the previously unsurveyed tract which I examined in carrying out this duty are, to the south the Kistna river; to the west the boundary of the Kadapa rocks, and further north the left bank of the Munièru; to the east a line coinciding with the eastern edge of Atlas-sheet 75; to the north a line running from the Munièru eastward to the edge of sheet 75 a little to the southward of Khammamett. To the north of this line lies a considerable tract extending up to the Singareni coal-field which had been partly examined by Mr. King and of which I completed the survey.

The geological formations met within the area thus defined belong to the following four divisions:—I. *The Gneissic rocks;* II. *The Kadapa* or *Transition rocks;* III. *The River Alluvia;* IV. *Subaerial Formations and Soils.*

Geological formations met with.

I.—The Gneissic Rocks.

Disposition of the gneissic rocks.

As will be seen from the map, the gneissic rocks of the Munièru (Moonyair) valley are extensions of the great granitoid and schistose bands seen south of the Kistna river and shown in the little sketch map given in my memoir on the geological structure of the eastern coast.[1]

The gneiss rocks of the Kistna district show two great bands of granitoid rock divided in the southern part of the area by a much narrower band of schistose beds. In the northern part of the area, however, the schistose beds extend considerably to the eastward whereby the eastern granitoid band is interrupted and apparently overlaid by this eastward extension of the schists. Whether this overlapping of the schistose beds over the granitoid really takes place or not, has not as yet been proved, but as it is believed on fair grounds to take place in the southern parts of these great bands in the Nellore district, it may for the present be assumed also to take place in the Munièru valley, and the separate patches of granitoid gneiss lying to the northward of the continuous band may *pro. tem.* be treated as inliers in the schistose area. The two granitoid bands and the intermediate schistose band have to the south of the Kistna a general strike from south-west-by-south to north-east-by-north, which continues till they cross that river and then commences to trend to due north and then to north-north-west. In the neighbourhood of the Singareni coal-field the strike becomes less constant for a distance of 4 or 5 miles, but then trends north-5°-east and continues so till the edge of the overlying Kadapa and Gondwana rocks.

The east granitoid band.

The eastern of the two granitoid bands forms the mass of the very picturesque Kondapalli (Condapilly) hills, as also the broad plain stretching from the foot of the hills past Juzzur (Joodjoor) westward nearly to the east bank of the Wyra river. To the northward the granitoid rocks extend under the alluvium of the Gumplagudum stream (the principal tributary of the Wyra) and run north and north-west-by-north for another 9 or 10 miles, when it is cut off by the east extension (? overlapping) of the schistose rocks above referred to. North of this spread of schistose rock, at a distance of between 4 and 5 miles, lies the first of the inliers also referred to above. It is of elongated elliptical form (in plan), and extends some 12 or 14 miles to the north-west-by-north with a maximum breadth of 5 miles in its southern half. The apices of the ellipse are rather pointed. By far the greater part of its area lies on the western side of the Wyra river. For convenience of reference it may be called the Gollapudi inlier from the

Gollapudi Inlier.

[1] On the Geological Structure of the Eastern Coast from latitude 15° northward to Masulipatam, by R. Bruce Foote, F.G.S, &c. Memoirs, Geological Survey of India, Vol. XVI, 1880.

principal village lying near its centre. The northern inlier which lies 4 miles north of the Gollapudi inlier is in plan a very broad oval about 4 miles long by 3 in maximum width, but its boundaries are much hidden by jungle. It may be conveniently called the Chintakurti inlier from the village of Chintakurti (Chintakoor of map) which stands a good mile to west of the position given to it in sheet 75.

Chinta Kurti Inlier.

Except close to the Kondapalli range of hills, this band of granite gneiss has been planed down by erosive forces to a very level surface, relieved in but very few places by low hills and a few great piles of tors and rounded masses. Of the hills, the Juzzur (Trig. Station) hill and the Kondakedimay (Trig. Station) on the eastern side of the southern inlier, and a low but bold rocky ridge on the western side of the inlier, a little to the north-east of the village of Nangielaygondah, are all that need be noted.

Hills in the eastern grauitoid band.

A large low ellipsoidal "whaleback" exposure of the granite gneiss occurs on the high ground north-east of Gollannapad (nearly in the centre of the southern inlier) and is, from its position and light colour, a very conspicuous object.

A rocky pile surmounted by an enormous tor forms a very striking object at the north-east extremity of the great tank east of Maddiré (Muddera).

The western granite gneiss band may be conveniently designated the Nandigama (Nundyganah)-Khammamett band from the two principal towns which stand upon it. It crosses the Munièru (Moonyair) valley near Pennagranchiprol, 10 miles north-by-west of Nandigama (but that part of its course was not examined). Its southern part is bounded by the overlying quartzite beds at the base of the Kadapa rocks of the Jaggayapetta (Batavole) basin, but further north it shows a considerable westerly extension; it was only examined along the east side of the Munièru valley. Its eastern boundary for a distance of more than 25 miles is formed by a narrow strip of Kadapa rocks which are faulted to the eastward against the median band of schistose gneiss before referred to.

The western or Nandigama Khammamett granitoid band.

The southern part of this band of granitoid gneiss forms a low rolling plain, the surface of which is almost everywhere marked by a thick layer of cotton soil, but in the central and northern parts the surface becomes much more broken and the extensive spreads of regur have been replaced by the gritty reddish loam derived directly from the decomposition of the rocks below. Protrusions of rock over the surface are seen on every hand, and much of the country can only be described as rugged. Besides the protrusions of the granite gneiss there are many long-stretched low ridges of barren rock formed by trap dykes which around the town of Khammamett form a perfect net-work that would offer no small obstacle to the construction of a railway. Northward of Khammamett the surface of the granite gneiss band becomes less rugged. To some extent this may only be apparent, for the country here is much less bare of wood than to the south.

Plexus of trap dykes at Khammamett.

Orography of the western band.

Although the surface of this granite gneiss band is much more broken and rugged in the northern Khammamett half than in the southern half or than in any part of the Juzzur band, very few of the eminences on it rise high enough to deserve the name of hills. In the southern part there is but one hill, the Cuddabode Trigonometrical Station, on the very edge of the Kadapa basin 9 miles north-west-by-west of Nandigama. The Cuddabode is about 200 feet high, and shows a very fine mass of great rocks around its summit.

A low hill consisting of great tor-like masses piled one over the other occurs at Mushti Kuntla (Mooshty Koontta) on the high road (as shown on the map) leading from Maddiré (Muddeera) to Khammamett. Another low hill of very typical rounded shape forms the Sitarampett-Trigonometrical Station hill 4 miles to the north-west-by-west. Various low but very typical granite gneiss hills run along the western side of the Munièru valley, but these did not come within the range of my survey. The highest and most conspicuous hill in the granite gneiss band is that on which Khammamett fort has been built. I estimate it at about 300 feet high above the surrounding country over which it commands a very extensive panorama. A rather lower hill, showing some good tors on its summit, lies about a mile north of the fort.

A small rocky ridge consisting of a very uncommon variety of hornblende-micaceous rock is to be seen at the north-eastern corner of the great tank north of Jastipalli (Jausteepully) 14 miles north-east-by-north of Khammamett.

General petrology of the granitoid gneisses.

As far as my observation went, the predominant character of the granitoid rocks is hornblendic; micaceous varieties however do occur here and there, and in some cases both hornblende and mica occur together in the same mass. Epidote in the form of pistacite, is a frequent constituent of the granitoid rocks, *e.g.*, in the Juzzur Trigonometrical Station hill where it forms a very handsome rock of dark greenish-black colour relieved by light pinkish spots and streaks due to the quartz and felspar. A very handsome salmon-coloured and black variety is seen in some large tor-like masses which form a little inlier within the area of the Kistna alluvium about a mile east of the Kanchakacherla travellers' bangalow on the Bezwada-Hyderabad high road.

Much pistacitic granite gneiss occurs at Mushti Kuntla (Mooshty Koontta) 14 miles south-south-east of Khammamett, also in the bed of the Munièru at the ford on the road to Warangal. This is a beautiful pale-green and pink variety, which has in places been much polished by the river current, and shows its capability for furnishing a splendid ornamental stone.

The general colour of the rock in the western band is greyish and its texture mostly very coarse.

Included boulder-like masses of older hornblendic rock are common in places.

Very few quarries are to be found, and as the great rounded weather-beaten masses are frequently impracticable to an ordinary geological hammer, much less information as to the composition of the rocks could be collected *en passant* than in more civilised regions where quarries are numerous.

Noteworthy varieties of the granitoid rocks in the two inliers are massive hornblende rocks often of highly trappoid aspect, but not occurring as dykes, nor as far as could be seen as intrusive masses. These cover considerable areas in the two inliers; indeed, they seem to constitute the mass of the Chintakurti inlier. In the Gollapudi inlier they occur around Khauwapuram (on the Wyra) and westward nearly as far as Gollapudi.

The schistose gneiss band.

The median band of schistose rocks lies in its southern portion chiefly on the left (or eastern) bank of the Munièru. Northward of the junction of the Munièru with the Wyra the schistose band is confined to the tract between the two rivers. Its western boundary is here hidden by the alluvium of the Munièru to opposite Pennaganchiprol, where the granite gneiss of the western band comes in. Beyond this to the north the boundary between the schistose band and the western granitoid band is hidden by the superposition of a long narrow strip of Kadapa rocks which runs northward for more than 25 miles. To the northward of this outlier of Kadapa rocks the two bands of gneiss must be in apposition, but no section could be found showing their actual contact.

Orography of the schistose gneiss band.

No eminence deserving of the name of hill occurs on the surface of the schistose gneiss band in its southern part, and very few in the central part. In the latter attention may be drawn to the rocky hill 7 miles north-by-east of Maddiré (Muddeera), which rises between 200 and 300 feet above the plain; to the low rocky hill a mile east of Pengol (edge of sheet 94) which will be described further on. Also to the low ridge on which stands the Pedda Gopatty Trigonometrical Station 9 miles south-east-by-east of Khammamett. The magnetic iron beds forming this ridge will be described further on.

The schistose gneiss area immediately south of the Singareni coal-field, which is a northerly continuation of the schistose band before described, contains numerous gneiss hills which may also be referred to, though they do not lie within the limits of the unsurveyed tract mapped by me. The principal hill in this quarter is the Gobugurti (Goboogoorty) Trigonometrical Station, which rises some 600 or 700 feet above the surrounding plains and forms a nucleus whence radiate some five or six lower jungle-covered ridges. To the east of the Gobugurti group of hills is the Ballapett (Bullapett) Trigonometrical Station hill and several other rocky or jungle-covered gneiss hills not shown in the map. Southwest of the Gobugurti hill is a small detached hill marked in the map (sheet 75) as "H. Tree," while to the north-west of the extreme spur of the Gobugurti mass lies the Irlapudi Trigonometrical Station hill, a bold mass of hornblendic gneiss some 500 to 600 feet high.

The other hills to the west and north of Gobugurti hill belong to the transition or Kadapa rock system, and will be referred to when dealing with those rocks.

Petrology of the schistose band.

The more general variety of gneiss met with in this median band is a hornblendic variety which is frequently intercalated between bands of micaceous gneiss of varying character. Some of them are very highly micaceous and almost deserving to be ranked as mica schists. Richly felspathic forms are uncommon.

Massive beds are occasionally met with, which are of such coarse texture and so obscurely bedded as to approximate very closely to typical granite gneiss. As a rule, however, the most massive beds in the schistose bands are very distinctly bedded, no matter how coarse their texture may be.

The beds in the southern parts of the schistose band offer nothing of special interest, and exposures of the rock are not numerous, nor do they afford any good sections, the face of the country being mostly much obscured by great spreads of cotton soil. The most noteworthy outcrops met with were some fairly rich beds of magnetic iron which form a couple of low ridges, on the south-western of which stands the Pedda Gopatti Trigonometrical Station (9 miles south-east of Khammamett). Unlike the magnetic iron beds in Nellore and Salem and other parts of the south, the grains, flakes, and crystals of magnetite are imbedded in schistose hornblendic instead of in granular quartzose laminæ, with intervening hornblendic laminæ of very schistose character.

Magnetic iron beds of Pedda Gopatti.

The amount of magnetite included in the ferruginous laminæ is sufficiently great to form a fairly rich ore, but I did not notice any indications of the ore having been mined in those parts of the beds which I examined. The iron beds stretch away a considerable distance to the southward, and it is not improbable that they are connected with a bed of similar hornblendic magnetite schist which is exposed for a few square yards on a small red knoll lying about half way between Naugilaygondah and Prodatur-Agraharam (Agrarum). The northward extensions of the Pedda Gopatti iron beds are lost sight of a very little distance beyond the north end of the ridges.

If the infra-position of the granitoid gneiss to the schistose band be assumed to be true, there is no difficulty in understanding its relation to the tract of schistose gneiss already referred to, which lies between, and to the east of, the Maddiré (Muddeera) end of the Juzzur granitoid band and its northerly re-appearances, the Gollapudi and Chintakurti inliers. The schistose spread in that case is simply a survival (if the term be allowable with regard to inanimate objects like rocks) of part of the overlying schistose series which has there escaped complete erosion, probably because it lies in a hollow. If the hypothesis of the infra-position of the granitoid series should be disproved by subsequent observations, then the relative positions of the two series of rocks can only be explained by supposing the metamorphic forces to have acted with far greater intensity in certain tracts than in other adjoining ones. This variation in intensity of the metamorphic forces may have been largely assisted by the original differences in texture and mineral composition of the original sedimentary deposits acted upon. It is quite conceivable, indeed very probable, that coarse thick-bedded gritty sediments would assume a much more massive structure under the influences of metamorphic agencies than fine-grained sandstones or shales which would retain a schistose appearance. The presence of small patches of granitoid gneiss within the general area of the schistose variety may very likely be safely explained by assuming them to have been local deposits of very coarse

Relations of the schistose gneiss extension to the eastern granitoid band.

texture, which were exceptionally affected by the metamorphic changes undergone by the whole mass of rocks.

Rocks of the eastern extension.

The rocks which occur in the eastern extension of the schistose band are chiefly hornblendic and micaceous gneisses, varying from nearly massive to highly schistose varieties. None of any special interest were noted.

The only schistose rocks which deserve separate notice are a few beds of magnetic iron of very small size (from 6 inches to 1½ feet thick) which occur on the eastern boundary of the area under consideration, between the villages of Pengol and Utur, both situated in an outlying portion of the Nandigama Taluq (Kistna district). They are but little exposed, though a good deal of debris derived from them is scattered over the surface.

Two or three small beds of similar character and size occur about 5 miles to the north. The ore is in all cases of fair quality, but the quantity is too small to give the beds any importance. They did not appear to have been ever worked.

Granular quartz rocks.

To the schistose series I reckon from their position some beds of granular quartz rock of precisely the same character as those forming the many remarkable bare ridges round the towns of Madura and Tinnevelly. These beds form a low broad rise beginning immediately north of the large village of Pengol (see page 16) and extending for 2 or 3 miles north-north-east. The granular quartz rock is frequently exposed, but only in low flat sheets in which the bedding is badly seen, while the extensive scrub jungle covering much of the rise helps to make the lie of the beds still more obscure.

Pengol hill beds.

A more instructive display of very similar granular quartz rock occurs a little to the south-east just within the limits of the country shown in sheet 94. Here a low rocky ridge rises out of a plain covered with red soil, and shows the bassett edge of a great bed running south-south-west to north-north-east, with a dip of 40° to 45° east. The quartz is (where freshly broken) of pale pinkish-white to pale reddish-brown colour and nearly diaphanous. It includes many minute and a few large brilliant spangles of reddish-grey specular iron. Where weathered the surface of the quartz rock is often covered in small patches with reddish-brown lateritic films. A direct connection between these granular quartz beds and those to the north-eastward of Pengol doubtless exists, but want of time did not allow of my tracing it out.

Further north the eastern spread of the schistose band is to a very great extent marked by great spreads of cotton soil, and the few outcrops, chiefly of hornblendic gneiss that are met with, are of no special interest.

Rocks north of Khammamett-Kullur road.

After crossing the road leading from Khammamett to Kullur the country begins to get hilly and broken and the spreads of cotton soil disappear, but the rocks are here much hidden by jungle. The mass of hills forming and surrounding the Gobugurti Trigonometrical Station consists of great beds of hornblendic and micaceous gneiss in frequent alternation. To the north-west of the Irlapudy Trigonometrical Station hill a large

Crystalline limestone.

bed of grey crystalline limestone intercalated among beds of hornblendic gneiss which have a local strike from west-by-south to east-by-north with a high southerly dip. The limestone cannot be much less than 50 feet thick. Further north still, and about half a mile east of Kamapalli, is a medium-sized bed of magnetic iron of rather poor quality running north-north-east and dipping 60° east.

The Singareni iron bed.

No connection was traced, though it may very likely exist under the surface soil between this bed and a very large and important bed of magnetic iron which commences about 2½ miles to the north and continues thence for fully 3 miles till it runs under the overlying mass of the Kadapa rocks at a point only about half a mile west of the edge of the southern boundary of the Singareni coal-field. As this bed of magnetic iron is traced northward from its southern extremity, it increases in thickness by the appearance of other beds above and below it till at last it forms the mass of a considerable hill some 150 feet high just under the parallel of 17° 30′ North. The iron-beds may be traced along the valley north of this hill for about half a mile when they rise again and form a considerable ridge 250 to 300 feet in height by estimate. The ore in these beds is very rich in quality and really appears to have been placed here by nature, in order that an iron industry might arise as soon as the coal measures close by are made to yield up their carbonaceous treasures. As the line of rail coming from Bezwada could with the greatest ease be carried close along the foot of these ridges, every facility exists for bringing the ore and fuel together at some handy spot, while the great limestone beds of Kadapa age, which occur at no great distance to the east and west of the coal-field would furnish an inexhaustible supply of flux for the smelting works.

Intrusive rocks.

The only intrusive rock occurring in any notable quantity is dioritic trap, dykes of which are numerous in some parts, as the middle part of the Munièru valley. All as far as my observation went are dioritic and mostly of medium coarseness of texture. Many are of considerable size, 50 to 60 feet or more in thickness, and from their superior hardness stand out well over the surrounding granite gneiss. Their surfaces have weathered into a very "blocky" condition, and fallen masses almost everywhere mask their contact with the granite-gneiss. Some of the ridges rise as much as 50 or 60 feet above the surrounding country. The most southerly of all the trap intrusions noted is the most important and of such size that it cannot be classed as a dyke proper. It lies about 5 miles north-west of the junction of the Kistna and Munièru, and immediately south of the village of Thoralapadu (Thoralapandoo). The intrusive rock is a diorite differing in no way from that in the true dykes of the neighbourhood. The trap mass extends for rather more than 3 miles southward, and is not less than a mile across near the middle. Unfortunately it is overlapped all round by a very thick and continuous sheet of regur which completely hides its boundary, and no contact with the gneiss around it was traceable.

All the trap intrusions noticed are, judging by their petrological aspect, to be reckoned as belonging to the great series which was injected into to the gneissic rocks prior to the deposition of the Kadapa or Transition rock system.

Granite veins are very rare and small both in size and length. The same may be said of true quartz veins, none of noteworthy size were met with.

Of brecciated quartz reefs such as play such a prominent part in the Cuddapah and Anantapur districts, and elsewhere, only one example was seen. This is a rocky ridge, about ⅓rd of a mile in length, about 2¼ miles west-north-west of Juzzur. It has a course from south-east-by-south to north-west-by-north. The peculiar brecciated or quasi-brecciated character of the reef is well seen on the pale greenish-white rocks which form the crest of the ridge in its northern part.

II.—*The Kadapa or Transition Rocks.*

Frequent reference has been made in the foregoing pages to the several outliers of the Transition rocks which occur in the Munièru valley and which by their position prove that the two great basins of rocks of that age which exist in the lower valleys of the Godavari and Kistna respectively were once united. Four of these outliers were mapped, and another is known to exist in the very jungly country south-west of the Junjurlagutt Trigonometrical Station hill. This latter outlier could not be mapped, as owing to the rough and jungly character of the country it would have required several days' work, which could not be spared because of the pressure of more important work. Starting from the south the outliers are:—

1. Ragavapur (Raugavapoor) Trig. Station Hill.
2. Pallagiri Hill.
3. Jennel Gudda Hill.
4. Shernavála ridge.
5. Mucherla (Moocherla) Trig. Station Hill (unmapped.)

Ragavapur hill outlier.

1. The Ragavapur Trigonometrical Station Hill is a bare steep Hill which rises some 500 feet above the valley of the Munièru and 574 feet above sea-level. It consists of two or three great beds of quartzite varying in texture from coarse grit to a fine jaspideous quartzite, which is very slightly hæmatitic, and here and there of reddish colour. The quartzite beds are separated by micaceous or argillo-micaceous schists of silvery-grey, greenish-grey, and red colours, the latter being of various shades. The beds have been considerably contorted. At the south end the quartzites show a low easterly dip; at the little gorge in the ravine which scores the east side of the hill, they are slightly inverted or vertical; while at the Trigonometrical cairn near the north end they begin to curve round westward in a strongly marked curve which looks as if its continuation would join the beds in the Pallagiri hill. No continuation is however visible in the valley between the two hills which is filled with the sandy alluvium of the Munièru. The dip of the quartzite beds close to the Trigonometrical cairn, and just where the westward curve commences, is from 40° to 45° east. It is quite clear from the position of these beds with reference to the gneiss, which appears very near to the eastern foot of the hill, that the Kadapa

rocks are the remains of a long anticlinal fold faulted down against the gneiss on the east.

2. *The Pallagiri Outlier.*

Pallagiri hill.

The structure of Pallagiri hill is very similar to that of the Ragavapur hill, and it is very probable that it is formed of the same series of beds, for in mineral character the Pallagiri beds agree closely with the Ragavapur beds, especially in the character of the quartzites, which vary locally from distinct coarse grit to very fine close-grained jaspidean schists. The dip of the beds is about 55° east, and there can be no doubt that here also the boundary is faulted down against the gneiss.

The gritty character of the original sandstone is very clearly revealed in parts by the action of weather, and may be made out even in unweathered parts by careful macroscopic inspection. The true water-worn rounded surfaces of the individual grains are quite clear.

3. *The Jennel Gudda Outlier.*

Jennel Gudda hill.

Jennel Gudda, 6 miles north of Ragavapur hill, is a round-topped steep-sided hill which throws out a couple of diverging spurs to the east and north-east. In plan the mass of the hill represents a strangely compressed horse-shoe, the sides of which form ridges which slope down slowly in the first half of their course and then steeply till they end in small bluffs which seem to indicate the position of the line of fault by which these Kadapa beds are thrown down against the gneiss. The actual boundary is not seen owing to thick soil. The ridges are formed by rather thick beds of quartzite separated into two series by micaceous and argillaceous schists. The uppermost beds on the hill stratigraphically are a very ferruginous argillite schist which lies in the valley between the two quartzite ridges. This is so bright a red in colour in parts that it is dug out to be used as reddle.

The northern extremity of the outlier is hidden under thick cotton soil, but may be traced for some distance northward as a low and steadily decreasing ridge forming the watershed locally between the Munièru and the Wyra.

4. *The Shernavála Outlier.*

Shernavála ridge.

The Shernavála outlier is the long narrow strip of Kadapa rocks which runs for a distance of 25 miles nearly parallel with the course of the Munièru at a distance of from 3 to 6 miles. For the greater part of the distance it forms the watershed between the Munièru and the Wyra. I have called it the Shernavála outlier because it was close to the village of that name that I first came upon it, and that the very remarkable quartzite breccia which there occurs at the base of the limestones enabled me at once to recognise the rocks as belonging to the Kadapa system. The southern end of the outlier lies 8 miles north-north-west of Jennel Gudda hill, and is formed by two small rocky hills showing strong outcrops of quartzite. The beds trend north-west for about a mile, and north-west-by-north for another mile, they then run north up to the Shernavála Trigonometrical Station. This southern part of the ridge is very low and much obscured by cotton soil and low but thick jungle, so that the eastern boundary is very difficult to make out. Near to Shernavála the ridge rises again and stands from 40 to 60 feet above the granite gneiss tract to the west, but to the east it slopes down almost imperceptibly to the schistose gneiss band.

Shernavála Trig. Station.

The rocks seen at the Shernavála Trigonometrical Station are highly cherty blue limestones which are underlaid by a remarkably fine-grained jaspideous quartzite breccia of rich reddish, yellowish, and brown tints. The breccia seems to be merely local deposit, and is wanting in many sections both north and south of Shernavála station. Underlying the breccia is a micaceous schist which might belong either to the Kadapa series or the gneiss, but I could not satisfy myself which series to assign it to.

Letchmapur hill.

North of the Shernavála ridge the outcrop sinks down a good deal but rises again a couple of miles further on in the Letchmapur Trigonometrical Station hill. The limestone beds which seem to be continuous all along the west side of the band shows in great force around the Letchmapur hill. The limestone is grey in colour, cherty, and greatly contorted and vandyked. The dark variety of limestone occurring here shows a decided blue colour when freshly broken. Overlying the limestone are beds of micaceous argillite with here and there small beds of limestone. Small lenticular inclusions of the same rock are numerous. The limestones are generally sub-crystalline, but sometimes really crystalline. The argillite beds which are of dark-greenish or bluish-green grey colour roll about a good deal, but have a general dip to the east. The eastern boundary is not seen at Letchmapur, owing to a great accumulation of kankur mixed with debris of the jaspideous breccia and limestone.

North of Letchmapur the surface of this strip of Kadapa rocks is much obscured by cotton soil.

At Narrainaypolliam (site of an abandoned village) the transition beds show very slightly, being traceable only by slight outcrops of quartzite.

Kodamur section.

At Kodamur highly cherty limestone with some ferruginous brecciated cherty quartzite forms a narrow rocky ridge 50 or 60 feet high above the surrounding country. To the north of the village the ridge rises considerably and joins the group of low hills which lie eastward of Khammamett, and here the outlier attains its greatest width of about 2 miles. The hills consist of rather shaly quartzites with numerous beds of limestone in the valleys between. The rocks in the western side of the band show some extensive contortions, but on the eastern side they have the normal easterly dip towards the faulted boundary. Considerable contortion of the quartzite beds is also visible still further to the north near Ragunadhapuram. North of Ragunadhapuram the base of the Kadapa rocks is again formed of limestones, but in this case they are very little altered and almost lithographic in their very fine and close texture. They are fairly thick-bedded and mostly of grey colour. They appear to be over-

Section east of Khammamett.

Ragunadhapuram limestones.

laid by quartzites, but time did not allow me to explore the thickly wooded hills lying between the limestone beds and the Chintakurti Trigonometrical Station.

5. *The Mucherla Outlier.*

This outlier consists of quartzites forming the crest and south face of the ridge which runs north-eastward from the Mucherla (Moocherla) Trigonometrical Station. The beds are cut off abruptly at their western extremity, and there is certainly no connection between them and the quartzites on the Chintakurti hill 5½ miles to the south-west-by-south, the whole intervening space being occupied by gneissic rocks. The quartzites appear to extend further eastward across the valley drained by the headwaters of the Wyra and to join the hills north and north-east of Mudlapad which contain numerous bands of quartzite. A bed of sub-crystalline limestone is exposed to the west of the small tank north-west of Mudlapad, and traces of ferruginous quartzite breccia are very numerous in the talus along the south foot of the hills. The hills are thickly covered in most parts with low tree jungle, and it is only when quite close to them that their petrological distinction from the neighbouring gneiss hills becomes apparent. This is especially the case at their eastern extremity.

The plain immediately south of these hills consists of gneiss with various beds of massive hornblende rock against which the quartzites are unquestionably faulted down. As before mentioned, want of time prevented my working out the details of this interesting outlier of the Kadapa rocks. It is I believe separated from the main spread of the Godavari basin of the Kadapa rocks by a considerable fault running nearly north and south, a little to the west of Junjurlagutt Station hill.

III. The River Alluvia.

But little can be said of the river alluvia, that of the Kistna excepted, no features of special interest having been worked in connection with them.

Alluvium of the Munieru.

The alluvium of the Munièru is generally very sandy, as might be expected from a river draining so large an area occupied by highly siliceous rocks. Near its mouth, however, the banks and small islands in it consist mainly of dark silts formed of washed up cotton soil.

Of the Wyra.

The Wyra, which through the greater part of its course drains a regur covered country, shows much dark silt in its banks, but here and there, as for instance just below its junction with the Gumplagudem stream, there are considerable shows of sandy alluvium. The valleys of the headwaters of the Wyra contain considerable deposits of loam, often with much kankar, resting upon or intercalated with beds of coarse shingle.

Gravels.

Much attention was paid to the gravels in the dry beds of all the rivers and streams in order to ascertain whether any debris of the carboniferous rocks might be contained in them which might help one to trace out the localities where outliers of the Gondwana rocks might occur, but no outliers were discovered by this mode of search. It was very remarkable how very few pebbles of the various Gondwana sandstones and of the softer members of the Kadapa rocks were to be found in the streams after the first few hundred yards below their original sites. All the softer masses of stone seem to have been speedily reduced to sand by the violent action of the streams, which only flow sufficiently to move the debris in their beds when swollen by heavy rains, but then become furious torrents. No organic remains were noted in any of the alluvia.

The diamond gravels of the Kistna.

The most important alluvial deposits within the area now under consideration are those lying on the left bank of the Kistna along what may be conveniently defined as the Amaravati (Umarawutty) reach of the river. These deposits consist of sandy shingle beds which have in many places been worked for diamonds. No workings were in progress at the time of my visit, though large areas of the shingle beds have not been turned over as yet. From enquiries I made from the people at Mugalur and Partial (Purtyall), I believe that the diamond industry is crushed by the heavy royalty levied and by other absurd restrictions imposed by certain people at court in Hyderabad. There is certainly no geological reason why the undisturbed gravels should not be as rich in diamonds as the positions of the same beds explored in past times. That the old workings were held to be of considerable value is evident from the fact of their having been retained by the Nizam when the Guntur circars were made over to the East India Company.

The shingle consists mainly of quartzite which has been very highly water worn. The number of gneissic pebbles occurring in the shingle is very small, while agates and trap pebbles derived from the Deccan Trap are of great rarity in the sections examined.

The gravels lie at considerable levels above the river, but it is almost impossible to trace their upper boundaries because covered by great cotton soil spreads.

IV. Sub-Aërial Formation and Soils.

The sub-aerial formations met with were very few and mostly of small extent and interest. Ferruginous pisolitic gravel is scattered in small quantity over the surface of the red soils where they are richly ferruginous and in the proximity of magnetic iron beds and of the hæmatitic granular quartz rocks, *e.g.*, of Pengol hill (see page 18).

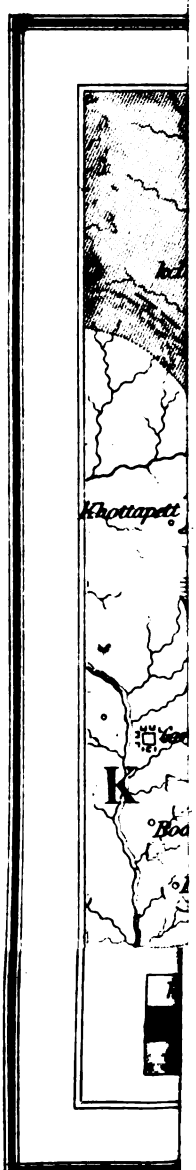
Hæmatitic incrustation in breccias.

The dark-brown to bluish-black often botryoidal incrustations of the outer surface of parts of the jaspideous breccia in the Kadapa rocks, especially on the knoll south of Shernavála Trigonometrical Station, and at Kodamur (5½ miles south-east of Khammamett) are due to weather action on small reniform masses of dense limonite (brown hæmatite) enclosed in the rock. The same action, but on a much larger scale, has taken place in some of the brecciated quartzites in the Mucherla outlier and in a breccia bed close to the boundary of the Kadapa rocks where crossed by the road leading from Singareni town to the centre of the coal-field near Yellindellapad, the cementing medium in these cases is red hæmatite, rich enough to have been used as an ore by the native smelters.

Kankar deposits.

Small deposits of carbonate of lime in the shape of vermicular or nodular kankar are common enough, as they are in all tracts where hornblendic rocks are abundant. Only one locality was

Foote.



Taken from Shee

noted where the kankar deposit was sufficiently extensive to attract attention. This was to the west of Rajawarrum (4½ miles north-east of Maddiré).

Only two classes of soil are represented in this region—the red and the black.

Soils.

Of these the black occupy nearly all the southern and eastern central parts of the country south of Khammamett and the hills to the east of it, these parts being open and approximately level. Wherever hills rise in the plain, or the surface is rugged and broken, red soil puts in an appearance. This is markedly the case along the western side of our area, where the granitoid rocks have a rough and broken surface. Very few patches of cotton soil occur here.

No spreads of soda or white soil were observed.

Geological Sketch *of the country between the* Singareni Coal-field *and* Hyderabad, *by* R. BRUCE FOOTE, F.G.S., *Deputy Superintendent, Geological Survey of India.* (With a map.)

The geological data here given were gathered while carrying a broad traverse from the Singareni Coal-field westward to Hyderabad, in order to ascertain whether any outliers of the Barakar or Indian carboniferous rocks occurred in that tract, the presence of which might influence the choice of direction for the new railway to be constructed between Hyderabad and Warangal.

The examination of the tract in question unfortunately dispelled the hope of finding any outliers of the coal-measure rocks westward of the Singareni coal-field.

Existence of coal-measures disproved.

The whole large tract included in this traverse was found to consist of bands of granitoid gneiss of slightly varying characters overlaid only by the local alluvia of the various small rivers traversing the country or by unimportant subaerial deposits of very recent character. Of intrusive rocks a considerable number of trap dykes were mapped, but many were not followed up through the extensive scrub jungles for want of time.

Physiography of the tract examined.

The country is, as a rule, open and undulating, but rocky hills both isolated and in small groups are not unfrequent, and some of them rise boldly out of the plain to a height of from 500 to 800 feet. Smaller hills are numerous, as are also great rocks and tors as well as low broad "whaleback" eminences, which afford a good lookout over the surrounding country. But for these frequent eminences a far greater time would have been requisite to enable one to acquire anything like a good idea of the country, as over great tracts the scrub jungle is just high and thick enough to shut out the view even when traversed on horseback. The jungle is not thick enough, however, to hide the character of the country when overlooked from an elevation of a few score feet or so, and the numerous rock exposures show up well, even when flat, or nearly so, because of their light colour and generally more or less glistening surface. The latter quality often makes them conspicuous at a distance of several miles.

Shape of area covered by traverse.

The shape of the area covered by the traverse may be described roughly as a scalene triangle whose shortest side corresponds with the course of the Munièru river for 6 miles northward from Khammamett and then for nearly 40 miles with the course of the Garlah, its principal northern tributary, the longer sides stretching away to Hyderabad with distances of 96 and 105 miles respectively.

The country east of the Garlah had been examined by Dr. King, who had also made a traverse from Khammamett to Warangal *viâ* Biravol (Beeroal), Murrypuddah, Nelli Kudru (Nelly Koondroo), and Kothoor, thus extending the known tract for a considerable distance northward of the triangular area of my traverse.

Hydrology.

All the drainage of the triangular area falls into the Kistna by the Munièru, the Paléru (Pallair), and Mussi (Moosy) and their respective tributaries. The Mussi is the only one of these rivers which has a pretty constant flow, but even it in the hot and dry months often shows a perfectly dry bed for reaches of several miles in length. This is doubtless due in very great measure to the absence of anything like real forest. Even in the most jungly tracts along and east of the upper courses of the Munièru the thin jungle, which as Hyderabad is approached dwindles to mere stunted scrub or disappears altogether, is utterly inadequate to shelter the surface against the vertical rays of the sun in the hot season. In its present condition most of it may be described as an arid country cursed by large flocks of goats. In no other part of South India have I seen so strong a tendency to consume all the cattle manure as fuel,—a fact which attracted the notice of more than one of my Madrassee servants.

Orography.

It has been already pointed out that many hills, some in groups and some quite isolated, rise from the surface of the granite gneiss tract here dealt with. The principal of these may be enumerated, as they afford fixed points for reference in a country where many of the villages do not now hold the same importance that they did when Atlas sheet No. 75 was originally constructed. They may be advantageously considered in groups, as far as possible, some of them hardly belonging to any one group because lying too far apart from any others.

Kandi Konda group.

The most important of these groups in the eastern part of the area under consideration may be called the Kandi Konda group from the hill of that name which lies a little south-east of the intersection of the meridian of 80° East by the parallel of 17° 80′ North latitude. To the north-west-by-north of Kandi Konda lies a considerable number of detached rocky hills rising out of the extensive but thin and low forest which here covers the whole face of the country. These hills all show, more or less, the typical rounded outlines of granitoid masses or equally typical bold rocky masses crowned in many places by great tors. In the northern part of the group Bali Konda and the two hills immediately north and south of it are the most lofty and striking.

Kandi Konda itself is a fine hill, rising 800—900 feet or more above the plain. It is crowned by a small temple (the "Pagoda Station" of sheet 75), and was formerly fortified, as shown by three or four ruined gateways one has to traverse in ascending and by a series of cisterns, partly natural, partly artificial, a little below the summit. These contained a good supply of water even in April. The hill was evidently of some importance formerly, as it has given its name to the taluq[1] in which it stands. From the summit of the hill the beds of granite gneiss composing it are seen to trend southward to the lower hills near Hydershaipetta on the Munièru. In the western part of the group the principal hills are the Narasimhapetta Pagoda hill, west of Kuppelvoy, and the Butchurazpully hill which lies 5 miles south-south-west of Kandi Konda. The continuation of the group south of the Munièru shows two very bold and picturesque hills the Goniguth (Trigonometrical Station) and the Jallipalli (Jullypully) Drug hill, each of them showing an approximately conical mass towering 600—700 feet above the plain around. The other hills which lie round Murrypuddah and Pindipol are much lower.

Urlagondah hill.

South of the Kandi Konda group, but hardly to be reckoned to it, is Jettygonta Trigonometrical Station, a rather remarkable pile of huge tors. Nine miles west-south-west of this hill is the Urlagondah Trigonometrcial Station, a fine bold hill rising some 500 feet or more out of the plain over which it commands a very extensive panorama remarkable for the great number of low flattish exposures of rock which show through the red soil here prevailing. The light colour of the rocks and their shining surfaces produce an effect unlike anything I have seen elsewhere in granite gneiss districts.

Arwapalli group.

About 20 miles west-by-north of Urlagondah lies a small group of bold rocky hills which I will call the Arwapalli (Arwapully) group from the Arwapalli hill, a station of the Trigonometrical Surveyors which is the most important and highest mass in the group. It is a fine bold mass nearly conical in form, rising fully 800 feet above the plain, and is the most conspicuous hill in that part of the country. Kundaguth hill (Station), the easternmost member of this group, is also a considerable hill and nearly as high as Arwapalli. This group includes a number of smaller hills and masses not shown on the map. They have all been denuded of the jungle which formerly clothed their flanks.

Vizianagram group.

Twenty miles or a little more north of the Arwapalli group lie the southern members of another small group which I will call the Vizianagram group after a small but interesting hill bearing that name. The beds of granite gneiss composing the hill have a north-westerly strike and can be very distinctly traced across the intervening plain into the Zaffarghur hills, a distance of 4 or 5 miles. The south-western part of the group is formed by the Kolonpalli hills, all typical specimens of granite gneiss hills.

Madapur group.

The next group of hills may be termed the Madapur group from the village lying nearest its centre. The group includes six considerable hills rather widely detached and a number of smaller ones, several of which are not shown in sheet 75. This group lies 12 miles south-west of Vizianagram hill. The principal hills in the group are the Kul Konda (Koolconda) at the northern extremity, the Madapur Trigonometrical Station hill,

[1] The Kasba of the taluq is not at Kandi Konda village, but at Nelli Kudru (Nelly Koondroo), 20 miles north-west-by-west.

two large hills north-east of Madapur, another large one to the west of the village, and lastly a very fine bold hill 700—800 feet high 6 miles to the south-east.

To the west of the Madapur group the country for a distance of over 20 miles, though rising steadily westward, shows many fewer hills, and those are with one exception of much smaller size. They are too scattered to be included in groups, and do not require special notice.

Sudi Konda.

The only one of importance is a lofty conical mass which rises on the north side of the Mussi river at a distance of 3 miles from the large village of Vemal Konda (Vamul Conda). The local name of this hill is Sudi Konda. It is the most perfectly conical granite-gneiss hill of large size that I am acquainted with, excepting possibly the Suttu Pottai in South Tinnevelly. Sudi Konda, which is fully 600 feet high above the plain if not considerably more, owes its shape chiefly to the concentric peeling off on a gigantic scale of thick layers of rock.

The numerous granite-gneiss hills south of the Mussi river did not come within the limits of my traverse.

Bhonagir hills.

Ten miles west-north-west of Sudi Konda commences a set of granite-gneiss hills that joins on to the Bhonagir group which culminates in the very fine hill on which Bhonagir Drug is built. This is one of the finest examples of a fortified granite-gneiss hill in South India and must in olden times have been a place of immense strength.

Of hills untouched by the hand of man the Raghir hill, 3 miles to the north-east, is a very beautiful example. The rocks here rise in bold peaked masses, amongst which a few fine trees are still growing, the whole being the most picturesque spot in the country between Hyderabad and Bezwada.

Parvatgiri hills.

The group of hills to the north of the road from Bhonagir to Hyderabad though picturesque is much lower than the Bhonagir hills. The low hills close to the road are of no special interest.

Crystalline rocks not closely examined.

The character of the work involved in making a search for coal-bearing rocks over a vast area of country in a very limited space of time debarred all close study of the older rocks. Such observations as were made in passing were necessarily rather rough. Quarries are in many parts but few and far between, and the greatly weathered surfaces of the undisturbed rocks do not afford sufficient information to admit of close determination of the exact character of the rock. The detailed description of the petrology of this region will have to be given after a much closer examination of the crystalline rocks than it was in my power to make. I can only roughly indicate the great features which could not escape notice.

Difficulty of distinguishing weathered rocks.

The granite-gneisses occur, as already pointed out, in great bands running in a north-north-westerly direction across the line of traverse. Of these great bands the most easterly belongs to the Nandigama-Khammamett band of coarse grey, generally hornblendic granite-gneiss. This includes the tract of country occupied by the Kandi Konda group of hills above described. Micaceous and epidotic (pistacitic) varieties occur occasionally, but are not common. It is not improbable, however, that the micaceous varieties are much more common than appears on cursory inspection, for the mica crystals are more affected by weathering than the quartz, felspar, and hornblende. The hornblende also is often unrecognizable on the weathered surfaces; it is therefore very easy to pass from a bed of hornblendic rock on to a really micaceous bed without being immediately aware of the change. As a matter of fact, it was generally unsafe to assume the special character without getting sight of a freshly broken unweathered surface, which was frequently impossible as the great rounded masses were too deeply weathered to reveal their internal structure to the questioning of an ordinary geological hammer.

Westward of the coarse hornblendic band comes a less coarse variety in which micaceous beds are rather more frequent, or at least more apparent. To this band belong the Vizianagram, Arwapalli, and Madupur groups of hills.

West of this, again, comes a band of coarser and more porphyritic granite gneiss of coarse texture. As seen in the quarries to the south-west of Mutkur (Mootkoor), it is a greyish pink rock, which when closely examined consists of pinkish orthoclase, black mica, and white quartz.

The bedding is only seen when large spreads of the rock are exposed.

Further west hornblendic varieties again appear to predominate and the granitoid character of the rock becomes more marked, the original bedded structure of the rocks having been entirely, or almost entirely, obliterated by excessive metamorphism.

Special varieties of the granite-gneiss.

Specially beautiful examples of granite-gneiss were met with at several places, *e.g.*, at Autapuram (Owtapoorum) near the southern end of the Vizianagram group of hills, where a lovely pale pink and green variety of rock occurs, the felspar being pale pink (flesh colour) in a matrix of pale green pistacite with a few spangles of graphite. About 13 miles south of this beautiful epidotic rock is a very fine black variety of close-grained hornblendic granite-gneiss forming the rocky hill on which stands the Punnagherry Trigonometrical Station.

One of the handsomest rocks to be seen in the country is a deep red and green epidote gneiss, which is exposed in the bed of a stream between Gutkassara and Auvunumpett, 12 miles east of Secunderabad.

Trap-dykes.

It would be a mistake to omit noticing the trap-dykes occurring in the granite-gneiss area, for they occupy important positions in many parts, and in not a few cases attain to very large size. For the most part they consist of moderately coarse diorite of black or greenish-black colour, rarely of a distinctly green tint; the few of the most important may be enumerated :—

1.—A group of large dykes, north of Maddallapatti and 3 miles west of Khammamett.

2.—A very large dyke at Pindipol (Pindypoal) at the south end of the Kandi Konda hill group.

3.—Two large dykes south of Kandi Konda.

4.—A very large dyke at Inkirti, 20 miles north-west of Kandi Konda.

5.—A very large dyke running for more than 12 miles north and south through the centre of the Madapur hill group and forming several considerable ridges.

6.—A large and lofty dyke north and south at Gurjalla on the south bank of the Mussi river, possibly an extension of No. 5.

7.—A pair of great dykes which form the crest of the southern part of the great Sudi Konda hill rising some 400—500 feet above the plain.

8.—A large dyke forming the crests of the Kanchanpalli (Kunchunpully) ridge, 8 miles north-west of the Sudi Konda dyke.

9.—A very large dyke running for 14 miles north-east-by-east, south-west-by-west, passing close north of Bhonagir Drug hill and forming several very conspicuous hill ridges along its course.

10.—A large dyke crossing the plain east of Gutkassara in a nearly north and south direction. It forms several considerable bare rocky ridges and is lost to sight at the northern end in the Parvatgiri (Purvatgerry) hills, while to the south it disappears across the crest of Bachawaram hill on the right bank of the Mussi.

Porphyritic trap.

In a few dykes the diorite is markedly porphyritic, and encloses large crystals of green felspar in a green matrix. Examples of this are to be seen at Nagawaram, 2 miles south-west of the great Inkirti dyke (No. 4) above mentioned, and at Surruwaillu, 5 miles south-east of Kandi-Konda.

Granite and Quartz veins.

No granite or quartz veins of any size were seen in the course of the traverse, but a great plexus of small and often anastomosing veins of common coarse pinkish-grey granite was observed cutting up the compact grey granite-gneiss in a very remarkable way in a hill 4 miles north-east of Autapuram (Owtapoorum). The granite veins are so numerous that they form very nearly half the mass. They strongly suggest the idea that they have originated not by intrusion but by excessive metamorphism along the lines of jointing and other fissures in the original rock.

Brecciated quartz rock.

Three good-sized and conspicuous runs or reefs of brecciated quartz rock form the mass of a moderately high ridge which runs north-eastward from the left bank of the Alléru (Allair) river, 3 miles above its junction with the Bikalèru (Beekullair).

Sub-aërial formations and soils.

With the exception of a few unimportant deposits of kankar no sub-aerial formations were noted.

Soils.

The soils are almost invariably varieties of *lal*, or red, soil, and mostly very poor and gritty. Here and there rich soils have been formed by the decomposition of the trap-dykes or of extra hornblendic varieties of the granite-gneiss.

Cotton soil is of very rare occurrence and only a few small spreads of it were noted a few miles eastward of Bhonagir.

Note on Coal *and* Limestone *in the* Doigrung River, *near* Golaghat, Assam, *by* TOM. D. LA TOUCHE, B.A., *Geological Survey of India.*

It has long been known that in the Námbar, a tributary of the Dhansiri crossed by the Nága Hills road 12 miles to the south of Golaghát, there are exposures of coal and limestone,[1] and some time ago I was informed by Mr. Clift, Executive Engineer, Assam Railway Surveys, that a native surveyor of his party had found coal and limestone in the Doigrung, a stream flowing parallel to the Námbar and 3 or 4 miles to the west of it. As his description seemed to indicate that there was a considerable quantity of the minerals there, I spent a few days on my way to Upper Assam this season in visiting the locality.

The coal is exposed in the Doigrung about 7 miles above the point where the forest path from the Dimapúr road to Murphulani crosses the river (see Topographical Survey Sheet No. 35, 1 inch = 2 miles), and where a forest bungalow has been recently built. The spot may be reached by following the path southwards from Murphulani, and turning south-east at the village of Burabassa (not marked in the map, but close to the site of the deserted village Leti). The coal is seen twice in the bed of the stream, being probably repeated by a fault, with an interval of about ¼ mile between the exposures, and in each case is overlaid by calcareous shales containing large nodular masses of limestone, crowded with fragments of shells. The seam is in each case about 3 feet thick, the greater portion of it being under water and extending nearly across the river with a low dip to west-north-west. The coal contains numerous nests and specks of the fossil resin characteristic of the cretaceous coal of the Khasia and Garo Hills, and is presumably of the same age. Gneiss occurs about ¼ mile further up stream, and the high ridge to the west of the Doigrung is apparently all of the same rock. It is difficult to form an opinion as to the extent of the coal, but this is probably a portion of the same bed as that found in the Námbar. Even if it were continuous between these streams, the greater portion of it would be below the water level of the valley, and seeing that far larger deposits are easily available in Upper Assam, I do not consider this coal to be of practical importance at present. In the event, however, of the Assam Railway being brought down the Dhansiri valley, this coal may turn out to be of some use, if the quality should improve to the deep; the sample taken at the outcrop gives the following very poor result on assay :—

Moisture	5·08
Volatile matter	31·06
Fixed carbon	15·10
Ash	48·76
	100·00

The occurrence of limestone in this locality is a fact of far greater importance, there being so great a scarcity of this rock in the Naga Hills, the lime for which is at present obtained at a great expense (about Rs. 10 per maund) from Sylhet. Mr. Medlicott in 1865 expressed his surprise that no use had been made of the

[1] Medlicott, Memoirs, Geological Survey of India, Vol. IV, Pt. 3, p. 26. Mallet, *Ibid.*, Vol. XII, Pt. 2, p. 17, note.

limestone on the Námbar, but from that day to this only one attempt, and that a feeble one, has been made to burn the stone.

The Doigrung limestone is found about 3 miles above the forest bungalow above mentioned, where a bed, of which from 3 to 6 feet is visible above water, is exposed on the left bank of the stream, dipping north-east at about 50°. Mr. Mitchell, Assistant Engineer, is at present engaged in cutting a path to the spot and opening pits at a short distance from the river bank, in order to discover the extent of the bed. The density of the jungle renders it impossible to see how far the bed extends without this being done, but I think that enough stone can certainly be raised without much difficulty to supply the wants of, at any rate, the Naga Hills. It will only be possible to obtain the stone during the cold weather, as the pits will be under water during the rains. The limestone is similar to that seen below the falls on the Námbar, and it is possible that it may be found on the low ridge separating the Doigrung from the Námbar, in which case quarries, not liable to be flooded every year, might be opened in it. In fact, it is not improbable that sufficient limestone may be obtained here to supply the wants of a large part of Upper Assam. An assay of the Doigrung limestone gave the following result:—

Carbonate of lime	72·97
" " magnesia	7·33
Oxide of iron, alumina and magnesia	9·00
Insoluble	10·70
	100·00

Homotaxis, *as illustrated from* Indian Formations *by* W. T. Blanford, F.R.S., Sec. G.S., F.R.G.S.[1]

In commencing an address to the Geological Section of the British Association on the first occasion on which that body has met outside of the British Islands, I feel much difficulty. Amongst the eminent geologists who have filled the post which you have done me the honour of calling upon me to occupy for the present year, there are several who would have been able, from their knowledge of both European and American geology, to treat with authority of the many points of interest elicited by comparison of geological phenomena on opposite sides of the Atlantic Ocean. My own experience has been chiefly derived from the distant continent of Asia, and I have not that intimate acquaintance with the geology of Europe, nor that knowledge of the progress of geological research in America, which would justify my entering upon any comparison of the two continents. It has, however, occurred to me that amongst the questions of wide importance connected with the correlation of strata in distant parts of the world, there is one to which some interesting contributions have been made by the work of the Geological Survey of India, and by the geologists of Australia and South Africa; and that a short time might be profitably devoted to a consideration of a few

[1] This is a reprint of Mr. Blanford's address as President of the Geological Section of the British Association, at Montreal, 1884.

remarkable exceptions to the rule that similarity of faunas and floras in fossiliferous formations throughout the surface of the world implies identity of geological age.

It has probably occurred to other geologists here present, as it has to myself, to be engaged in examining a country the geology of which was absolutely unknown, and to feel the satisfaction that attends the first discovery of a characteristic fossil form. A clue is at once afforded to the geology of the region; one horizon at least is believed to be determined, and from this horizon it is possible to work upwards and downwards until others are found.

It is, therefore, of special importance to those engaged in geological exploration to satisfy themselves whether the conclusion is correct that identity, or close specific similarity, amongst fossil forms, is a proof that the beds containing them are of the same geological age. It has been pointed out by some of the most careful thinkers, and especially by Forbes and Huxley, that a species requires time to spread from one area to another; that, in numerous cases, a migratory specific form must flourish in the region to which it has migrated, after it has died out in its original birth-place; and that the presence of the same species in two deposits at distant localities may rather tend to indicate that both were not formed simultaneously. Huxley, as is well known, invented the term 'homotaxis' to express the relations between such beds, and to avoid the possibly misleading expressions 'geological synchronism,' and 'contemporaneous origin.'

Despite such cautions, however, it still appears to be generally assumed by palæontologists that similarity between faunas and floras is evidence of their belonging to the same geological period; that the geological age of any formation, whether marine, fresh-water, or subaërial, can be determined by a comparison of its organic remains with those of other deposits, no matter how distant, of which the position in the geological sequence is ascertained: in short, that homotaxis of marine, fresh-water, and terrestrial forms implies geological synchronism.

That, as a general rule, homotaxis affords evidence that beds exhibiting it belong approximately to the same geological period, appears supported by a large amount of evidence. But there are some startling exceptions. I propose to notice a few typical instances, several of them Indian, in which the system of determining the age of various formations by the fauna or flora has led to contradictory results, before attempting to show wherein the source of the error appears to lie. Nothing would be gained and much time would be lost by entering upon the details of all the cases known, even if I were able to give authentic particulars, which is doubtful. It will be sufficient to cite some characteristic examples, concerning the details of which satisfactory evidence is forthcoming.

Pikermi Beds.—There are but few fossiliferous deposits on the face of the earth that have attracted more attention than the Pikermi beds of Greece. In one of the most classical and famous sites of the world, a few miles east of Athens, just where

> The mountains look on Marathon,
> And Marathon looks on the sea,

some red, silty beds occur, abounding in vertebrate remains. Some of the bones were described by Wagner and others, but for a complete account of the fauna we are indebted to Professor Albert Gaudry, who has himself collected by far the greater portion of the remains hitherto procured. The following is a list of the genera determined; it is unnecessary to give the specific names :—

MAMMALIA.

PRIMATES.—*Mesopithecus*, 1 sp.

CARNIVORA.—*Simocyon*, 1; *Mustela*, 1; *Promephitis*, 1; *Ictitherium*, 3; *Hyænarctus*, 1; *Hyæna*, 1; *Hyænictis*, 1; *Felis* 4; *Machærodus*, 1.

PROBOSCIDEA.—*Mastodon*, 2; *Dinotherium*, 1.

UNGULATA.—*Chalicotherium*, 1; *Rhinoceros*, 3; *Acerotherium*, 1; *Leptodon*, 1; *Hipparion*, 1; *Sus*, 1; *Camelopardalis*, 1; *Helladotherium*, 1; *Orasius*, 1; *Palæotragus*, 1; *Protragelaphus*, 1; *Palæoryx*, 2; *Tragocerus*, 2; *Palæoreas*, 1; *Antidorcas* (?), 1; *Gazella*, 1; *Antilope*, 3; *Dremotherium*, 2; *Cervus*, 1.

RODENTIA.—*Mus* (*Acomys*), 1; *Hystrix*, 1.

EDENTATA.—*Ancylotherium*, 1.

AVES.

Phasianus, 1; *Gallus*, 1; *Gen. gallinac. indet.*, 1; *Grus*, 1; *Gen. ciconidar. indet.*, 1.

REPTILIA.

Testudo, 1; *Varanus*, 1.

Of mammalia alone there are known from this deposit 33 genera, of which 22 are extinct, and 47 species.

Now, this fauna is almost invariably in European works quoted as Miocene. Of the species found no less than 14—*Simocyon diaphorus*, *Ictitherium robustum*, *I. hipparionum*, *Hyæna eximia*, *Hyænictis græca*, *Machærodus cultridens*, *Mastodon turicensis*, *Dinotherium giganteum*, *Rhinoceros schleiermacheri*, *Hipparion gracile*, *Sus erymanthius*, *Helladotherium duvernoyi*, *Tragocerus amaltheus*, and *Gazella brevicornis*—are met with in other European deposits assigned to the Miocene period. It is true that one of these deposits at least—that of Eppelsheim—has been shown on stratigraphical grounds to be much more probably Pliocene than Miocene, and the position of other deposits has been determined by the kind of argument which, as I shall show, has proved misleading in the case of Pikermi itself. Nevertheless so general is the consensus of opinion amongst palæontologists, that the beds with *Hipparion* at Pikermi and elsewhere are quoted as especially included in the Miocene system by the French Committee of the International Geological Congress. Amongst English writers the Miocene age of the Pikermi beds appears generally admitted, as by Mr. Wallace,[1] Professor Boyd Dawkins,[2] Mr. E. T. Newton,[3] and many others. Professor Gaudry himself is much more cautious; he classes the fauna as intermediate between Pliocene and Miocene, and only relegates it to Upper Miocene because that is the position assigned by other palæontologists to beds containing remains of *Hipparion*. However, in his subsequent works Professor Gaudry has classed the Pikermi fauna as Miocene.

Now, the lowest of the beds with the vertebrate fauna at Pikermi were by Professor Gaudry himself found to be interstratified with a band of grey conglo-

[1] *Geographical Distribution of Animals*, i. p. 115.

[2] *Q. J. G. S.* 1880, p. 389.

[3] *Q. J. G. S.* 1884, pp. 284, 287, &c.

merate containing four characteristic *marine* Pliocene mollusca—*Pecten benedictus*, Lam.; *Spondylus gœderopus*, L.; *Ostrea lamellosa*, Brocchi; and *O. undata*, Lam. It should be remembered that the Pliocene fauna of the Mediterranean area is the richest and most typical in Europe, and is as well known as any geological fauna in the world. It should also be remembered that the Pliocene beds are well developed in Greece at other localities besides Pikermi. Professor Gaudry especially points out that the vertebrate remains, supposed to be those of Miocene animals, are deposited in a stratum overlying a marine bed of undoubted Pliocene age, and he proposes the following hypothesis to account for the presence of Miocene fossils in a Pliocene stratum. The remains found at Pikermi are, he thinks, those of animals that inhabited the extensive plains which in Miocene times extended over a considerable proportion of the area now occupied by the Eastern Mediterranean and which united Greece to Asia; the plains were broken up by the dislocations that took place at the close of the Miocene period, and the animals escaped to the mountains, where they died for want of space and of food. Their bones were subsequently washed down by the streams from the hills and buried in the Pliocene deposits of Pikermi.

Professor Gaudry evidently has no very profound faith in this hypothesis, and it is unnecessary to refute it at length. One fact is sufficient to show that it is untenable. However sudden may have been the cataclysm that is supposed to have broken up the Miocene plains of Attica, a very long period, measured in years, must have elapsed before the Pliocene marine fauna could have established itself. Now, the bones of mammals exposed on the surface decay rapidly; the teeth break up, the bones become brittle. It is doubtful if bones that had been exposed for only five or six years would be washed down by a stream without being broken into fragments; the teeth especially would split to pieces. The condition of the Pikermi fossils proves, I think, that they must have been buried very soon after the animals died, that they were not exposed on the surface for any length of time, and that they could not have been washed out of an earlier formation, and it appears to me incredible that the Pikermi mammals were not contemporary with the Pliocene mollusca that occur in the same beds. In short, I cannot but conclude that the Pikermi mammals were Pliocene and not Miocene.

This view is entirely in accordance with the opinions of Theodor Fuchs.[1] He has given a good account of the geology of various places in Greece, and amongst others of Pikermi. He found, again, the conglomerate with Pliocene marine mollusca interstratified with the basal portion of the mammaliferous beds, and he concludes[2] that not only is it clear that these mammaliferous beds are of Pliocene age, but that a comparison of their geological position with that of the marine strata of the Piræus proves that the Pikermi beds occupy a very high position in the Pliocene, and are probably the highest portion of the system as developed in the neighbourhood.

Fuchs also shows that the principal Pliocene mammaliferous beds are of later date than the typical Pliocene (Subapennine) beds of Italy, and that some mammalia found associated with the latter comprise forms identical with those of the

[1] *Denkschr. K. Acad. Wiss. Wien*, 1877, xxxvii. 2e Abth. p. 1.
[2] *L. c.*, p. 30.

Pikermi beds. In subsequent papers on the age of the beds containing *Hipparion* the same writer shows reasons for classing these strata in Italy, France (Vaucluse), and Germany as intermediate between Miocene and Pliocene. This leaves the difficulty unsolved, for he had shown the Pikermi beds to be high in the Pliocene system. They rest unconformably upon certain fresh-water limestones, clays, &c., containing plants and mollusca, and classed by Gaudry as Miocene, but by Fuchs as Pliocene. Thus by both writers the mammaliferous beds of Pikermi are referred to a considerably later geological horizon than those containing identical species in other parts of Europe.

It would require too much time to enter into the still more difficult question of the various plant-bearing beds in different parts of Europe and in Greenland containing a flora classed by Heer and others as Miocene. Gardner has given reasons for considering the Greenland beds Eocene; Fuchs, as just stated, is of opinion that the Greek beds are Pliocene. One point should be noted, that the more northern flora is considered older than the more southern, and it will be remarked that the same observation applies to the supposed Upper Miocene fauna of France and Germany and the Pikermi fauna of Greece.

Siwalik.—The next instance which I shall describe is another of the most important fossil mammalian faunas of the Old World, that found in the Upper Tertiary beds that fringe the Himalayas on the south. The name applied to this fauna is taken from one of the localities in which it was first found, the Siwalik (correctly, I believe, Shib-wála) hills, between the Deyra Dun and the plains north by east of Delhi. Bones of Siwalik mammalia are found, however, throughout a considerable area of the Northern Punjab.

The Siwalik fauna has been worked out, chiefly by Falconer and Lydekker, the last-named being still engaged in describing the species. The following is a list of the genera found in the true Siwalik beds[1] :—

MAMMALIA.

PRIMATES—*Palæopithecus*, 1 sp.; *Macacus*, 2; *Semnopithecus*, 1; *Cynocephalus*, 2.

CARNIVORA.—*Mustela*, 1; *Mellivora*, 2; *Mellivorodon*, 1; *Lutra* 3; *Hyænodon*, 1; *Ursus*, 1; *Hyænarctus*, 3; *Canis*, 2; *Viverra*, 2; *Hyæna*, 4; *Hyænictis*, 1; *Lepthyæna*, 1; *Æluropsis*, 1; *Ælurogale*, 1; *Felis*, 5; *Machærodus*, 2.

PROBOSCIDEA—*Elephas*, 6 (*Euelephas*, 1; *Loxodon*, 1; *Stegodon*, 4); *Mastodon*, 5.

UNGULATA.—*Chalicotherium*, 1; *Rhinoceros*, 3; *Equus*, 1; *Hipparion*, 2; *Hippopotamus*, 1; *Tetraconodon*, 1; *Sus*, 5; *Hippohyus*, 1; *Sanitherium*, 1; *Merycopotamus*, 1; *Cervus*, 3; *Dorcatherium*, 2; *Tragulus*, 1; *Moschus*, 1; *Propalæomeryx*, 1; *Camelopardalis*, 1; *Helladotherium*, 1; *Hydaspitherium*, 2; *Sivatherium*, 1; *Alcelaphus*, 1; *Gazella*, 1; *Antilope*, 2; *Oreas*, (?), 1; *Palæoryx*, (?), 1; *Portax*, 1; *Hemibos*, 3; *Leptobos*, 1; *Bubalus*, 2; *Bison*, 1; *Bos*, 3; *Bucapra*, 1; *Capra*, 2; *Ovis*, 1; *Camelus*, 1.

RODENTIA.—*Mus* (*Nesokia*), 1; *Rhyzomys*, 1; *Hystrix*, 1; *Lepus*, 1.

AVES.

Graculus, 1; *Pelecanus*, 2; *Leptoptila*, 1; *Gen. non det. ciconid.*, 1; *Mergus*, 1; *Struthio*, 1; *Dromæus*, 1; *Gen. non det. struth.*, 1.

[1] Lydekker, *J. A. S. B.* 1880, pt. 2, p. 34; *Palæontologia Indica*, ser. x. vols. i, ii, iii; *Records, Geological Survey of India*, 1883, p. 81. I am indebted to Mr. Lydekker for some unpublished additions, and for aid in compiling both the Siwalik and Pikermi lists.

REPTILIA.

CROCODILIA—*Crocodilus*, 1; *Gharialis*, 3.
LACERTILIA—*Varanus*, 1.
CHELONIA—*Colossochelys*, 1; *Testudo*, 1; *Bellia*, 2; *Damonia*, 1; *Emys*, 1; *Cautleya*, 1; *Pangshura*, 1; *Emyda*, 1; *Trionyx*, 1.

PISCES.

Bagarius, 1.

Now, until within the last few years, this fauna was classed as Miocene by European palæontologists as unhesitatingly as the Pikermi fauna still is, and in the majority of European geological works, despite the unanimous opinion of all the geologists who are acquainted with the sub-Himalayan beds, the Siwalik fauna is still called Miocene. The geologists of the Indian Survey, however, classed the fossiliferous Siwaliks as Pliocene, on both geological and biological grounds. With regard to the latter, not only does the fauna comprise a large number of existing genera of mammals, such as *Macacus*, *Semnopithecus*, *Ursus*, *Elephas* (*Euelephas*), *Equus*, *Hippopotamus*, *Camelopardalis*, *Bos*, *Hystrix*, *Mus*, and especially *Mellivora*, *Meles*, *Capra*, *Ovis*, *Camelus*, and *Rhizomys*, but three out of six or seven clearly determined species of reptiles, viz.—*Crocodilus palustris*, *Gharialis gangeticus*, and *Pangshura tectum*—are living forms now inhabiting Northern India, whilst all the known land and fresh-water mollusca, with one possible exception, are recent species.

These data, however, although very important and very cogent, belong to a class of facts that have led, I believe, in other cases to erroneous conclusions. The geological evidence is far more satisfactory, and it is not liable to the same objection.

The whole Siwalik fauna, as given above, has been obtained from the upper beds of a great sequence or system. Beneath the fossiliferous strata at the base of the North-West Himalaya there is an immense thickness, amounting in places to many thousands of feet, of sandstones, clays, and other beds, from none of which recognisable fossils have been procured. The first beds of known age that are met with below the mammaliferous Siwaliks are marine rocks belonging to the Eocene system.

But as we pass from the Himalayas to the south-west, along the western frontier of India in the Punjab, and onwards to the south in Sind, the same Siwalik system can be traced almost without interruption, and in the last-named country the lower unfossiliferous strata become intercalated with fossiliferous beds. In Sind the upper Siwaliks no longer yield any vertebrate remains that can be identified, but far below the horizon of the Siwalik fauna a few bones have been found, and the following mammals have been identified[1] :—

CARNIVORA—*Amphicyon palæindicus*.
PROBOSCIDEA—*Mastodon latidens*, *M. perimensis*, *M. falconeri*, *M. pandionis*, *M. angustidens*, *Dinotherium indicum*, *D sindiense*, *D. pentapotamiæ*.
UNGULATA—*Rhinoceros sivalensis*, var. *intermedius*, *Acerotherium perimense*, *A. blanfordi*, *Sus hysudricus*, *Hyotherium sindiense*, *Anthracotherium silistrense*, *A. hyopotamoides*,

[1] *Pal. Ind.*, ser. x; *Rec.*, *Geol. Surv. Ind.*, 1883, pp. 82, &c.

Hyopotamus palæindicus, H. giganteus, Hemimeryx blanfordi, Sivameryx sindiensis Agriochærus sp. Dorcatherium majus, D. minus.
EDENTATA—*Manis (?) sindiensis.*

Although about one-third of the species above named have been found also in the upper Siwalik beds of the Punjab, it is unnecessary to point out in detail why the lower Siwalik fauna is clearly by far the older of the two. The absence of such living genera as *Elephas, Bos, Equus,* &c., and the presence of so many typically Middle Tertiary forms, such as *Dinotherium, Anthracotherium,* and *Hyopotamus,* shows a great change. The mollusca tell the same tale. All the forms known from the upper Siwaliks, with one exception, are recent species of land and fresh-water shells now living in the area. Of seven fresh-water mollusca [1] found associated with the lower Siwaliks, none appears to be identical with any living species, and only two are allied, one closely, the other more remotely, to forms now met with in Burma 30° of longitude further east.

Before proceeding with the argument it is as well to call attention to the very important fact just mentioned. It has been asserted over and over again that species of *mammalia* are peculiarly short-lived, far more so than those of *mollusca.* In this case, so far as the evidence extends at present, one-third of the species of *mammalia* survived the changes that took place, whereas not a single mollusk is found both in the upper and lower Siwaliks. It should be remembered that the recent molluscan river fauna of this part of India is very poor in species, and that we probably know a considerable proportion of that existing in Siwalik times.

The geological age of the lower Siwalik beds of Sind is shown by their passing downwards into marine fossiliferous beds, known as the Gáj group, of Miocene age, the following being the section of Tertiary strata exposed in the hills west of the Indus:—

		Ft.	
SIWALIK or MANCHAR	Upper	5,000 unfossiliferous	Pliocene
	Lower	3,000 to 5,000 fossiliferous	Upper Miocene or Lower Pliocene
GAJ		1,000 to 1,500 fossiliferous	Miocene
NARI	Upper	4,000 to 6,000 unfossiliferous	Lower Miocene
	Lower	100 to 1,500 fossiliferous	Oligocene
KHIRTHAR	Upper	500 to 3,000 fossiliferous	Eocene
	Lower	6,000 fossiliferous	

Clearly the lower Siwaliks of Sind cannot be older than Upper Miocene; therefore the Upper Siwaliks, which are shown by both biological and geological evidence to be of much later date, must be Pliocene.

Gondwana system of India.—In the peninsula of India there is remarkable deficiency of marine formations. Except in the neighbourhood of the coast or of the Indus valley there is, with one exception (some cretaceous rocks in the Nerbudda valley), not a single marine deposit known south of the great Gangetic plain. But in Bengal and Central India, over extensive tracts of country, a great sequence of fresh-water beds, probably of fluviatile origin, is found, to which the name of Gondwána system has been applied. The uppermost beds of this

[1] *Mem., Geol. Surv. Ind.,* vol. xx, pt. 2, p. 129.

system, in Cutch to the westward, and near the mouth of the Godávari to the eastward, are interstratified with marine beds containing fossils of the highest Jurassic (Portlandian and Tithonian) types.

The Gondwána system is a true system in the sense that all the series comprised are closely connected with each other by both biological and physical characters, but it represents in all probability a much longer period of geological time than do any of the typical European systems. The highest members, as already stated, are interstratified with marine beds containing uppermost Jurassic fossils. The age of the lowest members is less definitely determined, and has been by different writers classed in various series from middle Carboniferous to Middle Jurassic. The Gondwána beds from top to bottom are of unusual interest on account of the extraordinary conflict of palæontological evidence that they present.

The subdivisions of the Gondwána system are numerous, and in the upper portions especially the series and stages are different in almost every tract where the rocks are found. The following are the subdivisions of most importance on account of their fauna and flora, or of their geological relations.

Upper Gondwána	Cutch and Jabalpur. Kota Maleri. Rajmahal.	
Lower Gondwána	Panchet.	
	Damuda	Ránigánj and Kámthi. Barákar.
	Karharbári. Tálchir.	

The upper Gondwánas, where best developed, attain a thickness of 11,000 feet and the lower of 13,000 feet.

The Tálchir and Barákar subdivisions are far more generally present than any of the others.

Tálchir.—The Tálchir beds consist of fine silty shales and fine soft sandstone. Very few fossils have been found in them, and these few recur almost without exception in the Karharbári stage. The Tálchirs are principally remarkable for the frequent occurrence of large boulders, chiefly of metamorphic rocks. These boulders are sometimes of great size, 6 feet or more across, 3 to 4 feet being a common diameter; all are rounded, and they are generally embedded in fine silt.

Karharbári.—The Karharbári beds are found in but few localities. They contain some coal-seams, and the following plants have been met with[1]:—

CONIFERÆ.—*Euryphyllum*, 1 sp.; *Voltzia*, 1; *Albertia*, 1; *Samaropsis*, 1.
CYCADEACEÆ.—*Glossozamites*, 1; *Noeggerathiopsis*, 1.
FILICES.—*Neuropteris*, 1; *Glossopteris*, 4; *Gangamopteris*, 4; *Sagenopteris*, 1.
EQUISETACEÆ.—*Schizoneura*, 2; *Vertebraria*, 1.

The most abundant form is a *Gangamopteris*. The *Voltzia* (*V. heterophylla*) is a characteristic Lower Triassic (Bunter) form in Europe. The *Neuropteris* and *Albertia* are also nearly related to the Lower Triassic forms. The species of *Gangamopteris*, *Glossopteris*, *Vertebraria*, and *Noeggerathiopsis* are allied to forms found in Australian strata.

[1] Feistmantel: *Palæontologia Indica*, ser. xii. vol. iii.

Damuda.—The Damuda series consists of sandstones and shales with coal-beds; the floras of the different subdivisions present but few differences, and the following is the list of plants found[1]:—

CONIFERÆ.—*Rhipidopsis*, 1 sp., *Voltzia*, 1; *Samaropsis*, 1; *Cyclopitys*, 1.
CYCADEACEÆ.—*Pterophyllum*, 2; *Anomozamites*, 1; *Noeggerathiopsis*, 3.
FILICES.—*Sphenopteris*, 1; *Dicksonia*, 1; *Alethopteris*, 4; *Pecopteris*, 1; *Merianopteris*, 1; *Macrotæniopteris*, 2; *Palæovittaria*, 1; *Angiopteridium*, 2; *Glossopteris*, 19; *Gangamopteris*, 7; *Belemnopteris*, 1; *Anthrophyopsis*, 1; *Dictyopteridium*, 1; *Sagenopteris*, 4; *Actinopteris*, 1.
EQUISETACEÆ.—*Schizoneura*, 1; *Phyllotheca*, 3; *Trizygia*, 1; *Vertebaria*, 1.

The only remains of animals hitherto recorded are an *Estheria* and two Labyrinthodonts, *Branchyops laticeps* and an undescribed form formerly referred to *Archegosaurus*. The only European genus allied to *Branchyops* is of oolitic age.

The most abundant of the above-named fossils are *Glossopteris* and *Vertebraria*. With the exception of *Noeggerathiopsis* all the cycads and conifers are of excessive rarity. More than one-half of the species known are ferns with simple undivided fronds and anastomosing venation.

For many years European palæontologists generally classed this flora as Jurassic.[2] This was the view accepted by De Zigno and Schimper, and, though with more hesitation, by Bunbury. The species of *Phyllotheca*, *Alethopteris* (or *Pecopteris*), and *Glossopteris* (allied to *Sagenopteris*) were considered to exhibit marked Jurassic affinities. It was generally admitted that the Damuda flora resembles that of the Australian coal-measures (to which I shall refer presently) more than it does that from any known European formation; but the Australian plants were also classed as Jurassic. There is no reason for supposing that the more recent discoveries of Damuda plants would have modified this view; the identification of such forms as true *Sagenopteris* and the cycads *Pterophyllum* and *Anomozamites* would assuredly have been held to confirm the Jurassic age of the beds. So far as European fossil plants are concerned, the Damuda flora resembles that of the middle or lower Jurassics more than any other.

One form, it is true, the *Schizoneura*, is closely allied to *S. paradoxa* from the Bunter or lower Trias of Europe. Other plants have Rhætic affinities. But the connections with the Triassic flora do not seem nearly equal to those shown with Jurassic plants, and the reason that the Damuda flora has been classed as probably Triassic must be sought in the impossibility of considering it newer,[3] if the next overlying stage is classed as Upper Trias or Rhætic, and in the close affinity with the underlying Karharbári beds, which contain several Lower Triassic types.

Panchet.—The uppermost series of the lower Gondwánas consists chiefly of sandstone, and fossils are rare. The most interesting are remains of *Reptilia* and

[1] *Pal. Ind.*, ser. ii. xi. xii. vol. iii.

[2] De Zigno: *Flora Fossilis Form. Ool.* pp. 50, 53; Schimper; *Traité de Paléontologie Végétale* i. p. 645; Bunbury; *Q. J. G. S.* 1861, xvii. p. 350.

[3] Feistmantel; *Pal. Ind.*, ser. xii. vol. iii pp. 57, 129, &c.

Amphibia. The following is a list of the fossil animals and plants corrected to the present time :—

ANIMALS.

REPTILIA.

DINOSAURIA.—*Ancistrodon*, 1 sp.
DICYNODONTIA.—*Dicynodon* (*Ptychognathus*), 2.

AMPHIBIA.

LABYRINTHODONTIA.—*Gonioglyptus*, 2; *Glyptognathus*, 1; *Pachygonia*, 1.

CRUSTACEA.

Estheria, 1.

PLANTS.

CONIFERÆ.—*Samaropsis*, 1.
FILICES.—*Pecopteris*, 1; *Cyclopteris*, 1; *Thinnfeldia*, 1; *Oleandridium*, 1; *Glossopteris*, 3.
EQUISETACEÆ.—*Schizoneura*, 1.

The *Schizoneura* and the three species of *Glossopteris* are considered the same as Damuda forms. But with them are found two European Rhætic species, *Pecopteris concinna* and *Cyclopteris pachyrachis*. The *Oleandridium* is also closely allied to a European Rhætic form, and may be identical. The flora may thus be classed as typically Rhætic.

All the genera of *Labyrinthodonts* named are peculiar; their nearest European allies are chiefly Triassic. *Dicynodontia* are only known with certainty from India and South Africa, but some forms believed to be nearly allied have been described from the Ural mountains.[1] These fossils were obtained from rocks now referred to the Permian.[2]

Upper Gondwánas.—The different series of the lower Gondwánas are found in the same area resting one upon the other, so that the sequence is determined geologically. This is not the case with the upper Gondwána groups; their most fossiliferous representatives are found in different parts of the country, and the relations to each other are mainly inferred from palæobotanical data. Although, therefore, it is probable that the Rájmahals are older than the Cutch and Jabalpur beds, and that the Kota-Maleri strata are of intermediate age, it is quite possible that two or more of these series may have been contemporaneously formed in regions with a different flora.

Rájmahál.—The comparatively rich flora of the lowest upper Gondwána series is contained in beds interstratified with basaltic lava-flows of the fissure-eruption type. The following are the genera[3] of plants found :—

CONIFERÆ.—*Palissya*, 2 sp.; *Cunninghamites*, 1; *Chirolepis*, 2; *Araucarites*, 1; *Echinostrobus*, 1.
CYCADEACEÆ.—*Pterophyllum*, 9; *Ptilophyllum*, 1; *Otozamites*, 8; *Zamites*, 1; *Dictyozamites*, 1; *Cycadites*, 2; *Williamsonia*, 2; *Cycadinocarpus*, 1.
FILICES.—*Eremopteris*, 2; *Davallioides*, 1; *Dicksonia*, 1; *Hymenophyllites*, 1; *Cylopteris*, 1; *Thinnfeldia*, 1; *Gleichenia*, 1; *Alethopteris*, 1; *Asplenites*, 1; *Pecopteris*, 1; *Macrotæniopteris*, 4; *Angiopteridium*, 3; *Danæopsis*, 1; *Rhizomopteris*, 1.
EQUISETACEÆ.—*Equisetum*.

[1] Huxley; *Q. J. G. S.*, xxvi., p. 48.
[2] Twelvetrees; *Q. J. G. S.*, xxxviii. p. 500.
[3] *Pal. Ind.* ser ii.; Feistmantel; *Records, G. S. I.*, ix, p. 39.

The marked change from the lower Gondwána floras is visible at a glance; not a single species is common to both, most of the genera are distinct, and the difference is even greater when the commonest plants are compared. In the lower Gondwánas the prevalent forms are *Equisetaceæ* and ferns of the *Glossopteris* type, whilst in the Rájmahál flora cycads are by far more abundant than any other plants. The whole assemblage, moreover, is more nearly allied than are any of those in the lower Gondwána beds to European Mesozoic floras.

Of the Rájmahál plants[1] about fifteen are allied to Rhætic European forms, three to Liassic or lower Jurassic (two of these having also Rhætic affinities), and six to Middle Jurassic (two having Rhætic relations as well). The flora must therefore as a whole on purely palæontological grounds be classed as Rhætic.

Kota-Maleri.—The deposits belonging to this series are found in the Godávari valley at a considerable distance from the Rájmahál hills in Bengal, the locality for the Rájmahál flora. Both Rájmahál and Kota-Maleri beds overlie rocks of the Damuda series. It is not quite clear whether the Kota beds, which contain fish, insects, and crustaceans, and the Maleri beds, in which remains of fish, reptiles, and plants are found, are interstratified, or whether the Kota beds overlie those of Maleri. That the two are closely connected is generally admitted.

From the Maleri beds the following remains have been recorded.—

ANIMALS.

REPTILIA.—*Hyperodapedon, 1*; *Parasuchus, 1.*
PISCES.—*Ceratodus, 3.*

PLANTS.

CONIFERÆ.—*Palissya, 2*; *Chirolepis, 1*; *Araucarites, 1.*
CYCADEACEÆ.—*Ptilophyllum, 1*; *Cycadites, 1.*
FILICES.—*Angiopteridium,* 1.

From the Kota fresh-water limestone 9 species of ganoid fish—*viz.* 5 of *Lepidotus*, 3 of *Tetragonolepis*, and 1 of *Dapedius*—have been described. An *Estheria*, a *Candona*, and some insects have also been found. The fish[2] are Liassic forms.

The reptilia of the Maleri beds are, on the other hand, Triassic[3] and closely allied to Keuper forms. *Ceratodus* is chiefly Triassic (Keuper and Rhætic). The plants show relations with both the Rájmahál and Jabalpur floras, and, as the palæontological relations to beds in the same country are considered far higher in importance than those to deposits in distance regions, the Kota-Maleri beds are classed as intermediate between the Rájmahál and Jabalpur epochs.

Cutch and Jabalpur.—Jabalpur beds are found in Central India to the south of the Nerbudda valley, and form the highest true Gondwána beds. The Cutch beds, as already mentioned, are found interstratified with marine deposits of uppermost Jurassic age far to the westward, a little east of the mouths of the river Indus. The similarity of the plant-remains in the two series has caused them to be classed together, but it is not certain that they are really of contemporaneous origin.

[1] Feistmantel, *Pal. Ind.*, ser. ii., pp. 143—187; *Man. Geol. Ind.*, p. 145.

[2] *Pal. Ind.*, ser. iv., pt. 2.

[3] *Q. J. G. S.* 1869, pp. 138, 152, &c.; 1875, p. 427; *Pal. Ind.*, ser. iv., pt. 3; *Man. Geol. Ind.* p. 151.

The following is a list of the Jabalpur plants[1]:—

CONIFERÆ.—*Palissya*, 2; *Araucarites*, 1; *Echinostrobus*, 2; *Brachyphyllum*, 1; *Taxites*, 1; *Gingko*, 1; *Phœnicopsis*, 1; *Czekanowskia*, 1.

CYCADEACEÆ.—*Pterophyllum*, 1; *Ptilophyllum*, 2; *Podozamites* 3; *Otozamites*, 4; *Williamsonia*, 1; *Cycadites*, 1.

FILICES.—*Sphenopteris*, 1; *Dicksonia*, 1; *Alethopteris*, 3; *Macrotæniopteris*, 1; *Glossopteris*, 1; *Sagenopteris*, 1.

Of these thirty species nine are regarded either as identical with forms found in the Middle Jurassic (Lower Oolitic) of England or as closely allied.

The Cutch plants belong to the following genera[2]:—

CONIFERÆ.—*Palissya*, 3 sp.; *Pachyphyllum*, 1; *Echinostrobus*, 1; *Araucarites*, 1.

CYCADEACEÆ.—*Ptilophyllum*, 3; *Otozamites*, 3; *Cycadites*, 1; *Williamsonia*, 1; *Cycadolepis*, 1.

FILICES.—*Oleandridium*, 1; *Tæniopteris*, 1; *Alethopteris*, 1; *Pecopteris*, 1; *Pachypteris* 2; *Actinopteris*, 1.

Of the twenty-two species enumerated, four are identified with specific forms found in the Middle Jurassic of Yorkshire, and seven others are closely allied. The Cutch and Jabalpur beds, in short, are intimately related with European fossil floras.

One interesting fact should be mentioned. The Cutch flora occurs in the upper part of the Umia beds, the lower beds of which contain *cephalopoda* of Portlandian and Tithonian forms. In a lower subdivision of the Cutch Jurassic rocks, the Katrol group, shown by numerous Ammonites to be allied to Kimmeridge and upper Oxford beds of Western Europe, four species of plants have been found, of which three are met with in the Umia beds, and the fourth, an English oolitic form, in the Jabalpur series. This evidence seems in favour of the view that the flora underwent change more slowly than the marine fauna.

It will be as well, before leaving the subject of the Gondwána groups, to show in a tabular form the geological age assigned to the flora and fauna of each separately, on the evidence afforded by comparison with the plants and animals known from European formations.

		PLANTS.	ANIMALS.
Upper Gondwána	Cutch	Middle Jurassic	Uppermost Jurassic ? Neocomian (marine).
	Jabalpur	Middle Jurassic	—
	Kota	—	Lower Jurassic (Liassic).
	Maleri	Middle or Lower Jurassic	Triassic.
	Rájmahál	Rhætic	—
Lower Gondwána	Panchet	Rhætic	Triassic or Permian.
	Damuda	Middle Jurassic	Middle Jurassic ?
	Karharbári, Talchir	Lower Triassic	—

[1] *Pal. Ind.*, ser. xi., pt. 2.

[2] *Pal. Ind.*, ser. xi., pt. 1.

Flora of Tonquin.—Quite recently M. Zeiller has described a series of plants from some coal-bearing beds in Tonquin.[1] This flora is very extraordinary in every respect. It consists of 22 species, and contains only two peculiar forms ten, or nearly one-half, are European species found in the lower Lias or Rhætic; whilst of the remaining ten, five are Damuda forms—*Noeggerathiopsis hislopi, Macrotæniopteris feddeni, Palæovittaria kurzi, Glossopteris browniana,* and *Phyllotheca indica,* one species being common to the Newcastle beds and Carboniferous flora of Australia and two others closely allied to the forms there occurring. The other five are said to be Rájmahál forms, four *Tæniopteris* or *Angiopteridium* and an *Otozamites.* M. Zeiller unhesitatingly classes the Tonquin beds as Rhætic. It is most singular that these coal-beds, although more distant from Europe by 18° of longitude than either the Damuda or Rájmahál beds of India, contain a larger proportion of European fossil species than any known Indian plant-beds; whilst the association in the same strata of upper and lower Gondwána forms, if well ascertained, shows how hopeless is the attempt to classify these deposits by plant evidence alone.

Australian Coal-Measures and Associated Beds.—In the notice of the lower Gondwána floras of India it was observed that there was a great resemblance between some of them and those found in certain beds of Australia. These latter present even a more remarkable instance of homotaxial perversity than do the Indian rocks. The Australian plant-bearing beds are found in Eastern and Southern Australia, Queensland, and Tasmania. For a knowledge of the geology of the country we are chiefly indebted to the writings of the late Mr. Clarke,[2] whilst the flora has been worked out by McCoy, Dana, Carruthers, and Feistmantel, the last having recently published a much more complete account than was previously available.[3]

The following are the fresh-water or subaërial beds of Australia, according to the latest classification:—

6. Clarence River beds, New South Wales (Mesozoic carbonaceous of Queensland, Victoria, and Tasmania).
5. Wianamatta beds, N. S. Wales.
4. Hawkesbury beds, N. S. Wales (Bacchus Marsh sandstones, Victoria).
3. Newcastle beds, N. S. Wales.
2. Lower Coal-Measures with marine layers interstratified, N. S. Wales.
1. Lower Carboniferous beds, N. S. Wales.

To a still lower horizon probably belong some beds in Queensland, containing *Lepidodendron nothum* and *Cyclostigma.* They are considered Devonian by Carruthers, and there are some ancient plant-beds in Victoria that may be of the same period.

1. *Lower Carboniferous Beds.*—These underlie the beds with a Carboniferous marine fauna. The localities given are Smith's Creek, near Stroud, Port Stephens, and Arowa. The following plants are enumerated:—

LYCOPODIACEÆ.—*Cyclostigma,* 1 sp.; *Lepidodendron,* 2 *or* 3; *Knorria,* 1.

[1] *Bull. Soc. Géol.,* ser. iii., vol. xi., p. 456.
[2] *Q. J. G. S.* 1861, p. 354, and *Remarks on the Sedimentary Formations of New South Wales,* 1878, besides numerous other works.
[3] *Palæontographica.—Pal. u. mes. Flora im östl. Australien,* 1878-79.

FILICES.—*Rhacopteris*, 4; *Archæopteris*, 2 (?); *Glossopteris*, 1.
EQUISETACEÆ.—*Calamites*, 2; *Sphenophyllum*, 1.

This flora contains several species identical with those in the Lower Carboniferous (Bernician) of Europe, corresponding to the mountain limestone. The agreement both in homotaxis and position is the more remarkable because of the startling contrast in the next stage. The only peculiarity is the presence of a *Glossopteris*. This comes from a different locality—Arowa—from most of the fossils, and the species is identical with one found in a much higher series. Under these circumstances it is impossible to feel satisfied that the specimen was really from this horizon. The evidence is not so clear as is desirable.

2. *Lower Coal-Measures with Marine Beds.*—The following plants are recorded:—

CYCADEACEÆ.—*Noeggerathiopsis*, 1 sp.
FILICES.—*Glossopteris*, 4.
EQUISETACEÆ.—*Annularia*, 1; *Phyllotheca*, 1.

In the marine beds, which are interstratified, are found lower Carboniferous (mountain limestone) marine fossils in abundance, such as *Orthoceras*, *Spirifer*, *Fenestella*, *Conularia*, &c. The plants belong to forms declared to be typically Jurassic by palæontologists. As the interstratification of the marine and plant-bearing beds has been repeatedly questioned by palæontologists, it is necessary to point out that the geological evidence brought forward by Mr. Clarke is of the clearest and most convincing character, that this evidence has been confirmed by all the geologists who are acquainted with the country, and has only been doubted by those who have never been near the place.

3. *Newcastle Beds.*—By all previous observers in the field these had been united to the preceding and the flora declared to be the same. Dr. Feistmantel has, however, pointed out important differences. Unfortunately, as he has been unable to examine the beds, it still remains uncertain whether the distinction, which has been overlooked by all the field geologists, is quite so great as it appears from the lists of fossils given. The following is the flora.—

CONIFERÆ.—*Brachyphyllum*, 1 sp.
CYCADEACEÆ.—*Zeugophyllites*, 1; *Noeggerathiopsis*, 3.
FILICES.—*Sphenopteris*, 4; *Glossopteris*, 8; *Gangamopteris*, 2; *Caulopteris* (?), 1.
EQUISETACEÆ.—*Phyllotheca*, 1; *Vertebraria*, 1.

The only animal known from the beds is a heterocercal ganoid fish, *Urosthenes australis*, a form with Upper Palæozoic affinities.

It will be noticed that the difference from the flora of the underlying beds associated with marine strata is chiefly specific, and by no means indicative of great difference of age, though the only species considered as common to the two by Dr. Feistmantel is *Glossopteris browniana*, found also in the Damuda series of India, in Tonquin, and in South Africa.

The plant fossils of the Newcastle beds and of the underlying series with marine fossils are those which exhibit so remarkable a similarity to the flora of the Indian lower Gondwánas, and especially to the Damudas. The same genera of plants, especially *Noeggerathiopsis*, *Glossopteris*, *Phyllotheca*, *Vertebraria* prevail in both. But the lower beds of Australia, to judge by the marine fauna, are of

Lower Carboniferous age, and it is impossible to suppose that the Newcastle beds are of very much later date. They are said to be conformable to the lower beds with marine fossils, and even to pass into them, and they should probably, if the lower beds are Lower Carboniferous, be classed as Middle or Upper Carboniferous. Thus if the evidence of marine faunas be accepted as decisive, the Damuda beds of India are homotaxially related to Jurassic strata in Europe and to Carboniferous in Australia.

But the Australian Newcastle flora has been quite as positively classed as Jurassic by European palæobotanists as that of the Damudas. It would be easy to quote a long list of authorities—McCoy, De Zigno, Saporta, Schimper, Carruthers, and others—in support of the Jurassic age of the Australian beds. For years the testimony of Australian geologists was rejected, and doubts thrown upon their observations. There is, so far as I know, no case in the whole history of palæontology in which the conflict of palæontological evidence has been so remarkably displayed.

4. *Hawkesbury Beds.*—The fauna and flora are poor. Only two fish, *Clithrolepis granulatus* and *Myriolepis clarkei*, and one plant, *Thinnfeldia odontopteroides*, are known, and of the three forms two recur in the Wianamatta beds.

An important character of the Hawkesbury beds, to which further reference will be made presently, is the occurrence of transported boulders,[1] apparently brought thither by the action of ice.

Similar boulders have been observed in certain sandstones in Victoria known as the Bacchus Marsh beds. From these beds two species of *Gangamopteris* have been described by McCoy. *Gangamopteris*, it should be recollected, is a genus of ferns closely allied to *Glossopteris* and abundant in the Damuda and still more so in the Karharbári beds of the lower Gondwánas in India.

5. *Wianamatta Beds.*—These are the highest portion of the whole system in New South Wales. They contain the following organic remains :—

ANIMALS.

PISCES.—*Palæoniscus antipodeus, Clithrolepis granulatus.*

PLANTS.

FILICES.—*Thinnfeldia* (*Pecopteris*) *odontopteroides, Odontopteris microphylla, Pecopteris tenuifolia, Tæniopteris wianamattæ.*

EQUISETACEÆ.—*Phyllotheca hookeri.*

The fish from the Wianamatta, Hawkesbury, and Newcastle beds, four in number, were considered as a whole by Sir P. Egerton to be most nearly allied to the Permian fauna of Europe.

The Wianamatta plants, like those in the lower beds, are classed as Jurassic.

6. *Higher Mesozoic Beds.*—These, which do not appear to have been traced into connection with the Wianamatta and Hawkesbury beds, occur in widely separated localities, from Queensland to Tasmania. The correlation of these widely scattered deposits, and the assignment of them collectively to a position above that of the

[1] Wilkinson, quoted by Feistmantel, *Rec. Geol. Surv. Ind.*, 1880, p. 250.

Wianamatta beds, appear solely founded upon the fossil flora, and it would be satisfactory to have in addition some geological evidence or some palæontological data derived from marine fossils. The Queensland flora is said to occur in beds overlying marine strata of Middle Jurassic age.

The following plants are recorded from these higher beds :—

CYCADEACEÆ.—*Zamites* (*Podozamites*), 3 sp.; *Otozamites*, 1.
FILICES.—*Sphenopteris*, 1; *Thinnfeldia*, 1; *Cyclopteris*, 1; *Alethopteris*, 1; *Tæniopteris*, 1; *Sagenopteris*, 1.
EQUISETACEÆ.— *Phyllotheca*, 1.

Tabulating, as in the case of the Indian Gondwána system, the age of the different Australian sub-divisions as determined by their fossil plants and animals on purely palæontological grounds, we have the following result :—

	Plants.	Animals.
6. Higher Mesozoic beds . .	Jurassic	Jurassic (marine).
5. Wianamatta beds. . . .	Jurassic	Permian.
4. Hawkesbury beds . . .	Jurassic	Permian.
3. Newcastle beds . . .	Jurassic	Permian.
2. Lower Coal-Measures . .	Jurassic	Lower Carboniferous (marine).
1. Lower Carboniferous beds . .	Lower Carboniferous .	......

South Africa.—In connection with the later Palæozoic and older Mesozoic rocks of Australia and India it is of importance to mention briefly the corresponding fresh-water or subaërial formations of Southern Africa, although in that country there are not such marked discrepancies in the palæontological evidence, perhaps because the relations of the beds with remains of animals to the plant-bearing strata are less clearly known. It will be sufficient to notice some of the most prominent peculiarities of these formations here, as I hope that a fuller account will be given to the section by Professor Rupert Jones, who has made an especial study of South African geology.

In the interior of South Africa, occupying an immense tract in the northern parts of Cape Colony, the Orange Free State, Transvaal, and the deserts to the westward of the last two, there is a great system of sandstones and shales with some coal-beds, generally known as the 'Karoo formation.' The sequence of sub-divisions is the following[1]:—

Stormberg beds, about 1,800 feet thick.
Beaufort " " 1,700 " "
Koonap " " 1,500 " "

The beds are but little disturbed in general, and form great plateaux. They rest partly on Palæozoic rocks (Carboniferous or Devonian), partly on gneissic forma-

[1] *Q. J. G. S.*, xxiii, 1867, p. 142.

tions. As in Australia, the underlying Palæozoic rocks contain a flora allied to the Carboniferous flora of Europe.

At the base of the Karoo formation are certain shales with coal, known as the Ecca beds, and remarkable for containing a great boulder-bed, the Ecca or Dwyka conglomerate,[1] like those in the Tálchir beds in India and the Hawkesbury sandstone in Australia, the boulders, precisely as in the Tálchir beds, being embedded in fine compact silt or sandstone, which in both countries has been mistaken for a volcanic rock. The Ecca beds are said to contain *Glossopteris* and some other plants, but the accounts are as yet somewhat imperfect. The whole Karoo system, according to the latest accounts, rests unconformably on the Ecca beds, whilst the Ecca beds are conformable to the underlying Palæozoic strata.

Unfortunately, although a considerable number of animals and a few plants have been described from the 'Karoo formation,' it is but rarely that the precise sub-division from which the remains were brought has been clearly known.

The known species of plants are very few in number; *Glossopteris browniana*, and two other species of *Glossopteris*,[2] *Rubidgea*, a fern nearly akin to *Gangamopteris* and *Glossopteris*, and a *Phyllotheca*-like stem are recorded, without any certain horizon, but probably from the Beaufort beds. There is no doubt as to the close similarity of these plants to those from the Damudas of India and the Newcastle beds of Australia.

From the Stormberg beds there are reported *Pecopteris* or *Thinnfeldia odontopteroides*, *Cyclopteris cuneata*, and *Tæniopteris daintreei*,[3] three of the most characteristic fossils of the uppermost plant-beds in Australia, and all found in the Upper Jurassic Queensland beds.

The animals found in the Karoo beds[4] are more numerous by far than the plants. The greater portion have been procured from the Beaufort beds. They comprise numerous genera of dicynodont, theriodont, and dinosaurian reptiles, two or three genera of labyrinthodont amphibians, some fish allied to *Palæoniscus* and *Amblyplerus*, and one mammal, *Tritylodon*. Of the above the *Tritylodon* and some reptilian and fish remains are said to be from the Stormberg beds.

Tritylodon is most nearly related to a Rhætic European mammal. The relations of the reptiles called *Theriodontia* by Sir R. Owen are not clearly defined, but representatives of them and of the *Dicynodontia* as already noticed are said to be found in the Permian of Russia. The *Glossopteris* and its associates may of course be classed as Carboniferous or Jurassic, according to taste. Neither the fauna nor flora show sufficiently close relations to those of any European beds for any safe conclusions as to age, even if homotaxis and synchronism be considered identical. On the other hand there are remarkable points of agreement with the faunas and floras of the Indian and Australian rocks.

Away from the typical Karoo area on the coast south of Natal there is found a series of beds, partly marine, sometimes called the Uitenhage[5] series. A few

[1] Sutherland, *Q. J. G. S.*, xxvi, p. 514.
[2] One classed by Tate as *Dictyopteris*, *Q. J. G. S.*, xxiii, p. 141.
[3] Dunn, 'Report on Stormberg Coal-Field,' *Geol. Mag.*, 1879, p. 552.
[4] Owen, 'Cat. Foss. Rept. S. Africa, Brit. Mus., 1876, &c.
[5] *Q. J. G. S.*, xxvii., p. 144.

cycads (*Otozamites*, *Podozamites*, *Pterophyllum*), a conifer, and ferns (*Pecopteris* or *Alethopteris*, *Sphenopteris*, *Cyclopteris*) are quoted from them, and three or four of the forms are closely allied or identical with species found in the Rájmahál beds of India.

It was at first supposed that the plant-bearing beds were lower in position than those containing marine fossils, and the whole of the Uitenhage series was considered as of later age than the Karoo beds. The marine beds were considered Middle Jurassic. Subsequently, however, Stow[1] showed conclusively that a portion of the marine beds, judging by their fossils, are of uppermost Jurassic or even Neocomian age, and also that the relation of the plant-bearing beds to the marine strata are far less simple than was supposed.[2] Indeed, to judge from Stow's account, it is by no means clear that a portion of the wood-bed series or saliferous series, to which the plant-beds belong, is not higher in position than the marine Jurassic strata.

There is a very extraordinary similarity between the geology of the southern part of Africa and that of the peninsula of India. In both countries a thick fresh-water formation, without any marine beds intercalated, occupies a large area of the interior of the country, whilst on the coast some marine Jurassic and cretaceous rocks are found, the former in association with beds containing plants. The coincidence is not even confined to sedimentary beds. As in India so in South Africa, the uppermost inland Mesozoic fresh-water beds are capped by volcanic rocks.

It has been assumed, but not apparently on any clear evidence, that the marine coast-beds and the associated plant-beds are in Africa much newer than the inland sandstone formation, but it is not impossible that the relations may really be the same as in India, and that the Stromberg beds of the inland formation may be the equivalents of the Upper Jurassic or even the cretaceous marine beds on the coast. The discovery of plants identical with those of the Jurassic (probably Upper Jurassic) beds of Queensland in the Stormberg series may of course be taken for what it is worth; it is of quite as much importance in indicating the age of the rocks as the occurrence of dicynodont reptiles in the Permian of Russia and in the lower Gondwánas of India.

Altogether there is quite sufficient probability that the upper Karoo or Stormberg beds are of later age than Triassic to justify the protest which I made last year against a skull being described from these beds as that of a 'Triassic' mammal.[3] The practice, so common amongst palæontologists, of positively asserting as a known fact the geological age of organisms from beds of which the geological position is not clearly determined, is very much to be deprecated.

I have called attention to the occurrence of boulders in the Tálchir beds in India, the Ecca beds of South Africa, and the Bacchus Marsh sandstones and Hawkesbury beds of Australia. The idea has occurred quite independently to several different observers that each of these remarkable formations affords evidence of glacial action; and although, in the case of India especially, the

[1] *Q. J. G. S*, xxvii., p. 479.
[2] *L.c.*, pp. 505, 511, 513, &c.
[3] *Q. J. G. S.*, xl., p. 146.

geographical position of the boulder-bed within the tropics seemed for a long time to render the notion of ice action too improbable to be accepted, further evidence has so far confirmed the view as to cause it to be generally received. Even before the Australian boulder-deposits had been observed it was suggested that the Tálchir beds and Ecca conglomerate might be contemporaneous,[1] and that the evidence in favour of a Glacial epoch having left its traces in the Permian beds of England[2] might possibly indicate that the Indian and South African boulder-beds are of the same geological epoch. The discovery of two similar deposits in Australia adds to the probability that all may have resulted from the same cause and may record contemporaneous phenomena. It would be very unwise to insist too much on the coincidence.

It would be easy to call attention to further examples of discrepancies in palæontological evidence, but I should weary you and nothing would be attained by going through instance after instance of deposits in distant parts of the world, the age of which has been solely determined by the examination of a few fossil forms of land and fresh-water animals and plants. I have, therefore, only taken a few with the details of which I have had occasion to become acquainted. In some of the most important cases I have mentioned, such as those of the Pikermi and Siwalik faunas, the Cutch (Umia beds) flora and that in the lower coal-measures of Australia, the conflict is between the evidence of the marine and terrestrial organisms. Manifestly one or the other of these leads to erroneous conclusions.

The general opinion of geologists is in favour of accepting the evidence of marine organisms. The reason is not far to seek. So far as I am aware, no case is known where such an anomaly as that displayed in the Gondwánas of India has been detected amongst marine formations of which the sequence was unquestioned. In the Gondwánas we have a Rhætic flora overlying a Jurassic flora, and a Triassic fauna above both. In Australia we find a Jurassic flora associated with a Carboniferous marine fauna, and overlaid by a Permian fresh-water fauna. The only similar case amongst marine strata is that of the well-known colonies of the late M. Barrande in Bohemia, and in this instance the intercalation of strata containing later forms amongst beds with older types is disputed, whilst the difference in age between the faunas represented is not to be compared to that between Triassic and Jurassic.

There is, however, another and an even stronger reason for accepting the evidence of marine instead of that afforded by terrestrial and fresh-water animals and plants. If we compare the distribution of the two at the present day we shall find a very striking difference, and it is possible that this difference may afford a clue to the conditions that prevailed in past times.

Wanderers into what they fancy unexplored tracts in palæontology are very likely to find Professor Huxley's footprints on the path they are following. I have had occasion to turn to a paper of his on *Hyperodapedon*,[3] that very curious reptile

[1] *Q. J. G. S.*, xxxi., p. 528.
[2] *Q. J. G. S.*, xi., p. 185.
[3] *Q. J. G. S.*, xxv., p. 150.

already mentioned, of which the remains occur both in Great Britain and in India, and I find the following remarks, which appear so exactly to express a portion of the view to which I wish to call your attention, that I trust I may be excused for quoting them. Professor Huxley writes :—

'It does not appear to me that there is any necessary relation between the fauna of a given land and that of the seas of its shores. The land-faunæ of Britain and Japan are wonderfully similar; their marine faunæ are in several ways different. Identical marine shells are collected on the Mozambique coast and in the easternmost islands of the Pacific; whilst the faunæ of the lands which lie within the same range of longitude are extraordinarily different. What now happens geographically to provinces in space is good evidence as to what, in former times, may have happened to provinces in time; and an essentially identical land-fauna may have been contemporary with several successive marine faunæ.

'At present our knowledge of the terrestrial faunæ of past epochs is so slight that no practical difficulty arises from using, as we do, sea-reckoning for land-time. But I think it highly probable that sooner or later the inhabitants of the land will be found to have a history of their own.'

When these words were written more than fifteen years ago very few of the geological details to which I have called your attention were known. I need not point out how wonderful a commentary such details have afforded to Professor Huxley's views.

I have no desire to quote authority. I fear that in the facts I have been laying before you my quotations of the most authoritative writers have been made less for the purpose of showing reverence than of expressing scepticism. My reason for calling attention to Professor Huxley's views is different. I entirely agree with them; but there is, I think, something to be added to them. There is, I believe, an additional distinction between land and marine faunas that requires notice, and this distinction is one of very great importance and interest. It appears to me that at the present day the difference between the land-faunas of different parts of the world is so vastly greater than that between the marine faunas that if both were found fossilised, whilst there would be but little difficulty in recognising different marine deposits as of like age from their organic remains, terrestrial and fresh-water beds would in all probability be referred to widely differing epochs, and that some would be more probably classed with those of a past period than with others of the present time.

I had proposed to enter at some length into this subject, and to attempt a sketch of the present state of our knowledge concerning the distribution of terrestrial and marine faunas and floras. But I found that it was impossible to do justice to the question without making this address far longer than is desirable, and I have already taken up more time than I ought to have done. I can therefore only treat the subjects very briefly.

As you are doubtless aware, the most important work upon the distribution of terrestrial animals yet published is that of Mr. Wallace. He[1] divides the earth's

[1] Dr. P. L. Sclater was the original author of the sub-division adopted by Mr. Wallace.

surface into six regions—Palæarctic, Ethiopian, Oriental, Australian, Neotropical, and Nearctic. Some naturalists, with whom I am disposed to agree, consider Madagascar and the adjacent islands a seventh region, and it is possible that one or two other additions might be made.

These regions are essentially founded on the distribution of *vertebrata*, especially mammals and birds, and the following table, taken from Wallace's lists, shows the percentage of peculiar families of vertebrata and peculiar genera of mammalia in each region, mammalia being selected as being more characteristic than birds and better known than reptiles, amphibians, or fishes:—

REGIONS.	Total families of Vertebrates.	Peculiar Families.	Percentage of Peculiar Families.	Total Genera of Mammals.	Peculiar Genera of Mammals.	Percentage of Peculiar Genera.
Palæarctic . . .	137	3	2·2	100	37	37
Ethiopian . . .	175	23	13·1	142	90	63
Oriental . . .	163	12	7·4	118	54	46
Australian . . .	142	30	21·1	70	45	65
Neotropical . .	168	45	26·8	131	103	79
Nearctic . . .	121	12	9·9	74	24	32

The marine mammals and reptiles are too few in number to be compared with the land-fauna, but whales, porpoises, seals, sirenians, turtles and sea-snakes are for the most part widely diffused. The best class of the vertebrata for comparison is that of the fishes, and some details taken by Wallace from Günther's 'British Museum Catalogue' are very important. The whole class is divided into 116 families, of which 29 are exclusively confined to fresh water, whilst 80 are typically marine. Of these 80 no less than 50 are universally, or almost universally, distributed, whilst many others have a very wide range. Four families are confined to the Atlantic and 13 to the Pacific Ocean, whilst a few more are exclusively southern or northern. About 63 are found in both the Atlantic and Pacific.

Now, of the 29 fresh-water families, 15, or more than one-half, are confined each to a single region, 9 are found each in two regions, 2 in three regions, and the same number in four; one only (*Cyprinidæ*) is found in five regions, whilst not one is met with in all six. It is impossible to conceive a greater contrast: 50 marine families, or 62·5 per cent., have a world-wide distribution, whilst not a single fresh-water family has an equally extended range, and more than one-half are confined each to a single region.

The regions adopted by Wallace, as already stated, are founded on the *vertebrata;* he considers, however, that the distribution of the invertebrates is similar. So far as the terrestrial mollusca are concerned, I am inclined to dissent from this view. But for one circumstance the mollusca would afford an admirable test of the theory that marine types—species, genera, and families—are much more widely spread than terrestrial. I am assured that this is the case, but the difficulty of proving it arises from the fact that the classification of pulmonate terrestrial mollusca, as adopted by naturalists generally, is so artificial as to be worthless. Genera like *Helix*, *Bulimus*, *Achatina*, *Pupa*, *Vitrina*, as usually adopted, are not real genera, but associations of species united by characters of no systematic importance, and the attempts that have hitherto been made at a natural classification have chiefly been founded on the shells, the animals not being sufficiently known for their affinities, in a very large number of cases, to be accurately determined. Of late years, however, more attention has been devoted to the soft parts of land mollusks, and in Dr. Paul Fischer's 'Manuel de Conchyliologie' now being published, a classification of the Pulmonate Gasteropoda is given, which, although still imperfect for want of additional information, is a great improvement upon any previously available. In this work the first 13 families of the *Pulmonata Geophila* comprise all the non-operculate land mollusca, or snails and slugs, and these 13 families contain 82 genera thus distributed:—

Peculiar to one of Wallace's land regions	54
Found in more than one, but not in both America and the Eastern hemisphere	12
Common to both hemispheres	16

The last 16, however, include *Limax*, *Vitrina*, *Helix*, *Pupa*, *Vertigo*, and some other genera which certainly need further repartition. The operculated land-shells belonging to a distinct sub-order, or order, and closely allied to the ordinary prosobranchiate gasteropoda, are better classified, the shells in their case affording good characters. They comprise four well-marked families (*Helicinidæ*, *Cyclostomidæ*, *Cyclophoridæ*, and *Diplommatinidæ*), besides others less well marked or but doubtfully terrestrial. Not one of the families named is generally distributed, and the genera are for the most part restricted to one or two regions. The portion of Dr. Fischer's manual relating to these mollusca is unpublished, and the latest general account available is that of Pfeiffer, published in 1876.[1] From this monograph I take the following details of distribution. The number of genera enumerated is 64 (including *Proserpinidæ*).

Peculiar to one of Wallace's land regions	48
Found in more than one, but not in both America and the Eastern hemisphere	8
Common to both hemispheres	8

It is the distribution of the terrestrial operculate mollusca which induces me to suspect that the distribution of land mollusca differs from that of land vertebrates. One instance I may give. There is nowhere a better marked limit to two vertebrate faunas than that known as Wallace's line separating the Australian and Oriental regions, and running through the Malay archipelago between Java, Sumatra, and Borneo, on the one hand, and Papua with the neighbouring groups on the other. There is in the two regions a very great difference in the vertebrate genera, and a considerable replacement of families. The Oriental *vertebrata* contain far more genera and families common to Africa than to Australia. Now, the operculate land-shells known from New Guinea and Northern Australia

[1] *Monographia Pnemonopomorum Viventium Supp.* iii.

belong to such genera as *Cyclophorus*, *Cyclotus*, *Leptopoma*, *Pupinella*, *Pupina*, *Diplommatina*, *and Helicina*, all found in the Oriental region, and mostly characteristic of it, whilst the only peculiar types known are *Leucoptychia*, closely allied to *Leptopoma*, from New Guinea, and *Heterocyclus*, apparently related to the Indian *Cyathopoma*, from New Caledonia. Farther east in Polynesia there are some very remarkable and peculiar types of land-shells, such as *Achatinella*, but these do not extend to Australia or Papua. On the other hand, scarcely a single Oriental genus extends to Africa, the terrestrial molluscan fauna of which continent differs far more from that of the Oriental region than the latter does from that of tropical Australia.

The same is the case with plants. In an important work lately published by Dr. O. Drude, of Dresden, the tropics of the Old World are divided into three distinct regions—(1) tropical Africa; (2) the East African Islands, Madagascar, &c.; (3) India, South-Eastern Asia, the Malay archipelago, Northern Australia, and Polynesia.

A very large proportion of the families and even of the genera of marine mollusca are almost of world-wide distribution, and even of the tropical and sub-tropical genera the majority are found in all the warmer seas. I have no recent details for the whole of the marine mollusca, but a very fair comparison with the data already given for land-shells may be obtained from the first 25 families of Prosobranchiate Gasteropoda, all that are hitherto published in Fischer's manual. These 25 families include *Conidæ*, *Olividæ*, *Volutidæ*, *Buccinidæ*, *Muricidæ*, *Cypreidæ*, *Strombidæ*, *Cerithiidæ*, *Planaxidæ* and their allies, and contain 116 living marine genera, the known range of which is the following:—

Found only in the Atlantic Ocean	15	
Found only in the Pacific or Indian Ocean, or both	28	
Found only in Arctic or Antarctic Seas, or in both	12	
		— 55
Found in the warmer parts of all oceans	34	
Widely, and for the most part universally, distributed	27	
		— 61

That is, 52·6 per cent. are found in both hemispheres, whilst only 19·5 per cent. of the inoperculate, and 12·5 per cent. of the operculate land mollusca, have a similar distribution. This is, however, only an imperfect test of the difference, which is really much greater than these numbers named imply by themselves.

Some genera of fresh-water mollusca, as *Unio*, *Anodon*, *Cyclas*, *Lymnea*, *Planorbis*, *Paludina*, and *Bythinia*, are very widely spread, but a much larger number are restricted. Thus if *Unio* and *Anodon* are extensively distributed, all allied fresh-water genera, like *Monocondylæa*, *Mycetopus*, *Iridina*, *Spatha*, *Castalia*, *Ætheria*, and *Mülleria* inhabit one or two regions at the most. The same result is not found from taking an equally important group of marine mollusca, such as *Veneridæ* or *Cardiadæ*.

Throughout the marine invertebrata, so far as I know, the same rule holds good: a few generic types are restricted to particular seas; the majority are found in suitable habitats throughout a large portion of the globe. The marine provinces that have been hitherto distinguished, as may be seen by referring to those in Woodward's 'Manual of the Mollusca,' or Forbes and Godwin Austen's 'Natural History of the European Seas,' or 'Fischer's 'Manuel de Conchyliologie,' or Agassiz's 'Revision of the Echini,' are founded on specific distinctions, whilst the terrestrial regions are based on generic differences, and often on the presence or absence of even larger groups than genera.

Botany offers a still more remarkable example. I have just referred to Dr. Oscar Drude's work,[1] published within the last few months, on the distribution of plants. Dr. Drude divides the surface of the globe into four groups of floral regions (*Florenreichsgruppe*), and these again into floral regions (*Florenreiche*), fifteen in number, which are again divided into sub-regions (*Gebiete*). The first group of floral regions is the oceanic, comprising all the marine vegetation of the world; and so uniform is this throughout that no separate regions can be established, so that there is but one oceanic to contrast with fourteen terrestrial regions.

It is impossible to enter further into this subject now, and I can only allude to the evidence in favour of the existence of land-regions in past times. It is scarcely necessary to remind you of the proofs already accumulated of differences between the fauna of distant countries in Tertiary times. The Eocene, Miocene, and Pliocene vertebrata of North America differ quite as much from those of Europe in the same periods as do the genera of the present day; and there was as much distinction between the mammalia of the Himalayas and of Greece when the Siwalik and Pikermi faunas were living as there is now. In Mesozoic times we have similar evidence. The reptiles of the American Jurassic deposits present wide differences from those of the European beds of that age, and the South African reptilian types of the Karoo beds are barely represented elsewhere. But there is no reason for supposing that the limits or relations of the zoological and botanical regions in past times were the same as they now are. It is quite certain indeed that the distribution of land-areas, whether the great oceanic tract has remained unchanged in its general outlines or not, has undergone enormous variations, and the migration of the terrestrial fauna and flora must have been dependent upon the presence or absence of land communication between different continental tracts; in other words, the terrestrial regions of past epochs, although just as clearly marked as those of the present day, were very differently distributed. The remarkable resemblance of the floras in the Karoo beds of South Africa, the Damuda of India, and the coal-measures of Australia, and the wide difference of all from any European fossil flora, is a good example of the former distribution of life; whilst it is scarcely necessary to observe that the present Neotropical and Australian mammals resemble those of the same countries in the later Tertiary times much more than they do the living mammalia of other regions, and that the Australian mammal fauna is in all probability more nearly allied to the forms of life inhabiting Europe in the Mesozoic era than to any European types of later date. If the existing mammals of Australia had all become extinct, a deposit containing their bones would probably have been classed as Mesozoic.

The belief in the former universality of faunas and floras is very much connected with the idea once generally prevalent, and still far from obsolete, that the temperature of the earth's surface was formerly uniform, and that at all events

[1] Petermann's *Mittheilungen*, Ergänzungsheft, No 74, 'Die Florenreiche der Erde.'

until early or even middle Tertiary times the poles were as warm as the equator, and both enjoyed a constant tropical climate. The want of glacial evidence from past times in Spitzbergen and Greenland, where a temperature capable of supporting arboreal vegetation has certainly prevailed during several geological periods, is counterbalanced by the gradually accumulating proofs of Lower Mesozoic or Upper Palæozoic glacial epochs in South Africa, Australia, and strangest of all in India. Even during those periods of the earth's history when there is reason to believe that the temperature in high latitudes was higher than it now is, evidence of distinct zones of climate has been observed, and quite recently Dr. Neumayr,[1] of Vienna, has shown that the distribution of Cretaceous and Jurassic *cephalopoda* throughout the earth's surface proves that during those periods the warmer and cooler zones of the world existed in the same manner as at present, and that they affected the distribution of marine life as they do now.

The idea that marine and terrestrial faunas and floras were similar throughout the world's surface in past times is so ingrained in palæontological science that it will require many years yet before the fallacy of the assumption is generally admitted. No circumstance has contributed more widely to the belief than the supposed universal diffusion of the Carboniferous flora. The evidence that the plants which prevailed in the coal-measures of Europe were replaced by totally different forms in Australia, despite the closest similarity in the marine inhabitants of the two areas at the period, will probably go far to give the death-blow to an hypothesis that rests upon no solid ground of observation. In a vast number of instances it has been assumed that similarity between fossil terrestrial faunas and floras proves identity of geological age, and, by arguing in a vicious circle, the occurrence of similar types assumed without sufficient proof to belong to the same geological period has been alleged as evidence of the existence of similar forms in distant countries at the same time.

In the preceding remarks it may perhaps have surprised some of my auditory that I have scarcely alluded to any American formations, and especially that I have not mentioned so well-known and interesting a case of conflicting palæontological evidence as that of the Laramie group. My reason is simply that there are probably many here who are personally acquainted with the geology of the American Cretaceous and Tertiary beds, and who are far better able to judge than I am of the evidence as a whole. To all who are studying such questions in America I think it will be more useful to give the details of similar geological puzzles from the Eastern hemisphere than to attempt an imperfect analysis of difficult problems in the great Western continent.

Perhaps it may be useful, considering the length to which this address has extended, to recapitulate the principal facts I have endeavoured to bring before you. These are—

1. That the geological age assigned on homotaxial grounds to the Pikermi and Siwalik mammalian faunas is inconsistent with the evidence afforded by the associated marine deposits.

[1] 'Ueber klimatische Zonen während der Juras und Kreidezeit,' *Denkschr. Math. Nat. Cl. Akad. Wiss. Wien*, vol. xlvii. 1883.

2. The age similarly assigned on the same data to the different series of the Gondwána system of India is a mass of contradictions; beds with a Triassic fauna overlying others with Rhætic or Jurassic floras.

3. The geological position assigned on similar evidence to certain Australian beds is equally contradictory, a Jurassic flora being of the same age as a Carboniferous marine fauna.

4. The same is probably the case with the terrestrial and fresh-water faunas and floras of South Africa.

5. In instances of conflicting evidence between terrestrial or fresh-water faunas and floras on one side, and marine faunas on the other, the geological age indicated by the latter is probably correct, because the contradictions which prevail between the evidence afforded by successive terrestrial and fresh-water beds are unknown in marine deposits, because the succession of terrestrial animals and plants in time has been different from the succession of marine life, and because in all past times the differences between the faunas and floras of distant lands have probably been, as they now are, vastly greater than the differences between the animals and plants inhabiting the different seas and oceans.

6. The geological age attributed to fossil terrestrial faunas and floras in distant countries on account of the relations of such faunas and floras to those found in European beds has proved erroneous in so large a number of cases that no similar determinations should be accepted unless accompanied by evidence from marine beds. It is probable in many cases—perhaps in the majority—where the age of beds has been determined solely by the comparison of land or fresh-water animals or plants with those found in distant parts of the globe, that such determinations are incorrect.

Afghan Field-notes by C. L. GRIESBACH, F.G.S., *Geological Survey of India (on duty with the Afghan Boundary Commission).*

Route.

The march of the Afghan Boundary Commission was first from Quetta to Nushki, after crossing the Lora south of the Pishin valley; from Nushki to Khwaja Ali on the Helmund (east of Rudbar) by long and weary marches. We followed the river down to Chahar Burjak, where we crossed it. From this point we went in a more or less northward direction through Kalah-i-Fath past the Helmund Lakes to Lash-Juwain, through the Anardara pass, and passing Sabzawár westwards, to Pahri and eventually to Kuhsán on the Hari Rud, avoiding Herat altogether. Here General Sir Peter Lumsden, K.C.B., joined our party under Colonel Ridgeway.

On the 25th November, the General with a small party left us to go *viâ* Chasm-Sabz (not on the old maps) and Panjdeh to these our winter quarters on the Murgháb river. We followed next day by another route to Kushk, finally all meeting at Bála Murgháb. At Kushk, I obtained permission to go off by myself on a geological trip; I returned to the Herat valley by the Band-i-Bábá, went to within a mile of Herat city, afterwards returning over the Band-i-Zurmust to Kila Náu and to Bála Murgháb.

River drainage.

The march from India to the valley of the Murgháb has taken us from Eastern Biluchistan, which belongs to the Indus drainage into the Lora and Helmund basins (Seistan, &c.) and thence over the great watershed south of Herat, into the Central Asian basin of the Hari Rud and the Murgháb. The watershed which divides Southern Afghanistan from Central Asia, is formed as far as we know by the range of mountains called on our maps the Siah Koh, with its western continuation, the Doshakh mountains.

There seems to exist a marked difference in the geological features of the areas divided by this great range, and I intend therefore to treat them separately in these notes.

The time was too limited to admit of a regular geological survey of the country traversed, but I believe the notes collected with the experience gained in my former work in Afghanistan has enabled me to come to fairly accurate conclusions with regard to the geology of the country.

Southern Afghanistan and Biluch desert.

As will even be clear from a view of the old map of Afghanistan[1] the country lying between Nushki and the Helmund, with much of the area to the north of it, is nothing but a desert now, though water may be found in most localities by digging wells.

The features of the whole area are similar to those described between Kandahar and Quetta, consisting of more or less parallel ranges, which run between east—west and north-east—south-west, separated by wide stretches of dasht-deposits, which reach an enormous thickness in the Lower Helmund valley.

The ranges which we crossed in succession south of the Helmund are merely continuations of ranges which I have described already in my memoir on Southern Afghanistan, and I may at once say that, with the exception of one or two points, I could not elucidate any new fact in relation to the rocks which compose the hill ranges *south* of the Doshakh range south-west of Herat; north of these hills the character of the rocks entirely changes.

Ghaziaband range.

Between Quetta and Nushki, I crossed the "Ghaziaband" range at a point south-west of my old route of 1880, and near the village of Karnak. I wish I could have remained a few days in that neighbourhood; there are several points of geology connected with the section of this range which are not at all clear to me. The country is now, however, quite accessible to any one, and will no doubt before long be carefully surveyed.

Siwaliks of Biluchistan.

The range is skirted on its south-east slope by clays, of red and greenish white colour, which re-appear in considerable thickness in the Lora basin. In 1880, I believed them to represent the Gáj beds of Sind, which Mr. Blanford disputes, and I believe on good grounds. Since then I have had an opportunity of seeing the Siwalik rocks of the Deraját, Kohát district and the Trans-Indus Salt-range. There, especially in the latter area, a great thickness of red and greenish-white clays, sandstones and conglomerates overlie the cretaceous beds, and are considered by Wynne to be representatives of the Lower Siwaliks. I was struck with the lithological likeness of these Trans-Indus Siwalik beds with what I remembered the Ghaziaband beds to be

[1] General Walker's map, 1 inch = 32 mile, 1883.

I have had now a second opportunity of visiting the latter, and the resemblance of them to the Salt-range Siwaliks seems to me perfect. If my supposition is correct, then these beds do not represent Upper but the Lower Siwalik beds. Fossils I have none out of them.

Eocene sandstones of Karnak.

The greenish-grey sandstone and shales which compose the pass leading from Karnak to Panjpai, may be the same as the nummulitic sandstone (Flysch ?), which I saw in 1880 in the Ghaziaband pass; but if so, their character changes slightly towards the south-west. I believe the Karnak beds resemble rather the Khojak group of rocks.

Khojak beds.

Between Panjpai and Nushki one crosses the hill ranges which form the south-western spurs of the Khojak Amran mountains, and, as I expected, the geological structure of the hills is the same; the principal rocks are sandstones and hard splintery shales, all much contorted, of exactly the same lithological character as the Khojak beds. Near Kaisar, east of Nushki, I met traps and a granitic rock of similar characters to those of the trap and granitic rocks of Gatai and Dobrai, north of the Khojak.

When I first crossed the latter pass in 1880, it seemed to me probable that the hippuritic limestones, which compose the isolated hills on the north-west side of the Khojak Amran range, dipped below the Khojak sandstone; I therefore believed the latter to belong to the upper cretaceous series, equivalent perhaps to the "Vienna Sandstone" of the northern Alps. Since then I have had an opportunity of actually crossing the Sulemán range,[1] and I found there a formation of sandstone and shales underlying the upper cretaceous beds of the Takht-i-Sulemán, which appear to me to be of the same lithological character as the Khojak beds. If they represent these beds, then the latter would probably belong to the lower cretaceous series rather than the upper, and my interpretation of the broken section of the Khojak would be erroneous. A careful study of the hills between Panjpai and Nushki will, no doubt, settle this point.

Post-tertiaries of Biluchistan.

The valleys between the rugged hill ranges of this part of Biluchistan are partly filled by post-tertiary and recent deposits, mostly gravels and clays, with a capping of a widely spread bed of conglomerate and breccia, which I also found forming extensive plains in Southern Afghanistan.

Aerial formations.

Aerial formations in the shape of blown sand cover large tracts in these wide valleys, and practically all the level country between Nushki and the Helmund is covered with sand-hills. It is characteristic of them that they generally form low hills of crescent shape, with the horns and the scarp turned to leeward; the inclined plane formed by the currents of air are therefore generally dipping westwards and show a rippled surface, resembling closely the accumulations of drift snow on the high Himalayas.

As the sand-hills gradually advance, they uncover here and there the beds below, which are generally a thin plastering of clays on the top of the conglomerate already noticed.[2]

[1] *Supra*, Vol. XVII, part 4.
[2] Memoirs, Geol. Surv. Ind., XVIII, p. 14.

Igneous rocks, of the Biluch desert.

The higher hills between Nushki and Galichah are all formed of igneous rocks, most of them of a basic type. At a few points isolated masses of a granitic rock appear, and near Galichah (Malik Dokan) I met a calcareous contact rock with veins of gypsum and a serpentine with veins of chrysolite, which is quarried by the natives for ornamental purposes.

At Galichah one enters the Lut, a great desert which stretches down to the Helmund river, and the greater part of which is covered with blown sand.

The Helmund basin.

The geological features of the western part of the Helmund area are extremely simple. All the higher ranges are the western and south-western continuations of offshoots from the Siah-Koh, and are composed of upper cretaceous beds (hippuritic limestone) with associated traps and syenitic granite. The limestone is fossiliferous throughout: hippurites are found in great numbers in all beds of this formation. Near the igneous rocks the limestone is converted into a fine-grained white marble.

Hippuritic limestone. Igneous rocks.

Contact rock.

The contact rock between the hippuritic limestone and the trap is precisely of the same character as the rock which contains the gold near Kandahar, and is found in a similar position. It is *in situ* north of Sher Buksh.

Syenitic granite.

The range north of Kala-i-Kah and the greater mass of the hills crossed between this point and Pahri are formed of hippuritic limestone with intrusions of trap. The valley of the Karez-i-Dasht, north of the Anardara pass, is formed of syenitic granite, of later age and intrusive in the trap.

Tertiaries of South Afghanistan, near Pahri.

Red and white clays, very like the beds of the Ghaziaband pass, near Quetta, form some of the lower ranges and plateaux between the trap hills of Sher Buksh and Pahri. Near the latter place the beds of this formation are raised up and dip north-west at a varying angle. Near Chah Gazek I found some remains of mammalian bones in a bad state of preservation. Perhaps these beds are of Siwalik age. They are certainly older than the clays, sandstones, and conglomerates which overlie them, and which further south form widespread areas in the lower Helmund basin.

Mammalian bones.

Afghan Seistan. Newer tertiaries and recent rocks.

The geological features of Afghan Seistan are extremely simple. Only later tertiary and recent deposits are met with. The former are of fluviatile and aerial origin, and overlie the coloured clays with mammalian remains of Chah Gazek.

The prevailing rocks are clays, soft sandstones, and gravels, locally with enormous thicknesses of "loess" beds. The latter are thick unstratified beds of fine silt, with false-bedded sandy layers. Veins of gypsum are frequent, and cavities, occasionally still retaining some lignitic rootlets and stems of plants, are found throughout the deposit; such cavities are also characteristic of the "loess" deposits of Europe, which are now generally supposed to be of aerial origin.

These beds form high scarps along the banks of the Helmund, and lower down along the eastern shores of the Hamún, where they are well exposed. In lithological character they resemble the Upper Manchhars of the Nari gorge, near Sibi, of which they are probably an equivalent.

Post-tertiaries and recent.

Recent and post-tertiary deposits, soft sandstones and conglomerates, both containing worn material from the neighbouring hill ranges, are found in considerable thickness in the Farah Rud, the Kash Rudak, and capping the mammalian beds of Seistan and Biluchistan. Locally the conglomerate is replaced by a hard limestone breccia (near Galichah in Biluchistan), but the group of rocks is everywhere seen to overlap and even to rest quite unconformably on the underlying mammal beds of Seistan. They resemble in general character the post-tertiaries of Sind, of the Deraját, and the Punjab. In general outlines the drainage which produced these beds must have been identical with the drainage of the rivers of the present day, though here and there the area may have been much more extended.

The great watershed of Central Asia.

The range which runs more or less with the 34° North latitude, and which on our maps bears the names of the Siah Koh and Doshakh mountains, marks a complete change in the geological structure of Central Asia. Whereas south of this range no older rocks than of the cretaceous period are known to exist, the Doshakh range itself consists of palæozoic rocks, and between them and the Tir-band-i-Turkistan range is a series of beds all dipping more or less north or north-east, and comprising the entire upper palæozoic and mesozoic series.

Sections obtained.

Up to the present I obtained the following sections. In the Doshakh range, from Pahri to Zindaján (Herat valley); over the Chillingak pass, east of the Doshakh peaks, and from Zindaján to Robat-i-pai; in the Paropamisus, the Band[1]-i-Kaitu, the Band-i-Bába and the Band-i-Zurmust. Unfortunately these sections require connecting before I can form a perfectly clear idea about the structure of these mountain ranges, but I believe that I shall have another opportunity of crossing the Herat valley before leaving Afghanistan, to complete my work.

List of formations.

I found the following groups of rocks in the area between the Doshakh range and the Tir-band-i-Turkistan :—

In descending order :—

Recent and post-tertiary	Alluvium of Hari Rud and Murgháb sandstone and conglomerates.
Siwaliks, Upper	Sandstones, grits, clays of Ghorian and Tirpul (Hari Rud).
„ Lower	Red and white clays of Chesm Sabz, Sakhra (Murgháb).
Cretaceous	Tir-band-i-Turkestan beds.
Jurassic	Kushk sandstones, Chakán beds.
Trias and Rhaetic	Plant-beds of Band-i-Bába, Zurmust and Naratú.
Permian ?	Talchir conglomerates, sandstones, and shales. Trap.
Carboniferous	Productus beds of Robat-i-pai.

In describing the rocks I will begin with the oldest formation, which was also the first noticed on entering the Central Asian region.

[1] Band = pass.

The Doshakh range appears to be formed of one or more great anticlinals.

Carboniferous.

The south side of the range is composed of hippuritic limestone, but unfortunately I had no opportunity of finding out the relations of the cretaceous beds to the older rocks composing the main range. From what I could learn by crossing the Chillingak pass from Pahri to Zindaján, and from a section made from the latter place to Robat-i-pai (near the centre of the Doshakh hills), it appears that a grey sandstone with friable shales, somewhat resembling in its lithological character the Khojak beds, is overlaid by hard dark-blue limestone with calcspar veins which contains carboniferous fossils in great abundance. There are several species of *Producti*, amongst them *Pr. semi-reticulatus*, *Athyris roissyi*, *Fenestella*, and corals.

These limestones dip about 20° north to north-east below the alluvial deposits of the Hari Rud. Immediately north of Robat-i-pai, on the north side of the Hari Rud valley, all the older beds are hidden by extensive clay and sandstone beds of late tertiary age.

A section through the Paropamisus *viâ* the Ardewan pass (north of Herat) may probably reveal a continuous section, and this I hope to accomplish as soon as the weather becomes more favourable.

The section over the Band-i-Bába from Kushk to Herat is incomplete, as the

Band-i-Bába section.

route which I had to follow over the pass more often than not runs in the direction of the strike of beds and over the debris and recent deposits on the south slope of the range.

I found north-east of Herat the low spurs which reach to within 1,500 yards

Hills near Herat, gneiss.

of the city, and on which the Ziarat Khwaja Abdullah-i-Ansari at Ghazegah is built, to consist of a grey thinly bedded gneiss with granitic veins, dip north-east. The overlying beds I did not see, nor could I find again the carboniferous Productus limestone in the Band-i-Bába section. The part of the Paropamisus intervening between this point and the south side of the Band-i-Bába pass near Palezkár I could not touch anywhere, but from the debris found on the great "fans" south of it, I should say that carboniferous beds will be found north of Herat. The Band-i-Bába is greatly contorted, and the centre range itself is formed by a great anticlinal, which is followed towards the east and south-east by a succession of folds, which probably are continued to the Davendár range.

At the south side of Bába pass near Palezkár I found an extensive formation,

Talchirs near Palezkár.

all the beds of which dip to the east and south-east, seemingly quite unconformably to the gneiss of Ghazegah and the main range; I recognised it at once and without trouble as Talchir, the basal group of the Indian Gondwána system. Boulder beds, conglomerates, greenish sandstones, and shales predominate, accompanied by red and yellow clays and interbedded trap. The latter is a feature which reminded me at once of the boulder-bed of the Karoo formation of South Africa. Both the sandstone and the shales contain traces of plants, belonging to Vertebraria apparently.

Whether these plant-beds rest unconformably on the carboniferous limestones, as the differing dip and strike would indicate, I am at present unable to say, but hope to settle this point before very long. I could not go east of Kurukh to the Davendar range, where probably the upper beds of the Gondwánas would be met with.

Upper plant-beds of the Bába pass.

In the Bába pass the Talchirs seem to form the lowest beds of the anticlinal and are overlaid by a great thickness of sandstones, limestones, and shales, which form the top of the pass and the long sloping plateau of the north limb of the anticlinal as far as Chakán and Kushk. These beds I believe to represent the entire middle and upper Gondwána series. Plant-beds alternate with great thickness of grits and sandstones, and a few partings of Ostrea beds (limestones) are found towards the upper half of the group.

Sandstones of Band-i-Kaitú.

The sandstones and grits assume an enormous development towards the western portion of the Paropamisus; the Band-i-Kaitú is entirely composed of sandstones, grits, and conglomerates of the character of the Mahadeva sandstone.

Band-i-Zurmust.

Coral limestone.

The Band-i-Zurmust shows a similar geological structure with one difference. Within the group of Talchirs, and towards the lower half of it, appears a grey limestone, containing coral remains and a Nautilus. Plant-beds overlie this limestone, and the north slope of the Zurmust with the Naratú hill seems to be composed of plant-beds of middle Gondwána character. The upper strata of this series between Naratú and Chakán seem to have fewer plant-beds, whereas the Ostrea limestones increase in thickness.

Coast formation.

This group of rocks presents all the appearance of having been deposited along and near a sea-coast line; especially the upper portion of it north of the Zurmust must have been formed along a low sea coast probably of varying outlines, and we thus have beds presenting all the character of our Gondwánas with plants, the strata showing false bedding, alternating in the higher horizons with marine shell limestones.

Shell limestone of Kila Naú. Jurassic.

The plant beds are followed by thick strata of an earthy-white limestone of chalky texture, full of the casts of gasteropods and bivalves, alternating with a white calcareous sandstone with numerous bivalves. These beds form a belt north of the Paropamisus, and are well seen between Kushk and Kila Naú, wherever the affluents of the Kushk and Murgháb rivers form deep ravines in the plateaux.

Tir-band-i-Turkistan. Cretaceous fossils.

I believe this white shell limestone series belongs to the upper jurassic epoch; it is overlaid by the Tir-band-i-Turkistan limestones, amongst which I certainly found beds with cretaceous fossils, but the description of which I reserve for my next note.

Tertiaries: Siwaliks.

Red and greenish-white clays are in great force in the wide-stretching high plain of Chesm Sabz, north-east of Kuhsan, and are overlaid near Tirpul, in the Hari Rud valley, by sandstones, silts, clays, and grits. I believe that this series represents the Siwaliks. Similar beds, with great deposits of gypsum, and containing some fossils, casts of shells of Unio, and the casts of Annelids, I met near Sakhra on the Murgháb.

BALA MURGHÁB;

8th January 1885.

CORRIGENDUM.

The Phosphatic rocks *at* Musuri (Mussooree) (*supra*, Vol. XVII, p. 198).

In the determination of the composition of the phosphatic minerals sent by the Rev. Mr. Parsons from Mussooree, as given in the last number of the Records, two operators were implicated, and owing to the absence on leave of Mr. Mallet and myself it was not known that one of them, our new Museum Assistant, was very inexperienced in laboratory work. Mr. Mallet had taught him how to make the ordinary assay of a limestone, but of general chemical analysis he knew next to nothing. It thus befell that when heunder took to determine the lime in these stones, not knowing the peculiar behaviour of this substance in the presence of phosphoric acid, he only obtained the amount of lime that existed in excess of that present as phosphate, amounting to 8·42 per cent. Since Mr. Mallet's return he has had a full determination made, giving 26·5 of lime, of which 18·5 was present as phosphate, representing 34·1 of this salt or 15·6 of phosphoric acid, being about a third of the total quantity present. The stone thus remains still principally a phosphate of alumina, but the difference is sufficient to call for a correction of the previous statement, as the phosphate of lime is the most important ingredient. The stones are described as occurring in some abundance and at many different places in brown shales immediately overlying limestone, so they may yet prove of economic value.

Of even greater interest, considering the failure hitherto to find fossils in any of the outer Himalayan rocks, is the announcement by Mr. Parsons (under date of 21st November 1884), that he has observed in the nodules what appear to him to be minute organisms. Preparations are in hand to investigate so interesting a discovery.

H. B. MEDLICOTT.

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FROM 1ST OCTOBER TO 31ST DECEMBER 1884.

Fossils from Nila in the Salt Range, Punjab, from the bed below the coal.
PRESENTED BY DR. H. WARTH.

A model of the Gor-do-Norr diamond after cutting. Weight 24¼ carats. Valued at £25,000 in London and Paris. PRESENTED BY MESSRS. P. ORR AND SONS, MADRAS.

Specimens of quartz pebble, used as bearings and pivots in native flour-mills at Dehra Dun, Punjab. PRESENTED BY DR. H. WARTH.

Specimens of cut and polished ferruginous limestone, puddingstone, silicified palm, heliotrope, syenite, jasper, granite, chalcedony, chert, onyx, and agate, purchased at Banda, N. W. P. PRESENTED BY THE COLLECTOR OF BANDA, N. W. P.

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Specimen of a polished marble paper-weight from Kathiawar.
PRESENTED BY THE MONAVADA STATE, KATHIAWAR.

A specimen of polished marble, and two of polished igneous rock, paper-weights from Kathiawar. PRESENTED BY H. H. THE NAWAB SAHAB OF JUNAGAD, IN KATHIAWAR.

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Part 2.] 1885. [May.

A fossiliferous series *in the* Lower Himalaya, *Garhwal, by* C. S. Middlemiss, B.A., *Geological Survey of India.*

This note is to put on record a find of fossils made by me in March from rocks of the Lower Himalaya of British Garhwal, all which have hitherto proved barren, save for comminuted fragments of shells[1] in the Mandhális known as the Tál limestone, a series which I have in addition shown to be the westward extension of these same fossiliferous rocks.

The find is not large, nor are the specimens all that could be desired in point of preservation; for frequently, owing to subsequent crystallisation and to oolitic aggregation, many have been spoilt.

Corals, Belemnites, Lamellibranchs, and Gasteropods, usually all of small size, form the staple of the rock contents, but writing, as I am, from the field, I can do no more at present than indicate their probable jurassic age.

The places I found most suitable for collecting are the northern slopes of the Dhalniya-ka-danda, at Gajwara[2] (Gujbara of map), and five miles to the west-north-west in a small ridge east of Umrela (Oomrela).

Petrology.

The petrological characters of the fossiliferous rock series are as follows:—In the main it is either a grit or a quartzite, with here and there a tendency to become calcareous or conglomeratic. Though some irregularities seem to show that the calcareous band is not constant in vertical position, and that the conglomerate varies very much in coarseness in different localities, still a good general sequence can be made out. The lowest rock, when seen, is of millstone-grit type, a good sound rather coarse-grained stone that would make excellent building material. The quartz grains are quite distinct, slightly angular, and of a milky-white or smoky colour; they are set in a pale-yellow earthy matrix, and on weathered surfaces stand out white against black

[1] Brought to notice in 1864 (Memoirs, G. S. I., III, part 2, page 69).

[2] E. lon. 78° 42′, N. lat. 29° 47′. Sheet No. 7 of the 1-inch maps of Kumaun and British Gurhwal.

in a way unlike any other rocks in this neighbourhood. The conglomerate merely differs from this by having the milk-white quartz pebbles of larger size, but still retaining their slight angularity. At one place near Aldabou I found a variety containing limestone pebbles in addition to those of quartz. Besides becoming conglomeratic in parts, this same grit, in nearly every section I have seen, has at one horizon, generally near the base, a calcareous element, which, entering into the composition by small instalments in the more eastern parts of the area under consideration, becomes more pronounced on the northern flanks of the Dhalniya-ka-danda, the ridge at Gajwara, and generally in the direction of the Tál limestone, with which it ultimately coincides. The greater or less quantity of lime present has not, however, destroyed its marked external appearance; in every locality it shows up as an indigo-black rock, very often forming a scarp some 30 or 40 feet high. It is never pure limestone, but always shows the blebs and grains of quartz; even where the limestone is most crystalline these can always be detected outside in relief, whilst the finer particles have become nuclei for oolitic grains which sometimes crowd the rock. This is the fossiliferous bed, and it has an average thickness of not more than 50 feet.

In an upward direction the coarse grit, bearing its limestone and conglomerates, passes by insensible gradations into a compact massive quartzite, white, or faintly tinged with violet. This has a large, but unknown, thickness. To the east-south-east at Chaprait (sheet No. 8), and the higher hills north, it is seen in force, but beyond I have not yet had time to trace it.

Stratigraphy.

Though in the future, when the fossils are identified, this rock may form a horizon from which to reckon beds stratigraphically associated with it, at present it is well rather to speak of it in terms of the formations above and below it, and more especially as the overlying one, a massive blue-grey limestone, has already a very probable equivalent in the Krol limestone.

Beds below.

But to commence with those beneath it. They are purple and green slates and an angular volcanic ash or breccia. From their invariable nearly vertical bedding it was some time before I decided which was the upper. At length a section in the Khoban river gave me the clue: there the ashes slack off their high northerly dip, and above them the purple and green slates arch over to the south, and helped by a fault, cover them in entirely for a short distance. This note does not profess to enter into details with regard to these beds. It is enough at present to say that they must have very great thickness, reckoned probably by miles; that the volcanic breccia is itself, certainly in places, a mile thick without any important constituent change; that though undoubtedly volcanic in origin, either direct or indirect, it possesses very few fragments of igneous rocks; nor is it associated with any outpourings of lava, nor with igneous intrusions, of which I have seen none in this area. Of the purple and green slates, it suffices here to say that they are very uniform until Kálogarhi mountain is approached. The mass of that height is Chor gneiss;[1] and from whatever cause, the slates on approaching it become altered in two modes—they level

[1] An intrusive rock.

out dipping only slightly towards the mountain on all sides, and they at the same time become schistose, schists, and garnetiferous schists.

Relation of the fossiliferous beds to those below.

It is now necessary to say what is the relation between the fossiliferous beds and those underlying slates and ashes, and also to fix some few definite localities. To this end the section up the Mandál river, and on the ridge west of it, in the neighbourhood of Dobriah, is absolutely conclusive. That in the river bed from near Dhámdhar to Jámri exhibits nothing but the ashes striking about east and west, the strata either vertical or inclined at angles of 80° and 70° either one way or the other. Not a yard of the distance is unexposed. The lower parts of the ridge from Dhargaon to near Chaprait are the same both on its east and west sides. But the numerous summits into which the ridge has weathered are all formed of an approximately horizontal capping of the pebbly grit with a calcareous lower bed. At this place, however, the lime in the rock is not abundant, nor did I get fossils, though they may nevertheless be there, for my find was subsequent to mapping this part, and I was not specially on the look-out for them.

If more evidence for the marked unconformity between these two series were wanting, it is found in the further extension of the pebbly grit and calcareous band along the ridge. At a point almost due west of Dhámdhar, where is a gap over into the Haldgadi river, they rest on the purple and green slates, which are striking east and west with a nearly vertical dip similar to the ashes.

Relation of fossiliferous beds to those above.

Here too it is seen that they underlie the massive blue-grey limestone which forms the top of Dhargaon. From Dhargaon a tolerably well-defined ridge runs west-north-west up to the Kotedwar glen cut through at intermediate places by the Haldgadi and Palain rivers. Its formation is the same throughout as at Dhargaon, with a slight exception: the north flanks have always the pebbly grit, with its calcareous band below and quartzites above in a continuous exposure dipping at 30° or 40° south-south-west, whilst the summit and southern flanks have the superposed massive limestone, which is cut off to the south by the main boundary fault letting in the later tertiary sand-rock. The exception is near the Kotedwar glen north of Aldabou, where the limestone, having gradually lost its hold on the ridge summit and become confined to the southern slope, is at last entirely cut off by the main boundary fault. Of course it must not be supposed that there are no slight disturbances affecting these relations: at Gajwara inversions of the fossiliferous beds complicate matters a little; but on the whole the steady strike and the absence of important structural faults render the sequence perfectly intelligible, notwithstanding the violent contortions and the heavy jungle which clothes the hills.

It is now necessary to return eastward of Dhargaon for an exposure of importance. Just as in a westward direction the limestone was gradually lost by the strike of the beds and the strike of the main boundary fault meeting near Aldabou, so eastward, on account of their divergence, the south edge of the limestone becomes free at Jhirt, and is seen to lie not upon the pebbly grits but upon the purple and green slates. This evidence so far as it goes argues an unconformable position for the limestone; but it might not be so; the fossiliferous beds might, being conformable to the limestone, have thinned out; and this would indeed be plausible were it not for the great thickness which the quartzites attain north of Chaprait and Jámri, making it almost incredible that they could have thinned away to nothing in a distance of only 3 or 4 miles.

We have now seen that the fossil-bearing series lies in certain places unconformably above a set of slates and volcanic ashes, and unconformably beneath a massive blue-grey limestone of Krol type.

Relations with eocene beds.

But besides these local associations, there is another important one, *viz.*, the association with the nummulitic shales and limestone. The latter beds have been found up to date as far east as the Bodli-ka-sot, a tributary of the Palain river, where they lie, much folded, on the purple slates, and at several intermediate places between there and the Banás ridge. In consequence of the massive limestone series having vanished at Aldabon, the formerly subjacent fossiliferous beds have, in a westerly direction, their surfaces at liberty for still higher beds to occupy. Hence they become in this direction covered partially or wholly by the nummulitic clay-shales. Both series have indeed become in many places almost inextricably confused; for, starting probably with an uneven bottom for the tranquil deposits of the nummulitic sea, they have since been crushed together, causing the one to be displaced bodily, and the other to give by imperceptible folding and squeezing; whilst subsequent to all this, denudation has acted with a similar partiality, and land-slips have completed the ruin. For this reason it will be better to consider the two together in what I have further to say about them.

In the Kotedwar glen due north-north-west of Aldabon the main boundary fault of the usual reversed type cuts into the strata. North of it after some crush-rock and purple beds come the quartzites and calcareous beds vertical, and running as a minor ridge up to Umrela, beyond which in a gap in the ridge south-south-east from Charekh they dip at a rather low angle to the north-north-east, forming part of a synclinal curve, which again brings them to the surface with an opposite dip higher up on the ridge about 1 mile from Charekh summit. Below in the stream west of the ridge their continuous outcrop can be seen. Towards the Kotedwar glen the northern outcrop of this trough of the fossiliferous beds becomes lost, re-appearing again in the Kotedwar stream as a thin bed dipping south at the point where the Múhára and Kotedwar streams join. In this irregular broken-edged trough the nummulitic beds lie folded in a steep synclinal. They are very well exposed in the main stream, the Nummulitic limestone striking west-north-west along the mile reach between the points where the Umrela and Múhára streams flow into it. It is however impossible to realise this on the map, owing to this reach being erroneously drawn north-east and south-west.

The next point where these beds are seen is in the Sour glen, due west of Gaira and up the slope of the ridge north of Simalna. The trough has here lost its regularity, the calcareous beds and quartzites dip at 65° south-south-west in the Sour stream, climb the side-ridge towards Narai, and appearing here and there on the main ridge south of this return down the Simalna side-ridge. In the intervening side stream north of Simalna, and as pockets and films here and there on the adjacent slopes, are placed the nummulitic clays and clayey shales. The main boundary fault is immediately south of Simalna. On the main ridge due north-north-west from Simalna a small peak displays a good section of the quartzites above and the calcareous beds below: dip north-north-west 40°.

In the bay between this peak and Shálni there is a great film of nummulitic beds which a surface land-slip distinctly revealed dipping down hill steeply. On getting out of this bay on to the Shálni ridge all the nummulitics were left behind except some few beds around the village itself.

Coincidence of fossiliferous bed with Mandhális of Banás ridge.

On visiting the ridge north-west of Banás-talla, in order to join my work with Mr. Oldham's, I found, as I expected, that the Tál limestone series, classified by him as Mandhális,[1] are the identical calcareous and sometimes conglomeratic grits and quartzites from which I have obtained recognisable fossils.

It is interesting to note in passing that so entirely have the nummulitics in this easterly direction retained their Sabáthu character that the pisolitic iron-ore of the bottom bed besides being present near Syair is vouched for in the Sour and Kotedwar glens by loose fragments with grains somewhat larger than a pea.

I do not propose to do more here than put these few facts on record. Though the somewhat extraordinary positions of the eocene beds offer scope for theorising and certainly must have important bearings in elucidating the mode of building of the Himalaya, I think it better to await further information in the same direction.

Note on the probable age *of the* Mandháli series *in the* Lower Himalaya, *by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

That the discovery of recognisable fossils in Himalayan beds, recorded above by my colleage Mr. C. S. Middlemiss, will be of great value in establishing the age of at least one member of the Himalayan sequence, and in giving us a horizon to work from, cannot be doubted. But as in the meanwhile the acceptance as final of my ascription of the Tál beds to the Mandháli series might lead to misapprehension and confusion which would take long to pass away, I should wish to put the following explanation on record.

My identification of the Tál beds with the Mandháli series rested entirely on the discovery among the former of a bed of limestone conglomerate cemented by a limestone matrix, very similar to the one of most important members of the series as exposed at Mandháli in Jaunsár Báwar.

But the really characteristic feature of the Mandháli series is the occurrence of beds composed of a fine-grained matrix through which fragments, generally angular or subangular, of rock are scattered, the whole suggesting that the agency of floating ice was concerned in its formation.

No bed of this type was seen by me among the Tál beds, nor does my colleague mention the occurrence of any such bed in the area examined by him; and as the

1 *Supra*, XVII, p. 161. See also the paper following the present one.

age he assigns to the Tâl beds differs from that which on independent grounds I am inclined to ascribe to the Mandhâli series, it will not be safe to accept the two as equivalent.

As mentioned above, the general appearance of the characteristic member of he Mandhâli series and of the very similar Blaini conglomerate is that of an indurated boulder clay. In the latter case the resemblance has been noticed by other observers, and during the last working season a pebble was extracted from the Blaini conglomerate which showed very distinct striation similar to that generally attributed to glacial action. Though this corroborative evidence has not yet been obtained in the case of the Mandhâli conglomerate, it very probably is also of glacial origin.

I have elsewhere expressed an opinion that these old glacial boulder clays are of great value in determining the homotaxy of the beds among which they occur, and that they are at present the only means by which it can be determined with anything like absolute accuracy. But whether or no this opinion will bear the test of subsequent examination, there can be no doubt that between neighbouring areas the method is perfectly valid, and we may take it as practically certain that when the glacial boulder clays of Talchir age were being deposited in what is now the peninsula of India, glacial conditions must have obtained over what are now the Himalayas.

In the beds of the Himalayan sequence there are three distinct horizons at which similar beds are found, *viz.*, (1) the Mandhâli, (2) the Blaini, and (3) the Panjâl conglomeratic slates. Of these, the two last named are so low in the series that their contemporaneity with the Talchirs is practically out of the question; there remains only the Mandhâli conglomerate which we may therefore take as most probably the equivalent of the Talchir beds of India.

But the Talchirs are at the latest of triassic at the earliest of carboniferons and probably of permian age as judged by European standards; and we must for the present refrain from finally identifyng beds which are very probably of the same age with other beds containing such a characteristically mesozoic fauna as is described by Mr. Middlemiss.

Note on a second species *of* Siwalik Camel (*Camelus antiquus, nobis* (*ex* Falc. and Caut. M. S.), *by* R. LYDEKKER, B.A., F.G.S., &c.

In their original notice of *Camelus sivalensis*, Falconer and Cautley[1] said they had evidence of a second and smaller species of the genus from the Siwaliks which they proposed to call *C. antiquus;* but in the subsequently published plates (Nos. LXXXVI to XC) of the "Fauna Antiqua Sivalensis" all the remains are figured under the former name. A recent examination of the specimens in the British Museum has convinced me that the original view is in all probability correct.

Camelus sivalensis is a large species characterized by the rugose enamel of the teeth, the flatness of the inner walls of the lower true molars, and the

[1] *Vide* 'Falconer's Palæontological Memoirs,' Vol. I, p. 231.

long, slender, horizontal ramus of the mandible. The second species, for which I propose to revive the M. S. name of *C. antiquus*, is of smaller size, has a short, deep mandible, perfectly smooth enamel to the teeth, while the inner surface of the lower true molars is concave, and in its upper half is divided into two equal portions by a median vertical ridge, totally wanting in *C. sivalensis*,[1] and the existing camels. The specimens in the British Museum which can be referred to the new species are a maxilla, No. 15347; a young cranium, No. 40562 ("F. A. S.," pl. LXXXVI, fig. 2); part of a mandible, No. 16165 ("F. A. S.," pl. LXXXVII, fig. 5); another fragment of the mandible, No. 40568; and the greater part of a right ramus, No. 39599, with the teeth broken. At least one fragment of a mandible in the Indian Museum belongs to the same species.

I may also observe that both species of Siwalik camels are characterized by having the vertical ridge at the antero-external angle of the lower true molars which occurs in *Auchenia* but is absent in the existing camels. Both fossil species have the adult dentition numerically the same as in the existing ones; but at least one of them is distinguished by having the full complement of milk-molars in both jaws, *viz.*, M. M. $\frac{4}{4}$. The cervical vertebræ of the larger Siwalik camel are in some respects intermediate between those of the living camels and *Auchenia*.

Some further notes on the Geology *of* Chamba. *By* COLONEL C. A. McMAHON F.G.S. (With a plate and map.)

CONTENTS.

PART I.

DESCRIPTION OF A PORTION OF THE CHAMBA AREA PREVIOUSLY UNDESCRIBED.

In detailing some observations in the field made during the autumns of 1883 1884 I think the most convenient plan will be to note them in the order of the places visited.

I proceeded in a northerly direction from Dalhousie to Bhale (Balai) and Manjir (Manjere), and thence to Bhándal (Baundal). This section has already been described in a previous paper, and only a few additional observations will now be made.

[1] In the 'Palæontologia Indica,' ser. X, Vol. I, p. 61 (43), I gave these points as being characteristic of the molars of *C. sivalensis*, not being then able to notice the difference from typical specimens in those I had before me.

There is a superficial appearance of bedding in the outcrop of the "outer band" of gneissose granite, but I think it is only due to irregular jointing. The joints that run in the direction of pseudo-foliation are not continuous, but die out or run into each other.

Along the southern margin of the *inner* band of gneissose-granite the slates in contact with it are indurated, and I noted a small vein of granite intrusive in the slates near the swing bridge ("jhula") under Bhale.

On the northern margin of this outcrop of the gneissose granite, I observed some mica schists next the granite, but an examination of thin slices under the microscope has satisfied me that they belong to the margin of the granite itself. I can discover no essential difference, save in macroscopic aspect, between these schists and the gneissose granite. There is nothing surprising in the fact that the margin of the intruded sheet in contact with the slates should have assumed a specially schistose aspect.

In a previous paper I described the narrow outcrop of the gneissose granite below Bhale. I have now examined several slices made from specimens taken from the sides, middle, and intermediate parts of the sheet, and the result is to confirm me in my belief in its eruptive character. No points of difference exist between it and the Dalhousie granite, and it reminds me in particular of slice No. 15, described at page 132 of my paper in Vol. XVI of the Records. These specimens exhibit beautiful illustrations of the sort of fluxion structure detailed in my description of the Dalhousie specimens. The flowing lines of crypto-crystalline mica and of microlites do not at all suggest to my mind the appearance presented by foliated metamorphic rocks.

The orthoclase is much cracked and crushed; and the muscovite, which is in large crystals, is oriented in all directions, and appears to have been abundantly crumpled and compressed.

The minerals contained in the rock are the same as those in the Dalhousie specimens, though the microcline is sparse.

There are liquid cavities, with movable bubbles in the quartz, but they are much more abundant in the garnets, which probably crystallized at an earlier epoch, before the last phase of intrusion commenced. Inclusions have deposited mineral matter on cooling, and gas pores are associated with granular mineral matter.

The slates between the inner and outer bands of gneissose granite, in this section, are very micaceous, and at Bhale they are decided mica schists.

Between the northern boundary of the inner band of gneissose granite and Manjir, the succession appears to be as follows—micaceous slates; mica schists; slates; micaceous slates; slates; micaceous slates; slates.

I think in this section the Simla slates are folded up with older silurian beds in compressed isoclinal flexures. The decided mica schists are probably beds near the bottom of the series.

Just before the descent to the river Siul commences in the neighbourhood of Balori, I observed river conglomerate at an elevation of 3,320 feet above the sea, being over 800 feet, by my aneroid barometer, above the Siul. In the neighbourhood of Bilâspur, the capital of a Native State, south-west of Simla, I found river conglomerate[1] on an isolated hill, round which the Satlej flows, 980 feet above that river, and in my "Notes of a tour through Hangrang and Spiti"[2] I mentioned the occurrence of river boulders at the top of the Chandan Námo pass at an elevation of 12,340 feet above the sea, and about 2,400 feet above the present bed of the Spiti river. The explanation I offered, in the latter case, was that the Spiti river was formerly as high as the top of the Chandan Námo pass, but I now see that this explanation was incorrect. Whilst the Himalayan rivers were slowly deepening their channels and excavating the valleys through which they flow, the mountains themselves, there is reason to believe, were slowly rising at a rate probably equal to that of sub-aerial erosion. In the case of the river Siul, therefore, though it has undoubtedly cut its way through 800 feet of solid rock, there is no necessity for assuming that the river ever actually flowed at the elevation at which the boulder bed now rests.

I always thought that the elevation theory was necessary to explain the present position of the Satlej boulder beds in the neighbourhood of Biláspur, but I now see that it is applicable to boulder beds generally throughout the Himalayas.

The fact that the Himalayas have been slowly rising[3] whilst the rivers have been deepening their channels, explains, I think, why the Himalayan valleys are generally so steep and V-shaped.

The cause of the rising of the Himalayan area, which is probably still slowly going on, is discussed at length in the Revd. O. Fisher's Physics of the Earth's Crust.

Whether, however, the elevation of the Himalayas in most recent geological times is due chiefly to the flotation tendency assigned by Mr. Fisher, or to tangential pressure acting on an area losing weight from sub-aerial erosion, is a subject foreign to the scope of this paper. I am only concerned with the fact of elevation.

Geological observations to support the view that the Himalayas have risen in recent geological times, are not wanting; for instance, the "remains of *Rhinoceros* and other large mammals occur at an elevation of 15,000 feet in Tibet, and it is not probable that these animals lived in so elevated a region" (Manual of the Geology of India, p. 586).

From Bhándal I followed the Siul river as far as Sangni, and then turned up the valley leading to the high ridge between the Talai and Paterun[4] trigonometrical stations.

The valley is at first narrow, and the scenery all the way up it is extremely pretty. The foot-path runs for some distance along the banks of a roaring torrent through woods of hazel and horse chestnut; and then, mounting higher, passes along sloping pasture lands; and finally plunges into the dark shade of a

[1] The top conglomerate contained Satlej stones only, such as white quartz schist from Rampur, gneissose granite, purple and red quartzite from the upper Satlej or Spiti, and black basaltic-looking trap.

[2] Records, XII, p. 66.

[3] Physics of the Earth's Crust, p. 81.

[4] Not marked on the map which accompanies this paper. Paterun is the peak between Tala and Dunrat stations.

pine forest, in which the holly oak, stunted and weather beaten, seems to have a hard struggle for existence. Higher up, the forests cease, and a dwarf rhododendron is the only tree that bears the cold of that high elevation, though many flowers brighten the grassy slopes.

Among them a wild poppy of delicate purple blue merging into white is not the least beautiful; whilst a yellow flower, greatly resembling the English buttercup, reminds one of the home so far away. I have not observed the poppy at a lower elevation than about 11,000 feet.

Wild rhuburb abounds at the head of this valley. An officer of Artillery, on a shooting tour, whom I found encamped at Ghamkol,[1] told me that he used the rhuburb almost daily for tarts and found it good and wholesome. My friend, however, seemed somewhat bold in his gastronomical experiments, for I found that he was in the habit of putting many species of tree fungi under contribution for the table. The natives of these parts told him that all the fungi that grow on oak are wholesome, but that those that grow on pine trees are to be avoided. He induced me to try a slice of a huge yellow oak fungus. It had a faint suspicion of mushroom flavour in it, and was not unpalatable. On opening my eyes next morning I was thankful to find myself still in the land of the living.

After leaving Sangni the silurian conglomerate continued up to where the second affluent joins the main stream from the north-east. I saw numerous outcrops *in situ* as well as blocks of it. The dip was north-east, nearly vertical, with an occasional reverse dip. Subsequently the dip became more moderate.

As in other sections described, the conglomerate is not uniformly conglomeritic, but includes slaty bands. The conglomerate is succeeded by dark slates, some of which have a dark streak, and doubtless belong to the infra-Krol series.

Higher up the valley the dip became south-west and south-south-west, but finally reverted to north-east. On my way I came upon boulders of conglomerate, and near my encampment, at a place called Ghamkol, at the head of the valley (elevation 10,630 feet), and near the boundary of the trap, there are some thin beds of pale blue limestone. Above these beds, and between them and the trap, I came on conglomerate *in situ.*

At the very head of the Sangni valley, a long spur will be observed, on the map, running down from the water parting of the Bhadarwár (Badrawár) and Chamba territories, and dividing the head waters of the valley into two streams of about equal size. The trap comes in where this spur joins the main ridge, or water parting; it dominates the crest of the ridge for some distance and then strikes down in a broad band and joins the outcrop described in a previous paper between Tiloga and Dihur (Duire).

All along the north-eastern boundary of the trap down to Dihur the silurian conglomerate is in contact with the trap. The Paterun station[2] peak (elevation 12,260 feet by my barometer) is on the conglomerate. The trap just skirts the

[1] Not marked on the map. It is just under the crest of the ridge dividing Bhadawár from Chamba close to the outcrop of the trap.

[2] This is not marked on the map that accompanies this paper. It is the peak south-west of the Dunrat station at the point where the ridge strikes in a north-westerly direction to the Talai station.

edge of the ridge and keeps on the south-west side of its crest until the spurs running up from Bhándal meet the main ridge and culminate in a peak 11,755 feet high, where the trap rises to the crest of the ridge and forms the rock along its summit for some miles.

The trap along this ridge is very much jointed, the principal joints being transverse to the strike; and it affords instructive illustrations of the power of frost in combination with jointing to break up rocks. The very crest of the narrow ridge, which runs at a tolerably uniform elevation for some distance, is formed of a mass of sharp angular blocks of trap piled up one upon another, four, or five, or more deep, in the manner of a moraine, with deep holes gaping between them. A sharp shock of an earthquake, on my return to my tents, supplied a hint that seismic disturbances ought not, perhaps, to be altogether left out of view in accounting for the piling up of large blocks of rocks one upon another in the manner described.

The route I followed took me along the south-west boundary of the trap from the head of the Sangni valley as far as the spur running down to Digi.

It is a fine country, but as my tents were often pitched at an elevation of more than 10,000 feet above the sea, I found it cold at night, and two days after I descended to a lower level, my late camping grounds were white with snow.

The ridge at the head of the Sangni valley commands a fine view of a range of snowy peaks rising to over 21,000 feet in height, whilst my camp was usually pitched on grassy slopes, abounding in flowers, just above the limits of the dark pine forests that clothe the mountain sides lower down.

Bears, red and black, and Bára Singha (*Cervus cashmirianus*) allied to the red stag of Europe, and Tahr (*Hemitragus jemlaicus*) are pretty numerous, and I often saw their recent foot-prints, but not the animals themselves. During the summer months these grassy slopes support large herds of buffalos and sheep which are driven down into the plains of the Punjab when the cold season begins to set in. Sportsmen have a poor chance of a bag until these herds have departed.

Along the south-west boundary of the trap the rock in contact with it appears to be the silurian conglomerate. No reliance is to be placed on blocks as they might be derived from the outcrop on the other side of the trap, but I believe I saw the conglomerate *in situ* in two instances. The dip is usually north-east, but occasionally changes to the west.

The trap along the outcrop, described in the preceding pages, here and there passes into a porphyritic variety. It is a hard, dense, compact rock, ranging from a dark purple-grey to a dark greenish-grey colour. Numerous crystals of felspar are porphyritically imbedded in the dark base. Further remarks regarding the microscopic character of the trap will be found in Part II.

My return route to the Siul was along the spur which runs down from the main ridge to Digi.

The slates dipped from north-east-by-north to north-north-east, very high, and with an occasional reverse dip. They were of silurian type and not visibly conglomeritic, but as the outcrops were mostly the up-turned edges of the strata, opportunities of judging of their conglomeritic character were bad, for the pebbles are seen for the most part when the splitting surfaces of the rock are exposed.

About 600 or 700 feet above Digi I came upon a narrow calcareous band, the beds being earthy to slaty.

I have now made three traverses west of the outcrop of the carbo-triassic series seen typically below Dihur, *viz.*, up the Sangni valley, down the Digi spur, and from Himgiri to Digi; and in none of them did I come across any thing like the carbo-triassic limestones. The calcareous band above Digi, and the thin bed of limestone near Ghamkol, probably belong to the Blaini or to the infra-Krol horizon.

The carbo-triassic limestones extend very little to the west of Duta. Infa-Krol slates and the black crush rock are seen at and near the bridge over the Siul below Kotta. A thin band of these rocks may extend up the river as far as Pal, and some of them are doubtless implicated in the isoclinal folds between the outcrop of the trap and Bhandal, but the carbo-triassic limestones west of Duta have either been squeezed out in the plications in which the silurian series have been involved, or the area of deposition terminated at Duta.

Another point brought out by the field observations detailed above, is that the outcrop of the conglomerate on the south of the trap is as broad as that already mapped on the north of it. South of Manjir some of the streams running down from the north-west into the Siul contain blocks of conglomerate, showing that this formation is wide enough, south of Dihur, to overtop the crest of the ridge between Ain and Gutaun.

From Manjir I crossed the Siul and proceeded along the spur which culminates in the Dwaut trigonometrial station, and then made for the head of the valley under the Rundhar station.

Simla slates dominate along the crest of the ridge, but the conglomerates come in about half way down the north-eastern side of the ridge above the village of Mahdeb[1] (not marked on the map). The bed of the stream contains numerous boulders of typical conglomerate. The dip varied from south-south-west to a little east of north-east along the ridge, but in the valley under Rundhar from east-north-east to north-east-by-east.

The trap crops out under the village of Bhōlu (not marked on the map), and is here about 100 yards wide. It is succeeded by the carbo-triassic series which is here in great force and very typically developed. The rocks in immediate contact with the trap are very micaceous carbonaceous slates; then follow dark-blue unaltered limestones; these are succeeded by very micaceous ates; thin bedded unaltered limestones occur next and then micaceous slates ollowed by limestones.

These mica slates deserve, I think, some notice. Their micaceous character is clearly not due to contact metamorphism,[2] for those at a distance from the trap, and intercalated between unaltered dark-blue carbonaceous limestones, are

[1] A local corruption doubtless of Máhádeo.

[2] The trap according to my view is an ancient lava and older than the carbo-triassic series, so that beds of the latter cannot possibly have been metamorphosed by the trap.

as micaceous as those in contact with the trap. These micaceous slates—mica schists they might well be called—suggest, I think, the conclusion, that the metamorphism of the type which consists in the formation of hydro-micas—or micas of the species usually developed in slaty rocks—may be brought about by aqueous or hydro-thermal agencies, accompanied by a very moderate amount of heat. Here we have highly micaceous slates intercalated with dark carbonaceous limestones that give no trace of having been subjected to heat.

The outcrop of the trap in this region runs with the southern boundary of the carbo-triassic series. In the north-westerly direction the trap evidently extends beyond Bailaum to near Sanaira, for the stream that flows under that village into the Siul contains boulders of it. No outcrop of it is to be seen on the Kalel road or between Manjir and Dihur.

In its south-easterly extension, the trap runs past Chanena (not marked on the map); and crossing the ridge west of Hulh (Hul), makes for Kail and Dila. It tops the ridge east of Hulh above the village of Dhar, and then striking for Amraili crosses the Sao valley about three-quarters of a mile north of Sao. The outcrop is here about 200 to 250 yards wide.

The carbo-triassic series continues in contact with the trap across the Hulh and Sao valleys. In ascending the latter valley the last of the series seen appears to be a massive grey quartzite. The dip is north-east-by-north.

The carbo-triassic series is succeeded by a very fine-grained massive silicious rock of grey colour that gradually passes into massive slates. Some of the former weather brown and some greenish, and they have superficially a trappean aspect; they are also extremely tough and hard to break.

I explored the Sao valley for some distance beyond Lolaya in the direction of the glaciers at its head and then returned to Sao. The next day I proceeded up one of the side valleys in order to cross the high range that divides it from the Chánju valley. The first march took me to Sarrah (elevation 7,140 feet), a village not marked on the map. Dip perpendicular. The next day's march was rather a severe one, but fortunately I engaged ten extra coolies for my things; had I not done so I should not have seen any of them by nightfall. First we had a stiff ascent to the summit (11,525 feet above the sea), and then a walk for some miles along the ridge. No suitable place for an encampment presented itself, as the nearest water was about 700 or 800 feet below us, and firewood was almost as distant. We pushed on down a precipitous descent for some Gujar huts about 3,000 feet below, which we reached about 5 in the afternoon. The spot was indeed a lovely one—a grassy glade in a pine forest with the peaks and glaciers of Kailu and Kalka well in view; but alas the Gujars with their herds had left the spot, the streams had dried up, and no drinking water was to be had within a radius of 1½ miles. There was nothing for it but to push on for the nearest village, Sundri (Sunder), 3 miles further down the mountain, which I reached at dusk after walking for 11 hours, climbing 4,385 and descending 4,525 feet.

The first thing to be done was to send back men with torches for the coolies, who finally arrived without serious accident, my crockery only coming to grief by the way.

The march, though long, was a delightful one. From the crest of the ridge, the Kailu (18,639 feet in elevation) and its twin peak Kalka with the glacier between them, 8 miles distant as the crow flies, formed a beautiful subject for a picture. A snow-storm was going on in the back ground; the warm sun gilded the rich red and brown autumnal tints of the foreground; whilst checkered and ever changing lights and shadows were playing over the forests and the grassy slopes of the middle distance. The clouds tipped the peaks and cast their deep shadows over most of the snowy masses around; whilst the sun, bathing the glacier of Kailu in light, made it, by its contrast with the gloomy masses by its side, look like the portal of a heavenly world beyond.

At the village of Sundri there was not a square foot of available level ground, all the terraces being under crops, and so I had to pitch my tents on the flat roof of a house. The process of washing my face and hands in the morning was a source of great delight to a group of village maidens, who in these mountain villages seem wholly unacquainted with the cleansing properties of soap and water.

Between Sao and Sundri (Sunder) I saw nothing of the conglomerate; on crossing the stream under Chánju, however, I came on blocks of it, and encountered them in nine different places between that and Bagai. These blocks were not *in situ*, but they appeared to be fragments of the local rock with which the matrix of the conglomerate quite corresponded. The dip was at one time south but afterwards reverted to the normal direction. Below Bagai, on the left or south bank of the river, I found the conglomerate *in situ* twice.

From Kalel the conglomerate appears to strike nearly due east for Bagai and to continue thence towards the Chara Pass, where I am told that it occurs by Dr. Hutchinson of Chamba.

In the course of the plications in which the Chamba rocks have been involved, silurian rocks, lower in the scale than the conglomerates, appear to have been brought in between the latter and the carbo-triassic series, which in the Manjir-Kalel section is in contact with the conglomerates on both sides.

The dip between Bagai and Jasaor is about south-south-west.

On the Kalel and Balore road, on both banks of the river that flows between Daund and Balore, I came upon numerous blocks of the conglomerate (they are very abundant in the bed of the stream); and though, owing probably to the abundance of vegetation, I did not find any actually *in situ* on the ascent to Masrund,[1] I doubt not that the conglomerates, which are visible *in situ* in numerous places round Manjir, and which we have seen in the preceding pages, are abundant along the head of the Bailaum valley, are continuous between the two places.

During the summer of 1884 official duties led me to Simla, and I was unable to carry out a projected tour in Pángi; Dr. Hutchison, of the Chamba Mission, however, kindly undertook to make observations for me, and in particular to mark the boundaries of the silurian conglomerate. His notes are given further on.

[1] A halting place not marked on the map.

On my return from Simla I was able to make a short tour up the Káli Cho (Kali Chu) valley, in November, and I now proceed to give the results. Our party consisted of Dr. Hutchison, my wife, and myself. We proceeded eastwards from Chamba up the Ravi to a point opposite Basu, when we turned northwards and journeyed *viâ* Guh up the Belij (Bailj) valley as far as Kanaiter. A very stiff climb of 5,200 feet from our encamping ground in the bed of the stream, under Bulote, took us to the top of the Kanaiter pass, which we crossed at an elevation of 10,125 feet.

The hill sides were white with snow and the tracks of bears, probably the red bear, were rather numerous. Our route lay just under the Thala station, and we crossed the second ridge running down between Oure and Thala (Thale) at a high elevation. We encamped at the Dul,[1] a level plot of land that must once have been a mountain tarn, just above the junction of the stream flowing from the Silpiri station and the highest stream running into it from the north-east.

The march was a somewhat trying one, and though we started early our coolies did not get in until long after nightfall. About dinner time the sad news was broken to us that all our crockery had been left behind at the top of the pass; that the coolie carrying the load had given himself up for lost, and had sat down to cry; and, that as he was deaf and dumb, the eloquence of our servants had been exerted on him in vain.

Parties with a lantern and torches were sent back to aid those behind, and finally all our men arrived without accident.

The Dul we found to be interesting from a geological point of view: it is evidently a dried up tarn, and the mode in which it was formed is not far to seek. The bed of the dul is bounded on the south by what appears to be an old moraine. It rises abruptly from the bottom of the dul to the height of about 60 feet, and on the outer side, descends at a high angle to a considerable depth into the ravine below. This bund runs in a straight line at right angles to the course of the stream, which has cut a narrow channel through it, at one side of the little valley, at its junction with the solid rocks. The bund is apparently formed of angular blocks of rock; there is nothing in the conformation of the hill sides around to suggest the possibility of a land slip, and a careful inspection of the locality convinced Dr. Hutchison and myself that the bund is an old terminal moraine, and that the ancient tarn was formed by the shrinking of a glacier that has long since disappeared. The elevation of the Dul, measured by my aneroid, is 7,825 feet above the sea.

Our onward route was *viâ* Guar and Tanda to Chalaur, and thence through Manda and Bani along the right bank of the stream until we came abreast of Badra, when we crossed to the opposite side.

The last 3 or 4 miles of this march illustrates well the general character of the roads traversed during the whole of this tour and the kind of walking that the Himalayan geologists must be prepared to encounter. Our route lay along the precipitous sides of the mountain; the path was not more than 9 inches wide; a fringe of grass along the edge seemed to invite the foot but gave

[1] On the accompanying map the Dul is just below the O of the elevation of the Thala station 12,208 feet).

way the moment it was trodden on. A fall would inevitably be fatal, for there was neither tree nor bush to save you, and the mountain side sloped down to the river, some 1,500 feet below, at so high an angle, and was clothed with grass so slippery, that nothing could have saved a man once in motion downwards.

This was varied every now and then by rock work along precipices where you needed to use your hands, as well as your feet, and to be clever in prospecting your way.

The trying part of the march, however, came as a *bonne bouche* at its end. The torrent under Budra has cut a deep narrow gorge through the mountain; descent to the water's edge was impossible, and the only way to cross the stream was by a frail bridge stretched from rock to rock some 150 or 200 feet above the roaring torrent below. The bridge was formed of three poles about 30 yards in length, and across them small roughly hewn planks were fastened with twigs forming a roadway of about a yard in width. A plank was dangling by one end over the chasm below, leaving a gap in the roadway, and suggesting painful doubts regarding the stability of the rest of the structure. The bridge had neither railing nor hand ropes.

There was nothing to be done but to face the bridge, and so I mounted the pile of stones that kept the poles at one end in their places and started. I must confess that when I neared the centre my heart failed me, and I felt horridly tempted to turn back, but a moment's reflection convinced me that if I attempted to do so I should probably topple over, and so I strode onwards with hastened step and cleared the bridge with great thankfulness.

Now came my wife's turn. My guide doubted her being able to retain her presence of mind, and wanted to bandage her eyes and carry her over on his back, but she disdained to accept this mode of progression and walked over with steady and unfaltering step.

I was not surprised to find that one of the laden hillmen who arrived whilst I was resting at the bridge was unable to face it, and a man with a better head was obliged to cross over and relieve him of his load.

From Budra we proceeded up the stream as far as Luindi, a hamlet of three huts, the highest inhabited place in the valley. The season was too late to proceed any further, and there was no object in our doing so, for an inspection of the boulders in the bed of the stream, flowing down from the Káli Cho, showed that no new rocks come in between Luindi and the crest of the pass.

Our return route was along the left bank of the stream *viâ* Baragrao and Tatahu to Kani, on the right bank of the Ravi, and thence to Aulansa (Hulans). On a previous occasion[1] I proceeded from Aulansa to Chamba *viâ* Kote, but on this occasion we struck down to a new road in progress of construction along the bed of the Ravi, as that gave good exposures of the rocks.

From Bakaun I went up the stream running to the west of the Basu station and marked the boundary of the outcrop of gneissose granite there. In this region it is a porphyritic and perfectly granitic rock.

Having described my route, the rocks seen by the way can now be noted. The conglomerates crop out under Guh (north of Basu) and continue typically

1 Records, XVI, 38.

developed to the point noted on the map. They dip under limestones that remind me somewhat of the Blaini rocks, and which, like them, effervesce slowly with acids. The outcrop is about 100 yards thick, and it is followed by slates, some of which are rather dark. Limestones succeed at the stream to the south of Puger. These effervesce freely with acids. From this point up to the head of the valley the rocks are silurians, *viz.*, what appear to be Simla slates and fine-grained silicious beds, many of the latter being superficially of trappoidal aspect similar to those north of Sao.

In this section the lower silurians are nowhere reached. The apparent thickness of these beds is very great, but the rocks are, I think, repeated by flexures.

On the homeward journey we carried these silurians with us all the way to Kani. Just below this village the carbo-triassics come in. On the descent to the Ravi we noted five outcrops of them intercalated with slates; the first outcrop being about 300 yards in thickness. The limestones here are very earthy, and for the most part so shaly in appearance that the hammer and acid bottle had to be in constant use. A casual traveller might easily overlook these outcrops altogether.

The limestones are succeeded by the conglomerate; the limestone in actual contact with the latter weathers brown and effervesces slowly with acids, reminding one in both respects of the Blaini magnesian limestone.

The outcrops of the conglomerate between Aulansa and Chitrali (Chitrahi), along the Koti road, have been described in a former paper. Descending to the Ravi, I noted an outcrop of trap in the slates near the border of the conglomerate. It is only about six yards wide, but it appears to be interbedded with the slates, and to be on the same horizon as the Sao trap.

The conglomerates exposed on the new road are, as usual, not continuously conglomeritic, but they are seen typically developed on both margins and at least one other intermediate place. The total apparent thickness of the series is very great, and one must either suppose that the period during which the conglomerates were laid down was of great duration, and that the conglomeritic period recurred more than once, at long intervals, under conditions precisely similar to those of the first deposition; and that the rocks under denudation and the mode of deposition were identically the same on each recurrence of the conglomeritic period; or we must suppose that the thickness of the conglomeritic series is apparent only, and that the conglomerates are repeated by folding and flexures.

The latter supposition is the one I have adopted. The section along the river presents much to support this view. Dark slates, which are probably infra-Krol, are, I think, folded up with the conglomerate, whilst a very peculiar rock is undoubtedly reproduced. This is a very white rock which at first sight seems to be calcareous, but it refused to effervesce with acids.

Among the beds folded up with the conglomerates is a rock with dark bands in it that presents some interesting and instructive examples of small local faulting.

Throughout the area embraced by my tour of November 1884, the dip of the strata is uniformly north-easterly. From Kanaiter to Guar the dip is very high and in one place quite perpendicular. Opposite Budra the strata on the top of the mountain present to view a flat wavy synclinal flexure, whilst the beds below are in some places almost perpendicular, and in others crumpled into sharp folds like the capital letter M. At first sight one might suppose that the strata on the top of the mountain opposite Budra rested unconformably on the perpendicular and contorted rocks below, but I feel sure that this appearance is only the result of the great lateral pressure to which the rocks have been subjected, and is to be explained in the way suggested in my first paper (Records X, pp. 208, 209). The present contour of the mountains having been determined before the last Himalayan disturbances took place, the strata in the direct line of the squeeze naturally suffered more than the strata above that line.

The explanation which I have given in Part III of this paper of the section through Hulh (Hul) applies, I think, to the stratigraphy of the Belij and Káli Cho valleys, the only difference being that the silurians in their south-easterly extension have been involved in more flexures than those in the Sao section—their apparent thickening being due to this cause; and the Simla slates have been in the Belij section introduced next the carbo-triassic series, and are probably repeated further north.

The following notes on the geology of the Pángi valley south of Kilar have been written for me by Dr. Hutchison, and contain the results of his observations this year:—

"As far as the village of Haile,[1] the silurians continue with a low south-west dip, and beyond this a north-east dip sets in. About 3 miles north of Haile, where the second nallah from the north joins the main ice stream, the micaceous schistose beds give place to the Blaini conglomerate with white and grey quartz pebbles, which however did not seem to be very numerous. A little farther north the rocks are coloured with iron oxide, but they seemed to be of the same character as the conglomerates. Proceeding towards the Cheni (Chaia) pass the conglomerate rocks still continued, and were in places well marked; and the main ice stream contained numerous boulders of a conglomeritic character. About 2 miles from the top of the pass these rocks began to be mixed up with rocks of a slaty appearance and non-conglomeritic; and the top was composed of slates of much the same appearance and character as the coarse slates used for roofing. The dip from Haile to the summit was north-east at a low angle, getting higher and higher near the top; and a mile to the north of it the strata became quite perpendicular, and continued so till the Chandra Bagha river was neared when a high south-west dip set in. About half-way below the top of the pass, and the junction of the ice stream with the Chandra Bagha, there is a very well marked outcrop of conglomerate about half a mile or so in thickness. The rocks between the top of the pass and this outcrop did not seem conglomeritic, but I suppose they must be regarded as belonging to the conglomerate series. North of this point the rocks seemed silurian—micaceous and quartzose schists and slates.

From near Kilar to a point one mile south of the Mocha stream the rocks are silurians with a south-west dip. South of this there are two very narrow bands of a pale blue sub-crystalline limestone, each 9 or 10 feet thick. Succeeding these is a well-marked outcrop of conglomerates which continue to a point opposite the village of Phinphar. Throughout a considerable portion of this distance the road is partly cut out of the solid rock and partly supported on crowbars fixed horizontally into the face of the perpendicular cliff. The matrix of the conglomerate is micaceous schist, and the contained boulders are chiefly of white quartz, some of them as much as 9 inches in their long diameter. These rocks are succeeded by silurians with a south-west dip getting higher and higher till the strata become perpendicular to the south of the Cheni stream and opposite the village of Kalaul; and they continue so as far as the village of Sugwas. Here a band of limestone comes in, 140 feet in thickness, of a dark colour, soft and friable. Next come slaty rocks for half a mile or so, and then another band of limestone, sub-crystalline in texture,

[1] Haile is on the north side of the Cheni (Chaia) pass north of Debi Koti.

and also about 140 feet thick. This is followed by well-marked conglomerates, full of pebbles which continue nearly as far as the point where the river bends round to the south. The dip opposite Sugwas is still vertical, but beginning to incline to the north-east, and this inclination becomes more marked as the southern border of the conglomerate is neared. Next come micaceous and quartzose rocks with a moderate north-east dip till after crossing the stream coming down from the peak marked "snowy peak black cone 17,145 feet" and half way between that stream and the one to the south of it the conglomerates come in again and continue till the stream from the Drati pass is neared. The rocks abound in pebbles of white and grey quartz, and the rocks on the other side of the river are seen to be also conglomeritic and weathering a very black colour near the margin of the water. In the bed of the Drati stream the rocks are greenish in colour and not conglomeritic; they look like middle silurians. These continue with a moderate north-east dip to within a short distance of the large stream which joins the Chandra Bagha from the south—midway between Tindi and Silgraon. Here well-marked conglomerates come in again with pebbles of white and grey quartzite and granitoid gneiss, the latter becoming more numerous near Silgraon encamping ground. They have a north-east dip and continue to within a mile of the point marked "bridge" on the map. Immediately above the bridge and on the left bank of the river are seen (from the opposite side) several large blocks of quartzite from 2 to 3 feet long and 8 or 9 inches thick embedded in the slates beyond the border of the conglomerate.

These silurian slates continue on into Lahoul, the dip becoming perpendicular between Silgraon and Margraon and inclining over to the south-west beyond Triloknath. In the stream to the south of that place, there are many large and typical boulders of conglomerate, but I nowhere saw the rock *in situ*.

On my return journey I crossed the Drati Pass, but found no rock which appeared to me conglomeritic till I came within a mile of Chanju. The Chara Pass is I know composed of conglomerate which seemed to me, when I crossed it two years ago, to extend continuously from half way down the northern side of the pass to the village of Bagai (Baghi) below Chanju."

I have marked the outcrops of conglomerate noted by Dr. Hutchison on my map in consultation with him, and these outcrops I have connected with those observed by me on the north-east side of the Sach Pass, and on the western side of the snowy chain.

Dr. Hutchison believes that the outcrop at Phinphar (the most northern outcrop marked on the map, a little to the south of Kilar) is continuous with that which crops out on the north-east side of the Sach Pass. The latter outcrop, he believes, splits into two arms—one curving round to Phinphar, and the other joining hands with the outcrop at Sugwas. The latter supposition does not seem open to any doubt, as the conglomerate has been seen *in situ* by Dr. Hutchison on both sides of the Cheni (Chaia) Pass, and its boundaries on both sides of that pass have been carefully noted.

It is not improbable that the outcrop on the north-east side of the Sach Pass splits up in the manner suggested. The apparent thickness of the conglomerates I have all along supposed to be owing to flexions; and to older, and probably at times younger, slates having been caught up in thēir folds. The splitting up then of the Sach conglomerate into two arms seems to be only a reproduction of the conditions of the Hulh (Hul) section, where a great thickness of silurian slaty rocks have, in the manner explained in Part III, been inserted between the Sao and Bagai outcrop of the conglomerate.

The Phinphàr outcrop of the conglomerate apparently curves round to the north-east, for Dr. Hutchison tells me that he found numerous boulders of this rock as well as limestone near the village of Banu up the Hanan nála, which runs into the Chandra Bhága at Kilar.

Dr. Hutchison is also of opinion that the Sugwas and Sulgraon outcrops are continuous (which was also the view taken by Mr. Lydekker), and that the outcrops observed by him (Dr. Hutchison) on both sides of the Chara Pass runs into it.

The Salgraon outcrop apparently curves round and runs along the northern side of the Kali Cho, for Dr. Hutchison observed numerous boulders of it in the stream flowing down from the Cheroh snowy cone into the Chandra Bhága at Triloknáth; whilst we saw none in the bed of the stream at Luindi on the southern side of that mountain.

The slates associated with the upper silurian conglomerate in the parts of Pángi embraced by Dr. Hutchison's paper are probably middle silurians considerably altered by the proximity of granite.

It is interesting to note that, as in the Simla area, the conglomerates are rarely far separated from limestones; those immediately in contact with them presenting points of resemblance to the Blaini rock.

I have not coloured the limestone outcrops noted by Dr. Hutchison on my map, because the doubt remains whether they are of upper silurian age, or whether they also embrace some of the carboniferous limestones. This doubt was also felt by Mr. Lydekker with reference to the limestones observed by him in the region embraced by Dr. Hutchison's paper.

In the typical Simla area a thick band of infra-Krol (carboniferous) slates intervene between the Blaini (upper silurian) limestones and the carbo-triassic (Krol) series; but these carbonaceous slates seem to be sometimes absent in the Chamba area.

In view of this difficulty, and in the absence of fossils, I have thought it best not to give the limestones of Pángi, noted by Dr. Hutchison, a distinctive colour on my map.

Conclusion.

The result of the tours detailed in the preceding pages has been to confirm me in the view expressed in my paper on the Geology of Dalhousie, that the trap of the Dalhousie-Chamba area is of infra carboniferous age, and that in this region it comes in between the carbo-triassic and the silurian series.

To the north-west of Dihur, where the carbo-triassic limestones have either thinned out, or, more probably, have been squeezed out in the course of the plications in which the Chamba area has been involved, the trap is in contact with the upper silurian conglomerate along both margins; whilst at Dihur, and in the Bailaum-Sao direction, it comes in between the carbo-triassic series and the conglomerate.

The trap dies out between Dihur and Bailaum, but it will be seen on referring to the map that the disappearance of the trap coincides with a very sharp bend in the strike of the strata. The trap when it disappears in the neighbourhood of Dihur is in contact with the northern boundary of the carbo-triassic series, whilst when it re-appears it is in contact with the southern boundary of that series. On the supposition that the trap intervenes between the upper silurian conglomerates and the carbo-triassic series, this may be accounted for by the flexions in which these rocks have been involved. Moreover, the deposition of the lava streams of the infra-carboniferous volcanoes may have been limited towards the west in the Dihur area, and towards the east in the Bailaum and Sao area. Furthermore, it is evident that the plications in which the Chamba rocks have been involved resulted in faults, for the upper silurian conglomerates, which are in contact with the northern boundary of the carbo-triassic series at Dhar and Kalel, have been removed to a distance from that boundary in the Hulh and Sao sections, what appear to be silurian rocks lower in the series than the Simla states coming in between them.

The northern boundary of the carbo-triassic series in the Bailaum-Sao area, therefore, being evidently a faulted one, the non-appearance of the trap along the northern boundary of the carbo-triassic limestones in that area need occasion no surprise.

The fact that the trap dies out between Dihur and the neighbourhood of Bailaum may be due either to faulting or to the fact that the Dihur and the Bailaum flows were connected with different volcanic vents, and the lava flows did not extend into the area between Dihur and Bailaum. This last explanation is, I think, the true one, and it is the one which I have adopted in Part III of this paper.

Mr. Lydekker at page 241 of his memoir on Kashmir remarks that "It cannot be taken as certain that all the conglomerates of the Kashmir valley correspond to the Blaini conglomerate, since in the Pir-Panjál range the conglomerates appear to occur in the middle of the slate series, and are never even when the traps are absent in direct contact with the Zanskár rock."

I do not venture to offer any opinion about the Pir-Panjál rocks, but the result of my explorations detailed in this paper show that where plications and faults are abundant, some sections are apt to be misleading. A traveller journeying northwards from Hulh through Chanju would encounter a great thickness of silurian rocks on either side of the conglomerate; whilst another journeying northwards along a parallel line through Kalel would find the conglomerate in junction with the carbo-triassic series on both sides of the outcrop of the latter.

I have examined under the microscope a slice of the fine-grained sandstone which intervenes between the conglomerate at Chanju and the carbo-triassic series at Hulh. It is a highly indurated rock composed of grains of quartz and felspar with strips of muscovite in it here and there. The whole of the interstitial mud has been converted into mica, apparently paragonite. Under the microscope the sandstone has an ancient aspect, and its appearance confirms my impression that it is a silurian rock that occurs lower down in the series than the Simla slates.

PART II.

THE MICROSCOPIC STRUCTURE OF THE TRAPS DESCRIBED IN PART I.

I have already described in the preceding pages the way in which trap crops out along two distinct lines, one to the north, and the other to the south, of the carbo-triassic series. In the following pages I purpose giving the results of the examination of thin slices of these traps under the microscope, and then to compare the two outcrops with each other, and with that in the Dalhousie area.[1]

I shall begin first with the trap to the north of the carbo-triassic series.

Ridge above Bhándal—Altered Basalts.

No. 1.—A greenish-grey rock mottled with epidote. Sp. G. 2·86.

M.—The groundmass consists of triclinic felspar crystals radiating in all directions. Augite was originally abundant, but a considerable portion of it has been converted into epidote *in situ*. The augite is traversed by cracks stopped with epidote and viridite.

The slice contains much magnetite, or ilmenite, and some hæmatite and viridite.

The rock is an altered basalt approximating to a diabase. No glassy base can be made out and the slice contains no liquid cavities.

No. 2.—A greenish grey compact rock rather mottled in its appearance. Sp. G. 2·94.

M.—Epidote abounds in this slice, but no augite can be identified with certainty. Viridite is abundant. The felspar is in rather large crystals, many of which are visibly triclinic.

The slice contains a small amygdaloidal cavity stopped with viridite, calcite, quartz and a white zeolite. The quartz contains a few liquid cavities with movable bubbles.

I think this specimen belongs to the same class as the last, but it is a highly altered rock.

Andesites.

No. 3.—A greenish-grey compact rock. Two amygdules are visible in the hand specimen, composed of a white zeolite and a little epidote. Sp. G. 2·80.

No. 4.—A greenish-grey compact rock, little red specks being visible in it, here and there, due to the peroxidation of the iron. This sample is very like a typical specimen of the Mandi and Dalhousie traps. Sp. G. 2·82.

M.—Most of the felspar is visibly triclinic and it is grouped in the usual stellate manner. Crystals of epidote are here and there to be seen, and there is a considerable amount of viridite in irregular lake-like spaces. A green dichroic mineral, which appears to be hornblende, is present in minute prisms, fringing, or more or less connected with viridite.

Extinction takes place at an angle from the axis of the prism which agrees with the angle of extinction for hornblende.

There is a good deal of ilmenite, and possibly magnetite, present in the slice, besides some leucoxene, hæmatite and ferrite. The red spots seen on the hand specimens are due to the two latter secondary products.

These specimens, which appear to belong to the andesite group, are particularly interesting, as they seem to me to exhibit in its first stages those metamorphic changes, which have, I think, converted some of the igneous rocks of the Satlej area into hornblende schists.

[1] Described in Records, XV, p. 34.

No liquid cavities are present in slices 3 and 4.

No. 5.—A greenish-grey compact rock. It fuses under the blowpipe to a dark, almost black, magnetic bead. Sp. G. 2·79.

M.—This is a highly felspathic variety; it consists of congeries of felspar crystals, many of which are visibly triclinic, imbedded in a glassy base. A pale almost colourless viridite is rather abundant. Very little epidote is present. The slice contains a considerable amount of magnetite and a red product of its alteration. This specimen is, I think, a transitional variety between the andesites and felsites.

Felsites.

Nos. 6 and 7.—Greenish-grey compact rocks. Sp. G. 2·96 and 2·80. Both fuse under the blowpipe to a dark, almost black, magnetic bead.

M.—No. 6 consists of epidote in a colourless glassy-looking base, which remains dark when revolved between crossed nicols.

No. 7 has none of the microscopic characters of serpentine, and it unquestionably is not that substance, but nevertheless under the microscope it looks more like serpentine than anything with which I can compare it. In ordinary transmitted light it appears to be composed of granular matter imbedded in a colourless, or nearly colourless, base. Between crossed nicols the granular matter is seen to be isotropic, and the field remains dark between crossed nicols, relieved by stripes and irregular patches of the doubly refractive matter which polarise with a yellow tint.

A little epidote and calcite are to be seen here and there; whilst the slice is dappled with patches of a substance, white in reflected, and opaque in transmitted light. Neither specimen contains any trace of a basaltic mineral.

No. 8.—The weathered surface has a slaty aspect, but when a lens is used, unweathered portions present a mottled felspathic appearance. In colour the rock is a pale greenish-grey. Sp. G. 2·81.

M.—The groundmass consists of a glass of very pale yellow-ochre colour in transmitted light. In this there are little patches and strings of colourless granular matter, crystalline in aspect, which remain dark when revolved under crossed nicols. Clear lacunæ of the yellow glass are seen here and there: they have invariably a border of the granular matter, and patches of this product of divitrification penetrate into and are dappled over the lacunæ.

Under crossed nicols the pale yellow base breaks up into a black and white, mottled crypto-crystalline mass, whilst here and there portions polarise with a yellow tint.

The arrangement of the whole, both with and without polarised light, is highly suggestive of fluxion structure.

A few specks of red ferrite are visible in the slice.

No. 9.—A compact rock of reddish brown-colour mottled with green. Sp. G. 2·80.

M.—The base is crypto-crystalline like the last specimen. In this blebs of quartz are sparsely distributed, and there is a considerable amount of epidote. Some of the latter looks much like augite in process of conversion into epidote

There are cracks and veins in the slice filled with quartz, and some of these cracks penetrate the epidote.

The quartz contains liquid cavities with movable bubbles, but they are very minute and require high powers to be visible.

The magnetite has almost wholly been converted into an opaque red ferrite and to this change in the oxidation of the iron the red colour of the rock is due, the yellowish-green patches being due to the presence of epidote.

Specimens 6 to 9 must, I think, be as classed as felsites.

Basalt Porphyry.

Six hand specimens and seven thin slices of the porphyritic variety of the trap found on the ridge above Bhandal have been examined.

The porphyrite is an extremely tough rock and breaks with great difficulty, even when a heavy hammer is used. The matrix is perfectly compact, and it is generally of a dark bluish-grey colour, though in some specimens it is greenish-grey.

The specific gravity of the basalt porphyries ranges from 2·76 to 3·01, the average specific gravity being 2·89.

Under the microscope, the groundmass, in most of the specimens, is seen to be of basaltic structure, and consists of minute prisms, and crystallites of felspar, set in a matrix of fine granular matter; whilst in others this granular matter is comparatively sparse, and the groundmass approximates, in character, more to an andesite or trachyte, and consists of a net work of minute, but for the most part, imperfectly formed crystals of felspar.

Fluxion structure is more or less observable in all the specimens. In some the groundmass passes here and there into a micro-felsitic substance.

Magnetite is abundant in all the slices, being present in micro-grains of irregular shape. Ilmenite also is, or has probably been, present, as the slice is dappled with an opaque substance resembling leucoxene.

Augite in granules appear to be sparsely present in a few specimens.

The great majority of the porphyritic crystals, and a large number of the micro-prisms of felspar, are visibly triclinic. The former are much corroded, cracked and broken, whilst portions of the groundmass penetrate into their substance in the form of tongues. Some of those large plagioclase fragments are much bent, the planes of twinning being bent with the prism; whilst one crystal is broken into fragments which have been floated to some little distance from each other. These porphyritic crystals clearly belong to the first epoch of consolidation.

The slices contain rather large crystals of augite, but most of it is much altered, being converted into a brownish-yellow substance, or into epidote.

One of the slices, the groundmass of which is of unusually small grain, abounds in what appear to have been vesicular cavities. They are nearly all flattened and drawn out into irregular-shaped lacunæ. They are lined round the edge with granular epidote and stopped with epidote, and a serpentinous-looking substance, of the palest yellow tint in transmitted light.

Some of the large felspars contain cavities filled with viridite and epidote, which probably represent olivine or augite crystals: others contain small patches of calcite and viridite, the evident products of decomposition.

A few cavities contain secondary quartz and a zeolite.

In one of the slices, the magnetite, which here and there is crystallized in a regular manner, exhibits a tendency to assume semi-circular forms. One of these figures resembles the wheel of a cart cut in half, there being a thick semi-circular ring of uniform width with spokes radiating to it from a sort of nave.

I have not detected any liquid cavities in the secondary quartz or in the felspar.

This variety of the trap should, I think, be called a basalt porphyry.

Ridge above Tiloga. Volcanic tuffs.

No. 17.—A greenish-grey compact rock	.	Sp. G. 2·67
„ 18.—A grey compact rock	. . .	Sp. G. 2·82
„ 19.—A dark greenish-grey rock	. .	Sp. G. 2·93
„ 20.—A grey compact rock	. . .	Sp. G. 2·87
„ 21.—A greenish-grey compact rock	.	Sp. G. 2·70

In No. 17 the weathered surface presents a fine-grained granular appearance, which strongly suggests the idea that the rock is a consolidated ash. In No. 18 the surface is so overgrown with lichen that nothing can be made out; but in No. 19 the granular character is somewhat doubtfully discernible. In Nos. 20 and 21, the weathered surface gives indications of a laminated arrangement of the materials. Most of the specimens are more or less finely vesicular, or have empty interspaces here and there between the grains.

M.—The majority of the slices are distinctly vesicular, a structure which is very characteristic of an ash,[1] but, with the exception of No. 20, none of the slices give any indication of fragmentary structure under the microscope. In the last-mentioned slice, much of it is seen between crossed nicols to be fibrous in patches, the fibres in one patch running in a different direction to those of neighbouring patches,—an arrangement which imparts a fragmentary appearance to the whole. In No. 21 the remains of a crumpled lamination are distinctly visible, the old lamination being represented by irregular lines of viridite.

No augite, felspar, or other original mineral of the lava, except magnetite, is visible in any of the slices; but epidote, green mica, and patches of calcite are generally distributed throughout them.

A dull quartz finds a place more or less in all the slices; it is scattered about in minute flecks, or in micro-grains, which exhibit a strong tendency to cluster together, and form, with granular viridite, spots dotted over some of the slices. Magnetite also shows a tendency to form borders round these spots, and here it is probably a secondary product.

Irregular veins traverse some of the slices, and they are stopped with quartz, magnetite, and granular viridite. Some amygdaloidal-looking cavities are filled with calcite, and quartz, in micro grains.

[1] See Dr. Sorby in Q. J. G. S., Vol. XXXVI, p. 53.

Viridite forms a more or less prominent object in all the slices. There are no porphyritic crystals; the groundmass contains neither microlith nor crystallite and presents no characteristic structure.

The Tiloga specimens are all, I think, intensely altered volcanic tuffs. Nos. 17 and 18 might conceivably be highly altered vesicular lavas, in which case one would have to attribute the distinctly fine-grained granular surface to the effects of weathering on a very fine-grained vesicular mass, but this supposition is not a probable one. No. 19 may possibly be a highly altered felsite. "Finely bedded ash, when *highly altered*, is undistinguishable in microscopic structure from an undoubted felstone-lava;"[1] but in this case the high specific gravity of No. 19 is opposed to the view that it is an altered felsite. On the whole, taking into consideration the granular weathered surface of No. 17, the distinctly laminated structure of No. 21, and the general features of these specimens, I have with some doubt and hesitation come to the conclusion that Nos. 17 to 21 are *highly altered* volcanic tuffs.

Considering the age of these rocks it is not surprising that ash of so fine a grain should have been so highly altered.

The Bailaum-Hulh (Hul) outcrop. Altered volcanic ash.

The samples (1 to 21) above described are from the outcrop of the trap to the *north* of the carbo-triassic series running from near Dihur (Duire) in a north-westerly direction towards Badrawár. The following specimens were taken from the outcrop which occurs to the *south* of the carbo-triassic series between Bailaum and Hulh.

Nos. 22 and 23.—Greenish-grey compact rocks from Bholu, under the Bundhar Trigonometrical Survey station. The outcrop here is only about 100 feet in thickness. The Sp. G. of No. 22 is 2·84 and of No. 23, 2·88. No. 22 is somewhat fissile, and minute specks of mica are visible in it here and there. On the cut surface it has a streaky appearance. One of the surfaces of No. 23, which is perfectly flat, is distinctly granular.

M.—The groundmass of No. 22 is crypto-crystalline; no definite crystals of felspar are anywhere discernible, granules or fragments of what appears to be augite, are scattared about in it; the most prominent feature, however, is the presence of what I take to be hornblende in minute thin prisms, fibres, and irregular masses intermingled with mica. The hornblende in transmitted light is of the palest brown-green colour, and is not at all dichroic. Extinction takes place at from 3 to 20 degrees from the axis of the prisms. The prisms and fibres, generally, but not always, run in the same general direction, whilst the mica always does so. The slice contains several empty vesicular cavities.

No. 23 is much the same sort of rock as the last; the hornblende, however, is absent, and a mica ranging from a pale brown-green to a reddish-greenish-brown takes its place. This mica is abundant.

Crystals of felspar, most of which are visibly triclinic, are very abundant in this slice; their external outlines are highly irregular, and never exhibit straight lines.

[1] J. Clifton Ward, Q. J. G. S., Vol. XXXI, p. 405.

The slice contains a few patches of hæmatite. There are some vesicular cavities, some of which are stopped with calcite; calcite also occurs in minute granules throughout the slice.

Some of the felspars contain a few extremely minute cavities with movable bubbles.

Both specimens are, I think, intensely altered ashes.

Hulh. Hornblende andesites.

The following specimens were taken below the village of Hulh, in the valley of that name, from the same horizon as Nos. 22 and 23, but some miles to the south-east of Bholu.

No. 24.—A fine-grained pale greenish-grey rock. With a pocket lens it is seen to be sub-crystalline. Under the blowpipe it fuses to a very dark magnetic bead. Sp. G. 2·88.

M.—This is quite a typical lava: it is composed of an intimate mixture of triclinic felspar, in prisms radiating in all directions, and hornblende. The latter is in prisms fringed at the ends with microlites of the same mineral. The hornblende is of the palest conceivable green tint and exhibits no dichroism; here and there, however, the prismatic cleavage planes intersect at the angle characteristic of hornblende; extinction also agrees with that of this mineral.

No augite can be identified, but epidote, colourless in transmitted light, and which does not exhibit dichroism, is rather abundant. A little secondary calcite is also present. No magnetite or ilmenite is to be seen, but the slice is dappled with a granular opaque substance, white in reflected light, which seems allied to leucoxene.

A glassy base of very pale yellowish-green colour is visible here and there. The felspar contains nests of microlites which may possibly be apatite, but I think they are more probably colourless hornblende like those fringing the ends of the hornblende prisms. Their action on polarised light is swamped in that of the felspar.

The rock is evidently one that has suffered a large amount of alteration.

No. 25.—A greenish-grey compact rock much mottled with epidote and containing zeolitic amygdules here and there. Sp. G. 2·98.

No. 26.—A bluish-grey compact rock with specks of white zeolite showing in it. Sp. G. 2·89.

No. 27.—A bluish-grey compact rock. Sp. G. 2·91.

M.—These are all highly altered rocks. The ground mass is felspathic, passing, in No. 26, here and there into quartz. It contains mottled masses and fine acicular prisms of hornblende. The hornblende is of green colour and is feebly dichroic in No. 25, but is colourless and non-dichroic in the other slices.

Epidote is a prominent feature in No. 25, and it is more or less abundant in the other slices also. A mica of greenish-yellow colour in transmitted light is present in No. 26. Square and triangular sections of magnetite occur in No. 25.

All these slices (Nos. 25 to 27) contain amygdules composed of zeolites, quartz, calcite, epidote, and mica. The zeolites are full of liquid cavities with movable bubbles.

Conclusion.

Some of the specimens described in the preceding pages (Part II) very much resemble, in macroscopic appearance, typical specimens of the Dalhousie and Mandi altered basalts; but the result of the microscopic examination of the whole is to show that, in the region north of Dalhousie, the traps have changed considerably in type; they present more variety, too, than those south of Dalhousie.

In the ridge north of Bhándal basalt porphyries become prominent and afford an additional link between the volcanic rocks of Chamba and those of Kashmir, where similar porphyritic traps are not uncommon.[1]

I have termed the porphyritic rocks above described basalt porphyry, because in specific gravity they range as high as 3·01, and their average is 2·89; and because the groundmass of most of them is basaltic in structure. In some specimens, however, the groundmass approximates in character to that of an andesite or trachyte; but the felspars belong to the triclinic system, and the rock, therefore, is clearly not allied to the trachytes.

No olivine has been found in any of the specimens examined; but considering the age of these rocks and the extent to which they have undergone alteration, I do not, for the purposes of classification, attach much importance to this fact. Olivine is an unstable mineral and one of the first to succumb to aqueous or hydro-thermal agencies; the rock contains secondary products that commonly result from the decomposition of olivine; whilst the high specific gravity of the rock indicates that it belongs to the basic class.

Of the unporphyritic and compact traps described in the preceding pages, the microscope shows that Nos. 1 and 2 are altered basalts approximating to diabase. These specimens probably represent dykes of volcanic matter, injected, at some pressure, into rents in the accumulated lava, rather than surface flows. The rest of the specimens of compact trap examined exhibit a considerable change of type as compared with the volcanic rocks south of Dalhousie. As a whole they are more felspathic in character, so much so that I have classed Nos. 6 to 9 as felsites. Hornblende makes its appearance, and in some specimens it forms, with triclinic felspar, the predominating mineral. I have classed these as andesites and hornblende andesites. Some of these rocks, as for instance No. 24, are quite typical lavas.

Another interesting feature brought out by the examination of the specimens described in Part II of this paper is, that there seems reason to regard those from Tiloga, near the south-east termination of the northern outcrop, and those from Bholu, near the north-west commencement of the southern outcrop, as altered ashes.

This would seem to favour the view that the outcrop to the north of the carbo-triassic series belongs to an eruption distinct from that which supplied the lava to the south of that series; ashes taking the place of lava along the skirts of the pre-carbo-triassic volcanoes.

[1] Lydekker's Káshmir, pp. 221 and 218.

If the Tiloga and Bholu beds are, as I take them to be, altered tuffs, this conclusion will help us to understand doubtful rocks in other localities and confirm the inference already arrived at regarding some Kashmir traps.[1] This determination, moreover, supports the view advanced by Mr. Lydekker in his Memoir on Káshmir,[2] that the volcanic rocks of the North-Western Himalayas were derived from true volcanoes, and do not belong to the type of "fissure eruptions."

The supposed absence of ash-beds, I apprehend, was one of the reasons which prevented some early observers from recognizing the volcanic character of the traps of the North-Western Himalayas and Kashmír; but considering the age of these beds, it is not surprising that fine-grained tuffs have been altered almost out of recognition.

Another point in the microscopic examination of the specimens described in the preceding pages, which has interested me, is the connecting link which the hornblende andesites, and the altered tuffs, seem to supply between the palæozoic volcanic products and the hornblende rocks, and hornblende schists, of the Satlej valley.

In the andesite lavas and tuffs described in these pages, we see the augitic element, so prominent in the lavas south of Dalhousie, and in those of Mandi, disappearing, and hornblende taking its place. Quartz, probably, in this case, a product of the decomposition of felspar, begins to appear; the tuff No. 21 has a finely laminated structure favourable to its conversion into a schist; and I think we see in some of these hornblende andesites, and in the tuffs, the beginnings of metamorphic changes which were probably carried further in the Satlej area, the seat of extreme metamorphic action, and resulted in the conversion of similar volcanic products into the hornblende rocks and hornblende schists found there.

I need say no more on this subject here, as the microscopic structure of some of the Satlej rocks will form the subject of a future paper. I need only add that I do not intend to imply, by the above remarks, that *all* the hornblende bearing rocks of the Satlej valley are volcanic products. Some of the Satlej valley rocks are doubtless diorites and cannot therefore be supposed to have actually flowed out on the surface as lava, though they were probably connected with volcanic action.

PART III.

GENERAL OBSERVATIONS ON THE STRATIGRAPHY AND PETROLOGY OF THE DALHOUSIE AREA.

Owing to my approaching departure from India, this will probably be the last paper on the geology of the Dalhousie region that I shall have an opportunity of writing for the Records; it may be well, therefore, to state how far the views expressed in my first communications have been modified by further experience and observation in the field, and by the detailed study of thin slices of rocks under the microscope.

[1] Memoirs, Geol. Surv., Vol. XXII, pp. 218, 221.

[2] *Ibid*, p. 222.

In my first paper I gave expression to the opinion that the limestone-beds south of Dainkund were of carboniferous age, and that they formed a normal sequence from the altered basalts upwards. I now think that these beds, as suggested by Mr. Lydekker in his interesting memoir on "The Geology of the Kashmir and Chamba Territories," have been thrown into a compressed fold.

The hypothesis of a compressed synclinal flexure accounts better than the explanation previously adopted for the fact noted in my first paper, that notwithstanding the typical development of black infra-Krol rocks along the eastern border of the outcrop, some dark slaty rocks occur at one point on its western boundary.

This hypothesis, moreover, has the advantage of bringing the stratigraphy of the limestone series south of Dainkund into harmony with that of the limestone outcrop north of that ridge. In both, the trap (see section B.) occurs along the western margin of the limestones, and is absent on the eastern border. In both cases the explanation now offered is the same; namely, that a compressed fold in the rocks (the limestones being thrown into a syncline) resulted in a fault, the trap being cut off by the fault.

It is to be noted that the dark carbonaceous infra-Krol rocks visible in the limestone outcrop south of Dainkund are absent from the outcrop north of the Rávi, but this may probably be owing to the latter having been laid down in deeper water further from the shore.

I am unable to accept some other suggestions which Mr. Lydekker has made in his memoir. Mr. Lydekker never visited the Chamba area, and his suggestions were based principally on observations recorded in my papers published up to that date, and I think it will suffice to state briefly in the following pages the conclusions at which I have finally arrived.

When I wrote my first paper on the geology of Dalhousie I had not studied thin slices of the Dainkund granite under the microscope,[1] and I had to make the best I could of the facts known up to that date. I had no wish to strain or go beyond my facts. I had evidence of intrusion, on the one hand, and of distinct foliation, on the other, and it was necessary that any explanation I had to offer should harmonize these opposing facts. "The explanation that satisfies my mind most," I wrote (Records, XV, p. 47), "is that the intense metamorphism of the 'central gneiss' has been principally produced by granitic intrusion at a great depth below the surface; and that the perfectly granitic portion is the intrusive granite itself." After discussing instances of volcanoes bursting through gneissic beds, I added that I could "see no reason why what took place near the surface at Auvergne may not have taken place in other localities at a greater depth below the surface;" and added further on, "I can therefore readily imagine that under the conditions described a blending together of the granite and the gneiss would result, and that the latter would, for some distance from its contact with the granite, partake of its mineral character."

This view has been accepted and adopted by Mr. Lydekker in his memoir. Now however that the microscope has thrown so much new light on the subject,

[1] Owing to the pressure of official work I should have been obliged to postpone my first paper for a very long time had I waited to complete a microscopic study of all the Dalhousie rocks before writing it.

I am unable to confine myself to a view, which, though it went as far as my facts would carry me in 1881, seems, in view of the new facts brought to light, to only express half the truth.

The microscope has shown that not only the gneissose granite of the Dhuladhár, but the foliated beds in the Rávi valley and the outer band at Dalhousie, give evidence of having been, at one stage in their history, reduced to a plastic condition by aqueo-igneous fusion, and exhibit fluxion structure, namely, evidence of motion. Moreover, the numerous specimens taken from various distant points in the localities indicated above, however much they may differ from each other in macroscopic aspect, present under the microscope absolutely no difference in composition or structure.

There is thus a cogent argument for concluding that if portions of the crystalline rocks of the Dalhousie area are of eruptive origin, the whole of them are granites.

It would indeed be strange if metamorphic schists and gneiss of archæan age so exactly resembled comparitively modern eruptive granite that the microscope could detect no difference whatever between them either in composition or internal structure. This would be all the more remarkable, as the Dalhousie rocks do not, by any means, belong to a common type of rock, but, on the contrary, have special peculiarities of their own. When we see these special peculiarities permeate all the granitoid rocks in the same locality, the most natural inference to form regarding them is that they have had a common origin.

The Dainkund gneissose granite has been shown to have exercised a metamorphosing action on the rocks in contact with it; veins of it intrude into the slates and silicious rocks on both margins;[1] the gneissose granite contains veins similar to those caused by shrinkage on cooling in granites of admittedly eruptive origin; whilst it also contains inclusions of slates and schists imbedded in it, which are without reasonable doubt true slates and schists, and not the products of segregation; and these inclusions are met with not only along the line of contact with the sedimentary beds, but at least half a mile away from them.

A granitic mass that presents the above features must, I think, be considered an eruptive rock. The mere fact, taken alone, that portions of this mass display a tendency, more or less pronounced, to assume a parallelism in the arrangement of its crystals, is not, in itself, sufficient to support the theory that the foliated portions are of metamorphic origin, or to support the further assumption that has been made, that these portions are of pre-cambrian age.

The presence of parallelism of structure in some trachytes was demonstrated long ago by Naumann and Scrope, whilst the existence of gneissose granite, and the eruptive character of such foliated rocks as leptynite (granulite), is now admitted by many leading geologists, and gneiss-granite or gneissose granite has become a recognized geological term.

"It was formerly considered," writes Bernhard von Cotta,[2] "that all gneiss was of metamorphic origin, but it has of late years been established beyond a

[1] I have observed, but not heretofore noted, one on the Chamba side of the Chuári Pass.

[2] English Edition by Lawrence; new Edition, p. 225.

doubt that many kinds of gneiss are irruptive, and some geologists have gone so far as to regard all gneiss as of igneous origin."

If trachyte, a rock that has flowed out on the surface of the earth's crust, has in some instances been known to assume a "striped" and foliated appearance, how much more may we not expect to find a parallelism of structure in acid rocks forced through the walls of a fault in a viscid and partially cooled state under conditions of great pressure and strain?

Naumann[1] refers, among other instances, to a trachytic lava observed by Hoffmann in a crater in the Island of Pantellaria, "which throughout has a foliated texture resembling gneiss, and occurs in beds that dip regularly outwards from the centre of the island; and he refers to the observations of Darwin to the effect that "a volcanic rock" in the Island of Ascension has "a perfect gneiss-like texture and structure, the alternate layers of the component parts being extremely fine, and extending parallel to the direction of the lava stream."

Another observation of Darwin alluded to by Naumann in his paper is so apposite to the case of the Dalhousie crystallines that it is worth quoting. "Darwin informs us," writes Naumann, "that in the Cordillera of Chili, great beds of red granite occur, which must be viewed as an eruptive rock; but that it nevertheless exhibits, in parts, a decidedly parallel structure."

If the existence of a gneissose granite in the Dalhousie, Satlej and Chor areas be admitted—and my microscopical investigations have led me to this conclusion in respect of the crystalline granitoid rocks of those areas—I see no reason why very similar rocks in other parts of the North-Western Himalayas heretofore called "central gneiss," and "granitoid gneiss" should not be written down as gneissose granite also, unless, and until, their original sedimentary origin and archæan age be proved.

For instance, the description by Mr. Wynne of the Hazára gneiss (quoted by Mr. Lydekker at p. 103 of his memoir); its completely crystalline porphyritic and granitoid character; its behaviour in relation to the schists that border it; its intrusion "in dykes and veins" into those schists along the margin of contact, so exactly resembles the Dainkund and Chor rocks that Mr. Wynne's description of the Hazára gneiss might be read as a graphic and perfect description of the Dainkund and Chor gneissose granite.

The conclusion that much, if not all, of what has been called "central gneiss" and "granitoid gneiss" is really an eruptive rock, removes many difficulties from the way of the Himalayan geologist. "Despite the wonders performed by flexure of strata in mountain regions," wrote Mr. Medlicott in his annual report for 1883,[2] "the structural features presented by this rock in certain cases were impossible of satisfactory explanation on the supposition of its being really stratified gneiss. The Chor mountain in the Simla region and the end of the Dhuladhár ridge at Dalhousie are instances."

Other examples of difficulties capable of removal may be culled from Mr. Lydekker's memoir on Kashmir. Lenticular or ellipsoidal masses of gneiss are

[1] On the probable eruptive origin of several kinds of gneiss and gneiss-granite. Q. J. G. S., Vol. IV, 1848.

[2] Records, XVII, p. 3.

described as occurring in the midst of the silurian slates (pp. 231, 255); the passage from the slates to the gneiss appears to be generally gradual and imperceptible (pp. 255, 258, and 260); but at p. 250 we are told that "the lower part of the system" (*viz.*, the Panjál, which Mr. Lydekker at p. 47 correlates with the silurian and cambrian (?) systems) "next the underlying gneiss, may apparently consist either of mica schists, or of little altered slates, which would seem to be difficult to distinguish from the higher Simla slates. Finally it appears that there is generally a gradual passage from the lower beds of the system into foliated, and then into granitoid gneiss, but that there are instances where the junction is somewhat sudden." Or, in other words, there is occasionally a sudden passage from comparatively unaltered slates, undistinguishable from beds supposed to be of middle silurian age, to a perfectly crystalline granitoid rock.

Sometimes the gneiss appears to come in above the upper silurian or lower carboniferous traps (p. 230); and at other times next the upper silurian conglomerates (p. 290). Some of the gneiss is considered to be of pre-cambrian age (pp. 235, 265); some to be metamorphosed beds of middle silurian age (p. 251); and some to be the altered equivalents of rocks higher than the Panjáls (p. 265), namely, of more recent age than the silurian system.

Mr. Lydekker does not indicate any mode of distinguishing between the eruptive granites and the granitoid metamorphic rocks on the one hand, or between the pre-cambrian, silurian and younger gneisses on the other.

Some of our leading geologists, who have given special attention to archæan rocks, would, I think, be indisposed to believe in the existence of thoroughly crystalline granitoid metamorphic rocks of such diverse ages as those stated above, in the same mountain region; and they would probably suggest the introduction of a number of faults to account for the erratic appearance of a thoroughly crystalline granitoid gneiss sometimes at the bottom, sometimes in the middle, sometimes at the top of the silurian series, and sometimes in younger beds; and to account for the juxtaposition of comparatively unaltered slates and crystalline rocks in the last stage of extreme metamorphism.

I do not understand that Mr. Lydekker has resorted to an elaborate system of faulting to explain the facts noted above, but on the contrary, that he believes his metamorphic gneisses to belong to "more than one gelogical period" (p. 265).

For my own part, as I hold that there is sufficient evidence to justify the belief that the crystalline granitoid rocks of Dalhousie, of the Satlej valley, and of the Chor mountain, are eruptive granites, I would account for the cases noted above, and similar ones, by applying to them the explanation which has solved even greater difficulties in the Dalhousie and Chor areas.

If eruptions of gneissose granite on so grand a scale occurred along the Dhuladhár, the Chor, and in the Satlej valley region, it is only natural to expect that similar eruptions occurred in other parts of the North-Western Himalayas; and this expectation becomes almost a certainty when we find a crystalline granitoid rock undistinguishable from the gneissose granite of Dalhousie, and of the Chor, presenting itself in different horizons amongst the silurian and younger rocks. If the gneissose granite is really an eruptive rock, this is just what we should expect to find; indeed, if it never cropped out except along the same horizon, there might be some ground for regarding it as a metamorphic rock. But when we find a crystalline granitoid rock preserving its identity of character over very extensive areas, and yet cropping out along widely different horizons in rocks "of more than one geological period," it seems to me that the grounds for claiming it as a metamorphic rock are slender indeed.

On the assumption that it is an eruptive rock the difficulti s I have indicated above disappear. We no longer wonder with Mr. Lydekker why no case of the overlap of the "central gneiss" by the silurian series has ever been discovered (p. 302); and we at once understand why granitoid rocks are found along widely different horizons, and why, in some cases, there is an apparent transition from the sedimentary series to the crystalline rock, and why, at others, there is an abrupt passage from the latter to comparatively unaltered slates. Where the gneissose granite was erupted among lower silurian or cambrian (?) beds that had already been subjected to more or less regional metamorphism, and on which it would produce some contact metamorphism, an appearance of gradual transition would naturally be the result; where, on the other hand, the partially cooled gneissose granite was erupted along a fault and in contact with unaltered slates, the contact action would not be sufficiently intense, or extend far enough, to create an appearance of gradual transition, and the result would be, as at Dalhousie, a sudden passage from slates to gneissose granite.

I now pass on to offer some remarks in explanation of the diagrammatic sections attached to this paper (Plate).

Section I has been taken (see map attached to this paper) through Dainkund and Tisa to the Sách pass.

The tertiary series does not come within the scope of this paper, and the stratigraphy of the trap and the carbo-triassic series has already been discussed in the preceding pages. I pass on to the silurian series. Along the section under consideration, the silurian beds, on both sides of Dainkund, are in normal sequence. On the north-east of Dainkund we have the upper silurian conglomerates followed by typical Simla slates which pass into fine-grained silicious schistose beds. On the south-west of Dainkund, we have slates followed by fine-grained silicious schistose beds passing into mica schists. The silurian beds were thrown by lateral pressure into folds, as indicated by the dotted lines, and squeezed together until a fault was produced at Dainkund, and another further to the south-west, and a uniform dip in one direction was given to the beds. The gneissose granite rose along the line of fracture at Dainkund, and the "outer band" also forced its way through the more westerly fault between the carbo-triassic and the lower silurian beds. The upper silurian conglomerates, which to the north-east of Dainkund were thrown into a compressed isocline, were to the south-west of Dainkund squeezed out in the flexures in which the silurian beds were involved. To the north-east of the river Rávi, the upper silurian conglomerate has been thrown into compressed isoclines, the carbo-triassic limestones being caught up in a synclinal fold between the two isoclinal outcrops of the conglomerate. A synclinal flexure brings out the silurian beds after the conglomerates. The Simla slates have disappeared in this section, their place next the conglomerates below Tikri[1] being taken by micaceous schistose rocks that crumble to a whitish soapy powder, indicative doubtless of the presence of a hydro-mica. The slates here may either have been more highly metamorphosed than those at Dalhousie, or they may have been squeezed out by local flexure and faulting.

Continuing from Tikri along section A in a north-easterly direction the soapy schistose rocks are followed[2] by fine-grained quartz schists, mica schists, and slaty mica schists occasionally passing locally into micaceous slates, and these rocks continue to near the top of the Sách pass.

A south-westerly dip is set up in the outcrop of the conglomerates on the northern side of the limestones, and it becomes pronounced at the stream under Tikri; beyond this the dip rapidly flattens and becomes wavy until the top of the Sách pass is neared, when a high south-east dip is resumed. This rapidly becomes perpendicular, and ultimately, on the north-east side of the pass, the conglomerates dip under older silurian beds.

Section II, through Dainkund, Hulh, and Chánju, differs in some important particulars from section A. As described in Part I of this paper, a band of trap crops out along the south-western border of the carbo-triassic limestones, and the latter are followed by silurian beds. In both these respects, if we leave the outer band of gneissose granite out of consideration, the section north-east of the Rávi agrees with that south-west of Dainkund, and another fault must be brought in to explain the contiguity of the carbo-triassic limestones with silurian beds somewhat low in the series, and the disappearance of the trap and conglomerates. A glance at section B will, I think, show that the relations of the several series to each other are not to be explained without putting a fault on the north-east border of the limestones. From the limestones down to the gneissose granite the several series are in normal sequence; the carbo-triassics are followed by infra-carboniferous trap; then comes the upper silurian conglomerate which, in its turn, is succeeded by Simla-slates and then silurian beds lower in the series. A synclinal fold would bring up the trap and the conglomerates again to the north-east of the limestones, as in section A, but the flexure having resulted in a fault, the trap and the conglomerates have disappeared.

This section is, I think, an instructive one, and will help to remove difficulties in other localities.

In the Pir Panjál range the conglomerates occur in the middle of the slates (Memoir, p 241), and Mr. Lydekker, in view of this fact, thought that "it cannot be taken as certain that all the conglomerates of the Káshmir valley correspond to the Blaini conglomerate." And again at p. 249 the author writes, "they seem further to indicate that the Blaini conglomerate of the Simla district may either be strongly developed at the top of the series, or that it may occur less strongly developed among the slates themselves." And again at p. 248, "It is noteworthy that these rocks" [the supra-Kuling series] "are not immediately underlain by the Blaini conglomerate, showing the inconstancy of the petrological characters of that member in these districts."

This apparent inconstancy, however, is, I apprehend, to be put down to the countless plications in which the Himalayan rocks have been involved; a glance

[1] Records, XVI, 39. [2] Records, XIV, 307.

at the map attached to this paper will show that the conglomerate, which south of Himgiri (Himgir) is in contact with the carbo-triassic (supra-Kuling) series, is gradually removed to a distance of over 6 miles from it in the Chánju section by the interposition of silurian beds lower in the series.

The dip of the carbo-triassic limestones in the Hulh section (section II) is north-east-by-north. The dip of the silurians which succeed them is vertical, but somewhat curved when the dip can be traced for any distance down the mountain side. A north-east dip afterwards sets in which becomes south-west along the crest of the ridge. It wavers from north-east to south-west more than once, and at one place is high to south, but under Chánju it settles down to south-south-west.

A section drawn through Dihur (Duire) and Himgiri (see map) would differ somewhat from those already described, for the trap here crops out on the north-eastern border of the carbo-triassic series instead of as in the section through Hulh, on the south-western border.

A study of the Hulh and Dihur trap (see Part II of this paper) has led me to the conclusion that the dying out of the trap between Dihur and Bailaum (section A through Dainkund and Tisa) is owing to the original limitation in the area of deposition.

On a first inspection of the Bhándal-Dihur area I suggested (Records, XVI, 41) that the fact that "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:" and I expressed the opinion "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."

I think, now that I have reviewed the stratigraphy of neighbouring sections, that there is no need to call in the aid of a fault to solve the problem presented to us, and that it may be satisfactorily explained without one. Section V (Plate) represents a section drawn through Dihur in the direction of Himgiri, and IV and III sections drawn parallel to V a little more to the north-west. The folding of the strata in sections III, IV, and V is the same as that in section I. The explanation in all is that offered in my paper quoted above; namely, that the local strata have been thrown into a "crushed synclinal fold." On both sides of the limestones the conglomerates have been bent into isoclines, and the limestones are caught up between them and bent into a crushed syncline.

In I the trap is absent, this section being beyond the area of deposition. From the predominance of limestones, and the absence of the carbonaceous element here, it seems not improbable that the sea was comparatively deep in this locality at the end of the silurian period when the volcanoes were in an active state.

Section V represents the tail end of the volcanic deposition. The volcanic beds are thick on the north-east side of the limestone outcrop, and they thin out to the south-west.

In section IV we are further within the area of volcanic eruption, but we are getting nearer the bottom of the synclinal fold that is concerned with the upper-silurian conglomerates, and consequently the limestone outcrop (a crushed syncline) is getting comparatively shallow.

At III we have arrived at a further stage; the limestones have been squeezed out of the section; the trap is doubled up upon itself, and is in contact with the conglomerate on both sides.

In sections I and II I have represented the silurian beds between the outcrop of the carbo-triassic beds north of the Rávi and Dainkund as forming a normal sequence, whereas in Part I of this paper I have suggested that in the Siul river section[1] "the Simla slates are folded up with older silurian beds in compressed isoclinal flexures." I may as well point out in passing that there is no confusion or contradiction in these statements. A comparison of the diagrammatical section I with section II will show that even along the same line of strike local details change rapidly within the distances of a few miles. Along section II the silurians in the valley of the Rávi appear to have escaped complicated flexions, whereas in the valley of the Siul, in the same strike, they appear to me to give evidence of having been involved in them.

Indeed the area near the junction of the Siul and the Rávi appears to have been a region of special strain. Lower-silurian beds (decided mica schists) extend from the stream between Tipri and Seru (Sairu) to the outer band of gneissose granite; whilst in the Bhale (Balai) section (see *ante,* Part I) the slates between the inner and outer bands of gneissose granite are very micaceous and at Bhale are decided mica schists. In section I through Dainkund the upper-silurian conglomerates have disappeared; whilst in the valley of the Rávi, opposite the mouth of Siul, the middle-silurians (Simla slates) are missing as well as the conglomerates. I think the explanation is the same in both cases; namely, that the upper-silurians, in the section through Dainkund, and the upper and middle silurians, in the Siul-Rávi section, have been squeezed out in the flexions in which the strata have been involved. It is to be noted that in the Siul-Rávi section, where both the upper and middle silurians are missing, the Dainkund gneissose granite has reached its minimum development, being reduced to a narrow band of gneissose aspect, a fact which does not favour the hypothesis of the "absorption" of the missing beds by the rising granite, or of their having been metamorphised out of recognition by contact action.

I note in passing that though I have, for the sake of simplicity, in the diagrammatical sections I and II, represented the upper-silurians as unbroken beds of conglomerate, I by no means overlook the possibility that they may contain slates of a slightly higher or lower horizon. The plications in which all these rocks have been involved have been very great, whilst fossil evidence is *nil.* The conglomeritic series is not uniformly conglomeritic, and therefore the probability of other beds, slightly higher or lower than the conglomerates, having been folded up with them, is very great. Further observations on this subject will be found in part I of this paper.

I desire to point out, in conclusion, that the inference must not be drawn from any remark made in the preceding pages, that I deny the existence of true metamorphic gneiss in the North-Western Himalayas. In a recent paper I have

[1] The Siul runs under Bhale (Balai) and Manjere.

distinctly indicated my belief that some of the crystalline rocks in the North-Western Himalayas are metamorphic gneisses,[1] and the fact will be definitely asserted in a paper on the section from Simla to Wangtu that will appear in a future number of the Records; but I think it would be a grave error of judgment were we to allow the presence of metamorphic rocks of this character in the Himalayan area, to blind our eyes to what appear to me to be the leading facts in the past history of he Himalayas; namely, that volcanic eruptions on a large scale in upper-silurian and lower carboniferous times were followed by a gradual subsidence of the Himalayan area which lasted through several geological ages. A period of elevation which has not yet terminated, then set in, during which the strata, that had accumulated during the period of subsidence, were crumpled and compressed to an enormous extent; the period of elevation being marked by a re-kindling of the volcanic fires, the gneissose granite of the North-Western Himalayas misnamed "central gneiss" constituting the deep-seated portions of comparatively modern eruptive rocks. In short, the past geological history of the Himalayas is inseparably connected with volcanic activity.

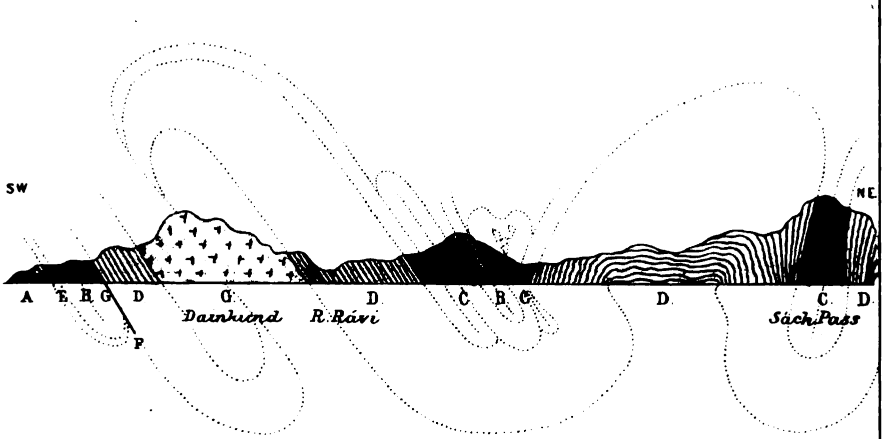
Memorandum on the probability of obtaining water by means of Artesian Wells in the plains of Upper India, *by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*[2]

In the broad plains of Upper India the need of an abundant supply of pure water must always be felt, and it is consequently not surprising that in the search for it borings have been sunk to greater depths and prosecuted with greater ardour than any that have been sunk in the search for coal. Of the many papers and reports bearing on this question, I do not propose to discuss more than the one published by Mr. Medlicott,[3] where the possibility of making a successful artesian well is discussed on the not unnatural assumption that there is a continuous zone of gravel and sand deposits, comparable to those of the *bhábar*, separating the clay deposits of the alluvium from the rock below.

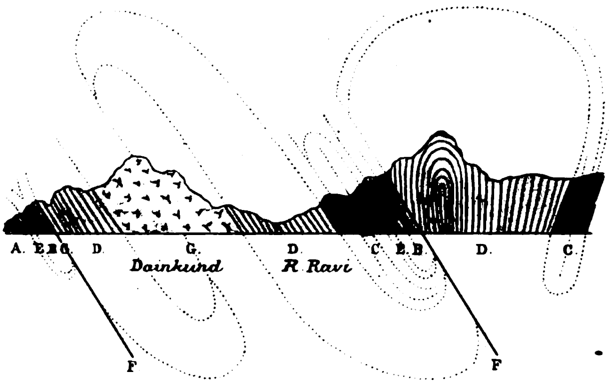
2. In the case of alluvial deposits, such as those of the rivers of the Indian peninsula, which have been formed as the land gradually sunk, a zone of coarse deposit will be found lying immediately upon the rock; but with the Gangetic alluvium the conditions are different, inasmuch as we have ample reasons for believing that the Himalayas were raised *pari passu* with the depression of the plains; and in this memorandum I propose to enquire how this would affect the assumption made by Mr. Medlicott in his memorandum already referred to.

3. Many different theories of mountain formation have been propounded at various times and by various authors, the latest of which is that of the Rev. O. Fisher, which demands that flanking every mountain range subject to denudation there should be a corresponding depression in which deposition is taking place, that the depression should extend by encroaching on the land separated by it

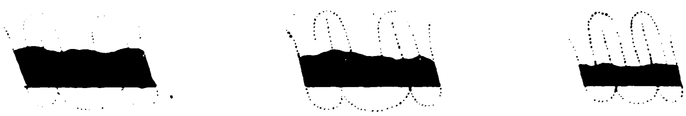
[1] Records, XVII, pp. 60 and 70.
[2] With this paper should be read the one following.
[3] Records, XIV, p. 205.



Section I through Dainkund and Tisa to the Sach Pass.



Section II through Dainkund. Odapura, Huth, and Chánju.



Section. V. Section. IV. Section. III.

A. Tertiary series. B. Carbo-triassic series. C. Upper silurian conglomerates.

D. Middle and lower silurians. E. Pre-Carboniferous trap. G. Gneissose granite

Longitudinal Scale of I and II. 1. Inch = 10. Miles.

On Stone by S Khadem Hossain. Printed at Geol: Survey Office.

from the mountain range, and that at the same time the deposits formed on the skirts of the mountain range should be gradually elevated and exposed to denudation. To take the case of the Himalayas, the mountain range would at first be small, and the corresponding depression also small; but, as the elevation of the Himalayas proceeded and the Gangetic depression increased in depth and width, the deposits formed along the foot of the hills would be disturbed, elevated, exposed to denudation, and form an integral portion of the Himalayan range; this encroachment of the hills on the plains would, however, be more than balanced by the encroachment of those on the land to the south, so that as the Himalayas increased in height, the Gangetic plains increased in width and the alluvium of which they are composed in thickness. Mr. Fisher has not followed up his theory beyond the growing stage of a mountain range; but, however interesting it might be to be able to prophecy the decay and extinction of the Himalayas and the plains of Hindustan alike, it would have no practical bearing on the question I am now considering, and I shall confine myself to enquiring whether the known facts fit in with Mr. Fisher's theory as far as he has carried it and, secondly, how, if true, it will affect Mr. Medlicott's fundamental assumption.

4. In the first place, are there any indications that the alluvial deposits extended further north than they now do? Most certainly there are; for there can be no reasonable doubt that the Siwalik beds were the *bhábar* deposits of their day, and that the ground they now occupy must have formed the northern margin of the Gangetic plain. But this does not sum up the whole of the matter; in every section of the Siwalik that has been examined we find at the base beds in which clays preponderate, and above these comes a great thickness of sandstone which passes upwards into conglomerate.

5. At the present day there are everywhere along the foot of the hills great banks of shingle formed by the streams whose velocity is checked as they issue from the hills, below the shingle come great stretches of sand, and beyond these again is the clay of the alluvial deposits proper. But as the shingle banks are added to, they must encroach on the sand, and this again on the clay deposits, and in course of time a section precisely similar to that to be seen in the Siwaliks will be produced, from which we may conclude that then as now the coarser deposits were being pushed forward from the north over the finer.

6. Nor does the strip of hilly country occupied by the Siwalik beds represent the whole of the southward encroachment of the Himalayas, for, close up against the older rocks of the Himalayas, we find sandstones and clays, which could not have been formed in that position, but must originally have been separated from the hills by a strip of country on which the streams deposited their coarser debris. From these facts we see that even the boundary of the Himalayan slates does not mark the original southern limit of the Himalayas, but that it must be placed somewhere, though not necessarily very far, to the north. To judge by analogy, it must have been on the average at least twelve miles further north in Náhan, and six in Middle Siwalik times, than the present main boundary of the slates and the Siwalik.

7. In the light of these facts, the assumptions that there is a continuous zone of coarse deposits, continuous with the existing *bhábar*, next to the rock floor of

the Gangetic depression, and that the deposits will become coarser on the whole as we sink into the alluvium at any point are not justified. At first, doubtless, coarser deposits were overlaid by finer ones, and in the southern margin, where the land has sunk and the alluvium spread over it, this still takes place, but at the northern margin,—and it is with this alone that we are concerned,—the coarse deposits have for long past been pushed forward over the top of the finer, and all direct connection with the coarse-grained bottom bed cut off by the elevation of the strata we now call Siwalik.

8. The only means we have of testing these suppositions are the Ambala and Calcutta borings. According to the hypothesis I have put forward, the beds should become finer on the whole, as a greater depth was reached in the first case but coarser in the second. With regard to the Calcutta boring,[1] an inspection of the record will show how markedly this is the case; in the Ambala boring the finding pebbles low down might be held to disprove the hypothesis; but, as far as I can make out, they were merely occasional small pebbles never forming shingle properly so called; and the table (given below [2]) of the thickness of sand and clay passed through in each hundred feet shows clearly that the deposits did on the whole increase in fineness with the depth reached; for, while in the first 400 feet sand was in excess of clay, during the next 300 the thickness of clay was greater than that of sand, and the proportion of clay throughout the section increased steadily till in the last 100 feet there was but 7 feet of sand in all.

9. Since, then, the sections met with in these borings are so strikingly in accord with what, according to hypothesis, they should be as almost to amount to proof, it is extremely probable that, as indicated in § 7, there is no zone of coarse permeable deposits continuous with those of the *bhábar*, and that in consequence there is but little prospect of obtaining water, except in small quantities, by means of artesian wells in the plains of Upper India.

Further considerations upon Artesian sources *in the* plains of Upper India, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

In the foregoing paper Mr. Oldham makes use of the artesian question as a peg whereon to exhibit a very neat combination of theory and observation to elucidate the formation and resulting structure of the Sub-Himalayan deposits, including those of the great alluvial plains, in their relation to the growth of the mountains themselves. I am glad to have afforded the opportunity for so interesting and instructive a discussion, and glad also for the occasion it gives me in return of adding some further considerations upon the same subject; it is

[1] Rec., Vol. XIV, p. 221.

[2]

0 ft. to 100 ft.	Sand 59 ft.	Clay 37 ft.	Soil 4 ft.
100 „ to 200 „	„ 56 „	„ 42 „	Kunkur 2 „
200 „ to 300 „	„ 58 „	„ 42 „	
300 „ to 400 „	„ 54 „	„ 46 „	
400 „ to 500 „	„ 46 „	„ 54 „	
500 „ to 600 „	„ 37 „	„ 63 „	
600 „ to 701 „	„ 6 „	„ 95 „	

however very needful to point out that criticism, both in its positive and its personal aspects, is quite too serious a responsibility to be treated as a lay-figure. It is easy to show that the dummy set up, to be so expertly knocked down again, never occupied the position assigned to it in the place whence it was taken. The condition in question—a continuous zone of gravel and sand deposits comparable to those of the *bhábar* separating the clay deposits of the alluvium from the rock below—may in Mr. Oldham's opinion be necessary to the success of artesian borings, and he is of course entitled to maintain it, but he was not warranted in representing it as "the fundamental assumption" of the paper he referred to. That condition is indeed there quoted as theoretically most favourable, especially as affording assignable limits of depth, but by illustration and example it is abundantly shown that success does not depend upon the supposition of which that condition would be the result.

2. The study of Mr. Fisher's admirable work[1] had the same effect upon me as upon Mr. Oldham, up to a certain point, to upset a supposition of primary simplicity regarding the underground conditions of the great plains; but as I had never held or represented that supposition to be essential to the existence of artesian sources, there was no occasion to proclaim a correction that might discourage a project which I hold to be quite independent of that particular arrangement. I did not however fail to represent the whole case on the first opportunity, and to indicate its bearings on the question of artesian sources, in a geological paper written two years ago for the Gazetteer of the Punjab, but which has not yet appeared. The following paragraphs (3 to 11) are reprinted *verbatim* from proofs that were set up in 1883.

3. "We have still to notice the depth or thickness of these deposits, as a point of practical as well as of speculative interest. The surface deposits belong everywhere, as we have seen, to the human period. In a cutting near the head of the eastern Jumna canal, Colonel Cautley dug out a fossil town.[2] Everything below is concealed. It would seem that near the 'outer' margin, *i.e.*, on the Himalayan side, of the plains a very close limit to the age of any beds conformably underlying the recent alluvium should be assignable; for the topmost beds of the Siwalik series, of latest pliocene age, if not pleistocene, are tilted up vertically; yet they are indistinguishable in composition and texture from the actual river deposits. Disturbance of such magnitude must, one would think, have extended to some distance south of these outcrops, and thus have involved total unconformity of the Siwaliks with any beds that are still undisturbed, within a considerable distance. If this were so, it would follow that any beds conformably underlying the surface deposits in the neighbourhood of the Himalayan margin must be long post-Siwalik. But, as will presently be shown, the disturbance to which the upheaval of the Siwaliks is due probably extended to only a small distance from that margin.

4. "Far from the mountains, anywhere within the protecting influence of the underlying hard rocks of the peninsula, it is evident from what has been said that the plains deposits might be in unbroken sequence with the whole tertiary

[1] Physics of the earth's crust, by the Rev. Osmond Fisher, London, 1881.
[2] Journal, Asiatic Society, Bengal, III, p. 43, 1834.

system; and on this 'inner' border of the plains even at the small depth to which observation has access, beds having some small comparative antiquity occur in close relation with the surface deposits. In the lower reaches of the Jumna, between Agra and Allahabad, where the river has eroded its channel to a depth of 100 feet below the level of the adjoining plains, bones of extinct forms having some affinities with those procured from the upper Siwalik strata have been found in perfectly undisturbed clays.

5. "Any surmise upon the underground features of the plains deposits can only be derived from the view formed of antecedent conditions as indicated by the features of adjoining areas. On the peninsular side there is good evidence to show that, so far back as in immediately pretertiary time, the drainage flowed from the south towards what is now the Gangetic basin: the whole northern scarp of the Vindhyan plateau existed at that time in approximately its present position. The Deccan trap poured over that scarp on to the gneissic area of lower Bundelkhand. How far it may have flowed over the low ground in that direction it would be impossible to say; on the plateau it does not seem to have reached so far north as Gwalior. The total absence of any remnant of tertiary rocks on this border of the peninsula suggests that it was then out of the reach of deposition, rather than that all such deposits have been since removed; but it would seem pretty certain that this drainage basin was part of that in which the eocene rocks of the Himalayan border were laid down. Only the lower stage of that series is marine; and the muddy character of these beds, contrasting with the clear limestones of the same age in the western Punjab, suggests estuarine conditions requiring a southern bank far to the north of the present south boundary of the plains, and of course also a limiting land in the actual Himalayan area. Already in nummulitic time these marine bottom-beds became mixed with and soon permanently replaced by others of distinctively Sub-Himalayan characters, consisting of fluviatile deposits with terrestrial and fresh water fossils; and these conditions have lasted throughout the Siwalik epoch to the present day, for, as has been said, the top Siwalik strata seen at many places in the Panjab are absolutely indistinguishable from those of the plains. These middle and upper tertiary fluviatile deposits were independent of the sea level, and would have spread over the whole basin according to its contour, and equally to the south in the valleys of the northern slopes of the peninsular area now concealed beneath the plains. From the foregoing observations it would appear that the Sub-Himalayan eocene marine basin was probably a narrow one; but that the supervening upper tertiary fluviatile deposits may have stretched southwards to an indefinite distance.

6. "To the foregoing consideration of the original conditions of the basin, there must be added what can be said regarding the Himalayan disturbance as affecting the floor, and therefore the whole condition, of the plains deposits. The extreme unconformity already mentioned as occurring between the horizontal plains deposits and the vertical Siwaliks along the Himalayan border, does undoubtedly establish an immense lapse of time (as reckoned in historical periods) between the two. But the inference as to how far this condition of unconformity extends beneath the plains to the south of the actual boundary depends upon the view

taken of the process of disturbance. It is difficult to resist the *primâ facie* impression, from the sight of an immense thickness of stratified rock turned up on end that great violence must have attended such results, and hence that the effects must have extended to far beyond the point where such intensity is exhibited. It was upon such natural impressions that the cataclysmal theories of the early geologists were founded. In the present case, the plausible supposition from such a point of view would be, that an elevation of the Himalayan area, coincident with the contortion of the Siwalik strata, had first resulted in a great valley of erosion from the mountains to the sea, forming a clean-swept basin for the deposits which now form the plains.

7. "To give meaning to this seemingly useless discussion it may be well to point out that it forms the only rational approach to the practical question often asked—where in the plains and at what depth would there be a prospect of success for an artesian boring? If the supposition just noticed might be counted upon, a very favourable answer could be given to this question. The base of the deposits would then be everywhere within reach; that base would generally consist of coarser materials, such as would form a capacious water-stratum; and it would be in continuous connection with the present upper zone of gravel beds at the foot of the hills, where copious absorption of water occurs.

8. "Careful observation and reflection are, however, against that *primâ facie* supposition. It will be shown that before the disturbance of the Siwalik rocks (*i.e.*, during the Siwalik period) the Himalayan rivers, great and small, flowed just where they now do in the mountains; so that there is nothing to support the supposition that any great elevation or violent movement of any kind accompanied the disturbance of the Siwalik rocks; for they probably were tilted up so slowly that the main rivers could *pari passu* erode their gorges across the rising strata. Another fact of corresponding import is found in the form taken by the Siwalik strata under disturbance. The *dúns*, or longitudinal valleys occurring so constantly inside the Siwalik ranges, are generally formed of the topmost Siwalik strata in a more or less horizontal condition, rising by a gradual increase of dip to form the range outside the *dún*, while on the inner side they either abut abruptly against the rocks of the inner range, or else are bent up sharply to form that range. Such a feature strongly suggests the probability that the final limit of the disturbance may be no less abruptly marked; so that beyond the extreme verge of the vertical Siwalik strata, these same strata may have remained permanently in their original gentle slope of deposition, and would thus be in conformable sequence with the most recent deposits of the plains within a very short distance of the hills. It is independently intelligible that the slow compressing force to which the bending of the strata and the consequent rise of the hills were due, would expend itself to the utmost on each flexure before giving rise to a new one.

9. "Such a process would of course involve great erosion of the Siwalik strata in the immediate region of upheaval; and there is abundant evidence of this, not only in the river gorges and the deep ravines of the minor streams, but along the whole outer edge of the hills, where, as a rule, the uppermost gravel beds of the plains rest upon the edges of low Siwalik strata near the axis of the

flexure, the whole of the outer and steeper side of which has been removed. Under the supposed conditions of disturbance this denudation would not have reached far; so that within a short distance there might be completely conformable sequence between the Siwalik deposits and those of the actual plains.

10. "One important direct observation has been made upon the underground constitution of the plains, in the boring for an artesian spring at Ambala to a depth of 700 feet. No gravel bed or other water stratum was met with, and the boring ended in stiff clay. If this section could be taken as representative, it would be conclusive evidence against the supposition of these deposits lying in a simple post-Siwalik basin of erosion; for the bottom of such a basin must at Ambala be within a much less depth than 700 feet, and the basal beds in such a basin must as a rule be coarse, porous, and water bearing. It is easy to explain a possible exception to this rule; and Ambala is just in the position where such an exception would be most likely to occur. It is about 20 miles from the foot of the hills, and this is beyond the distance to which gravel is now swept by the small streams and the rain-wash on the steeper slopes near the hills. It is only within the range of the great rivers, in the deeper parts of the supposed basin of erosion, that coarse deposits must occur somewhere in almost every section, especially at or near the base; and in river-formed deposits such as these, the range of the great rivers embraces in time more or less the whole area. Ambala, about midway between the Jumna and the Sutlej, and so near the hills, is just in the position most likely to escape that influence, as the whole growth of deposits might be directly from the hills, or by overflow of finer sediment from the main rivers. In this way there might be nothing there to mark the bottom of the basin or surface of erosion in so small a section as that given by a boring; and thus the passage from the recent plains deposits into beds of such similar composition as are those of the upper Siwaliks would not be noticed. It can however be affirmed that the boring did not reach beds that had undergone any considerable disturbance, for the frequency of alternation of beds in the lower part of the boring was as great as in the upper part, whereas a very moderate tilting of the lower beds would have given a perceptible apparent thickening of the several strata passed through by a vertical boring.

11. "There is yet to be taken into account a consideration of great weight in this discussion. It was long ago suggested by Herschell,[1] in seeking for a prime mover of the forces by which crust movements are effected, that the familiar process of denudation by the continual removal of matter from steep elevated tracts and the deposition of it in adjoining low ground, evidently disturbs the equilibrium of strain beneath those areas, causing a tendency to elevation in the former and to depression in the latter. Recent researches upon the nature of the earth's rigidity entirely confirm that inference; and it is the obvious explanation of the constantly observed fact of depression in deltas. Borings in the delta of the Ganges at Calcutta have discovered land surfaces far below the present sea level. Now these conditions occur in a very concentrated form along the fringe of the Himalayan border. An enormous amount of detritus is annually swept down from the mountains, a relatively large proportion of it being from the

[1] In note 1 to Babbage's Ninth Bridgewater Treatise, 2nd edition.

softer rocks of the Sub-Himalayan hills; and a relatively large proportion of that detritus is deposited in the upper marginal region of the plains. It thus becomes a matter of certainty that depression to an unknown extent has taken place in this latter area. This view considerably modifies the inference to be drawn regarding the lower beds in the Ambala boring as based on the supposition of extensive elevation and erosion. The probability would now seem to be that the boring did not reach beds of Siwalik age. It is evident that these later conclusions regarding the underground relations of the plains' deposits render more difficult than ever any speculation as to the position or depth of an artesian source, although by no means shaking the probability that such sources occur there."

12. These last words show how little dependence was placed upon the hypothetical condition of a continuous post-Siwalik surface of erosion covered by coarse deposits beneath the alluvium of the plains. Thus, from quite opposite sides, though from the same suggestion of a slow rising of the mountain area and depression of the adjoining region, Mr. Oldham and I have independenly shown the non-existence of the condition which he has characterised as the fundamental assumption for the success of artesian wells. Although in the paper under reference I gave ample proof that no such condition was necessary, I must plead guilty to having myself exaggerated not only the chance of its occurrence, but also its importance. From figure 1 of the experimental results (*l. c.*, plate facing page 207), it is apparent that any approach to a complete fulfilment of that condition would be fatal to success as affording equal capacity for percolation throughout, and therefore no compulsion to a rise, beyond what might be due to variation of slope. The proclivity to exaggerate the importance of this condition is the desire to make sure of porous deposits throughout, and their continuity from the source of supply; but it is plain that sufficient assurance on this point may be established without the assumption in question.

13. In the first place there is much misapprehension as to the facts of porosity and percolation. Although the statical porosity, the capacity for holding water in the interspaces, is the same in granular bodies whether the grains be large or small, the dynamical porosity, the facility of percolation, is much greater in the latter case, because of the much less surface of contact involving friction. Thus in the experiments described in the paper under reference, the discharge from the pipe (fig. 1) was 12 cubic inches per minute when filled with large shot (B. B.), and only 5 when filled with small shot (No. 8), the discharge from the same pipe when free being 322 cubic inches. A great mistake is however made in applying this fact to rocks. Conglomerates and gravels are not, except very rarely, made up only of large and small stones; there is always a matrix, generally of sand; so that in point of fact, gravel is less porous than sand, for every pebble is so much potential porosity abstracted. Sand of some sort is therefore, in every case, the effective medium of percolation. The maximum or normal porosity of a body composed of equal spherical grains, is about 40 per cent.[1]

[1] The Ganges sand at Narora is stated by Colonel Brownlow, R.E., to absorb 2·5 gallons of water to the cubic foot, *i.e.*, 40 per cent.

14. Next as to distribution: from Mr. Oldham's rough statement of the case it would be understood (though of course he did not mean it) that only clay deposists take place at a distance from the upper margin of the plains, but as a fact it is certain that the great rivers bring down sand in abundance to the very delta. In the total burden of solid matter discharged from the mountains, sand is certainly the chief ingredient, and I do not see how it can be doubted that such deposits were more or less freely continuous throughout the areas over which these rivers spread. The occurrence that took place last year in sinking a well in the Ganges for one of the piers of the railway bridge at Benares, when the well was burst by a sudden influx of water from below a bed of clay rising to a greater height than the river water outside the well, proves that partial artesian conditions exist at shallow depths, near to the lower margin of the plains. It is in the areas of tranquil inundation between the great rivers that deposit of clay prevails. The alternation of the two kinds of deposit is secured by the necessary process of growth whereby depositing rivers must in time change their course impartially over their basin of deposition. In taking the Ambála boring as a type of what may be expected in the plains, Mr. Oldham has ignored how peculiarly its position excludes it from being taken in that sense as is explained above (§ 10). In sinking the piers of the Jumna bridge east of Ambála at the same distance from the hills, large boulders were found at 40 feet below the bed of the river. It is no doubt conceivable that even in the open plains some spots may have successively escaped any adequate amount of sand deposits during the repeated oscillation of the great rivers; but on this point also much misapprehension exists as to what occurs in nature. In an official discussion upon this question, it was urged that the possible porous layers in these deposits would be represented by long strips corresponding with the courses of the great rivers, the idea being taken from the rivers of Upper India as now exhibited. But this is misleading; for these rivers now for the most part run in valleys of erosion, and are not adding to the adjoining plains. The state is very different under formative conditions, when the river in flood runs at the general level of the country and distributes its branches over a wide area, as is now the case with the Brahmaputra in Upper Assam. I therefore maintain that there is a strong presumption that porous beds do occur at various depths over a large proportion of the plains, and that they are almost necessarily in connection with like deposits up to the base of the hills.

15. Any one who has realized the process of growth of the plains deposits as indicated above, can have no difficulty in meeting the objection suggested by Mr. Oldham as to the state of things at the origin of the deposits, which is the third condition of success. Even granting his main contention that as the mountain border rises or the plains are depressed there is a growing tendency to widen the zone of coarser deposits by extension over fine deposits that had previously been laid down, the whole argument is only valid against the aforesaid fictitious "fundamental assumption." Though the ultimate general tendency may be as stated, it is quite certain that from the beginning the process was exceedingly irregular; that while the streams were pushing their coarser deposits in one direction, the finer deposits in the other direction must have encroached upon the

coarser deposits of a previous period,[1] and so the resulting structure of the de-posits in this region must be an entanglement of projecting wedges of coarser deposits between sheets of non-porous beds, thus producing the conditions most favourable for artesian sources as illustrated in the experiments given in my paper (*l.c.* p. 207)—a large sectional area of water-holding deposits at the head of supply, tailing off into beds of less capacity and between impervious beds. If there were any need to do so for the present argument, I think that a strong case might be made for an extension of the early post-Siwalik *bhábar* much beyond the range of the actual *bhábar*. The upper edge was certainly considerably nearer the plains originally than at present; for now it for the most part occurs along the axis of flexure, in contact with middle Siwalik strata, having overlapped the denuded edges of the Siwalik conglomerates; and it seems to me highly probable that in the early stages of Siwalik elevation, when the now buried conglomerates were under active denudation, the resulting *bhábar* may have reached much beyond the present limits of this zone, beneath the finer deposits of the present plains. I do not think that the fact of such depression as contemplated by Herschell or Mr. Fisher would practically have any direct effect upon the conditions of water percolation as originally established in the process of deposition.

16. When I first noticed in 1864 (Memoirs III, pp. 182-5) that there seemed a fair chance for successful artesian borings in the Gangetic plains, although Sir John Herschell's pregnant suggestion was in view (*l.c. p.* 198), I did not then consider the point which we have now shown to have little practical bearing on the question. My recommendation was based on the general aspect of the conditions. In 1867, a definite project for a boring at Ambála was referred to me for opinion. I then referred to a number of successful artesian borings in analogous positions, and quoted them as confirming my originial recommendation.[2] These examples were particularly instructive in showing how little did success depend upon any regularity in the deposits; how, among the promiscuous interlapping of fluviatile deposits, the continuity of water-bearing strata is somehow and in variable degrees sustained. Thus, when it came to the point, my recommendation rested chiefly on instances of success under like conditions, rather than upon theoretical grounds. On the occasion of successful artesian borings at Pondicherry, I again took up the question and discussed it in a more systematic manner in the paper under reference (*supra*, XIV, pt. 3), giving numerous examples. That at Venice may again be referred to with advantage in the present connection. It is in a deltaic area, below a broad *bhábar* zone which rests against disturbed pliocene strata at the foot of the Alps, the features thus in every respect corresponding to those in the case under consideration. The area, too, is one of considerable depression; the boring begins at about sea-level, and several old land

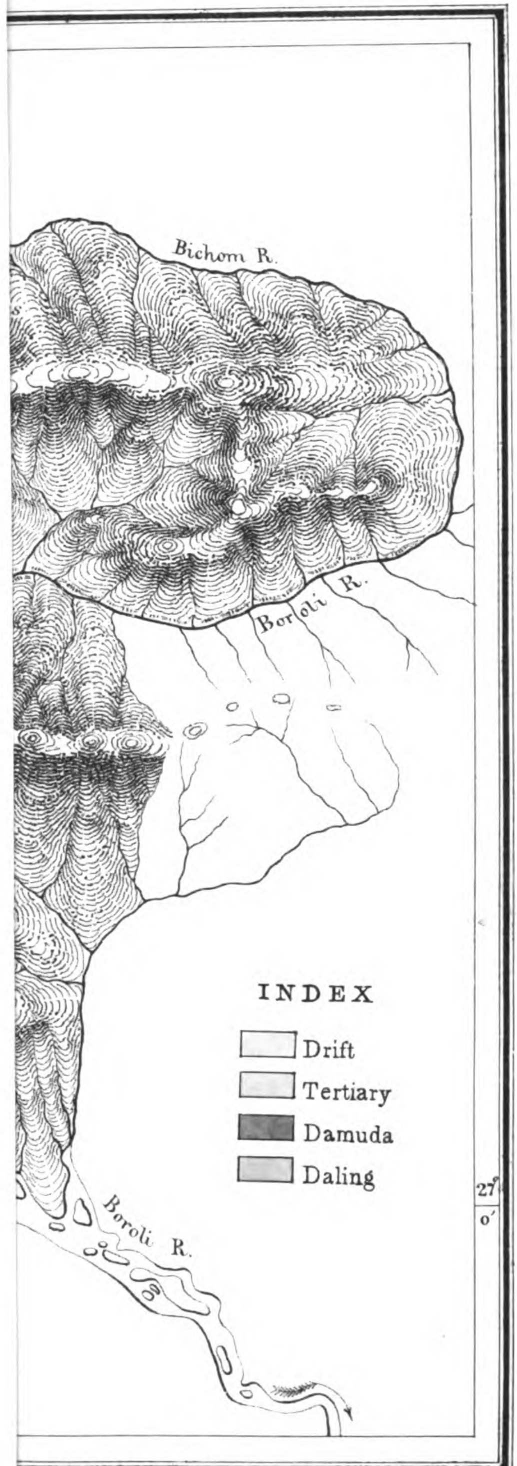
[1] Close to Hardwár, within the mouth of the gorge of the Ganges through the Siwaliks, a bed of stiff clay is seen resting upon coarse boulder gravel. Memoirs, Vol. III, pt. 2, p. 153. In the Siwaliks themselves the outermost (highest) beds seen are alternating clays and coarse conglomerates dipping at 80° towards the plains. *Ibid*, p. 118.

[2] The papers are published in No. 178 of Selections from the Records of the Government of India, Home Department, p. 47.

surfaces were passed through to a depth of 400 feet. No coarse deposits of any kind were struck within the depth explored (422 feet), only clay and sand with the occasional layers of peat that had once formed the land surface. The copious water bed occurred in sand at a depth of 200 feet. The circumstances of the Gangetic plains differ only in respect of magnitude. This is no doubt in itself presumably adverse, owing to the greater friction to be overcome in the percolation of the water stratum. On the other hand, these relative magnitudes are often self-compensating, and it would, I think, be a mistake to decline experiment in a matter of such importance for theoretical reasons of uncertain applicability.

17. After careful reconsideration of the whole case in the light of the rather imaginary difficulty raised by Mr. Oldham, I have to reaffirm my conviction that there is reasonable prospect of success.

18. It is most unfortunate for the cause that the experiments that have so far been made were fixed upon solely on grounds of local need, and not as in any degree favourable sites for testing the conditions. It has been shown above that Ambála is in a position most likely to be out of reach of water-bearing deposits, comparatively near the hills and midway, at a considerable distance, between the great rivers which are the vehicles for such deposits; and now a trial on a large scale is being made at Agra, for which I am in some degree responsible. I could not say there was no chance of success, but I did not fail to say it was about the last place I should choose for a trial boring. In discussing the question with the engineer who was getting up the projects for the water-supply at Agra, my written opinion was as follows:—"Agra is not perhaps the most propitious position for a boring, and if I were starting a series of experimental borings, I would not begin there, because of its much greater proximity to the south margin of the basin, while the water-supply to be expected would, I think, be from the north. Although Agra is now at the lowest point of the basin, the hollow of the original depression was much more to the north, the change being due to the more abundant supply of detritus (by rain and rivers) from the north, and the consequent encroachment and overlap of deposition from that side. Thus the boring at Agra will be in deposits having a different source of origin from those through which the water-supply is expected; and although the strata are contemporaneous and in the same basin, the continuity of porous or non-porous strata, and hence the connected percolation, may not be as free as if the boring were altogether in beds of northern derivation." Subsequently, in answer to a formal reference from the Government of the North-Western Provinces on the subject, I wrote (1st December 1881)—"It only remains for me to say that the grounds of possibility and hope are sufficient to recommend another trial. In order of merit I would choose Bareilly, Shajehanpore, Fyzabad, and Lucknow as propitious positions. Regarding Agra, I have already given an opinion, quoted in Major Jacob's report on the water scheme for that place. Although holding that an artesian spring would not be hopeless there, I was careful to point out that it was by no means a propitious place for a new venture, on account of its great distance from the northern sources and its actual proximity to the southern edge of the basin." It is obvious that the friction difficulty will be at its maximum here, and the free connection with the head of underground water at its minimum. On the


Bichom R.
Boroli R.
INDEX
Drift
Tertiary
Damuda
Daling
Boroli R.
27°
0'

19th of February the boring had attained a depth of 481 feet, with the section given in the following table. The thin bands of sand Nos. 30 and 32 are probably isolated in the clay. The experiment certainly cannot be considered as fairly completed at this depth.

Section of Artesian boring at Agra, 1884-85.

No. of bed.	Thickness of bed.	Depth.	
1	16	16	Loam.
2	10	26	Sand, loamy, with small kankar.
3	10	36	„ loamy.
4	8	44	„ fine.
5	19	63	Clay, loamy.
6	27	90	Sand, loamy (sweet water).
7	20	110	Kankar and sand.
8	29	139	Sand, white, and sandstone (water brackish).
9	5	144	„ white with kankar.
10	22	166	Clay, loamy.
11	58	224	„
12	56	280	„ loamy.
13	16	294	„ and kankar.
14	2′ 6″	296′ 6″	Kankar.
15	1′ 6″	298	Clay, loamy.
16	3′ 6″	301′ 6″	„
17	1	302′ 6″	Kankar.
18	8′ 6″	311	Clay.
19	1	312	Kankar.
20	15	327	Clay.
21	11	338	Sand, loamy.
22	7	345	„ red, and kankar (a little water).
23	15	360	Loam.
24	1′ 6″	361′ 6″	Kankar.
25	18′ 6″	380	Clay and kankar.
26	10	390	„ loamy.
27	4	394	„
28	2	396	Kankar.
29	44	440	Clay.
30	3′ 9″	442′ 9″	Sand running, full of water.
31	23′ 9″	467′ 6″	Clay, loamy.
32	3	470′ 6″	Sand running, full of water; some large angular grains of quartz and felspar.
33	10′ 6″	481	Clay.
34	......	......	Sand (dry), with small ferruginous concretions.

Notes on the Geology *of the* Aka Hills, Assam, *by* TOM D. LATOUCHE, B.A., *Geological Survey of India.* (With a map.)

In December of last year (1883) I obtained permission to accompany the expedition against the Akas, a tribe occupying the Lower Himalayas to the north of Tezpur in Assam, between the Bhutias and Daphlas. Although these hills had not been surveyed before, yet the observations made by Colonel Godwin-Austen in the Daphla hills about 40 miles to the east, and published by him in the Journal of the Asiatic Society of Bengal, Vol. XLIV, Pt. II, had shown a sequence of rocks similar to that found by Mr. Mallet in the Sikkim area to the west (Mem. Geol. Surv., India., Vol. XI, Pt. I), and therefore it was probable that, as the Aka hills are physically continuous with those on either side, the same rocks would be found in them, and this I found to be the case. Representatives of the rocks described by Mr. Mallet as occurring in the Teesta valley, *viz.*, Tertiary, Damuda, and Daling, were found *in situ*, and judging from the number of boulders of gneiss brought down by the rivers crossed during the expedition, there is no doubt that this rock forms a great part of the country to the north of the Daling series.

The first hills met with to the north of Tezpur form a long ridge on the south bank of the Borholi river, rising to 800 or 900 feet above the plains of Balipara. This ridge is of pleistocene age and consists entirely of an unstratified drift of well rolled boulders and pebbles derived from the hills to the north, gneiss and granite being the predominating rocks. Quartzites and hard sandstones from the Damudas and Tertiaries are also common. To the north of the Borholi, following the route taken by the expedition up the Diju stream, similar beds of drift form low hills and terraces on either side of the stream for 7 or 8 miles. This great accumulation of drift is probably the result of torrential action due to the greater extension of the Himalayan glaciers in post-tertiary times.

About 8 miles from the Borholi, the Diju valley becomes narrower, and beds of tertiary rocks are seen *in situ* on the banks of the stream. These are light-grey sandstones, with beds of shale, sometimes carbonaceous, much crushed and locally contorted, dipping to north-east at 55°. Further into the gorge other exposures are seen of micaceous fissile sandstone with shales dipping always at high angles to the north-east and becoming vertical at camp No. 1, about 12 miles from Dijumukh. In a large boulder of the sandstone in the bed of the stream, I noticed a fossil tree trunk about 1 foot in diameter, coated by a layer of lignite one inch thick, but one found no lignite *in situ*, nor did I see any fossils.

At camp No. 1, the path left the Diju and led over a ridge about 1,200 feet above the stream to camp No. 2 on the Maj Borholi. Owing to the dense jungle I could find no sections of the rocks forming the ridge, but the fragments on the path were all of brown ferruginous sandstone.

In the Maj Borholi valley the rocks exposed were entirely different from the soft tertiary sandstones of the Diju, and consisted of hard grey quartzitic sandstones interstratified with carbonaceous shales and seams of coal, the whole much crushed and contorted. A good section was obtained in a small stream running north into the Maj Borholi at camp No. 2. Here the rocks were dipping at high angles to the south, and the following beds were exposed, in descending order :—

		Ft.	Ins.
Light coloured quartzitic sandstones, much jointed	about	20	0
Shales with bands of sandstone 1 to 2 feet thick		45	0
Coal, fairly constant in thickness		1	6
Black shales		8	0
Dark grey sandstone		2	0
Hard dark coloured sandy shales		8	0

		Ft.	Ins.
Coal, thickness variable, much crushed	over	1	0
Light grey coarse quartzite with strings of flaky coal		60	0
Dark coloured sandy shales		5	0
Coarse hard grey quartzitic sandstone	about	8	0
Light coloured shaly sandstone		6	0
Black shales, centre portion very carbonaceous		4	0
Soft grey micaceous sandstone		14	0
Hard dark coloured micaceous sandstone and sandy shales with a thin seam of flaky coal at the base		25	0
Hard grey quartzitic standstone		?	

Above this section slips have occurred in the sides of the gorge, and where the rocks appear again they are so much contorted and crushed that it is impossible to identify the different beds, or to form any correct estimate of the thickness of the whole series. The Borholi above the camp runs along the strike of these beds, and outcrops of carbonaceous shale and coal occur at intervals for about 2 miles up the river; outcrops also occur on the north bank. On the return route from Jamiri to Balukpung, about 8 miles to the west, I was unable to identify this band of coal-bearing rocks with certainty owing to the dense jungle, but near the camp between Jamiri and the Borholi, we crossed some carbonaceous shales on the same line of strike which are probably a part of this series. These coal-bearing rocks are identical in position and composition with the Damudas described by Mr. Mallet in the Sikkim area, and found by Colonel Godwin-Austen to the east in the Daphla hills.

From camp No. 2 the path led over a jungle-covered ridge to the north, rising to 4,000 feet above the Maj Borholi, and descended about 3,000 feet to the Tenga Páni. Blocks of a micaceous slaty schist were common on the path, and in the Tenga Páni this rock was seen *in situ*, striking east and west, and nearly vertical. Some of the beds were very fine-grained and fissile, and might do for roofing slate, but their distance from the plains and the ruggedness of the country between render them practically useless. To the north of the Tenga Páni similar slaty schists form the ridge on which the Aka villages Mahdis and Labris are situated, rising to 6,000 feet above sea level, and extend to the west to and beyond the village of Jamiri, where they are silvery greenish mica schists, sometimes slightly talcose. These rocks are probably the equivalents of the Daling slates and schists of Sikkim, but I nowhere found any dolomitic beds or representatives of the Baxa beds as described by Mr. Mallet. And as I found no sections showing the junction of the Damudas and Dalings, I cannot throw any light upon the question as to which of these series is the older.

As to the practical importance of the coal seams in the Damudas, very little need be said. Even if the seams were thick enough to be worked, and not broken up and crushed as they are, their distance from the plains and the difficulties of transport would prevent their being worked with profit, especially as there are much larger coal-fields in Assam, and more easy of access, which have never been touched as yet. Even in the Teesta valley, where these Damuda beds contain thicker seams of coal close to a line of railway, the attempts to work them have so far resulted in failure, principally owing to the crushed condition in which the coal occurs, and the consequent necessity for a costly process to consolidate it.

Of other mineral products the country appears to contain little or none. The tertiary rocks contain a little lime which is here and there deposited as tufa by streams on the face of cliffs, and doubtless there are layers of lignite, but neither of these exist in sufficient quantity to be of any use.

On the alleged tendency of the Arakán Mud Volcanoes *to burst into eruption most frequently during the rains; by* F. R. MALLET, *Deputy Superintendent, Geological Survey of India.*

On the 10th December 1884 an eruption occurred from one of the Cheduba Mud Volcanoes, concerning which we have not as yet received any information officially. It was, however, witnessed by Captain H. G. Creft, Commander of the British India Steam Navigation Company's vessel *Coconada*, while passing through Cheduba Straits, and, in a letter received from him on the subject, Captain Creft describes the eruption as having been "of very short duration, not more than eight minutes, but while it lasted the flames must have been quite 400 feet, accompanied with large volumes of smoke."

As mentioned in a previous volume,[1] a notion is prevalent amongst the Arakán Islanders that eruptions from the mud volcanoes occur more frequently during the rains than at other times of the year. Were such an idea confined to the islands in question, it might possibly not be worth much investigation, but a very similar one is entertained with reference to the mud volcanoes of Java, which are said to explode most violently in the wet season. The main object held in view in recording the Arakán eruptions is the collection of sufficient materials for putting the truth of such supposed periodicity to the test. To generalise with safety, a far more extended record must be available than exists at present, but, pending the growth of such, it may be of some interest to place together the materials which have been collected up to the present time. Altogether the dates of 13 eruptions are accurately known.

LOCALITY OF VOLCANO.	Date of Eruption.	Reference.
Near Kyauk Pyu	26th Aug. 1833	Vol. XI, p. 197.
Ditto	3-4 A.M., 23rd March 1839	Ditto.
Ditto	11 P.M., 6th Feb. 1843	Ditto.
Submarine, a little S. of False Island	7 or 8 A.M., 26th July 1843	Vol. XI, p. 198.
Submarine, S. ¾ E. from W. Baronga Island	6 or 7 P.M., 2nd Jan. 1845	Ditto.
Near Kyauk Pyu	8-45 P.M., 25th Oct. 1846	Vol. XI, p. 199.
Near Peu-lay-na, Rámri Island	7 A.M., 19th March 1878 [2]	Vol. XII, p. 70.
S. of Cheduba ?	12th March 1879	Vol. XIII, p. 206.
Near centre of Cheduba	8 A.M., 27th Feb. 1881	Vol. XIV, p. 196.
South part of Cheduba	7-55 A.M., 31st Dec. 1881	Vol. XV, p. 141.
Minbyin Circle, Cheduba	23rd March 1883	Vol. XVI, p. 204.
Minbyin Circle, Cheduba (same Vol. as that of 31-12-81).	8 A.M., 28th April 1884	Vol. XVII, p. 142.
Cheduba	10th Dec. 1884	Vol. XVIII, p. 124.

[1] Vols. XI, p. 201, and XII, p. 70.

[2] There is no reason to suppose that eruptions were less frequent between 1846 and 1878 than before and after those dates, the gap being doubtless due merely to the imperfection of the record.

In the following table are given the number of eruptions that occurred in each month, and the average monthly rainfall at Kyauk Pyu (deduced from the observations of 17 years) [1]:—

	Eruptions.	Average Monthly Rainfall.
In January	1	·10
" February	2	·06
" March	4	·30
" April	1	·96
" May	0	10·12
" June	0	41·72
" July	1	46·62
" August	1	39·39
" September	0	21·23
" October	1	10·41
" November	0	4·19
" December	2	·34
TOTAL	13	175·44

From this it appears that, out of an annual rainfall of 175·44 inches, 173·68 inches fall in the seven months between the beginning of May and the end of November, while only 1·76 fall in the five months between the 1st of December and end of April. Of the 13 eruptions 10 occurred during the five dry months, while only three took place during the seven wet ones. The observations, therefore, as far as they go, tend to suggest a conclusion exactly the reverse of that held by the inhabitants of the islands. It is interesting to note in this connection that (as remarked by M. Dubois de Montpéreux)[2] out of six eruptions from the mud volcanoes near the entrance to the sea of Azov, five occurred between the beginning of February and the 10th of May, or at just the time of year when the dates given seem to indicate that eruptions from the Arakán volcanoes are most frequent.

Although scarcely capable of being regarded as more than a curious coincidence, one cannot but notice the large proportion of eruptions which have occurred within an hour or two of sunrise or sunset. At night, and during the hottest hours of the day, when people are less out of doors, the chance of an eruption escaping notice is perhaps somewhat greater than at other times.

Another point attracting the attention is that, while several of the earlier eruptions took place near Kyauk Pyu, nearly all the later ones have burst forth in Cheduba, suggesting that the main focus of activity may have shifted during the last few decades. But the list is so imperfect, and so many eruptions may have escaped record, that any generalisation must be regarded with the greatest caution.

[1] Report on the meteorology of India in 1882, p. 120.
[2] Vol. XI, p. 201. Geological Observer, p. 475.

Analyses of Phosphatic Nodules *and* Rock *from* Mussooree; *by* F. R. MALLET, *Deputy Superintendent, Geological Survey of India.*

In the last volume of the Records[1] an account is given of the discovery, by the Rev. J. Parsons and Dr. Wärth, of phosphatic nodules and rock at Mussooree. Their chemical examination was taken up by my colleague Mr. E. J. Jones, who made qualitative analyses of both materials, and had commenced quantitative ones, when a severe illness obliged him to suspend the work, which he was subsequently unable to resume owing to his leaving Calcutta for work in the field. As soon after my return from furlough as other duties permitted, therefore, I submitted (12 of) the nodules and the rock to quantitative analysis, with the results given below.[2] Mr. Jones' estimations of the phosphoric acid (the only constituent he weighed) agree with those now given within one or two per cent., a result as close as could be expected from the analysis of two different samples. How far the discrepancy (in as far as the relative proportions of alumina and lime are concerned) between the composition inferred from Mr. Jones' qualitative examination, and that given below, should be ascribed to want of equality of composition in the different samples operated upon, and how far to undue reliance being placed on mere qualitative results, which circumstances prevented being checked by quantitative estimations, is perhaps open to question.

	Nodules.	Rock.
Phosphoric anhydride	34·70 = tricalcic phosphate 75·75.	30·16 = tricalcic phosphate 65·84.
Lime	46·42	39·21
Magnesia	·30	·55
Alumina	3·50 (Alumina and Oxide of iron together)	5·58
Oxide of iron		2·68
Soluble silica	·20	·35
Insoluble siliceous matter	9·57 (together)	16·06 (together)
Barium sulphate		
Carbonaceous matter	·98	·92
Loss on heating to 100C°	·32	·53
Carbonic acid, sulphuric anhydride, fluorine, undet, and loss.	4·01	3·96
	100·00	100·00

The amount of carbonic acid and fluorine in the nodules is greater than in the rock, only traces of fluorine occurring in the latter. This element was not estimated separately, and only a portion is included amongst the last-mentioned constituents. There is a somewhat considerable quantity of barium sulphate in the rock, much more than in the nodules.

Both substances, and especially the nodules, are of high standard as materials for the manufacture of artificial manure.

[1] Page 198.

[2] It is unfortunate that the estimation of lime, given at page 64, which was made at a time when I was too fully occupied to undertake, or fully supervise the work, was published. The result, owing to the method employed, was not supposed to give more than a rough approximation, although, of course, the great discrepancy between the amount then obtained and that given below must be due to some error in analysis. For this, however, the operator is in no way blameable, as he was quite a beginner at such work.

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Two fossil turtles, lower eocene; one from 10 ft. below the coal at Nila, Salt Range, Punjab; and the other, from above coal outcrop at Hillanwala near Dandot, Punjab.

PRESENTED BY DR. H. WARTH.

Four specimens of fossil plants from Giridih, Bengal.

PRESENTED BY MR. J. WOOD-MASON.

Specimen of a mottled quartzite from the Kharakpur hills, Monghyr.

PRESENTED BY MR. D. MORIES, DURBHANGA.

Two specimens of native gold in calcspar, one with Malachite, said to be from one of the Khetri mines, Rajputana.

PRESENTED BY DR. J. R. STRATTON, POLITICAL AGENT, JEYPUR.

Two specimens of grindstones of Barákar sandstone, one measuring 3′ 6″ diameter and 5″ thick, and the other 10″ diameter and 2″ thick, quarried at Barákar.

PRESENTED BY THE BENGAL STONE CO. LD., HOWRAH.

A specimen of blende from Kashmir.

PRESENTED BY LIEUT.-COL. SIR OLIVER ST. JOHN, K.C.S.I., R.E., KASHMIR.

Specimens of mica, garnet, epidote, egeran, &c., from the Tonk district.

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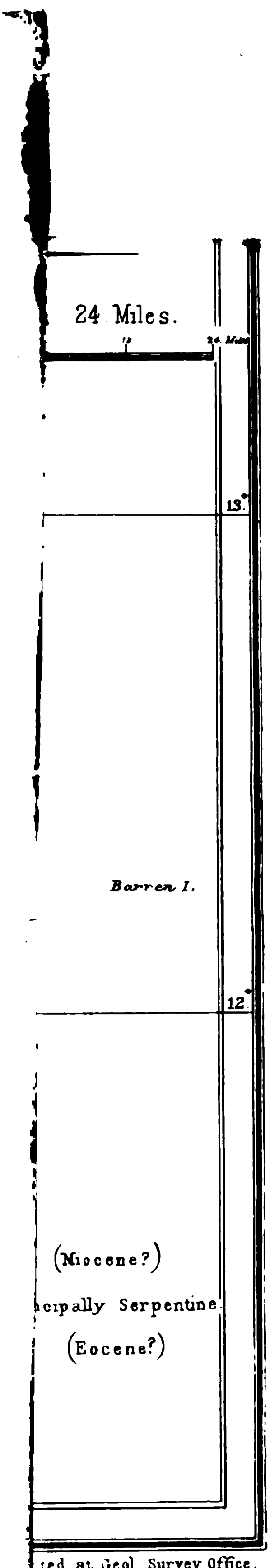
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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1885. [August.

Notes on the Geology *of the* Andaman Islands, *by* R. D. OLDHAM, A.R.S.M. *Geological Survey of India.* (With a map.)

Geography and general features.

The Andaman Islands form a small group extending in a nearly north and south direction, between the parallels of 10° 30′ and 13° 30′ North Latitude; they, or at least the four or five northern islands, form a range of low hills which, if we look merely to the height above sea level, nowhere rise to more than 2,500 feet, but if we regard the continuation of the land slope into the sea on either side, rise to the very respectable elevation of over 9,000 feet. They are described in the report of the Andaman Committee, where it is stated that "the highest land wherever seen is on the eastern side," and that "the watershed is therefore chiefly towards the west, and consequently it is on that side of the island that the marshy localities will most probably be found." The first statement is true enough, but I very much doubt the accuracy of the second. In the South Andaman the greater part of the drainage flows into the creeks, which ultimately lead off to the eastern shore, and on the Middle and North Andaman, where the creeks are not to be found, the bulk of the drainage seems to flow through gaps in the eastern range.

Previous observers: Helfer.

2. Though the various publications, papers, and notes referring to the Andaman Islands would make a lengthy list, there are but few among them which contain any references to the geology of the Islands. The first of these, arranging them according to their dates, is to be found in the journals of Dr. J. W. Helfer,[1] who visited the islands in 1840. His journal, which is all that remains, for he was killed by the Andamanese, contains but few references to geology. He visited one of the islands

[1] Dr. Johann Wilhelm Helfer's gedruckte und ungedruckte Schriften über die Tenasserim Provinzen, den Mergui Archipel und die Andamanen-Inseln. *Mittheil. k.k. Geogr. Gesellschaft.* III pp. 166—390 (1859).

of the Archipelago (probably Outram Island) and a small island which seems to have been the Middle Button, sailed through Homfray's Strait[1] and then round the north of the island till he was killed on the east coast, either at Cadell Bay or some spot in that neighbourhood. The only geological observations refer to the Archipelago and the Middle Button, the rocks of which he classes as "Quadersandstein."

Quigley.

The next reference I can find is contained in a pamphlet by a Mr. J. H. Quigley,[2] who visited Interview Island in a schooner called the *Sea Serpent*, which had been chartered by a friend of his to recover what was worth saving from the wreck of the barque *Emily*. His account has been stigmatized by Dr. Mouat as only worthy of a Munchhausen, but, though abundantly adorned (?) with what are meant for rhetorical flourishes which, however, give place to a more moderate tone when speaking of what he actually saw, it is far more entertaining, and, as subsequent knowledge has shown, more trustworthy on the whole than the dreary pages of the learned doctor's ponderous tome. Mr. Quigley's "geological observations" are just such as a man ignorant of geology might well have made, but such as he could not possibly have invented; all that can be made of them is that the greater part of Interview Island consists of sedimentary formations, but that the extreme west (*sic* in original, probably a misprint) is composed of igneous rocks described as "granite and greenstone," terms that may safely be translated diorite and serpentine.

Andamàn Committee.

The report[3] of the Committee appointed in 1857 to select a site for a penal settlement in the Andamans, contains but one single observation bearing on geology; in paragraph 41 it is stated that limestone "of the finest quality" is obtainable on a promontory a few miles north of Long Island.

Kurz.

Prefaced to a report on the vegetation of the Andamans by Dr. Kurz are some notes on the geology or more properly petrography of the South Andaman; he also gives some important observations as to the recent sinking of the islands, to which I shall refer later on.

Stoliczka.

In 1868, a short note by Dr. Stoliczka[4] was read before the Geological Institute of Vienna; being merely an extract from a private letter it does not contain any detailed observations, but refers to the general question of the correlation of the beds seen near Port Blair, to which he ascribes an eocene age.

[1] As this is, so far as I know, the only instance of these straits having been navigated by anything larger than a steam launch, it may be interesting to give the reasons on which I base this supposition; they are as follows:—(1) Sailing "north-westwards" from the Button he passed through a group of islands and found himself almost shut in by land; (2) he mentions very rapid currents in the straits; and (3) he describes the western outlet as also surrounded by islands with a very narrow passage out to the west. All these three fit in with Hemfray's Straits, while none of them would be applicable to the Middle Straits (*Helfer, loc. cit.*, pp. 384—385).

[2] Wanderings in the Islands of Interview (Andaman), Little and Great Coco. *Pmpht.*, Moulmein, 1850.

[3] Selections from the Records of the Government of India, No. 25, pp. 4—28 (1859).

[4] Die Andamanen Inseln, Assam, u. s. w. (Aus einem Briefe an Herrn Director v. Haeur, de dato, Calcutta, 30th März) *Verhand. k.k, geol. Reichsanstalt.*, No. 9, p. 192 (1868).

St. John.

In the Transactions of the Ethnological Society for 1869 there is a note[1] on the Andaman Islands by Lieutenant S. A. St. John, which contains some petrographical statements; he went on a trip in the S. S. *Diana* to search for limestone, and mentions the occurrence on the shore west of Long Island of what proved to be "the common igneous rock of former acquaintance," which, from its "light colour," might have been taken for limestone by one who had not landed to examine it. I cannot understand this sentence; can he have hit upon one of the pale clays, locally indurated, of the Archipelago series?

Stoliczka.

The Proceedings of the Asiatic Society of Bengal for 1870 contain another paper[2] by Dr. Stoliczka on the Kgökkenmöddings of the Andamans which contains a passage referring to the possibility of recent changes of level in the islands.

Ball.

The Journal of the same Society for that year contains two papers[3] by Mr. V. Ball on the geology of the vicinity of Port Blair and of Nancowry Harbour, in which he gives some geological details and essays to correlate the rocks of the Andaman and Nicobar Islands.

Mallet.

Since this date I know of nothing further relating to the geology of the Andamans until the recent publication of two[4] notices by Mr. F. R. Mallet in the Records of the Geological Survey of India.

Sedimentary formations.

Passing now to my own observations, I can only distinguish with certainty two sedimentary formations in the Andaman Islands, which I propose to call the Port Blair and Archipelago series respectively.

Port Blair series.

The Port Blair series consists principally of firm grey sandstone and interbedded slaty shales, not unfrequently containing nests of coaly matter, and, occasionally, beds of conglomerate and pale grey limestone as subsidiary members. The sandstone is the characteristic rock of the series, it is generally if not always non-calcareous and is easily recognized, where exposed between tidemarks, by its peculiar mode of weathering: owing to irregular distribution of the cementing material, bosses of harder stone are left standing up above the general level of the rock, and these bosses are invariably irregularly honeycombed by the solvent action of the sea water.

[1] Notes on the Andaman Islands by Admiral Sir Edward Belcher (from notes by Lieutenant S. A. St. John, H. M.'s 60th Regiment). *Trans. Ethnol. Soc. (new series)*, V, pp. 40—49 (1867).

[2] Note on the Kgökkenmöddings of the Andaman Islands, by Dr. F. Stoliczka. *Proc. As. Soc. Bengal*, 1870, pp. 13—23.

[3] Brief notes on the geology and on the Fauna in the neighbourhood of Nancowry Harbour, Nicobar Islands, by V. Ball, B.A., Geological Survey of India. *Journ. As. Soc., Bengal*, XXXIX, pp. 25—27 (1870). Notes on the geology of the vicinity of Port Blair, Andaman Islands, by V. Ball, B.A., Geological Survey of India. *ibid*, pp. 231—243 (1870).

[4] On Native Lead from Moulmein and Chromite from the Andaman Islands, by F. R. Mallet, Deputy Superintendent, Geological Survey of India. *Rec. G. S. I.*, Vol. XVI, 203 (1883). On some mineral resources of the Andaman Islands in the neighbourhood of Port Blair, by F. R. Mallet, Deputy Superintendent, Geological Survey of India. *Rec. G. S. I.*, Vol. XVII, pp. 79—86 (1884).

Possible older series.

In several places I found red and green jaspery beds very similar to what occur in Manipur and Burma, but I was unable to determine whether any of these belonged to an older series or no. In part at least they seem to belong to the same series as the sandstones and shales, in the midst of which they may be found cropping out, but it is by no means impossible that some of them belong to an older series, for, on the east coast of the South Andaman, close to the boundaries of the serpentine south of Shoal Bay, I found great banks of conglomerate containing pebbles of similar jaspery rock; it is of course possible that this conglomerate is newer than the sandstone, but the fact that, though found close to the serpentine, it contains no pebbles of that rock, indicates that it is probably of earlier date than the serpentine intrusions, and consequently probably of the same age as the Port Blair series.

Volcanic rocks.

On Entry Island and again in a small bay, not marked on the marine chart, immediately south of Port Meadows, I found beds of volcanic origin. In the middle of the small bay just mentioned a square rock composed of a breccia of pale-green felsite cemented by a matrix of felsitic ash stands out of the water, and on Entry Island, among a series of rocks indurated and contorted so as to baffle description, there are some beds full of angular fragments, and apparently of volcanic origin. The age of these is difficult to determine; they seem to pass northwards into beds among which jaspery slate and limestone are to be found, and at the northern extremity of the island there is some intrusive serpentine, but at the southern end of the island near the top of the section, if I read it aright, I found in a bed of sandstone an isolated boulder, about a foot long, of a serpentinous rock, evidently derived from the serpentine intrusion. On the whole, it is probable that these are of later date than the Port Blair sandstones.

Chatham Island.

Before passing on to the next series, I must mention one very peculiar rock which is exposed on Chatham Island, and which I have not seen elsewhere. On the south shore of the island, immediately east of the saw-mill, there is an exposure of sandstone, through which are scattered blocks of red and green slatey rock; these, as is shown by their angular outline and lamination, quite independent of, and divergent from that of the sandstone matrix, are evidently fragments of some pre-existing rock. It is difficult to explain their presence here; in the absence of any signs of volcanic action in the immediate neighbourhood, one would naturally turn to glacial agency; yet the apparently isolated nature of the phenomenon is against this explanation, while the fragments are too numerous, and scattered over too large a surface, for them to be satisfactorily explained by any theory of flotation by driftwood.[1]

Archipelago series.

The newer series, which I have called the Archipelago series, as the whole of the islands of the Archipelago are formed by it, consists typically of soft limestones formed of coral and shell-sand, soft calcareous sandstones and soft white clays, with occasionally a band of conglomerate the pebbles of which seem originally to have been coral, though no structure is now discernible. These beds seem to cover a large area in the

[1] *Confer* Theobald's description of some beds belonging to the axial (triassic) group. *Mem. G. S. I.*, Vol. X., p. 127 (1873).

Andamans, but I shall not here enter into the discussion of their geographical distribution.

Sandstones of Craggy Island.

On Craggy Island, I found a somewhat peculiar rock; it was a soft bedded very calcareous sandstone; the calcareous cement was irregularly distributed, forming spheroidal masses of harder rock which stood out from the general surface of the cliff, and this, combined with strings of small pebbles scattered through the beds, gave the rock an appearance very much resembling that of many of the Siwalik sandstones. Some of the pebbles were of serpentine, so that the rock is almost certainly of later date than the Port Blair series, yet it may be remarked that where exposed between tide marks, the projecting bosses weather away in a manner which feebly imitates the honeycombing of the very much more prominent knobs to be seen at Port Blair.

And south of Port Meadows.

There is only one other place where I have seen a similar rock in the Andamans, and that was on a rocky point a short way south of Port Meadows. I did not here notice any serpentine pebbles, but the position of the rock would lead one to associate it with the volcanic beds which, as I have mentioned above, are probably of more recent age than the Port Blair series. It is not impossible that the sandstones just referred to may belong to the Archipelago series.

Cinque Islands.

The Cinque Islands consist principally of intrusive rock of the serpentine series, but there are also some metamorphosed and indurated sedimentary beds; of these some are siliceous, but for the most part they are calcareous, the most remarkable form being a green chloritic or serpentinous matrix with numerous granules of crystalline calcite scattered through it; the rounded outlines of these granules seem to be due to attrition, and the crystalline structure to subsequent metamorphism. These rocks did not seem to me to belong to the Port Blair, but to the Archipelago, series, and at the first blush it would seem as if they had been metamorphosed by the intrusion of the serpentine; fortunately however at one or two places, and more especially on the eastern face of the southern island close to its northern end, there are exposures of a conglomeratic bed, in which the pebbles are of serpentine, and the matrix is fine-grained and very serpentinous. This conglomerate, both from its position and induration, belongs to the same series as the other sedimentary rocks of the island, and proves that they are of later date than the serpentine intrusion, and that in all probability their metamorphism is due to the contortion they have locally undergone. The conglomerate just mentioned is a curious bed, not of the type commonly known as conglomerate, but exhibits that structure, usually considered due to the action of floating ice, which is seen in the boulder bed of the Talchirs, or the Blaini conglomerate of the Himalayas. The matrix is, or rather was originally, a fine mud or clay, and through it the pebbles are scattered, not touching each other, but each isolated in the matrix; I have seen a similar bed of presumably the same age, though showing no signs of alteration, in a very similar position to the east of the Nijaong village in the harbour of Nancowry, but here the fragments were angular, not, as on the Cinque, rounded in outline.

Intrusive rocks.

As regards the intrusive rocks of the Andamans I have little to say; they are similar to those of Manipur and Burma to the north and of the Nicobars to the south, and, as far as I could judge from the manner of their occurrence, of certainly later date than the Port Blair series, the only section which seems to throw any doubt on this conclusion being that described above of the sandstones on Craggy Island. I have followed my predecessors in calling these rocks serpentine, that being the most prominent or remarkable form which they take, but they not infrequently pass into crystalline diorite or gabbro.

Two distinct formations.

It may seem strange that, before passing on to consider the correlation of these series, it should be necessary to discuss whether they really belong to distinct formations, or are merely local petrological variations of each other, but, as will presently be seen, such is the case. As regards the Andamans, I have no doubt that they are really two distinct formations, for in degree of induration and mineralogical composition they are as contrasting as could well be, nor have I seen any signs of transition from one type to the other (if we except the sandstones of Craggy Island) and in the Middle Andaman, where I saw the soft limestones of the Archipelago, and the hard grey sandstones of the Port Blair series within a few miles of each other; they each maintained their especial characteristics unchanged. While if my identification of the altered sedimentary rocks of the Cinque Islands with the Archipelago series is correct, they must be two distinct formations, one older, the other newer, than the serpentine intrusions.

Homotaxis of the beds.

In investigating the homotaxis of these beds, we may approach the question from three points of view, and determine the age of the beds either by the internal evidence of fossils, by connecting them with the known rocks of the Arracan Yoma, or by connecting them, through the Nicobars, with beds of known age in Java.

Fossils.

As regards the first, we have nothing beyond Dr. Stoliczka's statement[1] that he observed "at the north-east end of Ross Island several specimens of a Pecten, a small Cytherea-like shell, and fragments of Oysters, which fossils prove that the deposits are marine, and the aspect of these fossils is undoubtedly a tertiary one." I regret to have to say that though I searched the locality mentioned, I did not succeed in finding, either there or elsewhere, any trace of a fossil other than a few fragments of lignite.

Relations with the Nicobar beds.

In attempting to ascertain the age of the Andaman rocks by tracing them southwards through the Nicobars, we are at once landed into a difficulty through a conflict of authorities.[2]

[1] *Journ. As. Soc., Beng.*, XXXIX, p. 231 (*footnote*), 1870.

[2] Die Nicobarischen Inseln. Eine geographische Skizze, mit specieller Berücksichtung der Geognosie von *Dr. Phil. H. Rink*. Kopenhagen, 1847. *Translated and printed in* Selections from the Records of the Government of India, LXXVII, pp. 109-153.

Beiträge zur Geologie und physickalischen Geographie der Nicobar Inseln.—Geologischen Beobachtungen von Dr. Ferdinand von Hochstetter. Reise der österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859. Geologischer Theil, II, pp. 85—112 (Wien. 1866). *Translated and printed (in part), Rec. G. S. I.*, IV, pp. 59—73 (1870). *Reprinted* Selections from the Records of the Government of India, LXXVII, pp. 208—229.

For our information as to the rocks of the Nicobars, we have to rely almost entirely on the published papers by Drs. Rink and Hochstetter. The former of these describes the rocks of the Nicobars as belonging to three distinct formations, classed in order of their ages as (1) the brown coal formation; (2) the Plutonic rocks; (3) the older alluvium. The brown coal formation is confined to Katchal and the southern islands, while the "older alluvium" is only found on the islands of Nancowry, Trinkat, Camorta, and those to the north. Dr. F. von Hoschstetter, on the other hand, maintains that the "brown-coal formation" and the "older alluvium" of Rink are but petrologically different products of the same period of deposition, and that they are both of later date than the serpentine intrusions.

In his note on the geology of the neighbourhood of Nancowry harbour,[1] Mr. V. Ball states it as his opinion, that the sandstones of Rink are the same as those of Port Blair, but does not attempt to decide between the widely divergent opinions of Rink and Hochstetter.

"Older alluvium" of Rink represents Archipelago series.

In discussing this subject I may begin by stating it as my opinion, derived from personal examination of both, that the "Older alluvium" of Rink, and my Archipelago series, are most indubitably of the same age. As Mr. Ball has pointed out, Rink's name is utterly inappropriate if the word alluvium is to have any fixed value whatever in geology; the beds of which it is composed have been contorted and disturbed, and occasionally may be seen tilted on end. They are undoubtedly of later date than the serpentine intrusion, and agree very closely in petrographical characters with those of the Andaman Archipelago, even to the occurrence of clays containing polycistinœ in both regions and of iron sand on the Car-Nicobar, while iron sand was noticed by Dr. Helfer on the Middle Andaman, and is also found on Havelock Island.[2]

Difficulty regarding the sandstones.

As regards the sandstones, the matter is not so easily settled; if Dr. Rink has correctly determined the relative ages of the sandstones and the serpentine intrusions, Dr. Hochstetter must necessarily be mistaken in supposing that they are merely petrographically different members of the same series as the soft calcareous and argillaceous beds of the so-called older alluvium. The only direct evidence which Dr. Rink adduces as to the relative ages of the sandstones and the serpentine series is a section[3] on the western side of Teressa Island, where he saw a small patch of the sandstone, of the same type as that of the southern islands, only slightly hardened by the plutonic rocks which form veins in it. Here everything depends on the correctness of the correlation of this sandstone with that of the southern islands, a correlation which is certainly supported by Mr. Ball's identification of the latter with the sandstones of Port Blair. The latter observer gives no reasons, beyond the presence of fragments of driftwood and impressions of

[1] Brief notes on the Geology and on the Fauna in the neighbourhood of Nancowry Harbour, Nicobar Islands, by V. Ball, B.A., Geol. Surv. of India. *Journ. As. Soc., Beng.*, XXXIX, pp. 25—37.

[2] In the first and last case, and presumably in the second also, the so-called "iron sand" was magnetic oxide of iron; for a reference to the Havelock Island sand, see *Rec. G. S. I.*, Vol. XVIII, 83 (1884).

[3] Dic Nikobarischen Inseln, p. 56. Selections from the Records of the Government of India, LXXVII, p. 130.

plants resembling fucoids in both, for the identification, though it was presumably based on personal observation. On the other hand, there are not wanting indications that both these observers may have been mistaken, for Dr. Rink's description of the sandstones of the Little Nicobar, which he takes as the typical exposure is certainly very unlike that of any beds I know in the Port Blair series; he describes[1] both sandstones and interbedded clays as calcareous, and particularly mentions that the former were soft, and that the calcareous matter is irregularly distributed, forming spheroidal masses of harder rock which are left projecting from the general surface of the cliff—in fact the description agrees in every particular, except the absence of pebbles, with the sandstones on Craggy Island, in which I found pebbles of serpentine and which are consequently almost certainly of later date than the Port Blair sandstones. The whole question is shrouded in difficulty and will not be answered satisfactorily without a systematic survey of the islands.

Relations of Andaman and Javan beds.

Passing southwards into Java and Sumatra, there are intrusive serpentine and soft white clays identical with those of the Nicobars. Dr. Hochstetter[2] describes the sedimentary series of Java as consisting of (1) a lower coal-bearing group of quartzose non-calcareous sandstones and slate clay with seams of workable coal, in which marine fossils are very rare or absent; (2) an upper group of soft calcareous sandstones, plastic clay slates, and argillaceous marls with trachytic tufas conglomerate and breccias, containing numerous marine fossils and fragments of drift wood, but no workable coal. These rocks were originally classed by Hochstetter[3] as eocene, on account of the supposed discovery of nummulites in them, but according to Von Richthofen,[4] the so-called nummulites are in reality orbitolites, and a collection of fossils from the upper beds was examined by Mr. Jenkins,[5] who pronounced them to be of miocene, or later age. The lower series may be distinct from the upper, and of eocene age as Dr. Hochstetter supposes, and in that case is very likely a representative of the Port Blair series.

Relations of Andaman and Arracan beds.

In tracing the Andaman rocks northwards to Burma, we have little difficulty in identifying the Port Blair series with the Negrais rocks of Theobald.[6] Not only do they resemble each other in the petrographical features and relative proportions of

[1] Die Nikobarischen Inseln, p. 43. Selections from the Records of the Government of India, LXXVII, p. 126.

[2] Geologische Ausflüge auf Java. Reise der österreischen Fregatte Novara um die Erde in den Jahren 1857, 1858. 1859, Geologischer Theil Band II. Geologische Beobachtungen von Dr. Ferdinand von Hochstetter, pp. 113—152 (Wien 1866).

[3] Nachrichten über die Wirksamkeit der Ingenieure für des Bergwesen in Neiderländisch—Indien. Von Dr. Ferdinand Hochstetter. *Jahrbuch. K. K. Geol. Reichsanstalt* IX, pp. 277—294 (1858).

[4] Bericht über einen Ausflug in Java. *Zeitschrift der Deutschen Geol. Gesellschaft* XIV, pp. 327—356, 1862.

Über das Vorkommen von Nummulitenformation auf Japan und den Phillipinen. *Ibid.* 357—368.

[5] On some Tertiary Mollusca from Mount Sela in the Island of Java, by H. M. Jenkins, Esq., F. G. S., with a description of a new coral from the same locality, and a note on the Scindian fossil corals by P. Martin Duncan, M. B., F. G. S. *Quart. Journ., Geol. Soc.*, XX, pp. 45—73 (1864).

[6] *Mem. G. S. I.*, Vol. X, 110—123 (1873).

their individual members, but the peculiar mode of weathering where exposed between tide marks, which I have remarked in the former, is matched by the sandstones of the Negrais group, which have been described as usually presenting, when seen on the sea beach, a—"honeycombed or cancellated appearance, the result of a peculiar mode of weathering."[1] Unfortunately the age of the Negrais rocks cannot be determined with accuracy, but they are believed to underlie and be associated with some beds of known nummulitic age, so that we may class the Port Blair rocks as eocene or slightly older.

General conclusion.

Thus, whatever line we follow, we are brought up to the same conclusion, *viz.*, that the Port Blair series is probably of early tertiary, or possibly late cretaceous age, and by tracing them southwards, we find that the rocks of the Archipelago series are probably of miocene age or even newer.

Changes of level.

Since the publication of Kurz's Report on the vegetation of the Andamans, it has been an accepted fact that the Andaman Islands are, and have been, during recent times, undergoing subsidence. It was difficult to conceive how this could be the case, for the Arracan coast to the north and the Nicobar Islands to the south, between which the Andamans form the connecting link, are both fringed by raised beaches which show that they have recently been elevated, but the observations recorded by Mr. Kurz were so unanswerable that they were allowed to override the argument from analogy.

Evidence of depression.

Mr. Kurz's conclusions were based principally on the fact that he found the stumps of trees, belonging to species which only grow above high-water mark and beyond the reach of salt-water, in the mangrove swamps and on the sea shore, while, as corroborative evidence, he adduces the facts that according to the report of the Andaman Committee the sea had encroached some 40 or 50 feet since the first settlement on Chatham Island, Port Cornwallis, and that "Lieutenant Jameson of Chatham Island has informed me that a similar encroachment of the sea is taking place at that Island in Port Blair." As regards the latter point, there is no evidence that the "encroachment" of the sea at Port Cornwallis was due to subsidence, and as far as can be judged by the lithograph in the report of the Andaman Committee, and the woodcut in Dr. Mouat's book, both taken from a photograph, I should be inclined to look upon it as a case of encroachment by erosion of the sea shore and not by subsidence. The evidence of the trees is, however, almost conclusive, for the only explanation possible, apart from an outward set of the soil towards the sea, such as is known to take place under certain circumstances, is that the land is sinking, and I can myself produce an observation which supports this conclusion. The large bay on the north-east coast of Havelock Island is for the most part fringed with low lying land, next to the beach this rises some 4 or 5 feet above high-water mark, but in many places behind this it sinks to form a hollow, and then rises again to the same level as the outer ridge, or rather higher. The whole of this low land is covered with forest, but wherever there is one of the hollows just mentioned, there the forest trees are all dead, and the soil is often moist with salt-water; the soil of these low lying patches must have once

[1] *Loc. cit.*, p. 117.

been dry, like that where the forest is still growing, and the uniformity in size of the dead and the living trees shows that in all probability several generations have lived and died on rise and in hollow alike, until, as the land gradually subsided, the sea-water rose in the soil of the hollows and the trees succumbed to its fatal influence.

Raised beaches, South Andaman.

We may therefore take it as proved that the Andamans are at the present day gradually sinking, but there is ample evidence in the raised beaches that fringe the shores of the Andamans, that in the immediate past elevation has exceeded subsidence. These raised beaches have not, so far as I know, been mentioned by any previous observer, but are conspicuous enough, especially on the islands of the Archipelago. At Port Blair itself there is a small terrace at the north-eastern corner of Chatham Island; it has been enlarged artificially to form a site for the bungalow of the officer in charge of the island, but appears to be in part a raised terrace of marine erosion. A similar terrace may be seen north of the harbour where the road from North Point to North Corbyn's Cove runs in places on a terrace separating the steep hill side from the sea shore. In a small cove east of Perij, on the southern side of Shoal Bay, there is a narrow terrace, clothed with forest, from whose inner limit the hill rises in a bare, almost vertical, face of rock which could not have been formed, in this position at least, by any other means than marine denudation. Along the east coast of the South Andaman this raised beach can be seen forming a terrace, from a few yards to over half a mile in width in almost every bay. Apart from the theory that it is raised sea beach, the only one supposition on which this terrace could be accounted for is, that it is due to a gradual encroachment of the land on the sea, either through the action of vegetation in catching the wind-blown sand, and so raising the surface above extreme sea-level, or by the action of the waves which during storms might throw up sand and shingle far above the level which the sea would otherwise reach; the first supposition is inconsistent with the fact that shells and fragments of coral of considerable size may be found lying about on the forest-clad surface of the terraces in positions where they cannot be accounted for by either human or crustacean agency, while the facts that the forest trees are as large and old on the extreme edge of the terrace as further inland, and that the seaward margin often cuts into a miniature cliff of 3 or 4 feet high, is everywhere fringed with fallen and falling trees and tangles of roots from which the soil has been washed away, conclusively prove that so far from there being any extension of the land surface, it is being encroached upon by the destructive action of the waves.

Archipelago. Havelock Island.

The terrace is well developed in the Andaman Archipelago, especially on the west coast of Havelock Island, where the hills rise with a precipitous face out of the forest, being now separated from the sea by a stretch of dry land; but at one place, where the sea has cut away this terrace and formed a low cliff, a bank of coral and shingle, evidently of littoral origin, was seen resting on soft calcareous sandstone, well above the reach of even the highest tides.

Outram and Lawrence Islands.

The beach I have described is everywhere low, and not more than 6 to 8 feet above mean sea-level, but there are indications of a terrace of marine erosion, corresponding to that seen on the Car-Nicobar and elsewhere at about 30—40 feet above the sea;

both Outram and Lawrence Islands, and a large part of the other islands of the Archipelago, are low and flat-topped in outline, so that it would seem that they were plateaux—old plains of marine denudation.

Commencement of depression being of recent date.

There is not wanting evidence that the depression of the island, which is going on at the present time, has but recently commenced, for the kitchen-middens of the Andamanese are in positions where a very slight subsidence would submerge them, and the time that they represent may be understood by the section of one which I examined near Port Mouat; it was 12 feet in thickness in the centre, and in this there was a bed 1 foot 6 inches thick of vegetable mould, with shells scattered through it, marking a period when generations of shrubs and plants must have lived and died while the midden was abandoned, or only occasionally visited. This was doubtless started on a rock rising among the mangroves and gradually extended on to the mud; and it is a noteworthy fact that the surface of the mud under the shells does not appreciably differ from the general level of the mud outside. It shows that at a time when probably not one-sixteenth of the present bulk of the midden had accumulated, the level of the mangrove swamps was very nearly what is now. Had the soil surrounding the rock on which the midden was started been well clear of the influence of the tides, it would certainly not have supported a growth of mangrove, and so far as my experience has shown me, would consequently have been of a very different character to what is actually found, while, had the surface of the mangrove swamp stood much lower than what it now is, the mud would certainly have risen above what was the base of the kitchen-midden in its earlier stages; in other words the surface of the mangrove swamp was then very nearly at the highest level it could reach, and as this is limited by the height to which the tides rise, it shows that during the time represented by the formation of this midden—a period which must be measured by centuries, if not by tens of centuries—the land has not appreciably altered its level relatively to the sea.

NOTE.—On the map, I have incorporated Mr. Kurz's observations in part, but have not followed his maps in extending the Port Blair sandstones to the western shore of the Islands, as I feel sure that the rocks there must be largely of later date; I have coloured the islands off the two entrances to Homfray's Straits from information derived from Dr. Helfer's Diaries. Interview Island, I was informed by Mr. H. Godwin-Austen, is composed of the same rocks as are seen at Nancowry, and the two Sentinel islands have been described to me as being composed of coral; this, as I found from experience in the Nicobar Islands, almost certainly refers to the fantastical weathering of the limestones of the Archipelago series.

Note on a third species *of* Merycopotamus, *by* R. LYDEKKER, B.A., F.G.S., F.Z.S.

Among the collection presented to the British Museum by Mr. Charles Falconer on the death of Dr. Falconer, the writer has recently identified the tooth from Kushálgarh near Attock noticed in 'Falconer's Palæontological Memoirs,' Vol. I, p. 416, under the name of *Merycopotamus nanus*, and also the two smaller teeth noticed on the preceding page under the name of *Tapirus pentapotamiæ*. As these specimens are undoubtedly the property of the Geological Survey of India, the Director of the British Museum has consented to their transference to the Indian Museum.

With regard to the *Merycopotamus* tooth, which is the third right upper true molar, there can be no doubt of its specific distinctness from *M. dissimilis* and *M. nanus*, Lydekker,[1] both on account of its inferior size, and marked difference in structure. Its length is 0·75, and its width 0·8 inch; and the external surface of the outer columns is less inwardly inclined, thus causing the tooth to assume a character more approaching that of *Chæromeryx*, which the writer[2] is now inclined to regard as allied to *Dichodon*: the present specimen thus indicating an affinity between the latter and *Merycopotamus*. It is intended to figure the Kushálgarh *Merycopotamus* tooth in the Introduction to the 3rd volume of the 10th series of the 'Palæontologia Indica'; and the specific name *M. pusillus* is proposed for it.

The two small teeth noticed by Falconer as *Tapirus pentapotamiæ* are the fourth upper premolars of both sides belonging to the same individual as the upper true molar noticed by Falconer in the same passage and figured by the present writer in the 'Palæontologia Indica,' ser. 10, Vol. III, pl. VIII, fig. 17, under the name of *Listriodon pentapotamiæ* (Falc.).

Some observations on Percolation *as affected by* Current, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

In a previous paper (*supra*, XIV, p. 228), in discussing the possible water-head available for artesian sources in the Gangetic plains, I quoted an observation by Lieutenant W. E. Baker (one of the early collectors of Siwalik fossils, afterwards Sir W. E. Baker), showing a striking apparent defect of percolation in very coarse deposits close to a great stream. The passage is as follows:—"An account is given by Lieutenant W. E. Baker (Engineers) of the sinking of a well at Ráyanwála, near the base of the Siwaliks. It is 3 miles below Hátnikúnd, where the deposits terminate within the open gorge of the river, but the elevation is still 1,052 feet. The surface is less than 10 feet over the water in the river, and only 60 yards from the edge, but the well was sunk through boulders gravel and sand for 60 feet without finding water. Lieutenant Baker mentions the fact as an anomalous instance of the impermeability of the coarse river deposits at this spot, contrasting it with what takes place in similar deposits of the *bhábar* east of the Ganges, as already noticed. This is of course an erroneous impression: there is a deep and rapid current in the Jumna at Ráyanwála, and the traction of the stream does not give any particle of the water time to change its course and sink into the ground. The case is very different for small streams spreading out over the surface."

[1] 'Geol. Mag.' dec. 3, Vol. I, p. 545 (1884). The name *M. nanus* had been applied by Falconer in M.S. (*vide Pal. Mem.*, Vol. II, p. 407) to this species, before he applied it to the Kushálgarh specimen, which he evidently regarded as distinct. When the collection of Kushálgarh specimens were returned to India, a label bearing the name *M. nanus* was attached to a tooth referred to *Dorcatherium* (*vide* 'Palæontologia Indica,' ser. 10, Vol. I, p. 62 [44],) and the present writer naturally thought that Falconer had made a wrong generic identification.

[2] *Vide* 'Geol. Mag.' dec. 3, Vol. II, pp. 72—73 (1885).

Several friends who ought to know, expressed doubts that the reason her egiven by me was in any degree valid; so not being able to find an authority on the subject, I have attempted an appeal to experiment, with Mr. Mallet's assistance. In the bottom of a small wooden conduit, about 5 feet long, a rectangular hole was cut, 3 inches long by 1 inch broad. This was lined with sheet-tin, projecting below into a much larger tin box attached to the board, with openings along its upper margin for the escape of water. The hole was then packed with shot, flush with the bottom of the conduit, and up to the level of the openings in the box beneath. Arrangements were made to give a succession of fixed slopes to the conduit, and to measure the discharge from percolation in equal periods under the different conditions. From still water with a depth of about 1 inch the percolation was 1,045 grammes in 30 seconds. The comparative results are given in the following table:—

Statement showing percolation as affected by current.

Percolation.	Conditions.
1,000	Still water: end of conduit closed.
900	Conduit horizontal, end open.
806	" sloping at 25 feet in a mile.
783	" " " 50 " " "
770	" " " 75 " " "
747	" " " 100 " " "
729	" " " 125 " " "

The experiments were no doubt rough, but it can hardly be questioned that they give a true indication of what occurs, showing very decided reduction of percolation with increase of current. The loss is nearly 20 per cent. with a slope of 25 feet to the mile, which is about that of the stream at Ráyanwála. Although, however, the interpretation I gave of the supposed anomaly is thus shown to have but partial application, the main cause must be rather the reverse of that suggested by Lieutenant Baker. We must assimilate, rather than contrast, the conditions at Ráyanwála with those of the *bhábar* streams. The percolation downwards is so free and rapid that laterally it does not extend to a distance of 170 feet at a depth of 50 feet below the level of the stream; and the slope of percolation must be more than 1 in 3·4.

In support of this view I may refer to the instance given in the same paragraph of the paper under reference, of a well at the head of the *bhábar*, near Mohan. Although within a short distance of the Kotri *rau* (torrent), all the dry-weather drainage of which sinks into the gravel, water was only found in the well at a depth of 200 feet.

Notice of the Pirthalla *and* Chandpur Meteorites, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

In 1863 a requisition from the British Museum, respecting the collection of aerolites which may be procurable in the British dominions abroad, was forwarded by the Secretary of State for India to the Government of India, and was issued by it to the Provincial Governments for disposal. On the representation of Dr. Oldham in 1866, that this order was liable to be misunderstood, to the detriment of the very fine collection of meteorites in Calcutta, the Governor General in Council was pleased to approve, for general adoption, the recommendation that all meteorites should be sent to the Calcutta Museum, and suitable samples be forwarded thence to the British Museum. During the twelve years following this order, up to the end of 1878, specimens more or less complete of 11 falls were received, and samples of all were duly sent to London. For years after none were seen or heard of till 1884, when official notice came of the Pirthalla fall, but without any hint of compliance with the order regarding the disposal of such objects, although it was of course still in force. It was plain that the rule had passed out of recollection, as is so generally the case in India with matters that are not of almost routine occurrence, owing to the so frequent changes in the personnel of every office. A renewal of the order was therefore sought for and obtained, of which these two meteorites are the first-fruits.

Pirthalla: No. 189 *of the Indian Museum collection.*—This is a village in the Barwala tahsil of the Hissar District in the Punjab, in about 29° East Longitude and 29° 35′ North Latitude. The fall occurred at 2 P.M. on the 9th of February 1884. The stone was received in three pieces, and otherwise damaged, having lost perhaps an eighth of its original bulk. The pieces weighed severally 510·6, 425·7, and 224·2 grammes, or a total of 1160·5 grammes. The specific gravity is 3·40. The shape was roughly cuboidal with rounded edges and indented sides. The stone is of the most usual type, granular fracture, of light-grey colour, mottled pale brown. The numerous metallic grains of various size and shape only appear on a cut surface, being otherwise covered by a coating of the stony substance. This stone is rather friable. There is of course the usual film of fusion, of a dull black colour. The account of the fall received with the specimen is as follows :—

"The history of the meteorite briefly is, that it was seen to fall at 2 P.M., on the 9th February 1884, about 150 paces from the village of Pirthalla, P.S. Tohana, Hissar Division, by a sepoy on the Skinner estate and a boy of 12 years of age. It seems to have been red-hot when falling, and an explosion was heard while it was still in the air, which was followed by a report like that of a gun when it struck the earth, in which it was buried to the depth of 2½ inches. The ground was hard. It was dug up immediately, and is said to have been quite cold and broken in two."

Chandpur: No. 190 *of the Indian Museum collection.*—This is a village in the North-West Provinces, about 5 miles north-by-west of Mainpuri, in 79° 3′ East Longitude and 27° 17′ North Latitude. The fall occurred on the evening of the 6th April 1885. The stone was received unbroken, though about one-fourth of the crust, and perhaps a twelfth of the original bulk, had been chipped off. The shape was roughly cuboidal with rounded edges and angles. Before cutting, the weight was 1201·3 grammes; the pieces weigh 625·5 and 491·0 grammes. The specific gravity is 3·25. It is exactly of the same type as the Pirthalla stone, but not so brittle. The following is a translation of the report of the fall by the Native Sub-Inspector of Police:—

"On 10th April, Girdhari Chaukidar, of mouzah Chandpur, which is 8 miles south of the police station, came and reported that four days ago, on the night of Monday, there was thunder and lightning which lit up the whole sky, and after this a stone came down, which was found next morning and weighed 1 seer and 4 chittacks. I deputed Mahomed Hussan Khan, clerk, to fetch the stone and make full enquiry into the matter. The clerk accordingly brought the stone to the thana. Its surface is black. It is white inside, containing shining particles like those of sand. It is broken on two sides, which is due to the fact that the villagers broke it to see what was inside before the clerk reached the spot. The pieces broken off could not be found. Enquiry made by the clerk showed that on Monday, about one-and-half hour after night-fall, heavy clouds came over mouzah Chandpur; that Telok Singh Thakur and Bhagga and Manga Chamars were busy in stacking arhar stalks in a field about 100 paces south-east of the village, and that they first saw lightning in the clouds and then heard a roaring thrice; that afterwards it thundered slowly and then of a sudden the whole sky was lit up and a sound of something coming down (sam same) was heard, and subsequently the sound of a thud in the arhar field of Madariwala, which is one field beyond their own; that they then ran away to their respective houses fearing that hail was falling. As the whole affair was one of a surprising kind, they, on Tuesday morning, wanted to find out what it was, and on search, found the stone produced in Madari's field; that it was still warm, and the earth below it was blackened, and a plant of arhar, on which it had fallen, was scorched and broken down, but that no mischief was caused to other plants in the field. Other villagers also testified to these facts. I beg to forward the stone for your inspection."

Report on the Oil-Wells *and* Coal *in the* Thayetmyo District, *British Burma*, *by* R. ROMANIS, D. Sc.

Oil-Wells.—The oil-wells are at Padaukpin,[1] about 8 miles from Thayetmyo, on the Mindôn road. Of seven wells there are only three kept in repair, and of these only one was yielding oil at the time of my visit. The oil flows very slowly; the produce is only one barrel monthly. It occurs in fissures in a hard blue shale (dipping 35° W.), which contains fossil marine shells, which are generally much decomposed by the action of water; often there is only the cast of the shell in the clay remaining.

At Yenanchaung, in Upper Burma, the oil-bearing stratum is a similar blue shale with bands of sand, into which the oil diffuses from the shale and through

[1] Noticed by Mr. Theobald, *Mem.*, *G. S. I.*, Vol. X, p. 347 (1873).

which it percolates into the wells. The shale at Padaukpin seems almost impervious. I observed a place where the shale cropped up to the surface. It was converted superficially into clay by the action of water. The oil was found lining small cracks and cavities. When a piece of the shale was powdered and diffused through water the oil came to the surface in a thin film.

A specimen of the shale was analysed and found to contain 0·16 per cent. of oil.

The rocks overlying the oil-bearing stratum appear much harder than those at Yenanchaung. It appears to be a different geological formation, deposited under different conditions. A boring was put down to a great depth some years ago in one of the ravines to the northward. It ended in hard rock, without finding oil. I do not know why the place in question was selected; the whole district is very unpromising.

Coal.—The coal is found in a ravine of the south-western spur of the second or middle hill of the group of lime-hills south of Thayetmyo.[1]

When I visited the place, an escarpment had been made along the east side of the gorge; at the north end a drift had been driven into the hill side through a hard blue shale to a depth of about 20 feet; at the end of the drift there was a thin seam of coal and carbonaceous shale dipping at an angle of about 30°. Below this another drift had been made, but had fallen in. The seam of coal is said to be 4 feet thick. Further south, again, a pit had been sunk to a depth of 30 feet, following the course of the two small seams of coal here dipping at an angle of 75° to 80°. They are 4 feet apart at the top, but gradually approach and will unite probably 3 or 4 feet lower. Five or six yards further south there are seen two more vertical beds of carbonaceous shale. One of these is said to be the seam worked about 30 years ago. The traces of the old workings are now concealed under the rubbish thrown down from the escarpment above. The old drift is said to be vertically below the lime kiln on the hill side.

The blue shale below the coal is full of vegetable remains, apparently grasses or reeds. Above the coal the shales appear to be unfossiliferous. Over the shales are sandstones. Above these, again, there is a greyish-pink limestone; then over all, forming the crest of the hill, is a white limestone composed of fossil nummulites and marine mollusca.

It seems to me that the coal deposits of the Arakan Yoma have been formed in the swamps and lagoons of a river delta. We find similar deposits of very recent date in the neighbourhood of Rangoon. Thus, at Insein, a boring showed a thin bed of lignite. Beneath the alluvial soil on which part of the town of Rangoon stands, there is a stratum of decomposed vegetable matter about 2 feet thick, thinning out and disappearing where it meets the sandstones, on which the cantonment stands. Above this stratum there is a fine blue clay; above the clay is the sandy clay of the rice-fields. We have the same order at each of the coal outcrops in Burma,—argillaceous sandstones, blue shade, coal.

At Thayetmyo the deposits have evidently been formed while the land was

[1] Described by Dr. Oldham, Selections from the Records of the Government of India, Home Department, No. X, 1856; also by Mr. Theobald, *Mem., G. S. I*, Vol. X, p. 295 (1872).

slowly sinking beneath the sea, the limestones overlaying the shales and sandstones having been deposited on a sea bottom, when the head of the Gulf of Martaban was at Yenanchaung or Sagaing. The sudden change in the angle of dip shows that there has been a great disturbance of the strata.

It seems to me that the coal worked 30 years ago was a portion of the present 4 feet seam, and that a fault runs between the main hill and the southern spurs; but Mr. Lewis, who is carrying on the work, seems to think that the old drift was driven in the wrong direction, and that he will find the seam at the bottom of the pit he is sinking. On this theory there should be two seams 4 feet thick, separated by 60 or 70 feet of shale. The question should be settled in a few days.[1]

It is noteworthy that a similar nummulitic coal-field by the banks of the Indus has just been carefully tested by boring and found to be so irregular as to be worthless.[2]

A series of specimens illustrating the rocks at the Padaukpin and Yenanchaung oil-wells and the coal-mine at the lime hill has been placed in the Phayre Museum.

1*st January* 1885.

Note on some Antimony Deposits *in the* Maulmain District, *by* W. R. CRIPER, A.R.S.M., F.C.S.

From Maulmain a range of hills, called the Toungwayn, Toungmyo, or Amherst range, runs in a south-easterly direction through the province of Tenasserim. The following remarks apply to that part of the range between Maulmain and Amherst, a distance of about 50 miles. The range is densely covered with jungle, and is inhabited by a few Karens; a good road runs along its base.

These hills are mainly composed of a hard siliceous slate, the strata of which are more or less disturbed, but with a general direction of north-west—south-east and a nearly vertical dip; mica schists also occur. Overlying both are soft sandstones more or less horizontal, accompanied by quartzose rocks; while along the flanks and in the plains below, superficial deposits of laterite are occasionally met with.

Limestone does not appear to exist in this range, but isolated hills or rather peaks are found near, which are rapidly disappearing through atmospheric denudation. The existing hills show the power of this influence in their worn sides and sharp angular peaks.

The minerals occurring in the range of hills under consideration are iron ores and antimony. The iron ores might be of use should coal, good enough to smelt them, ever be found within a reasonable distance, and English competition cease.

[1] From recent information dated 22nd June, it would seem that the expected coal has not been found. The Agent of the Murray Coal Company is, however, persevering with the exploration.—H. B. M.

[2] *Supra*, Vol. XVII, Pt. 2.

As long ago as 1860, attempts were made at Toungwayn, near Maulmain, to work the antimony found there, in a hill called Tæ-læ-toung (antimony hill), but without success, the reason given being that the market value of the ore in Calcutta was too low. Other trials have been made since then, invariably with a like result.

The antimony is in the form of stibnite and occasionally cervantite. This latter mineral, which always occurs above the stibnite and is probably due to its oxidation, was not known to the Burmese until pointed out to some of them recently by me, it having too great a resemblance to yellow earth to be noticed by them. They are however well acquainted with stibnite, under the name of Tæ-læ-chouk (antimony stone) or Tæ-læ-byn (white antimony). The cervantite has obtained the name of Tæ-læ-wa (yellow antimony).

The stibnite occurs in pockets, or isolated masses in a whitish quartzose sandstone, the rock in the immediate neighbourhood being often stained of a bluish colour by the antimony itself. The deposits are generally found in or by the side of dykes or rather fissures traversing the sandstone, filled with a whitish quartzose rock, and usually having well-defined walls.[1]

The Tæ-læ-dwin, or so-called antimony mine, worked some time ago by Mr. O'Riley, then Deputy Commissioner of Maulmain, is situated on a hill called Lekka Toung, at the 23rd mile from Maulmain on the Amherst road. It is merely an open quarry, some 50 feet in length (north-west—south-east), roughly rectangular, with a breadth of 12 feet, and about the same in depth. The deposit is divided by well-defined walls from the ordinary yellow sandstone surrounding it.

The ore in these deposits dies out entirely, and no lode or even string is left to show in what direction more may be found. Sandstone surrounds it on all sides, and the only chance of any indication lies in the occurrence of an outcrop along or near the line of the dyke or fissure. From a single deposit a few tons only of ore is obtained. The richest ore is in the centre, and may contain as much as 70 per cent. of antimony (metal), and from this it graduates off into a blue slaty stone containing 2 or 3 per cent. only of the metal.

Practically the chances are small in favour of the idea that small unconnected deposits like this can ever be profitably worked. Should lodes be found however, the case would be different.

Through the energy and enterprise of a well-known advocate of Rangoon, mining operations on a small scale have lately been prosecuted to prove this range of hills, as to the existence or not of true lodes in them. A hill seemingly favourable for mining purposes was selected, and a level is being driven through at a short distance from its base. This work on completion will, in all probability, settle the question of lodes or no lodes for the Maulmain end of the range, the hill being a typical one as far as can be judged. A great expenditure of dynamite is found necessary in cutting through the siliceous slaty rock mentioned

[1] It is to be regretted that Mr. Criper cannot give a more precise description of these rocks. There seems even some doubt whether the 'sandstone' in which the stibnite occurs may not be a partially disintegrated metamorphic rock. The quantitative diagnosis of the deposit is however the important point of the paper.—H. B. M.

above. Iron pyrites is occasionally met with in this slate, and on the whole appearances are not entirely unfavourable for the occurrence of mineral in veins.

I may here remark that copper ("copper scoria") was said to be found at a place called Kyiek Myraw, on the Ahtaran side of this range, by Mr. O'Riley,—*vide* Selections from Records, Bengal Government, VI, 1852. On inspection I found three large mounds, each containing many thousand tons of rich iron slag. Enquiries on the spot from the old inhabitants and phungies (priests) failed to elicit any knowledge or even tradition of a furnace having been in operation there. No iron lode could be found and no excavations were known of in the neighbourhood. Probably a very rich form of laterite occurring there—almost an iron ore in fact—was used in the production of this slag. I have since learnt that more of such slag exists at a place called Wagardo, near Amherst.

Among the drawbacks to the carrying out of mining and prospecting operations in British Burma, the want of roads, badness of the conveyances, thickness of the jungle, and cost of labour, are the chief. An ordinary cooly's wages amount to Rs. 12 per month in Maulmain, and in the district 8 annas per day, except during the paddy season, when 12 annas per day is usually demanded. The coolies are chiefly Madrasis, with a few from Calcutta, the Burmese being too lazy and independent for hard work. Domestic servants are also Madrasis, a 'boy' requiring Rs. 16 and a cook Rs. 18 to Rs. 20 per month. In the district the usual means of conveyance on land is the Burmese cart drawn by two bullocks. As the body of the cart inclines from front to back at an angle of about 45,° a long journey in one does not afford the acme of comfort.

The best time for prospecting is from December to April, May and June being too hot, and from July to November every thing is under water, the rainfall being 170 to 220 inches in Maulmain, and nearly that amount in the other parts of Tenasserim.

Government dak-bungalows are few and far between, but along the high roads at frequent intervals zayats or rest-houses are found, built by pious Burmese, it being considered a good work to build a zayat and as helping towards the attainment of Nigbán.

Notes on the Kashmir Earthquake *of* 30th May 1885, *by* E. J. JONES, A.R.S.M., *Geological Survey of India.*

On the 30th May, within a few minutes of 2-45 A.M., at which time a pendulum clock, set to local time, at the Residency in Srinagar, stopped, a severe shock of earthquake was felt in the Kashmir valley, where much loss of life and damage to property occurred. The shock was also felt to a less extent in all the surrounding country, and at Simla, Lahore, Peshawar, &c.

The chief shock.

This shock, which seems from its effects to have been of a severe character, has been followed by slighter shocks up to the present time. On one day, soon after the chief shock, as many as thirty-three distinct shocks were counted at Baramula. The frequency of the shocks has, however, now considerably diminished, some days being quite free, and on

Subsequent shocks.

other days as many as four or five being felt in the day. As an example, on June 15th there was a shock about 4 A.M., which was more severe than those which have occurred recently; two hours after another shock was felt, but of a much less severe character.

Shock preceding the chief one.

The chief shock of May 30th seems to have been preceded on the evening of the 29th by a slight shock, which was noticed by several persons.

Damage done by the shock.

The loss of life and damage to property, though much less than was at first reported, has been very considerable. The number of persons killed by falling buildings according to the present official reports was something over 3,000, while the number of cattle, horses, &c., killed was very great.

Area over which the shock was severely felt.

The area over which the shock was sufficiently severe to do serious damage to buildings is also much less than was at first supposed; it extends from the neighbourhood of Srinagar on the south-east, round a little north of Sopur, and by Baramula down the Jhelum valley as far as the fort of Chikar near Garhi; the country south of Sopur has also suffered as far as Magam (or Margaon) on the road from Srinagar to Gulmarg. About 25 miles north-30°-west of Uri is a solitary case where a fort near Titwal on the Kishengunga river has been slightly damaged. Down the valley of the Jhelum between Uri and Chikar the damage has not been general, the forts being the only buildings that have suffered. The area over which the shock was severe enough to cause a large amount of damage may be roughly estimated as between 300—400 square miles, though the actual area including all the damaged buildings is something over this.

Style of buildings.

Most of the buildings consist of stones and wood in which mud takes the place of mortar, and they are covered by a heavy roof, frequently composed of dried mud supported by rafters, resting partly on the walls and partly on a few wooden pillars inside the building.

Difficulty of drawing conclusions from the effects on the buildings.

These buildings do not throw much light upon the direction in which the wave travelled, as they appear, when shaken by the shock, to have been unable to support the weight of the roof, which accordingly fell down inside the building and in most cases crushed any living thing of any size to death, while the walls having nothing to hold the mass of stones and (in many cases rotten) wood together fell to pieces; in some cases however parts of the walls fell down and the roof remained. Very little, if any, assistance can be obtained from these structures in obtaining data as to direction in which the wave travelled; the difficulty is also enhanced by the fact that the ruins were immediately disturbed and dug into in order to rescue the wounded and get out the bodies of the dead, and to obtain the wood for the purpose of erecting temporary huts.

Possible path of the wave.

There are, however, some circumstances that point to the conclusion that the wave path ran nearly north and south at Srinagar, as a hanging-lamp at the Residency was found after the shock to be swinging approximately north and south, though no exact observation of the direction was taken. The cracks in the walls of the Residency also tend towards this conclusion: those walls which run north and south exhibit cracks, while the long walls running east-west have not been cracked, though they have become separated from the north-south walls by cracks. At Baramula, of those buildings which are at all favourable for observation, the walls running east-west have fallen more generally than those running north-south, as for instance the dâk bungalow, a long building containing six sets of rooms, where the north wall facing the river and the roof covering the chief rooms, fell, while the back of the bungalow to the south suffered but little damage. In the fort at Baramula, which is partly built with mortar instead of mud, the tower at the north-west corner fell into the river, and the west wall running north and south has been cracked, and the top of both the east and west walls has fallen down.

The forts and huts which have been damaged along the valley of the Jhelum to the west of Baramula afford no trustworthy evidence.

Earth-fissures.

At Baramula and higher up the river a number of earth-fissures have been formed along the banks of the river, and occasionally at some distance from the river. The fissures I have seen were parallel to the course of the river, but owing to the water in the river standing at a very high level at the time I passed up, the surrounding country was flooded, and I was unable to see many of the fissures that are said to exist.

At Patan, which is some distance south of the Wular lake, there are some fissures running south-east—north-west and parallel to a line of low hills. I also noticed at this place one fissure running at right angles to and crossing all the rest. The size of these fissures varies from an inch to a yard in width. I saw no single ones of more than 100 yards in length, though they run into one another. The depth cannot well be seen, as the fissures are now blocked up.

Larger earth-fissures.

I am informed that there are some much larger fissures at a short distance from Baramula, some of them being 30 yards in width and a quarter of a mile or so in length. I hope to see them before my observations are concluded.

Sand craters.

In the neighbourhood of the fissures there are numerous patches of fine sand which have been forced up from some distance below the surface; they vary from 2 to 5 feet in diameter. The villagers state that at first this sand gave off a sulphureous smell. The sand resembles fine river sand, but differs slightly in character in the different localities where it is found.

Sounds accompanying the shocks.

The shocks were accompanied by a sound which, in the case of the chief one, was described to me as like a hundred cannon going off at once. The noise appears to have preceded the shock by a short interval of time and to have come from a northerly direction.

CAMP SRINAGAR,
The 18th July 1885.

Preliminary notice of the Bengal Earthquake of 14th July 1885, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

Some mention of this earthquake may be expected in the current number of the Records, but it can only be to announce that observations are being made by officers of the Geological Survey where the shock was most severely felt. Mr. C. S. Middlemiss is taking notes at Serajganj, Sherpur (in the Bogra district), Maimansing, and Dháka (Dacca); and Mr. P. N. Bose is visiting Nattore, whence some peculiar effects have been reported. The time of the occurrence was rigorously fixed for Calcutta by the stopping of the three regulator clocks at the Meteorological Observatory, from which the time-signals to the port are made, as checked by daily astronomical observations; the hour was 6h. 24m. 12s., on the forenoon of the 14th. The clocks stand due north-south, facing east. It is very doubtful that any comparable observation can be obtained elsewhere; but the time element is not the most important. As to the direction at Calcutta, the most reliable observation I have heard of was that by Mr. E. C. Cotes, of the recently filled cistern of a gasholder on the premises of the Indian Museum; the water was seen to spill to a little east of north. This is, too, the direction suggested by the general report of damage done, which is very markedly concentrated in the upper deltaic area traversed by the Brahmaputra. In parts of this area slight shocks and tremours have continued since the main shock until now. No notice of the shock has been reported from Cachar or Upper Assam, which is the region most frequented by such visitations in this part of India. As to the angle of emergence, I know of no safe data; cracks in the walls of houses are numerous enough, but it is very difficult to make sure that they are not old ones that had been plastered over. The most distinct case of overthrow that has come to notice was that of a heavy plaster cast leaning against the north wall in a recess some 12 feet above the floor in the palæontological gallery of the museum, but it must have been in a dangerous state of unstable equilibrium; for several others similarly placed, and by no means so stable as they ought to be, did not fall. For the comfort of visitors I may add that these are now being made fast.

The area indicated is, so far as I know, a hitherto unsuspected position for a seismic focus, at least from recorded earthquake observations; but it is noteworthy that within that area, north of Dháka and west of Maimansing, lies the ground known as the Madhopur jungle, which was described by Mr. James Fergusson in his admirable paper on the delta of the Ganges[1] as due to an upheaval, "which there is every reason to suppose took place in very recent times." It is described as presenting a more or less scarped face of deltaic deposits along its western side, raised about 100 feet above the actual alluvial area, and sloping eastwards under the old bed of the Brahmaputra, and losing itself in the Sylhet jheels (swamps). This form is certainly very suggestive of an actual upheaval along the western edge, and this line, running past the end of the Garo hills on towards Sikkim (where the recent earthquake was very sensibly felt), would approximately suit for the axis of the seismic area as now indicated. But this view of the Madhopur jungle

[1] *Quar. Journ. Geol. Soc., London,* vol. xix, p. 329, 1863.

needs verification, for there are grounds for supposing that it may be only an insulated remnant of a former more extensive deltaic surface, other remains of which are found in the terraces of old alluvium at many places on the borders of the present deltaic alluvium.

There is another feature described by Mr. Fergusson (*l.c.* 333) that must be taken into consideration in the present discussion, namely, the change that occurred early in this century in the course of the Brahmaputra. When Major Rennell surveyed these rivers in 1785, the whole Brahmaputra, which is perhaps a greater silt carrier than the Ganges, flowed by Maimansing, east of the Madhopur jungle, and did much work in filling up the depressed area of the Sylhet jheels. It was then driven back from this ground by the comparatively insignificant eastern streams, as is so well explained by Mr. Fergusson, and fell over into the area west of the elevated tract, where it now flows some 60 miles to the west of its former course, in the very ground where the recent earthquake has done such mischief. It is not impossible that the accumulation of 70 years' deposits from the great river may have had some influence in producing the catastrophe.

There has been in the daily papers so much loose writing upon earthquakes on the occasion of the recent events in Kashmir and Bengal, that it may not be amiss to make a few general remarks on the subject. It is only partially true, and in respect of details, that the subject is 'shrouded in mystery.' It is not disputed that every smallest cause must have some effect: when a musquito alights on a mountain the state of equilibrium is somewhat different from before, when the monster's weight was distributed by air vibrations. It is well known that the volcano Stromboli is looked upon as a barometer by the sailors of the surrounding seas; still to speak independently of variation in atmospheric pressure as the cause of volcanic eruptions, and still more so as a cause of earthquakes, is to lose sight of all sense of proportion. In the same connection, there is no doubt that high-pressure steam plays a conspicuous part in volcanic phenomena and their attendant earthquakes; and that even in other earthquakes steam is ever ready to flash into any temporary fissure that may be formed; but to speak of steam scouring through subterranean caverns, bursting from one to another, and so causing earthquakes, is to indulge in geological romance *à la Jules Vernes*, for which there is little excuse when we have so much solid ground to judge from. No one who has ever been in a region of true mountains, such as the Himalaya, with his eyes open, should have any misgivings as to the cause of earthquakes, on seeing around great thicknesses of bedded rocks that must once have been flat, now twisted into knots and snapped asunder like twigs. Of course the hiatus in thought lies in the familiar assumption that the rocks were made so, or that all this performance came off in pre-Adamite times. The truth is that that sort of thing is going on now; the Himalayas themselves have not done growing. The crust of the earth is continually in a state of strain, owing probably in some degree at least to relative changes of the internal and external volumes due to secular refrigeration, and to other disturbances of equilibrium, such as the wholesale removal of matter from one part of the surface to another (of which the case suggested is an instance), amounting in time to enormous quantities. Thus there are re-adjustments of equilibrium always going on. They for the most part take place so slowly as to be imperceptible, but sudden collapse must often occur, producing the shocks we know as earthquakes. It has been ascertained with much certainty that the greater earthquakes have their origin at considerable depths, as much as 30 miles, below the surface; though no doubt very destructive local shocks may arise from a much nearer focus.

The suggestion for warnings of approaching earthquakes is not promising, and it is only even plausible where seismic activity is more or less chronic. Of the greater disturbances that extend far from the focus there would probably be no symptom whatever, unless, perhaps, in the neighbourhood of the focus. Even at the seat of activity the attempt would probably be futile, for the many petty disturbances that pass off without serious sequel could hardly be distinguished from those that precede violent shocks, and the warnings would soon come to illustrate the "wolf, wolf" alarm of the nursery tale; so that such warnings might on the whole create a greater aggregate of anxiety and suffering than it was intended to relieve.

ADDITIONS TO THE MUSEUM.

FROM 1ST APRIL TO 30TH JUNE 1885.

Two specimens of alluvium—one from River Dharla near Mogul Haut Railway Station, Rungpore District, and the other from River Gangadhar, Assam.

PRESENTED BY MR. R. T. MALLET.

Lignite from Sivalik Sandstone, Bhútan, North of Barpeta, Assam.

FROM THE DEPUTY COMMISSIONER OF KAMRUP.

Various fossils (22 in number), from Perim Island and other places in Kathiawar.

PRESENTED BY AZAM VAJISHANKER GAURISHANKER, ASST. DEWAN OF BHAVNAGAR.

Cervantite, and antimony smelted from the same, from the Toungweine Range, near Maulmain.

PRESENTED BY MR. GEORGE DAWSON, MAULMAIN.

Specimens of phosphatic rock and phosphatic nodules, from Masuri.

PRESENTED BY REV. J. PARSONS, MASURI.

Section of a vertical pipe used for carrying the shaft water from one water ring to another in No. 3 Pit, Warora Colliery, the interior encrusted with a deposit of carbonate of lime, which was formed in fifteen months.

PRESENTED BY MR. C. J. BUNING, OFFG. DY. MANAGER, WARORA COLLIERY.

Specimens of egeran from the 'Rer' quarry, northern base of the Chattarbhaj Hills, Tonk.

PRESENTED BY LIEUT.-COL. W. J. W. MUIR, POLITICAL AGENT IN HAROWTEE AND TONK.

Three pieces of the meteorite that fell at Pirthalla, Burwala Tahsil, Hissar District, Punjab, on the 9th February 1884. The largest piece weighs 510·6 grammes; the second, 425·7 grammes; and the third, 224·2 grammes. Its specific gravity is 3·40.

FROM THE GOVERNMENT OF THE PUNJAB.

The greater portion of the meteorite that fell at Chandpúr, Mainpúri District, N.-W. P., on the 6th April 1885. It has since been cut into two; the larger piece weighs 625·5 grammes, and the smaller, 491 grammes, and its specific gravity is 3·25. It weighed 1201·3 grammes before cutting.

FROM THE COLLECTOR OF MAINPÚRI.

ADDITIONS TO THE LIBRARY.

FROM 1ST APRIL TO 30TH JUNE 1885.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1885. [November.

Sketch of the Progress of Geological work in the Chhattisgarh Division *of the* Central Provinces, *by* William King, B.A., D.Sc., *Superintendent, Geological Survey of India.* (With a map.)

The large area of country included under the above heading embraces, besides Chhattisgarh proper, a small tract on the eastern edge of Balaghat and Mundla on the one side, and a much wider extent of the Sirgujah and Gangpur territories of Chota Nagpur to the far east. At long intervals, since 1866-67, traverses across the whole region, or at several points on its borders and within it, were made by Messrs. Medlicott, W. T. Blanford, and Ball, their observations having been recorded in manuscript or in the publications of the Survey.[1]

The more connected examination of the area has been resumed within the last two years, and on the following already recognised provisional succession of formations:—

Deccan trap.	
Kamthi.	Lower Gondwana.
Barakar.	Lower Gondwana.
Talchir.	Lower Gondwana.
Limestone member.	Lower Vindhyans.
Sandstone „	Lower Vindhyans.
Chilpi beds.	? Do.
Crystallines.	

It was to be expected that closer work might possibly lead to a modification or even an enlargement of this list: as will be seen later on, this has been the case in so far as I have been led to look on certain rocks as belonging to a transition series rather than to the Lower Vindhyans,—a view at which I had arrived on

[1] Medlicott, M.S. 1866-67. Blanford, M.S. 1869-70. Records, G. S. I., III., pp. 54 and 71. Ball, Records, G. S. I., IV., p. 101; VIII., p. 102; X., pp. 167 and 186. Manual of the Geology of India, Part I, pp. 75, 128, and 199.

independent observation of strata which had not escaped the vigilant scrutiny of Mr. Medlicott, who was also struck with their sub-metamorphic facies.

The sequence of the limestone and sandstone members of the Lower Vindhyans of the Chhattisgarh basin has already been discussed to some extent by Mr. Ball in these Records,[1] partly without due regard to the extent and completeness of the basin in itself and through a comparison of these with certain members in adjacent regions. The evidence gained in the present examination is, however, so clearly corroborative of Mr. Medlicott's first position that all questions regarding it may now be laid aside. At the same time, not only on this point, but on the view of the interpolation of a transition series and the possible absorption by it of some at least of the rocks included under the Chilpi beds, it would long ago have been of the greatest advantage had Mr. Medlicott's progress report been published. Its reproduction is now more desirable than ever, and, with the Director's permission, it is embodied in the present paper.

The most striking feature of the Chhattisgarh country is its great plain or basin which stretches far to the eastward and southward from the foot of the steep-crested and ridged slopes fringing the Mandla-Amarkantak plateau, or that part of it which is called the Maikal range. This range, and a great N.-S. spur stretching into Balaghat and Bhandara as the Saletekri hills, form a sort of rectangular north-west corner of the basin. Not far from the southern end of the Saletekris, the southward limitation of the basin is formed by the much lower Raipur, Bilaighar, and Sarangarh hills, the skirts of the long northern slopes of which trend north-north-eastwards past Raipur and then away along the right bank of the Mahanadi ending in the Bara Pahar range, some 30 miles west of Sambalpur. The latter range drops down to the great river, on the opposite or left bank of which the rim or edge of the basin is continued in a series of high ridges striking north-westward past Raigarh, thus closing in the great plain at its eastern end. The hilly border is thence continued rather more west-north-westward across the Mand and Hasdu rivers, and so by detached and lesser ridges past Ratanpur (some 30 miles north of Bilaspur) to the foot of the slopes of the Maikal range below Amarkantak.

No more perfect geographical and geological basin could be instanced; for, except on the west and north-west sides, the rim-like edging of hills and ridges consists of gently or more strongly up-turned beds rising from under the flatter-lying strata of the plain with which they are formationally associated. We have thus come to distinguish what may be called the rocks of the plain, and those of the rim as synonymous with the 'limestone' and 'sandstone' members of the Chhattisgarh Vindhyans.

The Korba plains to the north-east of Bilaspur form a sort of supplementary or outside stretch of low country; but this cannot be looked on as a part of the proper basin, from which it is separated by the low ridges and larger hill masses of Ratanpur, Soti, and Dulha, while its main rivers, namely the Arpa, Hasdu, and Mand, cut across or through this part of the rim in their course to the Mahanadi. This tract is also geologically distinct, being made up of crystallines and Gondwana rocks.

[1] Vol. X, p. 167.

The Pendra upland to the north, which might also be considered a portion of the northern edge of the great basin, is remarkable as being a part of the divide between the great southern feeders of the Ganges and the northern drainage of the Mahanadi, as well as the connecting link between the Amarkantak end of the Satpura range and the lofty plateau highlands of Chota Nagpur.

CRYSTALLINE SERIES.

It is scarcely necessary, even if it were possible, considering the very cursory form of examination consequent on attention having been given to more important formations, to dwell at any length on the different gneisses and granitoid rocks constituting the floor of this field; though a general idea of their mode and style of occurrence may here be given.

On the north side of the basin, that is, by Lurmi, Pendra, Mahtin, Uprora, and Korba, good strong-bedded gneisses of the more massive quartzose, quartzo-felspathic, and hornblendic varieties, are common, particularly in the slopes or ghâts separating the Pendra country from the Bilaspur plains; though the upland itself, as far north as Pendra at any rate, is of unfoliated and very coarsely granitoid kinds. The ghât rocks are all more or less foliated, or laminated and bedded, in a general E.–W. strike, with a high dip to southwards, though this becomes less and less inclined towards the foot of the hills. A cross traverse from Pendra southwards by the Suknai and Arpa valleys shows the granitoid rocks to the edge of the upland, where they are succeeded by the foliated gneisses with which are associated frequent thick beds, or sheets of coarsely crystallized red felspathic granites, or more highly altered forms of gneisses. Strong quartzose gneisses, quartz-rocks, and some schists, still having the E.–W. strike, come in below the ghâts and occupy the low country (much covered up with alluvium) nearly as far as the Ratanpur group of hills. Other traverses in the same direction but further and further east, over the Lapha hills, or from Mahtin down to Korba, and in Uprora, show a similar succession of gneisses. The general E.–W. strike is not only seen in the rocks themselves, but it is, as it were, stamped on the face of the country in the wonderful system of long, narrow, and deeply-carved ridges and valleys to the south of Pendra and about Mahtin.

In the Korba valley, the crystallines are extensively covered up by Gondwana rocks; but a belt of granitoid gneisses, with subordinate hornblendic and quartzose schists, shows a few miles to the south and south-east of the town, and narrows off in the latter direction towards the Mand river. Gondwanas and Vindhyans then intervene as far as Raigarh, where a further thin belt of quartzo-felspathic granitoid rocks, with frequent ridges of quartz schists or quartz-rock (occasionally having more the character of fault rock) and bosses of hornblendic or syenitoid varieties, stretches in a south-east direction towards Sambalpur.

? TRANSITION SERIES.

In treating of these rocks, I labour under the disadvantage of having seen them in detached areas and then only on a traverse while marching across country to take up a far distant coal-field near Sambalpur; or, later again, when more especially following out the northern edge of the Chhattisgarh basin.

Further, they are at these places in contact or very close to, and in some of their characters not unlike bottom strata of the Lower Vindhyan outcrops.

On the march from Pendra south to Bilaspur, the gneissic rocks were traced into the rugged low country of Kenda; beyond which lies a wide stretch of superficial deposits in the Khaira valley, extending to the northern skirts of the low group of Ratanpur hills where are traces of quartz schists not so manifestly gneissic as those to the north in Kenda. The higher hill block west of Ratanpur, or to the north of the old city, is made up, on its south-western slopes at least, of a decidedly different set of rocks—namely, hard, massive, quartzose strata, generally of a green colour, associated with foliaceous and rather compact green mica schists or coarse clay slates weathering of pale-brown and reddish colours. There are also thick bands, apparently in the strike, of dark-green traps (greenstones) or trappoids. The low hillocks to the west and south-west of the old city consist of low-dipping quartzite sandstones and shales. There is some twisting and rolling about of the beds; but the general strike is N.W.–S.E., the dip being to the north-eastward. The low, but very steep, ridge on the western side of the Dulha tank is of much crushed and white quartz-stringed quartzite (nearly quartz schist) having a high dip to north-east.

Here, therefore, without taking into account the different style of the rocks, is a series having a strike in strong contrast with the prevalent E.–W. one of the proper crystallines; and not only is this the case, but even a stronger discordance exists between them and the Vindhyans, for these quartz schists of the Dulha ridge are crossed at their southern end by bottom sandstones of the latter series which are striking W. by S.–E. by N. and dipping 20°–30° southward. These sandstones are only some 60 or 70 feet in thickness, but they are well marked in the long low ridge forming here a part of the lip or rim of the great basin. The section is quite clear on the Bilaspur–Ratanpur high road.

The next exposure of similar rocks lies some 12 miles to the east-south-east, on the western slopes of the Soti hill (2,646 feet) mass. On passing eastward from the Vindhyan limestones of the plain, about Pondi and Bamini, I found that the first ridges are of strongly-crushed quartzite and quartz schists, exactly like those of the Dulha tank ridge, having very much the same strike and vertical or with a high inclination to the eastward. These are then succeeded, after a narrow strip of covering alluvium, in the slopes by strong compact schists or coarse clay-slates, and hard massive dark-green quartzose rocks, with which are associated, to all appearance in the strike, greenstones and trappoid rocks. Like rocks are traceable over the Nilagar valley into the Dulha hill (2,447 feet) mass to the southward and away in an east-north-east direction by Baluda, almost as far as Panora on the road to Korba; the more prominent exposures being, however, quartz-rock or quartz-schist still having a generally N.–S. strike.[1]

LOWER VINDHYANS.

Mr. Medlicott's so long reserved progress report will form a fitting introduction to the consideration of these rocks.

[1] As will be seen in the next section, Mr. Medlicott had also visited this Dulha-Soti area, but my observations were made without having previously seen his report.

Vindhyans of the Mahanadi.

"When I first came upon these rocks in this section of the Hasdu, I took them to be Talchirs, and even tried for a couple of day to accept them as such. The colouring of Mr. Hislop's map gave a direct determination to this view; and at this particular spot it chances that the rocks lend themselves to that supposition: there are thick beds of fine calcareous clays in abrupt contact with gneissose rocks. But the notice from the first of a considerable departure from the Talchir type rapidly widened into a total separation; although characteristic Talchir rocks were observed at a short distance to the north, I looked in vain for them here; and characters were soon observed, which have never been noted in Talchirs, but which are common in pre-Talchir groups.

Local resemblance to Talchirs.

"The sandstones are strongly bedded, often coarse and rusty, often pure and fine, quartzite sandstones.

Sandstones.

"There are massive fine homogeneous clays, often affecting a flat nodular structure (resembling somewhat the splintery clays of the Talchirs). There are also finely laminated siliceous shales; these are often calcareous, and pass insensibly into finely laminated siliceous limestones, in the manner so common with some of the lower-Vindhyan bands of the Sone and of Bundelkhand. These shales seem also connected with fine flaky siliceous and *quasi*-felspathic beds, very hard and compact (porcellanic) on a fresh fracture, but betraying their flakiness by weathering. These beds, too, find their exact analogues in the lower-Vindhyans.

Clays.

Porcellanic variety.

"Limestone is perhaps the commonest rock at the surface all over the plains of Chhattisgarh. It is seldom a pure homogeneous rock, being often flaky and earthy-siliceous, and often also the siliceous matter is distributed in strings or in irregular concentric concretions.

Limestone.

"It would seem to be only in the most general way that these several rocks observe any order of position. I think all these types may be observed as a bottom rock, resting upon the metamorphics. But there is a decided preponderance of the sandstone in this position. It would seem that the sandstones never attain a considerable thickness save at or near the base of the series; I would conjecture, too, that they are altogether absent towards the top. This variability in the deposits is also a point of similarity with the lower-Vindhyans, and with the rocks described this year by Blanford in the Godavari area.

General order.

"As the most frequent bottom rock, the sandstones are seldom seen in force, except near the boundary; but they are nowhere so much developed as in the south-east, resting on the gneiss of the Jonk area and of Sambalpur, and forming ridges running northwards from that area. If one wanted an appropriate name for the band, "the Chandarpur sandstone" might be adopted. I have nowhere seen them so well exposed, or in so great force, as in the ridges running south from the Mahanadi at Chandarpur.

Distribution.

"I can indicate no constant position for the limestone. It seems thoroughly associated with the shales overlying the Chandarpur sandstone.

"The position here distinctly assigned to the sandstone is the same as is conjectured by Blanford for the Pranhita sandstone, with reference to the Pem shales. In the Sone area a quartzite sandstone is the most general bottom rock of the lower-Vindhyans.

"In describing the boundaries of these rocks, the foregoing observations will be illustrated and amplified.

Southern boundary.

"The boundary of these Vindhyans with the crystalline rocks on the south is much more simple than on any other side. Here only is there a distinct and unequivocal case of simple unaltered super-position. Close to the right bank of the Mahanadi, east of Arang, the shaly, flaggy, dark siliceous limestone shows with a steady inclination of 3° to 4° to westwards; and on the rising ground to eastwards the strong-bedded sandstones pass up from beneath the limestones and shales to form a low range of hills. These hills present a gentle slope to the west, and are scarped along the eastern face, in which can be admirably seen the junction of the massive sandstone resting on coarse granitoid gneiss, and largely made uo of its debris; this debris is not coarse and water-worn, but gravelly, and still undecomposed. The very gradual nature of the junction is well seen in the east–west gorges, the crystalline rocks appearing in the valley for a mile or more to westwards of the general north and south line of scarp, and with sloping scarps of sandstone on either side. From the steadiness of this feature, I was led to conjecture that the eastern extension of the sandstone would be limited with much regularity by the north and south line of scarp. I was therefore surprised to find the sandstones at one spot half a mile in front of that line, and at the general level of the crystalline are of the Jonk; but this is little more than 100 feet below the line of junction in tne scarp; I imagine however that such outliers are exceptional on this side of the granitic area. In passing eastwards along the road, the scarped hill range I have just described is seen to the north curving round to the east towards Sarangarh; and I have no doubt the rock-features are quite similar to those on the east, the sandstones thus encircling the crystalline rocks on west and north.

"The Raipur and Sambalpur road runs nearly east and west, and for 50 miles there is no rock but crystallines; the sandstone hills appearing at a greater or less distance on the north. In Phuljhar there is a break; a bay (now a region of hills) of Vindhyan rocks stretches southwards from the main area of the Mahanadi, separating the crystallines of the Jonk from those of Sambalpur; the two being probably continuous on the south, in the Borasambar State. For a long distance to the west along the road the high scarped ridge of Siswal, in Phuljhar, betrays the presence of more regular stratified rocks. On the road, a few score yards to east of the Katli river, on meridian 83°, one comes, without any separating surface feature, upon fine crushed and slaty silt beds, with some associated beds of brown coarsish sandstone. Although much compressed, the stratification is not greatly disturbed, as can be seen by the lie of the sandstone, and by the position of the imperfect nodular structure of the clays which seems always to preserve the flatness in the plane of bedding. I at once recognised these rocks as identical with what I had seen about the north boundary and elsewhere in the Vindhyan area; and hopes were raised, that in the high scarped hills close by on the east I should find higher beds of the series than any I had yet seen. On approaching Bindala hill (some 16 miles north of the road) I was surprised to come again upon crystalline rocks on the low ground and reaching up to the foot of the scarp. Further exploration in the same north-easterly direction confirmed this observation: crystallines weather out here, there, or anywhere, from under the sandstone, with small regard to levels. Thus the general character of the junction here is the same as to west of the Jonk; the bottom portion of the sandstone in the Phuljhar hills is disposed to be shaly rather than coarse and massive like that of the boundary in Raipur; and the fine argillaceous beds, the first rock noticed in these eastern sections, was not observed in the single section I examined west of the Jonk (from the greater regularity of the boundary there, I dare say they are nowhere exposed); but, as already remarked, these argillaceous rocks are exactly like beds seen elsewhere, and I believe them here, as elsewhere, to underlie and partly to represent the sandstone which caps the gneiss of the higher levels. In these sections we thus find locally well exhibited what I have stated to be the relation of the sandstone generally—that it cannot be looked upon as a bottom group of the series, although very often seen as bottom rock. There is no presumption either that it is generally represented along any horizon. I can give no certain criterion of the beds which overlie the sandstones as compared with those which underlie them; the latter appear to be less shaly and more massive and of a darker colour, and perhaps, free from limestone, although apparent exceptions to this will be noticed.

"From Phuljhar I marched northwards along the sandstone range to Chandarpur. The sandstone must be several hundred feet thick, and most of it is a fine, white, pure quartzite-sandstone like much of the upper-Vindhyan rock. The range is on a distinct anticlinal; the pale shaly, flaggy, calcareous upper parts showing on both sides close to the base and inclined from it. The Kenkaradi river occupies a basin of these upper beds to east of the Chandarpur range; the hills to the south-east being, I have no doubt, formed of the sandstone sloping up in that direction and forming a scarp over the crystalline area of Sambalpur.

"Proceeding eastwards along the south boundary, there may be noticed a gradual change from the perfectly undisturbed condition of the normal junction in Raipur, as already described, to the greatly disturbed and very complicated junction that runs in a north-westerly–south-easterly direction through Sambalpur and Raipur and forming the eastern boundary of the Vindhyan area of the Mahanadi. The intricate and rugged hill group of the Bara Pahar is formed at the confluence of those two boundaries. Before attempting to sketch the features of the eastern junction, I will notice the less complicated one on the north.

North boundary.

"In going northwards from Bilaspur to Ratanpur, the shales, limestones, and subordinate flaggy sandstones, which spread horizontally beneath the plains of Chhattisgarh, are concealed by soil and alluvium to within 2 miles south of Ratanpur, where a low east–west range of hills rises abruptly from the alluvial flat. The ridge is formed by a band of strong-bedded standstones, mostly coarsish and with an insufficient rusty ochreous matrix, but some of it fine and pure. The band is not thick; may be 50 feet and under. It seems slightly to alternate with and to overlie streaked red and greenish slaty shales. Very locally one may observe apparent total unconformability between the sandstones and the shales below them, but I believe these cases to be entirely due to crushing between yielding and unyielding materials; for in the best sections, as well as in the general *allure*, there is full evidence of conformable association. The nature of the disturbing action along this zone is best seen by the behaviour of the sandstone; the elevation from the north does not seem to have been very marked or very direct; for several miles in width the sandstone may be seen forming little ridges having any direction and slope, and all at about the same level. In the little ridge over Ratanpur this strike is north-north-east and the dip 30° to east-south-east; a mere capping of sandstone resting conformably on the shales.[1]

"On the Ratanpur section the junction with the crystallines is concealed beneath a longitudinal valley. The zone of special disturbance may be about 5 miles wide.

"I crossed this boundary again at some 30 miles to west of Ratanpur, where the rocks are better seen, and one actual junction exposed. At Lurmi the same band of sandstone forms very low (40 feet) ridges, rolling about at small inclinations, and with little regard to direction, the same type of disturbance as at Ratanpur; and it soon settles down under the pale shales and limestones of the plains to the south. In the Muniari, just above Lurmi the rocks under the sandstones are admirably exposed. They are massive beds of fine (? siliceous) clays, some exceedingly fine, others more gritty; mostly of a red colour, often streaked with green, and some greyish-brown. A fine lamination is often traceable in all; and the bedding is easily discerned. The dip is variable, not exceeding 10° to 12°—a southerly direction prevailing; but the effects of great crushing are manifest in the irregularly intersecting systems of planes of jointing or pseudo-cleavage that traverse the whole mass. In these also an east–westerly strike is the most marked; the effect of which is such that in mere ground-sections on paths one would note the rocks to be slates, with an east-west cleavage. In the finer beds the disintegration of the rock is further complicated by an original, flat, concretionary structure, which produces concentric exfoliation.

"At 3 to 4 miles north of Lurmi there is a very steady range of hills, running about 5° north of east, south of west, the south face of the crystalline area to the north. This straight ridge is here several miles wide, and tolerably flat-topped. The gneiss lasts to the edge of the south face; but the spurs, from the very top, are of streaked reddish and greenish slaty rocks; very locally even there is an appearance of incipient foliation. The water from the higher level trickles down over a steep surface of gneiss into gullies through the slates. The junction is amply exposed; there is no clean-cut plane of separation; not a sign of intervening vein rock; no trace of slipping between the two; within a few feet or inches the change is complete, the rocks being just as it were soldered together.

"By aid of the lamination, and of an occasional flaggy layer, the bedding can be observed; at the spot I examined there was, for a few feet wide, a low

[1] It is in these shales that copper ore was reported to have been found and formerly worked; but I could find no definite foundation for the report, nor any confirmation of it in the rocks. The piece of 'ore' sent to me by the Deputy Commissioner (Mr. Chisholm) was merely a bit of red (copper coloured) shale.

inclination towards the gneiss, and then a low inclination from it; the whole state being exactly like what is seen in the river at Lurmi, only slightly intensified.

"The observations I have recorded seem altogether to indicate a normal relation between these series of rocks—an aboriginal contact. This view is strongly corroborated by the appearance, about half-way between Lurmi and the hills, of a band of gneiss on the low ground. Its presence is not marked by any surface feature or peculiar contact-rock; it seems simply to have weathered out from beneath its covering of shales. The only thing to suggest a faulted boundary here would be its straightness: the run of the junction north of Lurmi would just about cut its position north of Ratanpur, 30 miles to eastwards. But a geologist in India ought to be the last to ignore the effects of straight scarped boundaries among the original conditions of rock formation.

"For some distance, at least, the same boundary runs steadily to westwards, but I should think that it curves southwards before reaching the trap scarp, for there are some symptoms of the lower boundary of the Vindhyan rocks being not far off from the western limits of the present area, although now concealed beneath the trap of the Mandla plateau.

Western boundary.

"One of the most striking general features of this area of Vindhyan rocks is the almost undisturbed condition of the strata all over the central area up to within a comparatively narrow belt along the boundary. Except on the partial south boundary first noticed, such is markedly the case. It is a remarkable instance of geographical extension prescribed by structural features in very ancient deposits; and it is doubly interesting to find symptoms of those structural features themselves being connected with original conditions of deposition. It will readily be understood how the arrangement I have just indicated should introduce a difficulty to the correct appreciation of the Vindhyan series itself: the topmost strata are almost confined to the low grounds, where they show the minimum of disturbance; while the bottom bands rise along the boundary and are often much modified by contortion and compression. One has to seek far and wide for proof of the two being really continuous. The contrast I have here described is nowhere more marked than on the section of the Hasdu, where (unfortunately) I first came upon these Vindhyans; and the degree of contrast will be illustrated when I say that for two days I noted the upper bands as Talchir (although of abnormal character), while the lower beds passed as a new form of hypo-metamorphics.

"It was along the western boundary that I got the best instance of the upper group being subjected to the full measure of disturbance. The scraggy east—west ridge stretching past Pandaria on the north is principally formed by the pink and blue cherty limestones and the shales so intimately associated with them, the same as are found spread out at the surface all over the low plains of Chhattisgarh; in this ridge all are confusedly crushed up on an E.-W. strike. In the hills to south-west of Pandaria the N.E.-S.W., and N.N.E.-S.S.W. strikes that obtain along the western boundary come in.

"The western boundary, as far as I saw it, bears a general analogy to that on the north; from Ratanpur westwards, a belt, some 5 miles wide, of hills composed in the main of slaty shales separates the plains from the scarp of the Mandla plateau. A gradation of disturbance is observable from the base of the hills, wherever rock is exposed on the plains, the inclination being from the hills. In the outer ridges a band of sandstone is traceable; but towards the north it is very subordinate. The slaty shales forming the mass of the hills may well represent the similar rocks north of Lurmi. In the Chilpi ghât section, on the Bilaspur-Jabalpur road, they last up to the base of the scarp, where they are overlaid by the basalt, at a level corresponding to that of the general height of the fringing hills. There must be here a much greater thickness of shales than along the northern boundary; but here, too, the thickness need be much less than would be at first sight conjectured; for, although the strike is more steady than in the zone of disturbance along the northern boundary, reverse dips are observed, and also frequent exceptions to the N.N.E., S.S.W. strike, showing repetition of the same beds. There are also mineralogical characters corresponding with the stratigraphical differences I have noted. Well in towards the base of the main ascent trappoid rocks appear; but I failed to make out anything definite regarding them, or to separate them and the rocks with them from the general mass. I am disposed to think they may be local metamorphic forms of the Vindhyan shales in the line of maximum compression.

"I may here notice a peculiar rock only observed in this and in one other locality. For some little distance below the junction of the basalt on Chilpi ghât, I noticed the surface strewed with large (10″ to 12″) well-rounded boulders of quartz and of crystalline rocks. At first sight I took them to be debris from the infra-trappean conglomerate; but this notion was soon dispelled by the fact that many of the boulders were more or less shivered, and re-cemented, after slight distortion, by silica—an evidence of violence never observed in Lameta beds. I soon found the boulders in place in the underlying series imbedded in a crumbling earthy slaty matrix, in which I could detect a high westerly underlie. This is here the contact rock, overlaid by a few feet of white Lameta limestone, which is succeeded by a dark greenish-grey earthy crystalloid sub-amygdaloidal trap. This conglomerate may, perhaps, be taken as confirmatory of the conjecture already hazarded, that the crystalline rocks are not far off to westwards, although the boulders are so thoroughly rounded that they may have traveled any distance; the whole deposit has a diluvial character that suggests the proximity of fringing declivities. The other occurrence of this conglomerate is more obscure: it is on the east of the Vindhyan area. The sandstone ridge of Chandarpur has been described as running north and south; an axis of contortion (presumably in connection with subjacent features) between two basins of the upper strata. The range terminates in the Mahanadi at Chandarpur; but in the line of its continuation unusual disturbance is traceable, affecting even the upper beds of the series. At about 5 miles north of Chandarpur a small north-south chain of low hills occurs; to all appearance they are composed of a mass of well-rounded boulders just like those of the Chilpi ghât section. I could nowhere get at the matrix in which they are buried; it must be some soft material like that of the Chilpi ghât conglomerate.

"South of Chilpi ghât, the characters of the western boundary are similar to what has been described. Below Sahuspur, the sandstone becomes more prominent in the outer ridges, and the slaty and hypo-metamorphic rocks below it are also more developed; above Madanpur, they rise to the top of the main scarp, without any capping of Lameta beds or of trappeans. These rocks, underlying the sandstone, may probably be studied to advantage in the ground to south-west of Mohanpur.

Eastern boundaries.

"It was noticed along the southern boundary that there is a gradual increase of irregularity and of disturbance from west to east, coming to a climax in the Bara Pahar, north-west of Sambalpur, at the confluence of the two boundaries. There is a very similar change, but much more complicated on the north, where the Kamra hills offer a very close analogy to the Bara Pahar. The very regular and comparatively simple junction described to west of Ratanpur is altogether changed to east of that place; the crystalline rocks, which seem throughout to underlie the belt of disturbance at no great depth, rise to the surface; and the line of contact from close to Ratanpur to beyond Dulha hill, 20 miles to south-east, follows a very irregular course, which I had not time to follow out in detail. In this area, south-east of Ratanpur, there are decidedly metamorphic rocks, altogether different from the thorough gneissic rocks of the region to the north; there are also rocks which so exactly affect the characters of the bottom Vindhyans, that I must, provisionally at least, identify them as such, while at the same time I failed to detect any decided separation of these quasi-Vindhyans from those quasi-metamorphics. I can only hope to describe the facts and state the difficulties intelligibly, without offering a very decided opinion thereon. Let it be remembered that I made no stay to work out the case: I am only recording single observations.

Hasdu section.

"In the section of the Hasdu, the case is stated most clearly. Immediately below Satiguri there is a contact well exposed. The fine-grained gneissose quartzites, which form the rapids of Chicholi, are still vertical with a northerly strike. A strong bed of coarse rusty pebbly sandstone seems to rest upon a weathered surface of the metamorphic quartzites; the section is very low; and considering, as I did at the time, these overlying beds to be Talchirs I did not examine the contact so closely as I should otherwise have done, but I believe the relation to be as I have stated it. The sandstone slopes southwards, and is overlaid by fine pale shales, and these again by a strong band of tough grey (non-felspathic) sandstones with pebbly surfaces. Thick dark-grey shales succeed, and are overlaid by paler calcareous beds, locally a banded laminated limestone. The pale red varieties cover these and occupy the surface south of Nowagaon. These beds are the regular upper members of the series, and the sandstone represents that already so often mentioned. Its thickness here may be 30 to 40 feet in the two bands. It forms the little ridge running for miles to west-south-west from the river. It may be affirmed that no supposition could bring into original conformable relationship the rocks here in contact, they remain now as at the first.

"To one coming from the north the Kamra hills at once appear as something new: such steep clean cliffs, with well-marked lines of stratification, are never seen among the gneiss rocks; and, on the other hand, the rusty colour of the cliffs, and the sharp angularity of the outline at once distinguish them from the corresponding features in the hills of the secondary rocks. They are formed of a considerable thickness, not less than 200 to 300 feet, of quartzite sandstone resting upon a very variable thickness of reddish gritty shales. The condition of disturbance is exactly what has been so often described in the bottom Vindhyans of this area; the ridges run in every direction, and with any slope just as if the stratification had been broken up by horizontal converging pressures. I have one observation to complete the analogy of these rocks with the bottom Vindhyans of other parts of the area. In the gap to west of the village of Labed a thorough granitoid gneiss shows well up to the base of these covering rocks, so as to leave scarcely a possibility of any relation but one of normal superposition. The relation of these rocks to other metamorphics of this neighbourhood is by no means so simple. The Kamra hills reach up to the left bank of the Hasdu. In the little stream flowing northwards from the Rang ridge, there is an excellent section of the whole group, the sandstones showing in the cliffs on both sides and the red shales in the gorge; for a long way they observe a steady dip of 5° to 10° to north, and just before they disappear in that direction there is an appearance of contortion. In the lower ground further north one only finds rotten unrecognisable gneissose rocks. In the Hasdu the rocks come in all of a sudden at Jogipali. It was here I received the impression that the little-disturbed, little-altered rocks of the hills become rapidly contorted, and at the same time metamorphosed into the fine-grained, sharply bedded gneissose quartzites (a most decidedly metamorphic rock), which come in immediately below and occur more or less continuously with a varying strike down to the junction at Satiguri, as already described. If such be the case, these Kamra rocks cannot by any possibility be grouped with the strata to the south of Satiguri. I am, however, so strongly impressed with the view that the Kamra beds are the bottom Vindhyans, that I fully expect a close examination will prove them quite distinct from the sub-gneissose rocks of the Husdu.

"In the region of the Nilagar the same puzzle is even more strongly marked: the limestones greatly predominate in the upper beds on the low ground, and so occur close to schistose rocks at the same level; I conjecture that they may even be found to lap over in contact with them. They are thus found not far from the base of Dulha hill, on top of which the Kamra quartzite sandstones are easily recognised, resting on schistose and pebbly gneissose massively-bedded rocks. The Soti hill group is altogether formed (at least on the south side) by this new hypo-metamorphic series, a massive trappoid variety being prominent. A northerly and southerly strike is as markedly prevalent in these metamorphic rocks, as the E.-W. strike is in the granitic metamorphics to the north.

North-east boundary.

"Between the Kamra hills and the Bara Pahar, the boundary of the Vindhyans is marked through the Raigarh State by a single ridge, on a line with the outer (eastern) flanks of those hills. This ridge is formed of strong beds of quartzite much crushed and altered, gneissose rocks showing everywhere along its outer base. To the north these are of a coarse, highly felspathic, and granitoid type; but towards the Mahanadi they have a very mongrel character, which greatly obscures the distinctness of this junction. Close sections are obtainable at the passage through the ridge in the stream north of Padampur; the quartzite shows within a few yards of the bank at the point of the ridge having apparently a high dip towards the crystallines; in the river the quartzite seems to be cut out, and there only appear reddish, flaggy, slaty shales, much crushed and rolled, but also on the whole having an inclination towards the crystallines, which are in place some 30 yards up stream. They are variable gneissose and trappoid schists. Here and in other similar positions (as in the stream under Laka to the north-west), I noticed a highly siliceous angular rock to be prominent among the metamorphics, suggesting the possibility of its being a transformed condition of the quartzite; but the general evidence is so strongly against such an interpretation that I must explain this special circumstance as either a coincidence (may be attributable to pre-Vindhyan denudation), or else as an effect of percolation-metamorphism along a plane of junction. The features here reminded me very forcibly of those at the boundary of the lower-Vindhyans, where the ridge of bottom quartzite is cut by the Sone at Bomarsan.

"The junction is tolerably well exposed in the Mahanadi at and below Padampur, and the section is altogether obscure and exceptional. The curve in the river above the town corresponds with a regular curve in the ridge of strong quartzite sandstone on the right bank. From a steady dip of 20° to westwards this sandstone bends round to a similar steady dip to north and north-north-east, apparently passing under the limestones and shales which are freely exposed in the bed of the river, with the same inclination as the sandstones towards the left bank. In this bank under Padampur, and lower down stream, there are those quasi-remnants of a quartzite (as described in last paragraph) adhering to and transfused into the dirty crushed gneiss. Just below the village the channel is about 30 yards wide between these rocks and an island of strong pink limestone with shales. The boundary runs very obliquely across the river; and at its last appearance on the left bank there is a remnant of the limestone and shale, quite unaltered, in actual contact with the mass of pseudo-quartzite and the crushed gneiss rocks. The section exposed is very small, but I could detect no special signs of faulting, such as slickensides or vein-rock, although the features described (with upper rocks at the contact) would *primâ facie* suggest such a phenomenon, and I am not fully prepared to deny the possibility of it. However it may be, it is evident that the passage of the Mahanadi at this spot is connected with the peculiar arrangement of the rocks.

"There is in the Vindhyans of this neighbourhood another exceptional appearance awaiting solution. The ridge of sandstone that has been noticed as bending round with the curve of the river on its right bank, encloses on the west and north the little valley of Dongri, forming a scarp over it. On the floor of the valley strong-bedded limestone with shales, exactly like the usual rocks of the upper part of the series, is exposed, showing little or no disturbance, and thus appearing to pass under the sandstone of the scarp. On the east side of the valley a strong band of exactly similar sandstone slopes up from beneath these limestones and shales. I had not time to examine whether there was a repetition by faulting, or whether the Lahansara sandstone is a local band in the upper strata of the Vindhyans. The latter supposition seemed the most likely. It is from the Dongri valley that most of the 'Padampur' limestone is obtained.

"There is evidence in this region that the boundary I have described was not always the limit of extension of the Vindhyans. At about 3 to 5 miles from that boundary on the north-east there is a broken chain of ridges running parallel to it, and formed I believe of the bottom quartzite. It would seem to be the continuation of the outer ridge of the double range to north-west of Raigarh. From the debris noticed in the valley of Tarukpur, I conjectured that the crystallines were exposed somewhere within it. Thus here, as on the south-east side, we seem to have the actual base of the series exposed all along, the leveling by denudation having here been much aided by the compression and disturbance of the deposits."

The route taken by Mr. Medlicott in this traverse certainly placed him in very close *rapport* with the whole geology of the basin; for he entered it first on the north side from Korba by the Hasdu river, and thence proceeded westward, southward, and eastward all round the edges to the crossing of the Mahanadi at Chandarpur. Then, northwards from this up the valley of the Mand, thus crossing the eastern end of the basin; and so down again along the north-eastern edge by Raigarh to the extreme eastern boundary at Padampur. Little room was therefore left for other than the corroborative evidence which might be accumulated during the progress of connected work. This closer work so far has embraced the greater part of the middle and north-eastern tracts, and the whole of the western portion down to south of Raipur.

All the indications on the north-eastern tracts bear out the original recognition that the Chhattisgarh Vindhyans of the plain and the edging ridges consist, broadly speaking, of a sandstone and a limestone member, the former being the lower of the two: and there is ground for belief that such may be the conditions for the western side. However, I leave the conditions of the geological structure of this side an open question, because the evidence obtained by Mr. Bose in that part of the field, though as yet incomplete, shows that the relations between the rocks of the plain and those of the adjacent hill slopes of the Saletekri range are not so easily interpreted as Mr. Medlicott's reconnaissance would seem to imply.

It is true that occasional narrow seams of slaty shales and coarse schists do come in under, and in association with, the bottom sandstones along the northern boundary, but these are so insignificant as not to affect the general sequence. What they do seem to show, however, is that the bottom member—an essentially sandstone formation on the north-eastern, eastern, and southern sides—either gradually changes from a poorer and poorer sandy series to a stronger and stronger shale or slaty one with subordinate sandstones on the north-western edges, or that it continues on in this impoverished condition, sometimes being overlapped by the limestones, over a different and older series.

Later observations on the north-east boundary.—There is no necessity at present for going into detail regarding the style of the boundary from Padampur north-westwards past Raigarh. For the most part, it is a generally faulted one, the bottom quartzites, which must be here of great thickness, cropping up at high angles from under the much less disturbed limestones and shales of the plains, and having—what look to be—their lower strata, at the eastern bases of the great ridges, in close and abrupt juxtaposition with the crystallines of the low grounds beyond. I am myself inclined to suspect that there has been re-duplication, if not inversion, with a crushing-up and fracture of long ellipsoidal dome-like undulations. Be this as it may, the whole aspect of the boundary is very analogous to that of much of the eastern frontier of the great area of Kadapah and Karnul rocks in the Kistna and Nellore districts of the Madras Presidency.

Some 5 or 6 miles to the south of the passage of the Mand river across the sandstone rim of the basin, a most instructive example of a crushed-up and partially faulted dome of the bottom sandstones is exhibited in the Gida hill mass which has been cut into and scoured out by denudation until the internal core of crystallines is fully exposed to view. A good deal of faulting and crushing is disclosed here and there along the contact edges in the interior; but the easy lie of south-easterly dipping strata is quite plain under Bamandai hill and on the path leading out to Basnajhar. A very thin streak of brown rusty, reddish and greenish schists, and sandy—rather sharp gravelly—shales occurs at the very contact, just between the gneiss and the thicker beds of quartzite sandstone on this path. Round the southern skirts of the hill the sandstones run easily under the red-purple calcareous shales and grey-blue limestones of the plain.

Some idea of the thickness of the sandstone series is also obtainable at this point,—a feature which had hitherto only been guessed at in the Raigarh ridges, where undoubted bottom beds are not recognisable in contact with the gneiss. Here, however, the base is known, and a fair estimate can be formed from the lofty scarped faces and under-cliff of Bamandai hill (1,439 feet), and from a scramble across the Gida ridge near its summit (1,480 feet) where the beds are vertical, though down either slope the dip is generally to westward, the angle decreasing towards the foot of the western side. In this way the conclusion is forced on one that there must be at least 1,000 feet of more or less altered (quartzite) sandstones, rarely coarse and gravelly, oftenest thick-bedded and fine-grained, and without any conglomerates as far as I could see. Their likeness to those of the Raigarh ridges is strong in every way; indeed there cannot be a doubt of the two belonging to one and the same group.

To the northward of this dome, after an interval of shales (and strong blue limestones at Banipathar) in abrupt contact with a north-south exposure of crystallines, the sandstone hills of the rim hade up in long gentle slopes, the beds lying at 5°, 10°, 20°, southward, with surfaces wonderfully worn in sinuous curves and zig-zags of contour. This easy lie only lasts for about half the width of the hills; when undulation, at first slight and then quick, has allowed of more rugged denudation, giving the broad and humpy masses overlooking the low-lying wide expanse of the Mand valley coal-field, the rocks of which lap up against the sandstone hills, or are only denuded for short distances, giving exposures of crystallines in abrupt juxtaposition with the Vindhyans.

Away to the north-west, the sandstone hills attain higher elevations as in the Gar hill (1,948 feet), the floor crystallines being exposed in the valleys and on slopes below lofty scarps; while outlying isolated strips of Vindhyans occur in such abrupt relation to the surrounding gneisses of the plains beyond that their position can only be accounted for by their having been let in by faulting.

No better display of faulted or squeezed folds, remnants of arches, and natural boundaries below scarps, can be pointed out than that of the Kamra range still further westward. The Kamra mass (2,878 feet) itself has its lower slopes of crystallines crowned by a somewhat crushed synclinal of thick-bedded sandstones, with a good band of overlying red shales in the hollow above, giving scarped edges on the northern face of some hundred feet high; and, in the deep valley between this mass and the proper rim, one may recognize the remains of the great core of crystallines and its covering arch of sandstones.

A magnificent display of dip slopes occurs in this neighbourhood, on the southern flanks of the Pidadei (2,836 feet) ridge. Broad bed surfaces of dark black-brown weathering sandstones slope up from the narrow valley, inside the low foot-hills edging the plains, at an angle of 30° or so, with hardly a break, to the very crest of the ridge, the sharp and jagged bed edges of which stand out clear against the sky. There is scarcely a foot-hold on these slopes for any but the local jungle people; and it is merely where jointing and weathering have facilitated the scouring out and breaking up of ledges and the gathering of angular debris in stream-like heaps tailing up the slopes, that scrub and low jungle have been able to grow and vary the dark expanses of bare rock sheets.

Westward of the village of Labed, at the foot of the Kamra hill, an open country of crystallines extends to the Hasdu river, its southern edge being fringed by the low slopes leading up to the now simple and much less lofty edging rim of sandstones in the Sidapat (1,524 feet) and Rang, or Maruarani (1,713 feet) hills. In this direction, too, the thickness of the sandstones diminishes very rapidly; so much so, that beyond the Hasdu, in the Sandadi and Jogia (1,113 feet) undulations there can scarcely be more than 150 to 200 feet. The natural pose of the sandstones on the gneiss is fairly well displayed; but it is here that their lowest strata become decidedly thinner and more flaggy, while associated with them are sharp gravelly sands, sandy shales, and coarse schistose and clay-slate layers; in fact a stronger show of the contact beds seen in the Gida hill.

An interesting feature about this Rang or Maruarani region is, that though the hill appears at a distance to be capped with sandstones, and to have a certain slight scarp, after the fashion of the edging hills over the country already described, it is really only covered or scarped with those more flaggy, shaly, and coarse sandy gravelly strata just described. The bulk of the massive sandstones lies well in from the scarp or outer edge, being underlaid by about 30 feet of clayey and sandy flags, shales, and flagstones, which crop up and form a good deal of the upper part of Rang and Maruarani, as well as the edge of the low scarp topping the slopes on the left bank of the Hasdu river and overlooking the villages of Jika and Mohara. This western scarp is very instructive; for it shows the bottom beds of the sandstone series all along its crest as they rise gradually northwards to the Rang spur, over which they roll easily and bend down almost to the plains. In descending from the hills to Jika, the scarp or edge of the descent is very thin, about 10 feet or often less, consisting of a bed or beds of coarse black or reddish-brown ferruginous grits, made up of grains of white and glassy quartz in a ferruginous matrix, gravelly or pebbly towards the base, or sometimes having larger scattered pebbles of the same kind of quartz. This hard bed lies directly on east to west striking micaceous schists, or coarsish crystalline granular micaceous rocks easily weathered; or there is at intervals a varying thickness of greenish and dirty-grey earthy micaceous clay-slates coming in between it and the sub-metamorphic rocks.

It is necessary to state here that this undoubted bottom bed of the Vindhyans is lying unconformably on the micaceous schists and other rocks constituting the slopes leading down to the Jika river flat. At the same time, it struck me that these subjacent schists could hardly be considered as belonging to the regular crystalline or gneissic series, though they look more metamorphic than transitional. There is an E.–W. strike in the slopes and away down in the plain, the general strike in fact of the true gneisses to the north; but this is apparently only local, as they seem to trend round on the opposite bank of the river and assume the N.–S. strike exhibited by the peculiar quartzite or quartz-schist bands lower down about Satiguri, and away to the westward towards the Dulha and Soti country already treated of as showing rocks having a transtional aspect.

The style of the bottom sandstones westward from this point on the Hasdu is given in Mr. Medlicott's paper (*ante*); but it may be mentioned here that I have representatives of them at the extreme north-west corner near Borla where quartzite sandstones and pebble beds occur underlying the limestones.

The rocks of the great plain are essentially limestones and shales which roll about in long, easy undulations, or are comparatively flat for many square miles at a time. It is only here and there, however, that exposures are frequent or of any extent, the most of the plain being covered with alluvial clays or soils of various kinds, beneath which the limestones or the shales may be found at a moderate depth. The shales are nearly always of a red-purple color, with pinkish or greyish shades: very rarely are they of green or dirty grey, or dark colors, though this is their style in the immediate neighbourhood of Raigarh. The limestones are generally grey or fawn-colored, sometimes pinkish or pale-reddish purple, often almost black, or dark blue-grey; thick-bedded compact splintery, or flaggy coarse and earthy or clayey where they shade up or down into shales; they are very often siliceous throughout, or seamed with fine films of siliceous matter, and chert bands. The more clayey and shaly laminated bands are often remarkably concretionary with polygonal, sub-spheroidal, and flattened oyster-like masses packed together over the bed surfaces, or along inter-laminar bands of more compact clayey constitution. Both shales and limestones are more or less cleaved round the edges of the field, more particularly so perhaps at the north-west corner. It is difficult over such a flat and ill-exposed country to say whether there may not be more than two steady bands of these rocks: it appeared to me that, broadly speaking, there is a tendency in the whole member to be generally shaly at the bottom, the limestones coming over in varied force; though there is also a tendency in the shale band to have subordinate seams of limestones while the limestone has its shale intercalations.

Local intercalations, or even apparent super-jacent exposures of thin sandstones pebble beds and sandy flags, or lydian stone bands, are exhibited at places; the latter occurring to the north-east of Bilaspur about Norgoru, and the former to a very wide extent in the Raipur country, or on the Mahanadi near Chandarpur, or in the low Sai Dongri group of hillocks towards Padampur.

A curious, and as yet stratigraphically unsettled, outcrop of apparently higher sandstones and extremely coarse conglomerates occurs on the right bank of the Mand where it crosses the plain before joining the Mahanadi, as the Girgiri and Tundri ridges. These low hills lie in a sort of broken chain, with intervening stretches of low country, between the Gida hill on the north and the long north to south Dadarpali range on the right or south bank of the Mahanadi. Mr. Medlicott surmised that these outcrops might be northerly prolongations of the anticlinal roll in the Dadarpali range; but a closer examination of them seems to me to point to their being portions of a crushed synclinal which might be expected as a complementary hollow wave in the strata on one side of the hidden portion of the anticlinal exhibited in Dadarpalli and the southern end of Gida hill.

In the first place, it is really only by the merest chance exposures that rock is seen *in situ* in these ridges, for they are to all appearance made up entirely of loose well-worn pebbles, shingle, and largish boulders of various kinds of quartzite, quartz-schist, and some crystalline rocks. The whole facies is that of great shingle banks formed in comparatively recent times alongside the bank of the Mand river: even the tops of the ridges consist of loose debris. However, I found good hard quartzite sandstone and conglomerate in a small cross valley north of the Govindpur peak, obscurely bedded but apparently vertical and striking north to south. Again on the extreme north end of the western Tundri ridge, there are coarse pudding-stones, having a hard purple clay-stone matrix, which are traceable along the crest of that part of the ridge into massive heavy conglomerate rock having no definite bedding. The pudding-stone is very obscurely associated by super-position on the red-purple shales forming the slopes of the ridge the dip of the latter being 40° to 50° eastward. The main portion of this western Tundri ridge shows no bedded rock, but it has its steeper side to the west. The eastern Tundri ridge, on the other hand, looks to have a westerly dip, and this agrees with the lie of the shales and gritty beds in the plain at its northern end.

The shales and limestones in the plains below these ridges have never been traced into actual contact with the sandstones, though they are often quite close enough to accentuate the fact that on both sides their dip is rolling and inwards towards the ridges; while at the north end of Girgiri, by the village of Bailagarh, the shales strike round east—west and dip southwards.

All these conditions point, I think, to the preservation in a couple of ellipsoidal hollows or synclinal waves of a remnant of overlying sandstones; the southern or Girgiri synclinal being in an extreme state of crush. Looking at the rapid change from heavy conglomerate to scattered pebble bed or pudding-stone at the north end of the west Tundri ridge, it would appear as though their extremely coarse detrital constitution may after all be only a very local development in an insignificant sandstone band, the lateral extension of which may be indicated by the occasional outcrops of sandy flags and pebble beds occurring in the limestones and shales to the westward in the valley of the Baghar stream; or it may be an extension of the sandstones in the Sai Dongri hillocks near Padampur. Mr. Bose has also indicated a large spread of sandstones in the Raipur country, overlying, to all appearance, the limestone group; and the Girgiri beds may be related to these. There is, of course, no certainty that these various and detached sandstone occurrences are of one and the same band, or even that some of them are not merely local intercalations with the limestones; so that it would be rash to conclude that the Girgiri conglomerates or the Raipur sandstones belonged to a further and superior member in the series; at the same time there are evidences of the possibility of such a succession in the detached area of Vindhyans, near Nawagarh, to the south of this basin, described by Mr. Ball in his papers on the "Mahanadi basin and its vicinity."[1]

Chilpi beds.—At the north-west corner of the basin, the route from the Bilaspur plains to the Mandla plateau goes by the Chilpi ghât; and as it was on this pass that they were first examined, the rocks now to be treated of may, for present convenience, go by its name. Mr. Medlicott has suggested the possibility of their being of lower Vindhyan age, and as either lower than or partially representative of the sandstone member of the Chhattisgarh series. It was thought that Mr. Bose's examination of the western side of the basin, in the Saletekri range and its slopes, in so far as it took up a southerly continuation of the Chilpi rocks, would have cleared up all difficulties or obscurities in the way of settling their relations to the rocks of the plain; but, as already hinted, that examination was not sufficiently exhaustive. My march into Mandla, at the end of the season, gave another opportunity of examining the ghât section; and this experience taken in connection with what I had already seen *en passant* at Ratanpur and about the Soti hill, enables me to connect in a distant way, the rocks of both areas and compare the relations of each with the plain series.

As far as the Chilpi ghât and its immediate neighbourhood are concerned, there is no contact section: the strata of the foot-hills are separated from the limestones and shales of the plains by a belt, a mile or so in width, of alluvial deposits, and such seems to be the condition of obscurity all the way southwards along the western edge of the plain. Taking the section along the road to Chilpi from Borla village on the edge of the plain; the traveller's dâk bungalow is built on grey or pale flesh-colored hard quartzite sandstones in strongish beds, somewhat pebbly and conglomeratic which are here exposed by denudation as a roll up from under the limestones and shales of the immediate neighbourhood. The small temple hill in the village consists of these latter rocks; and to the westward there is about a mile width of alluvial deposits. The road then rises gradually from the alluvial flat over brown and buff-weathering clay-slates, internally of dirty dark green color, constituting the main mass of the first ridges or foot-hills, their strike being about north-east–south-west, with a rolling or undulating general dip to north-west. To the southward of Borla, about the neighbourhood of Chahata and Gungho, just within the edge of the plain this strike has a more southerly trend; and here the clay slates are overlaid by thin sandstones and gravels with a rolling easterly dip, though, as usual, there is the tantalizing blank of alluvium and cotton soil between them and the limestones out in the plain of Minminia. Chahata is on dark-green, reddish-brown weathering, coarse clay-slates, and these are tolerably well traceable towards Gungho where they gradually become overlaid by rolling yellow and buff sandy and clayey shales, which in their turn are succeeded by thin sandstones and gravels, having an easterly dip.

[1] Records, G. S. I., X, p. 172.

The difficulty is to say decidedly whether these shales come in over the clay-slates in conformable or unconformable succession; for the lie of the latter is not well displayed, and they could easily have rolled over from their high westerly dip at Chahata. My own opinion is that the shales and sandstones are unconformable, and they certainly do look very like the thin gravelly and shaly bottom beds at Ratanpur, and on the Hasdu.

Taking up the road section again; it crosses the foot-hills by a winding course to the open valley of the Banjari stream, always over dark-green clay-slates (weathering buff-brown and reddish colors) with which are associated subordinate beds of harder compact claystone and—less frequently—beds of hard sandstone (quartzite) much stringed with white quartz. Similar rocks, with perhaps coarser and more sandy cleaved shales, sometimes weathering a bright ferruginous red, fill up this valley and constitute the greater part of the ridges on its western side, and beyond this occur traces of hard green quartzose beds, or grits, full of particles of white quartz and felspar or larger sub-angular fragments of granitic and crystalline debris. Then, at the foot of the old ghât or pass up to Rajahdar are massive, granular, and somewhat porphyritic greenstones, and red and green mottled brown trappoid rocks, in somewhat banded outcrops and apparently striking with the green quartzose grits, and slaty strata even higher up the pass.

The strike over all this ground is about north-east—south-west, and the dip appears to be generally north-westward, though rolling and folding almost amounting to reduplication are evident. Towards the foot of the old ghât, however, the strike trends round to nearly north and south.

Following up the Banjari stream towards Palak, the change of strike becomes more quickly developed, until at the camping place it is south-south-east to north-north-west, with east-south-east dips. Here, too, there is a decided and sudden change from the clay-slates of the foot-hills to what would appear to be—from the dip—an underlying band of hard massive green white-speckled grits, associated with coarser and more massive cleaved shales and shaly grits, and clay slates. The speckled grits become, as the strike is crossed against the dip, coarser and coarser in their contained debris, until a thick and strong band of hard, but irregularly-bedded, extremely coarse and heavy conglomerate is reached, which is best seen in the river north of the road. This band is a closely packed but very obscurely bedded mass of well-worn, rounded, sub-angular and angular fragments of various kinds of quartz, quartz-rock, quartzose rock, or fine quartzite and quartz-schist, hard green shales and cherts, through which are scattered small pebbles or rounded masses of white felspar. The speckled green grits above it are fuller of bits of white quartz and felspar; and when they are very fine grained and compact, they certainly have a sort of igneous look. Below, or to the westward of the conglomerate band, are further dark-green massive slaty bands, with softer slates at intervals, and there are also frequent outcrops, perhaps repetitions, of the white speckled grits. Towards the foot of the main ascent of the ghât, indications of a lower easterly dip are frequent, and there is some undulation among hard thick-bedded massive slaty quartzose rocks. Next comes a long display of trappoids and dark-green massive trap or greenstone; giving perhaps an exaggerated view of their possible thickness, as the road keeps a good deal on what may be their strike, if they are associated in this way with the more manifestly bedded rocks of the foot and upper part of the pass. Near the top a heavy conglomerate, exactly like that below at Palak, occurs with a westerly dip; and this rock is succeeded by the Lameta limestone and the overlying basalts of the Deccan series.

On the plateau, the basalts, after some distance from the edge, and to the north of Rajahdar, have been denuded along the valley of the Phen river, until the thin underlying Lametas again become exposed; while further down the valley there are occasional outcrops of a strong conglomerate answering exactly to that at bottom and top of the ghât. Thence westwards to Motinala, clay slates and green quartzose and compact schistose rocks are prevalent. Schistose micaceous sandstone flags occur in the bed of the stream below Motinala, with a dip of 5° north-west; and similar sandstones and slaty shales are common in every small water-course of this small valley, rolling about at all angles.

So far the Chilpi facies is clearly recognizable; but somewhat more generally schistose, hornblendic and micaceous rocks come in over the Halon valley and extend to the Bichia basalt plateau, without however any sudden change, or any more steady strike or lie. On the other hand, in descending from the western edge of the Bichia plateau to the Anjania valley, the more generally massive and crystalline gneissic rocks would indicate that the limit of the Chilpis had been passed.

In reviewing the lithological and stratigraphical conditions exhibited on the Chilpi ghât, as well as over the area of what are manifestly the same set of rocks westwards towards the Hasdu river, or again southwards in the Saletekri ridge, it is difficult to avoid noticing certain points which seem to militate against the relation suggested by Mr. Medlicott as existing between them and the Lower Vindhyans of the basin.

In the first place, the Chilpi rocks have a decidedly different facies to those of the plain and its proper rim, while they seem to pass gradually or without a break into more and more thoroughly sub-metamorphic rocks. I do not, however, here lose sight of the fact that in Mr. Medlicott's Lurmi section, the junction between the crystallines of the Khathar hill and the slates and shales on its southern flanks is comparatively sharp.

2. There are rocks on the Chilpi ghât which can be very closely matched by those of the Ratanpur 'old city' hills and the Soti hill, where as I have already described, there seems to be a transitional facies emphasized by a strongly discordant relation with the bottom sandstones of the rim of the basin.

3. The Chilpi series occupies a broad tract of country, and though this may be shewn to narrow down in a gradual way to the Hasdu river, the strange fact remains—supposing they are Lower Vindhyans—that it should come in in such a marked and rapidly thickening manner at one side or corner of the basin either from under, or in association with a thinning out of an essentially sandstone group which has been over the remaining two-thirds of the basin edge the absolute basal member of the Chhattisgarh Vindhyans.

4. Although there is no known occurrence of the thin band of bottom sandstones (with shale intercalations) on the Chilpi ghât itself; an apparent

representative of them occurs to the south of Borla overlying, I think unconformably, the green clay slates of the foot-hills. Similar sandstones have been recognized still further to the south, but under the disadvantage of not as yet having been clearly distinguished from other sandstones which are associated with the slates and trappoids in the Saletekri hills. Nevertheless these questionable occurrences have some value in this stage of the enquiry, in so far as they lend color to the expectation that a distinct and recognizable thin sandstone representative of the Chandarpur beds may exist all round the western side of the basin.

5. The apparent parallelism of strike in the rocks of the plains, and in those of the foot-hills, can be accounted for by north-westerly crush of the easy-lying basonal beds against a series which may have already had somewhat of the strike exhibited in the Lurmi, Chilpi, and Saletekri slopes.

There are other exhibitions not unconnected with the Chilpi rocks which might be referred to now; such as the occurrence at Sakoli of coarse conglomerates, trappoids, and green rocks in the extreme southern spurs and prolongations of the Saletekri hills, already known through the work of Messrs. Blanford and Ball,[1] but they have not been connected up with the present work.

I may point out, however, that Mr. Bose has mapped in a tract of rocks on the southern edge of the Raipur part of the field, separated entirely by crystallines, from those of the Saletekri hills, near Khussumkassa, which he considers representatives of the Saletekri, or in other words the Chilpi series. The awkwardness of this occurrence is that the relations of the bottom sandstones of the basin edge to those underlying rocks are not sufficiently displayed, or closely enough described by Mr. Bose, for the acceptation of the unconformity which might be inferred.

The relations of the Chilpi series and the proper Chhattisgarh Vindhyans must therefore still remain an open question; and though I have tried as well as I could to put forward some of the points which strike me as not satisfying the requirements of Mr. Medlicott's suggestion, it will be safer to hold by it until better evidence can be accumulated.

LOWER GONDWANA.

The general limits of this formation in the present field have been long known through the work of Messrs. Medlicott, W. T. Blanford, and Ball, and papers by the two last authors on the numerous coal-fields have appeared from time to time in these records. Thus our later work has been little else but the filling in of unsurveyed intervals, or the ascertaining of details.

A remarkable physical feature in this region, paralleled in many other Lower Gondwana areas, is the generally straight south-western boundary, extending as it does with tolerable precision from the neighbourhood of Korba nearly down to Sambalpur. It is not proposed here to enter further into the general discussion as to whether such straightness of boundary is due to faulting in great part, or merely to deposition in a straight-sided valley or basin; but, as bearing upon the local feature, the fact of the occurrence of a small and hitherto unknown area of

[1] Records, G. S. I., X, p. 180.

Talchirs and Barakars actually within the Chhattisgarh basin is of considerable interest.

This outlier occurs on the eastern flanks of the Gida hill, and being in the plains, is at about the same level as, or very little lower than, the proper Mand valley coal-field to the north of the river pass. It occupies an area of about 5¼ square miles; the Barakars, which are in contact with the Vindhyan sandstones of the hill, taking up about half the space, while the Talchirs hade out from underneath them and fill up the remaining half, the latter resting on the red purple shales of the plain. Both groups are well displayed in the vicinity of the village of Kunkuni, lying with an easy dip of 5°—10° west-south-west. Actual contact of the Barakars on the Vindhyan sandstones was not found, but the junction is so close at the southern end where the Balu stream issues from the central valley of the hill mass, and the baying-in of the sandstones over the easterly dipping quartzites is so clear that natural and easy contacts cannot be doubted.

The Barakars resemble very closely those of the Raigarh-Hingir country, but without any trace of coal that I could see, and they have near the base the same ferruginous flaggy and clay-stone band, giving lateritic weathering, which, here too, is worked for iron by a colony of *lohars*. The Talchirs are the usual greenish silts or very fine sands with occasional boulders of gneiss and quartzite, and at the southern end of the field a local exhibition of fine pale-yellow or buff sandy shales occurs in a bend of the Balu stream.

I will not go so far as to suggest that this little field was once connected with the main area to the north; indeed, the character and lie of the rocks in the river gorge is rather against such a view: but there is no doubt that the conditions of deposition and subsequent movement must have been much the same in both areas, as well as in the more distant area of Talchirs and Barakars to the eastward in the Sambalpuri-Kodibuga valley near Raigarh. The only difference in the occurrence of the groups in the latter region is that the Talchirs are not exposed on what may be called the off-side with regard to the Vindhyan sandstone edge, but crop up at intervals where the Barakars have been denuded on the inside or next the hill ridge: but this does not alter the fact that here, as on the flanks of the Gida hill, the Barakars simply overlap natural-lying Talchirs by thickness of deposition against a rather steep wall of more ancient rocks. My examination of the Sambalpuri valley was very close, and it soon became evident that the boundary where the Talchirs are seen in close juxtaposition with the Vindhyans is not straight but wavy, and delineatable (to coin a word) as such on the 1-inch map. Indeed, if general straightness were to be taken as at all conclusive of faulting, it might be doubted whether the straight limitation (always covered up by alluvium) between the Kamthis and Barakars on the opposite side of this narrow valley were natural. The turning up of the Talchirs at low angles along the skirts of the Sambalpuri ridge of quartzites is, at the same time, really not more than is consistent with the peculiar filling-up and banked style of very many curious Talchir exposures, yet to be noticed, in other parts of the field.

Talchirs.—Further survey has marked out a strong development to the northward of Korba town, in the Chhuri, Mahtin, and Uprora zemindaries, and on north-eastward into Sirgujah by Lakhanpur. On the Chhuri and Mahtin side, the formation fills up the bottoms of several long and deep valleys running between high hills of gneiss, while there are also outlying patches of the characteristic silts and boulder-bed on the hills and uplands; and in this way the intervals—if indeed they do exist—which separate the Mahanadi tract of Gondwanas from that of the Son in South Rewah must be very short. In Uprora, the Talchirs are continued eastward and north-eastward by a narrow fringe bordering the northern edge of the Phutka mass of hills, and thence below the steep slopes of the Lakhanpur plateaus.

The thickness over this part of the country is very unsteady: and the presence of boulder-bed, or fine laminated shales, or fine silty sandstones is equally capricious. The floor of crystallines is most rugged and uneven; valleys, ravines ridges and bosses of these rocks having been filled up or covered over until the more even surface was produced upon which the succeeding Barakars were deposited. To the north-eastward, or at the foot of the Dulapur (3,169 feet) and Jaun (3,197 feet) range, the fringe is very narrow and of little thickness; but further south or below the Samar (2,411 feet) cliffs, the boulder-bed and fine uneven-bedded sandstones are well spread out over the Arsena upland, with a most variable thickness, evidently filling up hollows which were as numerous and deep as the existing valley system of the head drainage of the Gandhar stream. The Arsena display is very curious and puzzling, for one could not be always sure that the frequent occurrences of very large masses of gneiss and granites were not *in situ*, or that the extraordinary amount of gravel and shingle associated with them was not merely Talchir debris. However, one soon meets with almost as frequent big masses of quartzite sandstone; while the different lithology of the crystalline masses becomes apparent: and in the end similar blocks are seen embedded in the fine silty sandstones forming the very steep sides of some of the minor valleys.

As usual, there is no fixed horizon or level for the coarser or finer forms of deposition: fine sandstone, shales, or boulder bed may be met anywhere in the ravines or on the shoulders of the downs or rounded hills of this tract; and the general facies is that of irregularly banked-up accumulations of fine silts, shales, or boulder bed having only very local lamination or signs of bedding.

The small water-course rising on the Arsena side of the remarkable crystalline ridge (with a dyke core of basalt), gives a fair display of the Talchirs as it flows down towards Lemru. The bottom rocks, plastered as it were over the crystallines, are blue-green silts and shales full of pebbles and big boulders of all kinds of quartzite sandstones, hardened shales or clay-stones, and crystallines, not crowded together but scattered at irregular intervals. There is no steady lamination or bedding, merely a sort of inconstant or wavy arrangement indicative of irregular and interrupted sedimentation. The boulder banks are overlaid or succeeded by yellow-green and buff sandy shales—still holding a few boulders—which in their turn shade up into a very thick accumulation, sometimes bedded, of yellow and greenish sandstones. These last are succeeded by coarser sandstones, but without any passage being seen in any exposure that I could find, which must be taken as Barakars. The low ridge immediately south of Arsena, for example, has its summit of thin-bedded brown ferruginous sandstones and grits of the lower Barakar type of the Hingir coal-field; but they come in quite gradually and naturally over the Talchirs.

Between Lemru and Deopani to the west, the out-crops of huge masses of gneiss in the fine buff sandstones are so strong at times that some of them can hardly be other than knobs or crests of irregular ridges, once more exposed through denudation of the Talchirs; and this form of occurrence is not so strange when the conditions of the very remarkable system of east-west crystalline and basaltic ridges in Mahtin and Uprora is considered. The crystalline ridges undoubtedly stood out very much, as they do now, in Talchir times; for silts, boulder bed, and sandstones can be seen in both regions lying flush against the base of some ridges, even on both sides; as is more particularly the case in the valley to the north of Uprora, and in the two long and narrow valleys leading westward from Mahtin to the Pendra upland: but the basaltic dykes forming some of their cores are of later age, for in other parts of the field they cut right up through the Gondwanas into contact or junction with the overlying Deccan trap.

The lie of the formation is generally very easy; but the different elevations within short distances, at which one finds bottom deposits, are apparently so great that it has been thought necessary by previous observers to call in more than ordinary elevatory forces to account for them. The highest show of Talchirs in this field is on the Rer valley, near Meria, at about 2,500 feet over sea level, while the nearest low-lying tracts of the same rocks are on the head-waters of the Mand near Rakhob, at an elevation of about 1,000 feet, with an interval of about 19 miles horizontal; or in other words with a fall of 1,500 feet in 19 miles. There is undoubtedly some faulting in the neighbourhood of Rakhob, but an average dip of not more than 11° is all that is required to carry the Talchirs of the Mand up to their elevation on the Rer. Much sharper differences of level, though the absolute height is not so great, are frequent, according to the observations recorded by Sub-Assistant Hira Lal, in the Chhuri and Mahtin country; but these are all, I think, explainable on the peculiar filling-up tendencies or ballasting powers of a ground-ice, or floating-ice formation such as the lower portion of the Talchirs appears to have been.

The puzzle about the formation here is to say where it ceases in an upward succession, or at what stage the overlying Barakars come in: all that one can be sure of is, the being on Talchirs of the more typical form, or on Barakars of well-known and widely distributed type; and thus the boundary between the two is to a large extent arbitrary, though after all it cannot be far out on either one side or the other. I was enabled to follow the succession with fair closeness at two points: first along the bed of the Kesla tributary of the Dhongur river on the south-west skirts of the Phutka mass of hills in Korba; and next, down the Katora pass, from the Sirgujah high-lands to the lower upland of Uprora, in the extreme north-east of our area. I was on undoubted Barakars with coal seams in the Kesla stream, and in following its course downwards, I passed, without once losing sight of rock, insensibly from great thick-bedded pot-hole-worn sandstones to finer and finer-grained thick beds of greenish-yellow and buff sandstones almost like some varieties of Talchir sandstones. Then after a blank of alluvial deposits, the next rocks seen lower down the river towards Risdu are silts and the boulder bed. On the Katora pass, the interval between the undoubted boulder-bed and silty flags at the bottom near Bahue and the thick-bedded fine yellowish or buff sandstones of the lowest run of cliffs is much shorter; but it is covered, as usual, on that side of the country by a talus of debris which has gathered below these cliffs.

One other but isolated occurrence remains to be noticed of Talchirs and Barakars in tolerably close contact. On the head-waters of the Rer river, that is, on the upland to which the Katora pass leads, about the villages of Kesura and Merua, Mr. Ball had already distinguished Talchirs, or rocks which he considered lithologically undistinguishable from them. There can be no doubt as to their occurrence here, but the boulder bed is in such close and abrupt juxtaposition with thick-bedded fine sandstones of the type indicated in the last paragraph that the junction has certainly an appearance of unconfirmity about it. Unfortunately, I was here struck down with a sharp attack of fever which necessitated my marching out of the valley as soon as I could be moved, so that the clearing up of this point remains over for a later visit.

Barakars.—This formation is fairly distinguishable over most of the Korba, Mand, and Rer regions, while it possesses the valuable characteristic of being coal-bearing in several localities. Ball had already followed it out over the east side of the Mand valley and Blanford had traversed the Korba field; while I have closed in the country between, carrying the coal-bearing horizon into the lower portion of the great Phutka hill block. There is no difficulty about recognition on the south, south-eastern, and eastern flanks of the mountains, where the slopes are long, giving good exposures of typical rocks; but it is not at all so easy to do this on the steep-cliffed north-western frontage, for in the first place I failed to get a trace of coal or carbonaceous shale, and the rocks themselves are not so clearly of the *Barakar* type. It turned out, however, that the lower line of cliffs is made up of thick and fine-grained beds like those of the lower reaches of the Kesla river, and the bottom of the Katora pass already referred to; and that the more usual form of Barakar sandstones is higher up in the cliffs or rather in the short terrace between the two tiers of cliffs, generally marking the north-west faces of the range. The key to this interpretation is afforded by the succession of strata as exhibited in the Mand valley below the western slopes of the Phutka range, particularly on the Bijakharra and Labed streams. In these sections a fairly well-developed seam of coal and carbonaceous shales is overlaid by softish fine-grained yellow or buff sandstone, dashed here and there with sheets of salmon and red colour. High bluffs of this form of rock occur every now and then at the sharp bends of the stream, sometimes 50 feet in height, without a single bed parting; or if there be such, it is only for short distances. Often there is just a thin bottom layer or bed, 6 to 8 inches in thickness, coming in over the blue and grey shales of the coal seam. The features of this variety of Barakar sandstones are thickness of bedding and fineness of texture. Up above and for some distance in from the face of these cliffs the rock is so soft and devoid of any trace of lamination that it might be taken for a semi-hardened or cemented form of superficial deposit. In the Bijakharra river above the Kulgao-Phulsari crossing, one may walk for a mile or so over coal and carbonacious shales with the superincumbent thick-bedded, even-textured, fine-grained buff and yellow red-dashed sandstones rising up in clean cliffs on either side; and still further up, these are gradually succeeded by massive coarse and pot-hole-worn sandstones of the type so prevalent in Hingir and in the Wardha and Godavari valleys.

This soft lower member is traceable on northwards to Amaldiha at the head of the Mand valley, and is recognizable again in the Matringa valley of the Sirgujah upland on the head-waters of the Rer. Indeed, the constitution and texture, and fair horizontality of these rocks has contributed greatly to the peculiar terraced contour of the bottom of the Matringa valley: the steam runs in what looks exactly like a terraced alluvial plain at the bottom of a long and wide mountain valley, but the terrace is of these soft Barakar rocks which give the 30 to 50 feet step to the proper river plain. The villages of Matringa, Merua, &c., the cultivated lands, and all the beautiful stretch of *sal* jungle are on this terrace and overlook as from a vantage ground the lower flat with its winding river. Similar strata terrace the valley of the Borki tributary of the Rer to the westward, up which the road to the Katora pass runs; and over that pass and down its western slopes in the Bahue valley the same beds are again found forming a terrace step and cliff descent of nearly 200 feet to the underlying Talchirs.

Kamthis.—The Barakars of the basal portion of the Phutka range are gradually succeeded by a great thickness of more open-grained coarser-textured and often pebbly, generally white or purple-streaked felspathic sandstones, with frequent intercalations of white clays, in moderately thick and well-defined beds; the only sign of a break or passage being the occurrence of a badly-defined band of varying thickness of brown-weathering ferruginous sandstones which may be taken to represent the more generally surface-exposed tracts of red and brown Kamthis in the Hingir-Raigarh country. The pale colour and wonderfully pebbly constitution of the upper strata led me at first to suspect that the higher parts of the hill mass might turn out to be of Upper Gondwana rocks; but the occurrence of much crushed, though recognizable, specimens of *Vertebraria* in the white clays of the Guarduari (3,250 feet) hill effectually stopped this expectation.

That the brown ferruginous band of sandstones marks the basal portion of the Kamthis in the Phutka range, is pretty evident from the fact of Mr. Ball having been able to distinguish his Hingir or 'upper sandstones' (*Kamthis*) up to and across the Mand river, as far as the little Gumar plateau; and from my having carried the same rocks into the larger Jobi plateau and thence after an intervening plain of *Barakars,* into the Kakaigadra (1,602 feet) group of low hills, about Nunbira and Sendrapali, forming the extreme end of the southern spurs of the Phutka range. Similar brown sandstones make up the lower parts of the loftier Raka and Bitrahi group, and are there succeeded or overlaid by paler-coloured white or purple-streaked open-textured and coarse pebble-seamed beds with white clay intercalations, containing *Vertebraria.*

I did not come across any section showing actual contact of the Kamthis on the Barakars, but there always appeared to be perfect conformity between the two. On the other hand, overlap is very clear at this southern end of the Phutka spurs, there being only a very narrow strip of Barakars in the Sendrapali and Dongama plain below the low Kamthi scarps of the Kakaigadra range, and this is edged on its south side by a thin fringe of Talchirs next to the rising ground of crystallines on the flanks of the Pipra ridge.

The apparently diminished ferruginous element in the Phutka Kamthis is very marked; while there is little, if any, sign of the red clays so common in the Hingir country. This may arise in great part through insufficient exposure and denudation, or from the overpowering influence of the greater thickness, sometimes in great scarps, of lighter or paler coloured rocks, and the very large amount of their debris scattered over the lower slopes. It must also be remembered that the best exhibitions of ferruginous strata and red clay bands must necessarily be where denudation has laid bare extended plateau surfaces of those particular members, as is the case in the Hingir country. A rather prominent form of debris, scattered about the skirts of the Phutka range, consists of huge fragments of a pale-red clayey form of laterite which seemed to point to the existence of red clay bands; but this soon turned out to have fallen from the capping of laterite, or a lateritized form of weathered trap occurring on many of the loftier flats of this mountain mass, at levels of from 2,000 to over 3,000 feet.

At the same time, there is an almost absolute thinning out of the lower brown ferruginous member on the northern flanks of the Phutka range, or more especially in that deeply eroded portion of it joining on to the Sirgujah plateaus overlooking the Rer drainage. I always passed on that side of the country, wherever there is a gap in the hills, from Barakars of the fine-grained type to coarse and harsh open-textured grey or pale buff and white purple-streaked sandstones, having frequent seams of gravel and large pebbles of white or glassy quartz, without seeing a trace of the harder brown beds.

Boring Exploration in the Rampur Coal-Field.—The most important practical feature of the great tract of Lower Gondwanas fringing the eastern side of the country treated of in this paper, is of course the occurrence of coal at several points. The thick carbonaceous outcrops of Korba are well known as giving promise of fairly good fuel, but the place is still far out of reach of probable railway traffic. Then, again, the Mand Valley gives very favourable exposures at several places, as in the bed of the Bijakharra stream already referred to, or at Amaldiha at the northern end: only in these cases, also, the present inaccessibility of the region is against all prospect of development.

At the south-eastern extremity of the area however, within about 40 miles of Sambalpur, the rather large field of Hingir, reported on so many years ago by Mr. Ball,[1] lies right in the track of the proposed Chhattisgarh railway, under which circumstance its development becomes as it were a necessity. I was deputed to examine this field during the season before last with a view to selecting sites for boring, the results of my survey being given in the Records of August 1884 (Vol. XVII, p. 123). An Assistant Mining Engineer, Mr. T. G. Stewart, already favourably known through his borings in the Narbada Valley

[1] Records, VIII, p. 102.

and at Umaria, in South Rewah, was then placed under my guidance by the Central Provinces Government. I had divided the rather large and somewhat unapproachable area into several sections, the most favourable, as far as contiguity to the railway trace is concerned, being that on the valley of the Lillari, partly in Hingir and mainly in the Rampur zemindari; and it is on this that the boring exploration was commenced in what is now officially designated the Rampur Coal-field.

All the surface indications point to the probable occurrence of two rather thick bands of carbonaceous deposits, the lower—some 50 to 60 feet thick—being well displayed in the river near the village of Durlipali, while two outcrops of coal higher up the stream, about Bonjari and Kuliabahal, point to the upper; and as it appeared to me that the latter outcrops are more promising than that of Durlipali, and that it would be possible to strike their coal by bore-holes within a convenient distance of the proposed railway station at Hingir road, I determined to try this band first.

The borings were selected near the villages of Girandola and Chowdibahal on what I took to be—for much of the rock is covered by superficial deposits—either the uppermost beds of the Barakars or the lower red-clay zone of the Kamthis. As it turned out, all the borings, six in number, were started in the red-clay zone, through a greater or lesser thickness of which five of them were run down into the carbonaceous band beneath. Two of the holes were abandoned, but four were run down to depths varying from 225 to 287 feet. These four bore-holes (Nos. 1, 2a, 3, and 4) enclose a sort of triangular area of about half a square mile in extent: No. 1 being at the southern apex, No. 3 nearly a mile due west of it, and No. 2a being about half-way between the two; while No. 4 lies more than half a mile northward of No. 1. The dip of the strata is low to north-westward, perhaps just here rather more to the west-north-westward; occasionally, indeed, it must be quite flat, or nearly so, though it is mostly at an angle of from 5° to 10°. No. 1 bore-hole was run down 225 feet right through the upper band of carbonaceous deposits, or, at any rate, a good part of it which it entered about 30 feet from the surface and left at 219 feet when the chisel began to cut into white sandstone. Three seams of 6, 8, and 4 feet of coal, besides others of inferior thickness, were met with in this band; but though the samples brought up were favourable-looking enough, laboratory assay proved them to be quite unfit for railway purposes. That taken from the 6-foot seam, at 77 feet from surface, gave the following analysis :—

Moisture	10·00
Volatile matter, exclusive of moisture	24·50
Fixed carbon	29·90
Ash	35·60
	100·00

Does not cake.

Ash, pale-yellowish brown.

Another sample from the 8-foot seam, at 142 feet from surface, assayed foot by foot, gave the further depressing result.

	1½	1½	1½	1½	1½	1½	1½	1½	A well mixed sample of Nos. 1-8.
Moisture	11·08	10·58	12·00	11·02	9·40	7·44	8·04	13·38	9·98
Volatile matter, exclusive of moisture	22·14	21·26	22·66	22·06	20·52	19·00	18·60	23·84	21·22
Fixed carbon	27·08	25·70	28·36	26·42	24·04	19·48	20·32	32·90	24·62
Ash	39·70	42·46	36·98	40·50	46·04	54·08	53·04	29·88	44·18
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake. Ash, pale-yellowish brown.	Does not cake. Ash, pale-yellowish brown.	Does not cake. Ash, muddish brown.	Does not cake. Ash, yellowish brown.	Does not cake. Ash, muddish brown.	Does not cake. Ash, muddish brown.	Does not cake. Ash, light brown.	Does not cake. Ash, yellowish brown.	Does not cake. Ash, muddish gray.

In the meantime, that is, while these assays were being made, the other bore-holes were being carried out; and further samples from them of what appeared to be the same seams were discarded through showing no signs of improvement, or sent down to Calcutta. Among them, the following scarcely better result was obtained from a 6-foot seam in No. 4, at 69 feet from surface, the seam indeed which appears to correspond to that at 77 feet in No. 1, 174 feet in No. 2a, and 183 feet in No. 3; in all of which and in the continuations of the other seam of No. 1, we failed to strike any better coal.

No. 4, 69 feet from surface, seam 6 feet thick; foot by foot.

	1	2	3	4	5	6	A well mixed sample of Nos 1-6.
Moisture	12·42	9·96	12·20	13·18	13·08	12·86	12·44
Volatile matter, exclusive of moisture	26·40	24·92	26·10	26·90	26·86	26·82	25·86
Fixed carbon	34·12	27·88	32·92	37·00	36·98	35·74	34·66
Ash	27·06	37·24	28·78	22·92	23·08	24·58	27·04
	100·00	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake. Ash, red gray.	Does not cake. Ash, pale red.	Does not cake. Ash, red gray.	Does not cake. Ash, pale red.	Does not cake. Ash, red gray.	Does not cake. Ash, pale red.	Does not cake. Ash, pale red.

There seems no doubt whatever but that the upper 6-foot seam is fairly constant in thickness, and, unfortunately, in quality also throughout the area tried. The still lower seam of 8 feet at 143 feet in No. 1 hole appears also to have been struck at 221 feet in No. 2a; 248 feet in No. 3, and 128 feet in No. 4; but it is not at all so constant in thickness or so even in constitution. The lowest seam in No. 1 is apparently represented in No. 4 by a 4-foot seam: there is no improvement in quality.

It may seem rash to judge, from so small an area as that now bored, of the probable or possible condition of the lateral extension of the seams so proved; but considering, as I do, that some of them represent the upper outcrops on the Lillari river, I think I am justified in arguing concerning their condition from a really much larger area than that merely included within the three corners actually tested; and so from what they and these outcrops show, and from what I have seen of the rocks round the eastern skirts of the Hingir plateau, the conclusion is forced upon me that there is no fair ground for hope that the seams of this upper band of carbonaceous deposits can improve laterally or to the deep within a workable depth (for Indian collieries) in this Lillari section at any rate.

There still remains, however, what may be a considerable thickness of Barakars between the horizon now reached and the lower band of Durlipali, in which there may be workable seams; and this must now be searched. For instance, the horizontal interval of country between the Bonjari outcrop and that of Durlipali is a long one, fully 2 miles, which, if the lie of the strata be at all regular and constant, would at so low an average angle as 8° give 1,450 feet of rock. At the same time, from all that can be seen of the behaviour of the rocks in the neighbourhood, the indications seem to favor the conclusion that there cannot be such a great thickness: and that the Durlipali band is carried under the Bonjari horizon at a somewhat lesser depth by an anticlinal or arched wave of the strata. It is possible, therefore, that an idea of the quality of any lower seams will be ascertained by the new bore-holes at a lesser distance south-eastward of the now proved tract than the interval and apparent dip would imply.

DECCAN TRAP SERIES.

The coarse pale-colored upper member of the Kamthis in the Phutka hill mass and the high plateaus on the edge of the Sirgujah upland were pared down by denudation to a tolerably even surface on which the basalts of the Deccan trap period were subsequently laid down. Only small remnants of this basaltic covering now exist in the area under consideration, and these are entirely separated by a long interval of crystallines from the great connected area of this formation, the eastern extremity of which is at Amarkantak. Mr. Ball had already mapped in some of the basalt cappings of the plateaus around Matringa, and I have added to these: he also noted the occurrence of trap dykes about Amaldiha and Rakhob at the head of the Mand valley. The trap cappings are not very thick, 50 or 60 feet at the most, but they consist also to a certain extent of laterite the true relation of which to the basalt is not clear and must be worked out perhaps on the larger plateaus, such as the Main Pat immediately to the eastward of the Matringa valley. So far as I could ascertain, the upper portions of the cappings are either laterite altogether, or only partly so; and from what I have seen of the laterite on the edge of the Mandla and Amarkantak plateau, it certainly seems to me that the rock here is in both regions very often, if not altogether, a lateritized form of weathered or decomposed basalt or other volcanic rocks.

The higher portions of the Phutka range were not traversed in any detail, so that I am not sure whether some of them may not be capped by basalt; but in the general absence of trap debris in the valleys I should question whether there be any of much importance. At the same time I know of a few cappings which are apparently altogether lateritic.

The trap dykes cutting along and up through the Gondwanas of the valleys and slopes are marvellous in their length and the height to which they run up the lofty slopes into what appears to be absolute contact with the basalt cappings. My observations of the junctions, owing to illness and lateness of the season, do not unfortunately possess that accuracy required for the complete settlement of the question of junction, the bearings of which on the question of the fissure eruption mode of discharge of part at least of the great Deccan flows is of the greatest importance. Nevertheless, I am inclined to be almost positive that the great dyke striking about west-north-west—east-south-east past Lemru, in Uprora, does actually cut right up through the Sumhaulata hill (over 3,000 feet) into junction with its basaltic cap. Again, in the Stump hill of the same group, the capping trap certainly appears to be in junction with a great buttress of similar rock standing out in clear relief from the lofty sandstone scarp on the eastern face, the buttress being also apparently continuous with a run of trap outcrops on the spur leading down to the Amaldiha dykes.

Report on the Bengal Earthquake *of July 14th*, 1885, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

Introductory.

A preliminary account of this earthquake, by Mr. H. B. Medlicott, Director of the Geological Survey, has already appeared in the preceding number of the Records, briefly setting forth what inferences could be drawn concerning it from such information as was then at hand. Since then, from data personally gathered on the spot in the region of greatest violence, and from all available newspaper reports, I am able to put the following facts and deductions on record.

Extent of shock.

Taking its rise in Bengal, this earthquake of the 14th July was felt with violence throughout that province. It extended westwards into Chota Nagpur and Behar, northwards into Sikhim and Bhutan, and eastwards into Assam, Manipur and Burmah. The area over which it was sensibly felt may be roughly laid down as 230,400 square miles. An irregular ellipse drawn through Daltongunge (in Palamow), Durbhanga (in Behar), Darjeeling, Sibsagar, Manipur and Chittagong will give the external boundary of that area. Within this, again, another irregular figure may be drawn through Calcutta, Sitarampur, Monghir, Purneah, Siligori, the Garo hills, Chattack and Barisal, which will enclose an area over which the shock was felt with such considerable violence as to shake loose objects, rattle windows, and produce small cracks in double-storied houses. Finally, we have another figure within this bounded by Rampur, Bogra, Sherpur (Maimensing District), Maimensing, Dacca and Pubna, where destruction to buildings is greatest and loss of life has occurred.

I shall now proceed to describe the results of an examination of the last-mentioned district, where it was hoped that some reliable data would be obtained, judging by the accounts of fallen chimneys, and fissured houses which had appeared in the newspapers.

Treatment of subject.

It is of course unnecessary for the purposes of a scientific journal to enter into lengthy accounts of damage to property and demolished towns, however great and terrible that loss may be; consequently it will readily be understood that such objects as are mentioned below are not chosen because of their size or magnificence, or because of the lakhs of rupees represented in their ruins, but, solely because either from their form, position, or from some other accidental circumstance, they best illustrate those points in connection with the earthquake which are of the greatest use to the scientific investigator.

In an examination of a country devastated by an earthquake, there is sure to be a great deal of evidence which at first sight appears to be contradictory, partly because of complications in the structure of the objects from which such evidence is taken, and partly because of the reflections and refractions of the earth wave, which hinder in some degree the search after the true centre of disturbance. And on the other hand, certain classes of objects, such as chimney-stalks, towers, temples, and tombs, by their form and isolation, are evidently much better suited for observation than complicated double-storied houses with verandahs and innumerable doorways, windows and arches. For this reason, I shall divide the series of examples of the effects of the earthquake into two groups; the first of which will comprise all the more trustworthy cases, and the second those of a more doubtful value, together with certain exceptional phenomena.

(I).—Examples of first importance.

Chimney-stalks of the Serajganj Jute Company.

On arriving at Serajganj, I found it to be one of the towns which have suffered very severely from the earthquake. It may not be out of place, for the benefit of foreign readers, to briefly state that the native town and the European houses in Eastern Bengal are both built on two entirely distinct plans, and with entirely different materials. One style of house is single-storied, erected by driving roughly-shaped tree trunks or wooden posts into the ground, filling in the interspaces with split-bamboo mats, and throwing a highly-pitched thatch roof on to bamboo rafters; the whole of the latter being held in position by means of ropes and thongs attached to the main posts. These bamboo grass houses are well calculated to stand the stresses due to an earthquake shock on account of their ready pliability. The other kind of house, though differing architecturally according as it is of native or European design, agrees in having brick walls, frequently raised to two, and sometimes to three, stor covered with plaster or stucco, and usually bearing a heavy solid flat roof of brick and cement surrounded by a parapet. These houses have all been badly rent, sometimes beyond repair, or even ruined. There is also occasionally a kind of house which partakes of both the above described styles, having brick walls and a thatch roof, and there are, in addition, many huts of dry mud and thatch belonging to the poorer natives. Both these kinds have suffered very much, for the former, whilst possessing all the defects of unpliable walls, has none of the advantages of a strong flat roof to tie them together, and the latter of course readily cracks and crumbles on account of its material lacking coherency.

Most of the Europeans at Serajganj, which is a very small station, had left their solid-built dwellings, and were living in bamboo houses and offices. The former were too much split to allow of remaining in them with safety, especially as repetitions of small shocks daily indicated that the disturbing forces at work below were not yet in a state of complete equilibrium. I shall return to the house cracks later on, at present dealing only with the chimneys.

The two chimneys of the jute works (see figure 1, which is reduced from the original plans, kindly lent me by Mr. Allister Macdonell, the owner of the mill), were both broken by the earthquake. The heights of the mill and factory chimneys were 135 feet and 95 feet respectively; and 40 feet from the summit of the larger and 11 feet from the smaller were shot away.

Mr. Robertson's account.

Mr. Robertson, the manager, was fortunately an eye-witness from a position between the chimneys at the time of the earthquake, and he asserts that there seemed to be a sudden thrust from below, by which the upper part of the south chimney was first shattered, and jerked off; and for some time a shower of bricks and mortar continued to fall all round the base. A moment after the large chimney had gone, the factory chimney to the north was affected in exactly the same way; its upper part being jerked off into the air, and a shower of bricks subsequently descending from the broken edges. If these impressions are to be relied on, two points of importance come out, (1) that the earthquake wave with a steep angle of emergence shot away the upper parts of the chimneys by its first and second semiphases combined, but was unable to overturn them as wholes, because of their flexibility, which would considerably relieve the strain, and because of their breaking above, which would further ease them; and (2) if the south chimney was the first to fall—and there seems no reason why a very slight difference in the order of breaking should not have been appreciable by the eye—then it is clear that the shock must have come from some point generally speaking towards the south: it is in fact easy to demonstrate that the difference in time of the arrivals of the shock at the two chimneys would have been appreciable. For the chimneys are 338 feet apart, lying very nearly north and south: now Mallet gives 825 feet per second as the rate at which a wave of elastic compression travels through sand, and though the soil at Serajgunj is clay and sand combined, it would certainly not be a much higher rate than this. Hence about $\frac{3}{7}$ths of a second would have been consumed in travelling between the chimneys, a period of time well above what can be detected by the eye. In reality, however, some small reduction on this value must be made on account of the probable direction of the shock being something east or west of south, a condition which would have diminished the time occupied by the wave in travelling between the chimneys.

My own observations.

I now come to my own observations of the ruins. The large chimney, the only one which had been in use for some time, I found had been hastily repaired by knocking away the loose bricks at the top and putting on a temporary coping. The old factory chimney had been left untouched while this work was going on, and I could examine everything in the state just as it was immediately after the earthquake. The broken surface I found was exceedingly jagged and irregular, with its highest part towards the north-west, a feature agreeing in every way with the statement of Mr. Robertson, that the edges, during the secondary vibrations, crumbled away, and not by any means presenting the appearance of a clean cut fracture. From photographs of the large chimney, I was able to see that its original state before the repairs was very much the same as that of the small chimney. On the other hand, at about middle height of the chimney, there was a very distinct crack, showing on the east-north-east and north-north-east faces of the factory chimney which is an octagon in section. The crack was such that, roughly speaking, it might have been made by a plane of fissuring, which for convenience, and in conformity with geological nomenclature, we may speak of as "dipping" towards the north-west. The same was observable in the mill chimney. The angle of dip would be steep, perhaps 60°, but owing to the great height of the chimneys, a reliable observation could not be made. An examination of the debris around the base of the factory chimney brought out many points of interest, and corroborated the account of Mr. Robertson. I found the ground so covered was elliptical in shape (see fig. 2), with its long axis running north-40°-west and south-40°-east; but whilst in the former direction the fragments extended 29 feet from the base, in the latter they only extended 25 feet, showing that the mass of the material had gone over towards the north-west. And besides, there was a very conspicuous difference in the nature of the fragments on either side. Towards the north-west, the broken parts of the chimney were to some extent coherent in themselves, being made up of groups of 20, 30, or 40 bricks still showing traces of the shape of the walls; but in the opposite direction nothing but individual bricks, and fragments of bricks could be found. Again, towards the north-west, some 2 or 3 feet from the outermost edge of the debris, we came upon the broken remains of the iron coping. Thus we have very clear evidence from the ruins, that the mass of the broken part of the chimney, together with the iron coping, fell in the direction north-40°-west, whilst only bricks and mortar, loose or broken, fell towards the south-40°-east. The mill chimney, though not so adapted for observations on account of the debris having been cleared away, nevertheless gave some information from the circumstance that in falling, the broken part had crashed through the workshop roof and parapet. As in the preceding case the area of the debris, or marks of the debris, was elliptical, but with the long axis running in this case nearer north-north-west and south-south-east, though these directions were not got so satisfactorily as in the case of the factory chimney. Here, too, the broken roof showed that the fall had been much greater towards the north-north-west; for up to a distance of 32 feet from the chimney the roof was broken-in in that direction, whilst in the opposite one the bricks were only scattered on the ground 17 feet from the base of the chimney. The iron coping in like manner was found towards the north-north-west, in a position pointed out to me by the manager, where it had penetrated through the roof into the workshop.

Deduction.

Now putting these colligated facts together with the statement of Mr. Robertson, we may from them draw the safe conclusion that the shock came from the direction south-east or south-south-east, and shot the bulk of the broken part of the chimneys over towards the north-west or north-north-west.

Temples at Sherpur. (Bogra district.)

The cracked condition of these form the next piece of evidence which I place among those of first importance. They are small Hindu shrines to the god Siva, octagonal in shape, the height being usually two or three times the diameter; and either entirely isolated, as the one shown in fig. 3, or with sometimes a porch on one side. In every way they were good subjects for observing the direction of the cracks, for their solidity and symmetry prevented the fissures from being influenced by any pre-disposing lines of weakness. The diagram, fig. 3, shows the general appearance of a couple of cracks in one of these temples. They were exceedingly well-cut fissures, and discernible at a good distance. The dip of the fissuring plane was 45° north-west. In two more examples of temples of the same build and size, except that a porch was attached to one, I found fissure planes respectively dipping west-north-west at 55° and 60°. Attaching a little more value to the evidence of the first temple, inasmuch as it was more decidedly rent than the others, we may take as relative means north-50°-west for the direction, and 50° for the angle. From these we get south-50°-east as the direction from which the earthquake shock came, and 40° as the angle of emergence at that place. Besides the temples, there were some good examples of house corners shot away, generally in a north-west direction, the fissure plane making an angle of 55° with the horizon in some places; but as a rule among the 100 destroyed houses at Sherpur, the collapse was so complete, owing in a great measure to the buildings being old, that neither directions nor angles could be obtained. Since Sherpur lies to the north-west of Serajganj, we may take it that the observations there corroborate the truth of the conclusions drawn from the jute works' chimneys, whilst in addition we get a rough estimate of the angle of emergence for the alluvial soil of Sherpur; though this, it must be remembered, will probably be steeper than the real angle owing to refraction in passing from the highly elastic solid rock to a clay stratum of very low elasticity.

Tomb, Jamalpur.

Hearing, when at Maimensing, that a tomb had fallen in the Jamalpur cemetery, a report considerably qualified by the fact that an order had been issued for it to be cleared away, I hastened to that place, and fortunately arrived before the order had been carried out. It was a small cemetery, containing some ordinary graves, and this one large tomb, erected in 1837 to Anne, the wife of Major Cox of the 58th N.I. The erection consisted of the tomb proper, a rectangular raised sarcophagus, surrounded by eight pillars in a circle, and covered by a hemispheroidal dome, or canopy. The whole was built of brick and stucco, and represents a common form of tomb in Eastern Bengal cemeteries (see fig. 5). The appearance, when I saw it, was as shown in fig. 6; the pillars had all fallen in one direction, and split up into various lengths; whilst the great heavy canopy had fallen towards the south-10°-east, and coming into violent collision with the low wall of the cemetery, had split into several pieces, some of which fell into the road beyond, and the rest lay, partly on the foundation base, and partly on the ground between it and the wall. The tomb itself was uninjured, except at the upper corners, doubtless by the canopy just grazing it as it fell. A glance at the elevation, and the overthrown state, will at once illustrate the manner of its fall. The weight of the massive canopy, and the slenderness of the pillars, make it clear that the inertia of the upper part of the mass was sufficient at the time of the earthquake to prevent it moving along with the pillars, and consequently the tomb fell in the direction *from which the shock came.*

The following are the dimensions of the parts and adjuncts of the tomb, gathered from the ruins themselves:—

Base, 12 feet 10 inches square; 9 inches thick. One side faces north-3°-east.

Tomb proper, length from east to west 4 feet $4\frac{1}{2}$ inches; breadth 3 feet $4\frac{1}{2}$ inches; height from base 6 feet.

Pillars (8), 6 feet 10 inches high; 1 foot 8 inches in diameter.

Stone capital on each pillar, 2 inches thick.

Circle of pillars, diameter of outer edge 11 feet 4 inches, equal to diameter of canopy.

Height of hemispheroidal canopy 5 feet 8 inches; thickness 1 foot 7 inches.

I shall discuss the figures later on in their bearings on the velocity of the wave particle, together with the data afforded by the chimneys at Serajganj, at present merely drawing attention to the fact that the line of the shock, north-10°-west and south-10°-east, when laid down on the map, is seen to cut the line from Serajganj at a point between Dhamra and Atia, on the south-west side of the Madhapur jungle. This gives us approximately the position of the seismic vertical.

Gateway arches, Muktigarchia.

This example is put with those of first importance, because the nature of the construction was such as to favour overthrow by reason of its inertia; and notwithstanding the fact that the conclusions which may be drawn from it contradict, in some degree, those previously arrived at. The arch is a brick and stucco arrangement, and, as will be seen from the diagram (fig. 7), very problematical in its uses, since it supports nothing whatever. There is a duplicate one some 30 or 40 yards away, and both open into a garden belonging to a local zemindar. As both have been affected similarly a description of one will be sufficient. The gateway faces south-13°-east, and when I saw it the arch had been cut clean off on a level with the top of the gate-spikes. The fragments were piled in a heap on one side, but from the freshly patched indents on the cement pathway, and from the broken spikes, it was evident that the falling arch was not displaced horizontally to any great extent in a direction at right angles to the gate; but that, probably snapping into two or more fragments, it dropped nearly vertically down on to the gate spikes, but with sufficient leaning towards the south side to turn all the fragments in that direction. The indents however were not situated midway between the gate posts, but more towards the east than west, showing that the shock was not orthogonal to the plane of the arch. From the gate facing south-13°-east, and the obliquity of projection of the fragments, we must look for the destroying force in a south-east direction. But Muktigarchia stands nearly north-north-east of the seismic vertical already obtained on the best evidence; and the only way for the apparent contradiction to be reconciled is either by the assumption of another minor centre of disturbance south-east of Muktigarchia, or of a reflected wave.

Temple, Maimensing.

This was one of a kind similar to those mentioned at Sherpur, but slightly more lofty, *i.e.*, a Hindu shrine to Siva, octagonal in form and with a conical apex. A fine, but perfectly distinct crack, was discovered cleaving through the lower story. Viewed from the inside where it was seen better, the highest point of the crack was seen to be at the south-south-west angle. Hence the fissuring plane would dip towards the north-north-east. The angle was low, about 35°. This gives a direction for the shock south-south-west, and a very high angle of emergence. The direction, when laid down on the map, is seen to cut the point already obtained as the seismic vertical. It should be mentioned, however, that a heavy brass water-vessel, threaded on an iron rod, which forms an ornament for the summit of the conical roof, was bent over towards the south-east at an angle of about 60° with the horizon. It was prevented from falling by a heavy chain attached to it, and which hung down from the roof in the interior of the temple. I was unable to learn whether the ornament was free to turn on its base, as on a pivot, or not, and so the value of the direction here indicated is lessened by the doubt that it might have had a rotatory motion given to it, and eventually have settled into its present position quite irrespective of the direction of the shock.

This brings to a conclusion my examples of the first order of importance. Those of secondary importance, and some few exceptional phenomena, will be now described.

(II).—*Examples of secondary importance.*

Wall cracks, Serajganj Jute Works.

The mill being a rectangular building, with one wall facing externally towards the south-68°-east, it will readily be seen that the direction of the earthquake shock, as obtained from the chimneys, was very nearly diagonal with regard to the four main walls of the building. It is probably due to this circumstance, and to the fact that iron tie-rods are used throughout to bind the walls together, that comparatively little damage has been done; though it should not be overlooked that a mill, with the jar of machinery constantly throwing every wall into a state of tremor, would be much more likely to stand an earthquake tremor than any other building that was, so to speak, not so accustomed to vibrations of its parts. Such damage as has been done is just in the position we should expect. From the circumstance that the shock was diagonal to the main walls, we may imagine it resolved into two equal component shocks, each at right-angles to one set of parallel walls, and each doing about the same amount of damage. But whereas the east-south-east and south-south-west walls[1] are those which would tend to be driven inwards by the shock, and would be supported by the neighbouring walls to a large extent, the north-north-east and west-north-west walls being respectively driven outwards by the shock, and having no walls in

[1] *N.B.*—East-south-east wall means a wall facing east-south-east.

that direction to support them, it is more than probable that they would be the ones to crack. An examination of the building shows that this has been the case. The north-north-east wall, between the mill and the factory, but quite unconnected with the latter, and so unsupported by it, has a line of crack near its junction with the roof running the whole length of the building; whilst on the west-north west side of the mill, the wall between it and the 'softening-room' is also cracked for about half its length. Another parallel wall, east-south-east of the 'baling-house,' in connection with the mill, has similarly started a crack, which, dipping at an angle of 50°, penetrates the line of arches running down the centre of the said room, and this is crossed by another, parallel in strike, but dipping at right angles to it.

Mr. Macdonell's house, Serajganj.

I take this as another example of wall cracks, partly because it is the largest house in the station, and has been the most decisively cracked; and partly because, unlike the mill, it lay with its walls fronting, or at right-angles to the direction of the shock, and well exemplifies, both in the direction and magnitude of the cracks, how much more severely a house thus lying is shattered, than one lying diagonal to the shock. There is no impediment in this case to the house freely rocking to the shock, but the momentum thus accumulated becomes fraught with great danger on account of the unpliability (practically speaking) of the walls in such structures. The house is a double-storied one, in the Calcutta style, with a lower and upper verandah facing south-52°-east. As in all cases of double-storied houses, the upper part has been the most damaged; for such rents as go completely through the house from top to bottom, are wider above than below, and there are many others which only penetrate through the upper story, and then die away. The main cracks are best seen in plan on the flat roof for this very reason; and I may here state that every house which I subsequently saw of this type, and which lay at right-angles to the shock, or very nearly so, has four types of cracks as seen on the roof. There is first of all the verandah crack, dividing the verandah from the house, and usually the worst, inasmuch as it takes its origin along a very conspicuous line of weakness. On the opposite side there is usually the portico crack, in a similar way starting along a line of weakness. Thirdly, there is the main crack, near the centre of the house (see diagram, fig. 8), usually the most reliable, cutting like a knife through parapet, pillar and roof, and rending the house from top to bottom. Lastly, there are some few corner cracks at right-angles to this. Such are the cracks in Mr. Macdonell's house. When their projections are traced on the vertical side-walls, all but the verandah crack are seen to dip about 60° north-52°-west in their upper parts, but lower down they usually wander more irregularly along windows and doorways, finally branching in various directions at a very low level where the momentum of the moving walls would have been less.

A tower, about 24 feet high, built above the stables, was also cracked in the same direction, the angle being about 55°.

Joint Magistrate's house.

Of other houses in the station, mention may be made of the Joint Magistrate's, which lay even more in the direct line of the shock than the previous one, the verandah facing south-40°-east. It was a single-storied house with brick and plaster walls, but with a thatch roof. It had accordingly suffered very severely, the main crack and verandah crack dipping north-40°-west with an angle of about 70.°

A single-storied house with flat solid roof and solid walls showed as many as three main cracks, and a verandah crack in plan on the roof, and several minor ones. The house was north and south; and the cracks dipped slightly west of north. They were vertically inclined near the verandah, but in the other direction gradually assumed an angle of 60 or 70.°

Mr. Mollison's house.

Several native gentlemen's houses were also shattered, but with one exception gave no fresh data. This exception, which is rather an old house, is double-storied, and faces south-13°-west. The shock came diagonally upon it, and shot away one corner by a plane of fissuring, dipping north-32°-west in an irregular manner.

Other houses.

At Subornkholi and Muktigarchia, though some houses were cracked, and a small chimney stalk rent near the summit, there was nothing which afforded safe evidence. In like manner an inspection of the Rajah's palace at Muktigarchia, which has suffered terribly by the earthquake, on account of its peculiar construction, was equally barren in results.

At Maimensing there were some better results. The jail has its enclosure wall facing north-north-east cracked for a long distance near the bottom; and at the corner where it joins the east-south-east wall it has parted from it outwards, leaving a gap of an inch or so wide. The south-south-west wall near the entrance gates is also cracked more or less horizontally for some distance. But neither of the two walls at right-angles to these have been cracked, save one for a short distance. This is what should happen with the shock coming from the south-south-west, the direction of the seismic vertical. Many of the buildings within the enclosure are nearly new, and such cracks as they show would favour a shock from either of the opposite directions. One older building, however, has a crack at its north-north-east end of very serious size, dipping nearly vertically. This better agrees with the evidence of the enclosure walls.

Maimensing jail.

The dispensary on its south-east and north-west end walls showed a set of intricate fissures, crossing one another at right-angles, and such as could have been produced by a fissuring plane dipping either north-east or south-west at 45.° Those in the former direction were the most conspicuous, inasmuch as they started originally from the summit or sides of the walls, whilst the others started from some point on them.

Dispensary.

A mosque (see fig. 9), near the dispensary, is interesting because it has had its north-north-east corner walls shot away, evidently by a shock coming from the south-south-west, which has also rent the north wall in three places, and one of the domes. There is also an approximately horizontal crack in the west wall at about half its height.

Mosque.

A house belonging to the Rajah Saruja Kantu Acharji was fortunately placed, and received the full effects of the shock. It was rectangular, and lay with its ends facing east-south-east and west-north-west, very nearly. These end walls were also fortunate in not being too much pierced by windows and doorways. They revealed cracks produced by planes of fissure dipping north-north-east 50° and south-south-west 40° which crossed one another at right-angles. If anything, the planes dipping south-south-

House.

west were slightly the more pronounced, of the two. This house, and the dispensary already mentioned, were both good examples of the effects of an earthquake wave rising upon a building exactly at right-angles to its path.

The new Kachahri.

This is the only other building which left any legible record. It is in an unfinished state of building, but beyond some few small cracks no permanent injury has been done. There seems no doubt that this leniency is mainly to be put down to the newness of the mortar, and the consequent pliancy of the walls. The cornice running along the top of the walls has however fallen at several points, because it needed the binding effects of a roof to keep it in place. The fall has only taken place from such walls as faced north-22°-west, or south-22°-east, and slightly round corners on the east-north-east walls. The largest piece has gone from the north-north-east corner. As the building lies with its long axis east-north-east and west-south-west, no doubt there would be more tendency in the walls to rock at right angles to that line than with it; but, as the shock came diagonal to the building, some small resolved part of it must be allowed to set the end walls in a tremor, though not so violently on account of their relative shortness. The results show that the more conspicuous shaking *was* imparted to the long walls facing north-north-west and south-south-east, and a smaller shaking to the shorter ones at right angles to these; whilst the far larger piece of the cornice tumbled from the north-north-east corner shows that that was the point the least supported, as would be the case with the shock from the assigned south-south-west direction. It may also be noted that the small cracks in the arches of the lower story are also at this corner of the building.

Dacca.

At Dacca I got very little evidence of the earthquake, though from all accounts the shaking here was very severe. The police reported a temple fallen at Barisur on the opposite side of the river, but on visiting the place I found only the blackened ruins of one which had collapsed from decay some years ago. Fig. 10 represents a house on the river bank that has had the stucco mouldings shot away on its south side and south-east corner. The south-west corner also showed two cracks dipping south-east roughly.

Several other houses also showed the same thing, both cornices and plaster falling towards the south or south-east, and never towards the north. A careful scrutiny in the cemetery was unrewarded by any fall greater than bits of brick and plaster, and an earthenware vessel from the summit of a tomb. The vessel, originally threaded on an iron spike, had broken, and only half of it fallen to the ground, and was, in consequence, of doubtful value as evidence. It fell towards the south-south-east, which was also the general direction of the plaster chips. Thus there was just sufficient evidence here to bear out all previous conclusions with regard to the position of the seismic vertical, but nothing to corroborate it. On the whole, the damage done in Dacca is disproportionately small compared with other places equally near the centre of disturbance. The reason for this I shall consider later on.

(*III*).—*Exceptional phenomena.*

Earth fissures.

Earth fissures opened at Serajganj, Subornkholi, and Jamalpur, and some few other places. In every case that I examined they had taken place either by the banks of a river, or elevated road way, or the sloping sides of a tank. In one case at Subornkholi, near Mr. Webster's jute mills there were some irregular cracks, opened apparently on the flat, though not many yards from some water. They were fringed all round the margins by fine sand, which bore testimony to the statement made by Mr. Webster that water oozed up through these cracks carrying the sand with it, and sometimes even spurted up into the air some few feet. When at Jamalpur, I received from the Deputy Magistrate some pieces of lignite which had been similarly thrown up through fissures along with sand and water at Sherpur (Maimensing district). There is no reason to imagine that these fissures differ in origin from those so well described and explained by Mr. R. D. Oldham, in his discussion of the Cachar earthquake of 1869, published in Vol. XIX of the Memoirs of the Geological Survey of India, and to which I refer the reader. It is there shown that during the passage of an earth wave, contiguous vertical zones are moving respectively forwards and backwards at the same moment, but that on level ground the cohesion and inertia of the motionless masses of clay in front and behind are sufficient to prevent rupture. On the other hand, when a bank is approached, the particles of clay moving forward have no inert clay mass in front to stop them and take on their motion, and consequently those particles break away from the zone of backward driving particles and a fissure is formed.

Wells.

In three cases wells were curiously affected by reason of the same causes. At Serajganj a well pipe, 13 feet 7 inches long and 1½ inches in bore, was filled throughout with sand tightly jammed into it. I was told that, at the time of the earthquake, water rose in the well, and that since then the bottom of the well had broken through into the underground vacancy made by the ejection of the sand. At Subornkholi I saw a well which had had its tiled casing, about 1½ feet in diameter, moved towards the north-west, so that, looking down through the brick mouth of the well, it was seen to be entirely on one side instead of in the centre. I also heard of another well in the neighbourhood out of which a brass vessel had been hurled some distance.

Tank, Serajganj.

The water of a tank close by the jute company's works, Serajganj, was thus affected, according to an account of the manager. The long axis of the tank lay north-20°-east, and the water seemed to run east and west from the sides, gathering up in the centre, and then to spread out again to the sides.

Brick stacks.

Some brick stacks in a brick yard at Maimensing were partially overthrown. They all stood 3 feet 9 inches in height; and the north-north-east corners were the ones shot way. The outermost bricks fell at a distance 4 feet 9 inches from the outer edge of the stack, a distance obtained by taking the mean of eight different measurements.

(*IV*).—*Discussion of data.*

Seismic vertical and depth of focus.

If we take a mean of the directions of the fallen chimneys at Serajganj, also the direction of the tomb at Jamalpur, and that drawn from the cracks at Maimensing, we have to place the seismic vertical as emerging on an area 3½ miles in diameter with its centre 37 miles south-37°-east (true) from Serajganj, or 90° 6′ 30″ East Long., and 23° 59′ 20″ North Lat. But there is still another method of procedure open to us. If we take some three towns on the map where the destruction to buildings is markedly greater than elsewhere, and describe a circle through them, the centre of that circle will be the position of the seismic vertical. Now there is no doubt that Sherpur (Maimensing district), Bogra and Nattore are three such places, as reference to the telegrams and letters published in the *Englishman* between the 15th and 25th July will show. These three places are all about equidistant from the assigned position of the seismic vertical near Atia, and thus the position of this point is made doubly certain. In discussing the depth of the focus we have also a double method, the first method being to take the angles of emergence as deduced from the fissures, and apply the formula—

$$D = C \tan E,$$

where D=depth of focus, C=distance from seismic vertical, and E=angle of emergence.

At Sherpur (Bogra district), C=61 miles, and E=40°,

$$\therefore D = 61 \times \tan 40^\circ,$$

that is, $D = 51{\cdot}18510$ miles, or about 51 miles.

At Maimensing we had 40° and 45° as the angles of emergence, taken from the cracks in the Dispensary, and one of the houses belonging to the Rajah. Now, taking 42½° as the mean angle, since Maimensing is 55 miles from the seismic vertical we have—

$$D = 55 \times \tan 42\tfrac{1}{2}^\circ,$$

that is, $D = 50{\cdot}39815$ miles, or about 50 miles.

In the second method, the depth equals the diagonal of the square described on a radius of the circle passing through three or more points where the destruction to buildings is greatest. So that, taking the radius of the circle described about the towns Nattore, Bogra, and Sherpur (Maimensing district) as 74 miles, we have—

$$D = \sqrt{2 \times 74^2,} = 104 \text{ miles nearly.}$$

The second method thus gives a far greater depth for the focus than the first. But both are far higher values than are usually assigned to an earthquake focus. This may be partly accounted for by the fact that, in its passage from the lower solid strata into the upper alluvial soil of Bengal, the earthquake wave must have been refracted; and so the emergence angle would appear too steep.

On the whole, owing to reasons which will be given below, when treating of the arc of violence, we may place more reliance on the former than on the latter method in this particular case. So, if we take the mean depth of the two first calculations, and subtract ten per cent. for refraction (an arbitrary amount), we have about 45 miles as the depth of the centre of disturbance.

The arc of violence.

In considering those points on the earth's surface where the greatest damage has been done to buildings, which points, as before mentioned, can be included in a circle with the seismic vertical for centre, we are at once struck by the fact that it is not at every point alike of this circle that great disturbance has occurred, but only at certain of them forming an arc of about 90° having Maimensing at one extremity and Nattore at the other. This arc of violence is indeed wonderfully contrasted with the rest of the circle;

for if we take into consideration a large station like Dacca, which is not quite so far from the seismic vertical as Serajganj, we find the destruction caused there in no way comparable to that at that place. At Pubna also no very great damage has been done, whilst from Faridpur and Kumila (Comillah) there have been absolutely no reports nor telegrams in the newspapers. To understand the reason for this a geological map must be consulted: it will then be seen that, whilst places on the southern arc of the circle of greatest possible destructibility have no outcrop of metamorphic rock nearer than 200 or 300 miles, all those places situated on the actual arc of violence are within 75 miles of solid rock, namely, the metamorphics of the Garo hills, or the Rajmahal trap; some places being even as little as 37 miles from the Garo hills. In other words the great plain of Bengal, though 325 miles broad between Chittagong and Balasore, narrows in a northerly direction between Rajmahal and the Garo hills to 135 miles. Now from the fact that the latter places are where the two masses of metamorphic rocks of Chota Nagpur and Assam respectively most nearly approach one another, we may infer that a line joining them would cross that part in Bengal where the depth of alluvial soil is less, and where the metamorphics come more nearly to the surface than at any place further south. We thus see that the arc of violence is situated near where this shallowing of the alluvial soil takes place; and we at once recognise that the latter is the cause of the former.

In support of this, and also the better to enlarge on my meaning, I will take the liberty of quoting from Mr. Mallet's report on "Earthquake phenomena" in the Report of the British Association for 1850, when speaking of the great Calabrian earthquake. He says:—

"The centre of effort in this earthquake was under the great plain, and probably about under where once stood the village of Oppido, but at an unknown depth. The observations made amount to no more than this; that the shocks did less mischief to structures on the granite or slate rocks of the hills, than they did to those on the plain of clay, &c.; that the destructive effects of the shocks were very great along the line of junction of these, at the bases of the hills (from which some philosophers of that time concluded that the earthquake came from the mountains), and that along this line, shocks in close succession were felt, not only horizontally and vertically, but also in opposite directions.

"Now we may *a priori* account for these facts, on the principle that the velocity of the shock or earth wave depending on the density and modulus of elasticity of the formation through which it passes, and its velocity being greatest in those whose elasticity is highest, while its range of motion is most limited in the same; therefore the shock here was of less velocity in the plain than in the rocky hills; but had in the former a longer range of oscillation, and hence did most mischief in the plain. Along the line or plane of junction of two formations of different elasticities, &c., the earth wave will change its course and also its velocity (like light in passing from one medium to another), and here the wave will be divided, part of it will be refracted. and part reflected (or total reflections may take place if the angle of incidence be suitable to the plane of junction); and the latter portion of the wave will in such case double back upon itself, and give rise to a shock in the opposite direction to the first one. Hence, along such a line of junction, the destructive effects will be very great."

The case we are considering, though not quite agreeing with the one quoted, differs only in degree; such difference as there is depending on the fact that the centre in our case was too far away from the hills for the circle of greatest destructibility to cut at any point the line of junction between the metamorphic hills and the plains of clay. Still, the fact that the destruction is accentuated along the arc of violence, *i.e.*, the arc nearest the hills, shows that reflected waves from the quickly transmitting rocky basin must have started out back from the hills before the slowly travelling wave in the clay reached them; and those reflected waves, though not strong enough of themselves to produce destruction on the actual line of junction of the plains and hills, must have had some considerable power in augmenting the effects of the direct waves when the two sets met, and even for some time before and after meeting, since many objects caught still vibrating from either shock would be more easily overturned by the succeeding one.

And once more, the smaller depths of alluvial soil along the northern arc of the circle of greatest destructibility would receive the full effects from the direct shock, whilst the thicker pad of clay on the southern arc would, by being violently moved as to its particles in its lower part, have in some measure dissipated the motion before it arrived at the surface.

We thus see that primarily it is owing to the shallowing of the deltaic deposit of the Ganges and Brahmaputra, as the metamorphic hills or their sub-alluvial representatives are approached, and also to the proximity of the two latter, that more destruction has been caused north of the seismic vertical than south of it.

We may also expect that owing to the same causes the circle of greatest destructibility to buildings, as laid down on the map from the arc of violence, is of much larger diameter than it would have been in a perfectly homogeneous country; and therefore estimations of the depth of the focus from the diagonal of the square of the radius of that circle will have far too great a value; as we were led to expect by their non-agreement with the angle of emergence method.

Velocity of the wave particle.

This can be obtained within limits from the tomb at Jamalpur and the chimneys at Serajganj, the dimensions of which have already been given.

In the first case we have to treat the fallen body as one upset in the direction from which the shock came by its inertia of rest, during the first semiphase; and in the second case we have an example of oscillation of a body beyond its limits of flexibility, due to its inertia of motion during the second semiphase.

Overthrow of the tomb canopy.

Let us first take the simpler case of the tomb at Jamalpur. If we call 8 W. the weight of the canopy, then, since it is supported by eight pillars, each of them bears a weight equal to W, that is $\frac{1}{8}$th of the whole. Now since the whole canopy is symmetrical about any vertical plane passing through the centre, we may look on the mass of the canopy as also divided into eight parts and individually placed vertically above each pillar, at the same level as the centre of gravity of the whole, that is, 2 feet 2 inches above the pillars. For, if we take any pair of pillars opposite one another, we see that, just as much as the one is helped in its upsetting by the mass of the canopy being on one side of it, the other in like manner is hindered to the same extent, and since they are in rigid connection by the canopy the one condition balances the other. Thus the problem narrows itself to the overthrow of one column supporting a mass proportional to W at a point $2\frac{1}{6}$ feet above its upper end.

It is now necessary to ascertain the proportional weights of the column and the supported mass. We obtain this by calculating their respective volumes, since the material being the same, the weights will be proportional to the volume. The whole of the canopy contains 412,142 cubic inches, and therefore $\frac{1}{8}$th contains 51,518 cubic inches. Each pillar contains 26,389 cubic inches, and will therefore be about half the weight of the portion of the canopy it supports; and since the mass of anything is proportional to its weight at the same point on the earth's surface, we have the mass of the portion of the dome supposed concentrated above the pillar equal to twice the mass of the pillar itself.

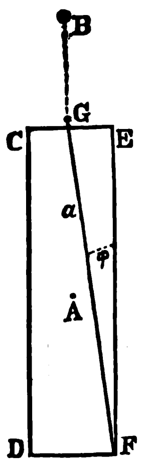
We must now get the moment of inertia of the whole in order to find the centre and radius of gyration. For since the whole may be considered as a compound pendulum swinging on one edge of the base of the pillar, we need to find the length of the simple pendulum which gyrates in the same time, *i.e.*, the distance of the position of the centre of gyration (where we may consider the whole mass of the pillar and its burden concentrated) from the axis of gyration. By dividing the system of pillar and its portion of the canopy into suitable portions, and taking the sum of the products of their masses into the squares of their distances from the axis of revolution, we obtain—

$$m\left(\frac{2557}{12}\right) = \text{the moment of inertia of the whole system,}$$

where m = the mass of the pillar, and therefore 3m = the mass of the system.

$$\text{then } r^2 = m\frac{\left(\frac{2557}{12}\right)}{3m} = 71\tfrac{1}{8} = (\text{radius of gyration})^2,$$

that is to say, the position where we may suppose the whole mass of the pendulum concentrated into a single heavy bob is distant $\sqrt{71\frac{1}{8}}$ feet from the axis of revolution.



In the annexed figure let CDEF = the pillar of which A is the centre of gravity, and let B = the point where the mass of $\frac{1}{8}$th of the canopy is supposed aggregated. Then dividing BA into three equal parts, of which BG is one, gives us G the centre of gravity of the whole system, since the masses at B and A are proportional to 2 and 1. The point G is 2 inches above CE or 7 feet 2 inches above the base DF. Join GF and let the angle GFE = ϕ. Then since DF = 1 foot 8 inches and EF 7 feet, we can get the length of GF = $7\frac{5}{24}$ feet.

Now in order to upset the system we must cause G to revolve about the axis F through the angle ϕ, and the measure of the velocity of the horizontal force acting at G competent to raise it to the height entailed by going through that angle is the measure of the velocity of the horizontal component of the earth wave that is at least necessary to overthrow the system.

Let a denote the distance in feet of the centre of gravity of the system from the point F, then the statical work done in upsetting the body whose weight is W^1 is—[1]

$$W^1 a\,(1 - \cos.\ \varphi$$

[1] See Mallet. Neapolitan Earthquake of 1857, p. 125, Vol. I.

This must equal the dynamical work acquired which is equal to the work stored up in the centre of gyration or

$$W^1 a (1-\cos. \phi) = \frac{W^1 \omega^2 r^2}{2g}.$$

where ω is the angular velocity of the body at starting, r the radius of gyration, and g the velocity acquired by a falling body in one second of time.

Equating these two values of the work done we find

$$\omega^2 r^2 = 2ga (1-\cos. \phi).$$

But ω the angular velocity = the statical couple applied divided by the moment of inertia or

$$\omega = \frac{V a \cos. \phi.}{r^2}$$

Squaring and substituting

$$V^2 = 2g . \frac{r^2}{a} . \frac{1-\cos. \phi}{\cos.^2 \phi}$$

Now putting the actual values for these letters we have

$$V^2 = 64 \times \frac{71\frac{1}{4}}{7\frac{5}{24}} \times \left(1 - \frac{7\frac{1}{8}}{7\frac{5}{24}}\right) \div \left(\frac{7\frac{1}{8}}{7\frac{5}{24}}\right)^2$$

therefore $V^2 = 4$ nearly,

or $V = 2$ feet per second, the velocity of the horizontal component of the earthwave. Then, since the angle of emergence here was 39°, we have

$$V^1 = \frac{V}{\cos. 39^\circ} = 2{\cdot}56 \text{ feet per second.}$$

V^1 here represents the least value necessary to overthrow the canopy, and, so far, the actual velocity might have been anything above 2·56 feet per second.

Tomb itself.

But, from the fact that the body of the tomb itself was not overturned, nor even fractured at the base, we know that the velocity was less than would have been required for that purpose; and so we can limit the velocity in two directions, though not within very narrow limits.

The following is the formula for the fracturing of a solid parallelopiped at its base by a subnormal wave:—

$$V = \frac{2}{3} g \times \frac{L\beta}{a^2} \times \frac{\cos.\phi}{\cos. (\phi + e)}$$

where g as before = 32 feet per second
ϕ = 25°
e = 39° the angle of emergence
a = 6 feet, the height of the tomb
β = $3\frac{1}{3}$ feet, width of the tomb
L = 4 the modulus of dynamic adhesion between the bricks and mortar.

$$\therefore \quad V = \frac{2 \times 32 \times 4 \times 10}{3 \times 3 \times 36} \times \frac{{\cdot}90}{{\cdot}43}$$

$$V = 23{\cdot}22 \text{ feet per second,}$$

or the velocity necessary to fracture the tomb from its base. Now as this has not occurred, the velocity must, at greatest, be not so high as this value.

Projection of canopy.

But again, we have in the case of the canopy, not merely a body upset, but also one projected some distance.

For the centre of gravity of the whole system had travelled horizontally 11·50 feet from the position vertically beneath where it was when the structure was just on the verge of falling. Now, if the canopy had been gently lowered over on its side, so that no centrifugal force generated was sufficient to overcome the pressure due to gravity, it would have lain with its centre of gravity 3·50 feet short of this, or the distance from the point of revolution would have been equal to the height of the centre of gravity, plus half the diameter of a pillar, that is, 7 feet 2 inches and 10 inches. This $3\frac{1}{2}$ feet extra throw must have been due either to one cause alone, or to two combined. It must either have been caused by the centrifugal force of the body revolving under the influence of gravity alone, or by the combined effects of it and the projecting force of the earthquake. If it had been due entirely to the first of these causes, we should have had the system springing away from the centre of revolution when the cosine of the angle through which it had turned was $\frac{2}{3}$, and not before. Now it is easy to see by noting the proportions of the parts shown in the elevation fig. 5, Pl. II, and joining the necessary angles, that if the body had not left its point of revolution at an earlier period, the north edge of the canopy would have struck the upper part of the tomb over half its surface, causing a collision which would have left undoubted traces. But it has not done so, or rather the south edge of the tomb has only just been grazed as represented in the figure. Consequently there must have been some other force in addition to that of gravity acting on the body, and so helping the centrifugal force due to gravity to project the body at an earlier moment. Also, since the upper surface of the tomb is 1 foot only below the canopy (when the latter is on the verge of falling), it must have been shot away before that vertical distance had been descended, though not much before, inasmuch as the canopy did just graze the tomb. We shall not be far wrong if we take it that the pressure on the ground was overcome by centrifugal force at the moment when the canopy had descended $\frac{3}{4}$ foot.

The centrifugal force due to gravity alone at that position would have been

$$\sqrt{2g \times \tfrac{3}{4}} = 6{\cdot}928 \text{ feet per second.}$$

And if we now calculate the velocity of the force for projecting the body the $3\frac{1}{2}$ feet, and then subtract the previous rate, we shall arrive at the true velocity of the shock that it possessed over and above what was just sufficient to overturn the body.

By the formula

$$v^2 = \frac{a^2 g}{2 \cos^2 e \, (b - a \tan e)}$$

where $a = 3\frac{1}{2}$ feet, the horizontal distance.
$b = 7\frac{1}{4}$ „ the height of the centre of gravity.
$e = 39°$ the angle of emergence.

we get $v = 8{\cdot}364$ feet per second.

Now, subtracting 6·928 for the reason assigned above we have—

1·436 feet per second

as the projecting force which acted in addition to the overturning force. The latter we found previously to be 2·560 feet per second, and therefore by adding we get

3·996 feet per second

as the velocity of the wave particle at Jamalpur 74 miles from the seismic vertical.

It may be said that the smallness of the velocity, 1·436, just deduced, leaves very little room for fractional errors in the measurements which must always occur; but when we consider that it is certain there must have been some projection, certain, too, that it was only small, and when the conclusion here come to is corroborated by the next example, we have good grounds for thinking it correct.

The breaking of the chimneys.

In the previous case of the tomb we had to deal with objects which were considered as approximately rigid, or without any elasticity that need be taken into account; but coming now to the consideration of the chimneys, we have to bear in mind the very important fact that high brick-work structures of this kind are extremely flexible, and are capable of swaying through many feet in a high wind without breaking. What we have in fact is the case of an inverted compound elastic pendulum oscillating about a fixed point. If in such a building the greatest velocity that can be acquired by the centre of oscillation as it passes the vertical, during a maximum vibration, be greater than the velocity of the earth-wave shock in that direction, it is easy to see that the structure would not be forced to the limits of its flexibility and so would not be broken. If, again, they were about equal it would be a matter of uncertainty whether the chimney fell or not and in which direction it fell. But if the velocity of the shock were greater than the maximum velocity of the oscillation consistent with the elasticity of the chimney, the chimney would be broken in its weakest part during the first semi-phase, and the broken part would fall in the direction from which the shock came. In estimating, then, whether the velocity of any earthwave is sufficient to break a flexible structure such as a high chimney stalk, it is first necessary to know within what extremes the chimney can oscillate without breaking. For answering this question with rigid accuracy, many data respecting the modulus of elasticity of brick-work would be necessary, which are not at the present day determined satisfactorily. But there are other sources of information from observed oscillations of chimneys acted on by wind storms, which may be of use.[1] The Townsend chimney, over 326 feet high, was struck by a gale of wind which bent it beyond recovery 7 feet 9 inches out of the perpendicular, so that its length of oscillation without breaking was 15 feet 6 inches at the top. It seems probable, however, that if neglected it would have ultimately come down, for the deflection was observed to be increasing for some time whilst the workmen were straightening it. This chimney was more than twice the height of the mill chimney at Serajganj, but another one at Messrs. Matthews and Son's Chemical Works, Pitchcombe, was 132 feet high, or only 3 feet less than that at Serajganj, and like it octagonal in section. It was observed, when tested in 1875, to be 3 feet 10 inches out of the perpendicular, giving a range of oscillation without breaking

[1] See Supplement to Spon's Dictionary of Engineering, page 355.

of at least 7 feet 8 inches, at the summit. If we take 10 feet as the limit of possible oscillation of the mill chimney at Serajganj without breaking, we shall not be over-estimating it, since the Pitchcombe chimney was not so far gone relatively as the Townsend, and was easily straightened.

But first, as in the case of the tomb, it is necessary to get at the radius and centre of oscillation in order that we may learn what is the simple pendulum whose time of vibration corresponds to that of the compound pendulum of the chimney. By dividing the chimney into suitable lengths, and deducing the varying masses of these lengths from their mean internal and external diameters respectively, we can get their several moments of inertia about the axis of oscillation, and by adding them together get the moment of inertia of the whole mass.

This we find to be 407,414.

Having got this, it is easy to deduce the radius of gyration, and the radius of oscillation. The latter we find to be $69\frac{37}{48}$ feet from the base or nearly 70 feet. Thus the simple pendulum whose time of oscillation is the same as that of the chimney has a length of 70 feet.

Now, by the formula,—

$$t = \pi \sqrt{\frac{l}{g}}$$

where t = the time of oscillation; l = length of pendulum; and g = the accelerating influence of gravity in one second, we have

$$t = 3{\cdot}141 \sqrt{\frac{70}{32}} = \frac{8{\cdot}366}{5{\cdot}656} \times 3{\cdot}141$$
$$= 4{\cdot}647 \text{ seconds.}$$

Now, taking 10 feet as the range of oscillation of the summit of our chimney, we have 5¼ feet as the length of oscillation of the simple pendulum, 70 feet high, which represents it.

Then the greatest velocity attained during its maximum oscillation without breaking will be when it passes the vertical and will equal

$$\frac{5\frac{1}{4}}{2} \sqrt{\frac{g}{l}} = \frac{13}{5} \sqrt{\frac{32}{70}} = 1{\cdot}64 \text{ feet per second nearly.}$$

Now an earth wave shock at an emergent angle of 60°, and with the above horizontally resolved velocity, would have a rate of 3·28 feet per second along the normal, since sec. 60° = 2·0 and would cause just this oscillation. Therefore the velocity of the wave particle must have been just a little higher than this, or about 3·3 feet per second; for if it had been greatly higher, the chimney would have broken during the first semiphase, and its fragments would have been precipitated in the direction from which the shock came, whereas their actual position, as shown in fig. 2, Pl. I, declares that it was during the second semiphase that they were overthrown.

It might be thought that in that semiphase one-half the velocity afore-mentioned would have been sufficient, provided the period of oscillation of the chimney coincided with the period of vibration of the earth wave, but from the slow oscillation necessary for such a high chimney, 4·647 seconds, it will be at once seen that such a coincidence is impossible.

Putting together the evidence for velocity, we have the lowest and highest limits fixed by the Jamalpur tomb, 74 miles from the seismic vertical, at 2·56 and 23·22 feet per second respectively; and also a probable rate of nearly 4 feet per second deduced from the same data, whilst at Serajganj, 36 miles from the centre, we have corroborative evidence for a probable rate between 3 and 4 feet per second.

Small as this rate sounds to the ear, there is abundant testimony brought forward by Mallet in his report on the Neapolitan earthquake to convince every-one that its effects on badly built or unstable dwellings may be immense.

Velocity of transmission of the wave.

The data for obtaining this with accuracy are unfortunately wanting; such as there are being scarcely reliable as approximately correct. At Alipur Meteorological Observatory, Calcutta, the time of the shock was indeed fixed rigidly at 6 hours, 24 minutes, 12·6 seconds, but from only two other places, namely, Dacca and Sibsagar, have times been forwarded. From Sibsagar Observatory a seismometer form was received partly filled up, stating that a very slight shock of earthquake occurred there lasting about half a second, but that no seismometer cylinders were overthrown, and no damage done. The time given was 6 hours 48 minutes (local time), which corresponds to 6 hours 22 minutes Calcutta time. That is to say, the shock was felt 2 minutes earlier at Sibsagar than in Calcutta. Now allowing that the rate of transmission of the shock was twice as great (and this is the most liberal allowance possible) through the rocky strata towards Sibsagar as through the clay to Alipur, we still have more than double the distance for the shock to have travelled in the former than in the latter case, so that at least the shock should have arrived some little time later at Sibsagar than at Alipur. Thus we must put aside the time evidence here as unsatisfactory. From Dacca, a letter from the Traffic Superintendent of the Dacca and Maimensing State Railway, gave the time as 6·22 at the "last of the vibration." The time is telegraphed daily from the Government Telegraph Office, Calcutta; and was marked on the clock dial at the Dacca Railway Station accurately the day before. As Dacca is 35 miles, and Calcutta 158 miles from the seismic vertical they will be 57 miles and 164 miles respectively from the focus, reckoning the latter at 45 miles deep. Hence the difference in distance is 107 miles. This gives 53½ miles a minute for the velocity of transit; a result much too large, even if some fraction of a minute be allowed for the vibration to have ceased at Dacca before the time was noticed.

On the whole, then, we have no reliable data that can in any way advance our knowledge concerning the velocity with which an earth wave is propagated through the rocks.

Minor earthquake shocks.

There seems to be no doubt that the forerunner of the destroying earthquake of the 14th July is to be found in the gentler, but still violent shock, of the 25th June, which convulsed a great part of Bengal, and was felt in Calcutta and Darjiling; whilst it is certain that the later small shocks and tremors have proceeded from about the same centre as that of the 14th.

These later ones happened on the following dates; and, though doing no damage, they kept the population in a constant state of expectant alarm:—

21st	July	about	5-40 P.M.
22nd	"	"	4-30 A.M.
22nd	"	"	3-50 P.M.
23rd	"	"	3-30 A.M.
23rd	"	"	7-20 "
23rd	"	"	10-40 "
26th	"	"	5-30 "
26th	"	"	9- 0 "
26th	"	"	1-30 P.M.
4th	August	"	9- 0 "
5th	September	"	11-30 A.M.

Connection with Kashmir earthquake shocks.

On the 17th July at Murree a shock was felt, but this is no doubt rather to be relegated to the Kashmir set of earthquake shocks than to those of Bengal. And this brings us to the question whether there may be any connection between the two sets of earthquakes thus widely separated, or whether we are to look on them as due to causes working singly and unaided in their own localities. Doubtless there can be no definite answer to such a question, but it may be noticed that if we answer in the negative, if we put down their contemporaneity to mere chance, we tacitly admit that the causes of each are local, and by inference superficial. Hence we might find room in this case for the possible explanation offered by Mr. Medlicott in his preliminary notice of the earthquake, that the change in the course of the Brahmaputra and the consequent deposition of its vast sediment in a different area might have so disarranged the balance of the earth's crust and so brought on a bending in the strata that might have culminated in a violent snap sufficient to produce the phenomena of the 14th.

On the other hand, if we take their near coincidence in time as a sign of their connection in reality, we must look for no local and superficial cause, no mere change of a drainage system to account for them, but we must search for some deeper cause underlying the very roots of the mountains, and sufficient, by throwing the whole of the northern parts of India into a state of strain, to bring on earthquake phenomena in those parts of the earth's surface less able to stand the stress or more intersected by lines of weakness.

European earthquakes. Ischia, Krakatoa.

And in the same way if this relation be granted as probable, there seems no reason why the certainly marked increase of seismic and volcanic activity during the last year or so both in Europe and in some parts of Asia should not, in like manner, be due to some great underlying cause which, on a large scale, has been making itself felt here and there in weak places; now in Italy, now in Spain, now in England, Germany, Switzerland and Austria, and other places in the Eastern Hemisphere. Nor would it, perhaps, be too much to look back to the Ischian earthquake and the eruption of Krakatoa in the summer of 1883, as perhaps the great forerunners of this consecutive series of siesmic and volcanic phenomena.

In conclusion, I should mention that such observations as are recorded in

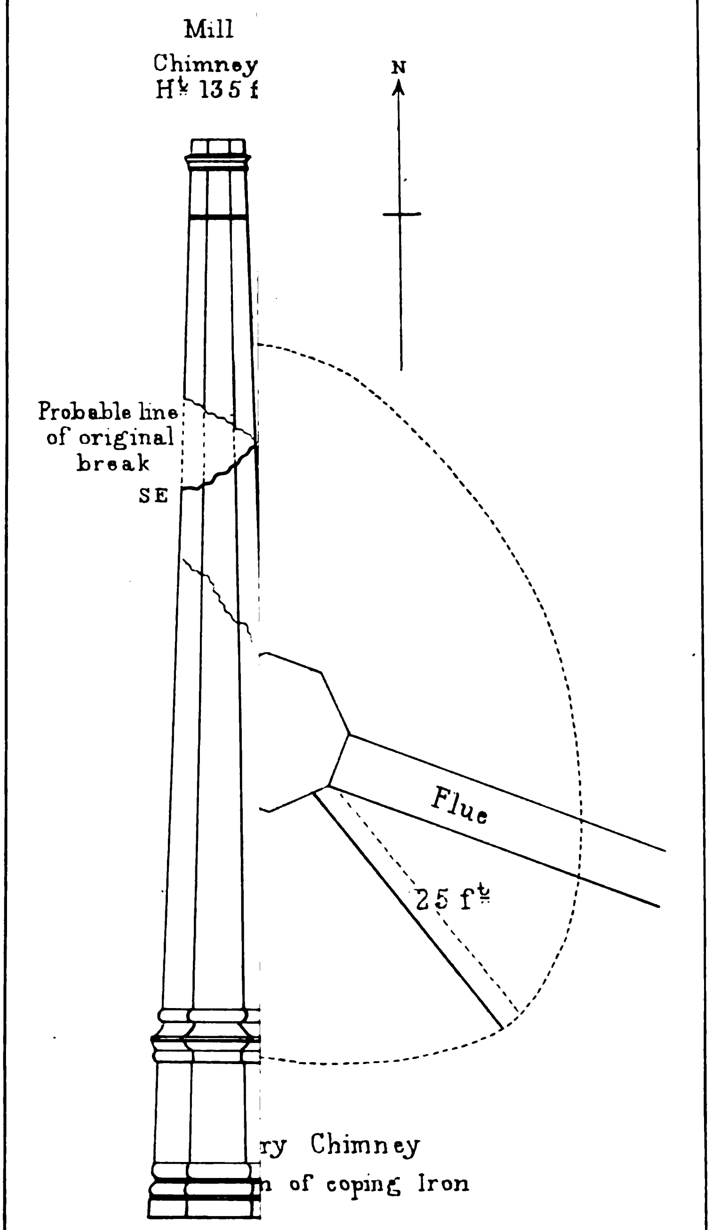


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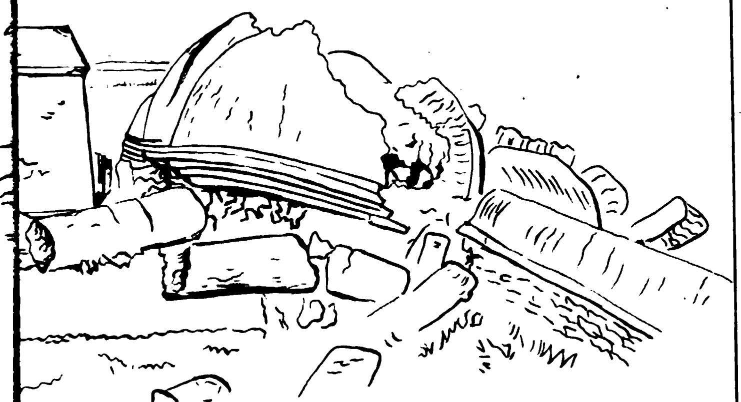
Fig. 6.



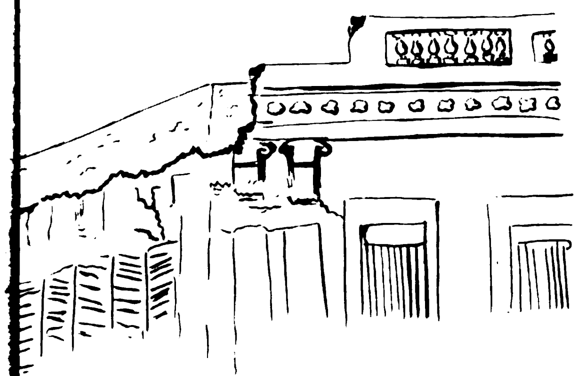


Fig. 10.

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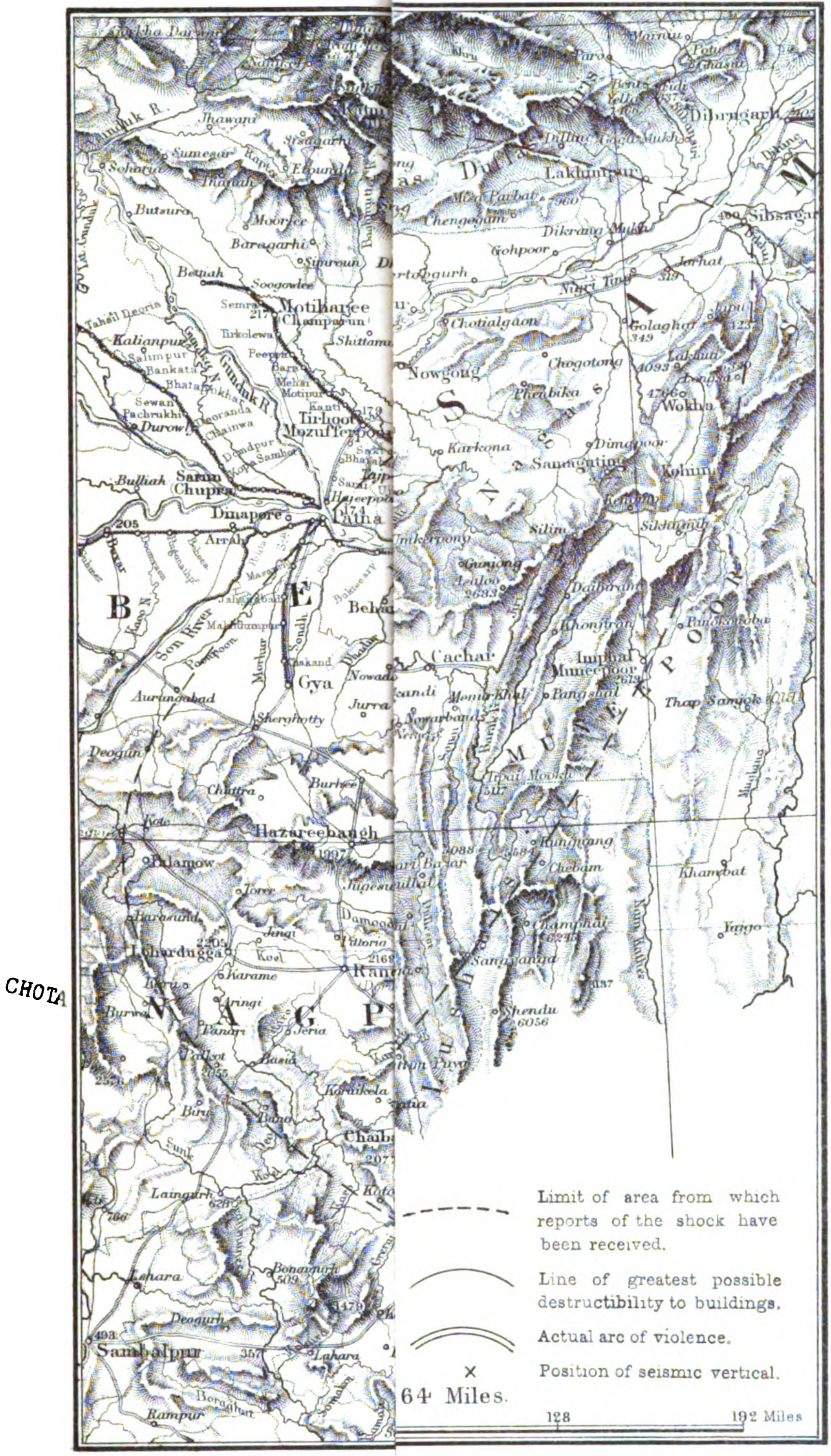
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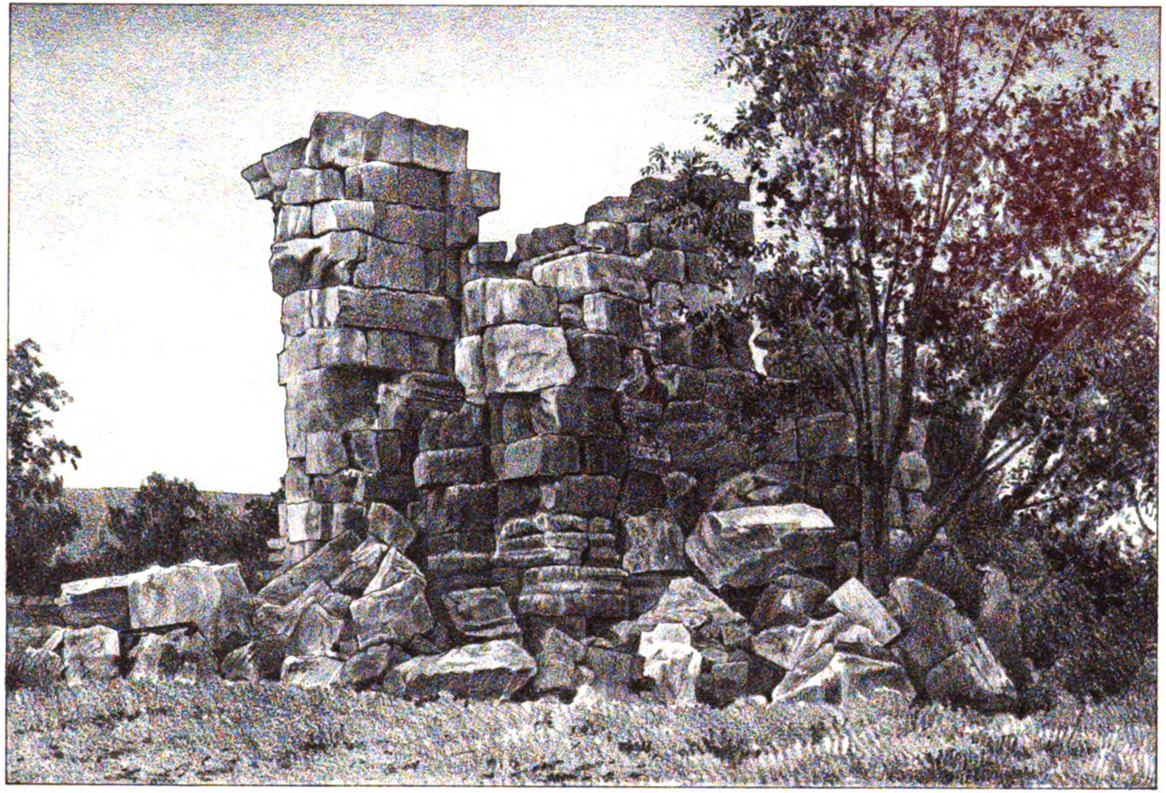
Sherghotty
Hazareebagh
Palamow
Lohardugga
Ranchi
Sambalpur
Rampur
Dibrugarh
Sibsagar
Lakhimpur
Jorhat
Golaghat
Nowgong
Samaguting
Kohima
Wokha
Cachar
Munneepoor
Shendu
6056
Khambat
Limit of area from which reports of the shock have been received.
Line of greatest possible destructibility to buildings.
Actual arc of violence.
Position of seismic vertical.
64 Miles.
128
192 Miles



RUINED BUDDHIST TEMPLE NEAR PATAN, KASHMIR.

this paper are in a great measure due to the assistance I received from the Government officers at Sherpur, Maimensing and Dacca; and in an especial degree to the kindness and hospitality of several gentlemen residing at Serajganj, Subornkholi, and Maimansing, without which, in a district destitute of hotels or dâk-bungalows a cumbrous camp equipment would have been necessary.

Report on the Kashmir Earthquake *of* 30th May 1885, *by* E. J. JONES, A.R.S.M., *Geological Survey of India.*

Exaggerated reports.—The newspaper and other reports of this earthquake, at first, as is usual in all such cases, much exaggerated the importance of the event.

Heavy loss of life.—But, in spite of the comparative mildness of the shock, the loss of life was very great, being in round numbers about 3,000. The cause of this is to be looked for in the very insecure manner of building in vogue. This, at the same time, has necessarily prevented the possibility of many accurate observations being taken from the ruins.

Style of building.—The greater number of the buildings may be divided into two classes:—

(i) those situated in the hilly parts of the country;

(ii) those situated on the more level country, in the wide portion of the valley of the Jhelam.

The first class are low structures, usually isolated, and frequently covering a large area of ground, being generally built upon a terrace on the side of a hill with one side resting against the perpendicular face of the terrace above. These huts consist of walls built of rubble loosely held together with mud; resting on these are a number of beams (roughly trimmed trunks of trees), which are also supported along their length by wooden posts; upon the whole of this with the interposition of some cross pieces of wood, a layer of dry mud is laid, which is added to year by year and forms a flat roof.

The second class are built either detached or several in a row; they consist sometimes of as many as three stories. The materials used in their construction are very various, blocks of dried mud measuring 2 to 3 feet in length, breadth, and depth and made in moulds *in situ;* sun-dried and burnt bricks held together with mud, or rarely in the case of the burnt bricks with mortar; rubble stones held together with mud. It is also usual in these buildings to place at intervals of 2 to 4 feet horizontal lengths of wood, and occasionally vertical and inclined ones; no attempt is made at bonding in these walls, and the mud between the bricks is about one-third the thickness of the bricks. Above this is placed a thatched gable-ended roof, into the composition of which heavy beams of roughly hewn timber enter very largely. The whole roof is supported on several square pillars of sun-dried bricks or other material carried above the walls and measuring 2 feet to 2 feet 6 inches along the side.

It will be readily understood that such structures are not of a nature to successfully withstand earthquake shocks, even when not of any great degree of intensity. In a very considerable number of the cases in which huts were damaged, the supports of the roof had given way and allowed it to subside, frequently carrying the walls down with it and leaving only a mass of rubbish to indicate the spot where the house had stood.

Scattered through the country there are, however, a few buildings of a more substantial character, some of which were more or less injured by the shock.

Patan.—This village is situated on the road from Baramula to Srinagar, and near it is an ancient Buddhist temple, of which a view is given in the annexed plate. The temple is very nearly cardinal (*i.e.*, its four sides face nearly N-S. and E-W.), and is built of large trimmed blocks of limestone laid together without any cement. In each face there is an arched recess, and inside is a small open space about 10 feet square. From the western face three stones have fallen from near the top of the arch. The greatest damage was done to the S. and E. faces, especially at the S.E. corner, the greater part of which fell. The long axis of an ellipse drawn around the fallen stones as they lie upon the ground runs E. 22°S.–W. 22° N., which gives an approximate direction for the wave path at this point.

Srinagar.—In the Sher Garhi (the Maharaja's palace) the long walls of the large dining-room run east—west, and the one on the south side, which is an outside wall, consists of a series of brick pillars 3 feet wide with openings between them 4 feet 6 inch across. Three of the pillars are cracked; the two most decided cracks make angles of 27° and 37° respectively with the vertical, and are inclined towards the east. If we take the mean of these two, we obtain an angle of 32°, which, on the assumption that the fractures are formed at right angles to the line of shock, is equal to the angle of emergence of the shock.

A high wall outside this room and facing to the west was partially overthrown in a westerly direction into the court-yard. These two observations point to a wave path at this point in an E.–W. direction; and though the wall to some extent would have vibrated at right angles to its long axis and have fallen even under the influence of an oblique shock, yet the fissures in the pillars indicate pretty exactly the line of shock.

At the Sangin Darwázi, which is a gateway in the wall between the city and the Hariparbat fort, several stones have been thrown down from the top of the gateway in a more or less westerly direction, the only two whose original position I was able to discover had fallen to W. 1° N. and 12° N.; if we take the mean of these two, we get W. 6° 30′ N. as the direction from which the shock came. This gateway is built of brick with a facing of stone-work and looks towards W. 22° S.; on the eastern side of the arch a good deal of brick-work fell.

In the Tashwan division of the city is a bath-house, which is cardinal, and built of brick and mortar. Both the east and west walls of this building have fallen outwards, carrying some of the arched roof with them, and the west wall carried a small portion of the south wall with it. This indicates an east-west direction for the wave path.

Gondikallel.—At this small village, which is situated about half a mile to the west of Tregaon, near Shadipur, there was a small hut built of mud, the ends facing S.E. and N.E.; these ends both fell outwards, indicating a N.E.–S.W. direction for the wave path.

Mujigund—is on the left bank of the Jhelam, below Srinagar, nearly opposite Bakpura. Here there was a long building forming a stable belonging to the Maharaja; it was built of brick and mud pillars at intervals of about 6 feet, the spaces between the pillars being filled up with unburnt bricks. The long axis of the building ran N.–S. The whole of the walls, with the exception of the one at the south end, fell. The fall is reported to have taken place towards the east, but the debris had been removed in order to allow of its being rebuilt. This indicates a nearly E.–W. direction of shock.

Kaosa.—This village is situated on both sides of a small stream near Magaon. On the left bank is a large three-storied house of bricks and mud built in 1884, surmounted by heavy wooden beams for supporting the roof, which at the time of the earthquake had not been put on; these consisted of five cross beams resting on brick pillars and running N.W.–S.E., and one longitudinal ridge-pole above, running S.W.–N.E. The pillars on which these beams rested had been broken down, and the beams were lying on the floor of the attic; the longitudinal beam had moved 5 feet in a S.W. direction and 1 foot 8 inches towards N.W., the cross beams had moved in a N.W. direction 3 feet, and about 1 foot 6 inches to S.W. This would indicate a W.–E. direction of wave path.

Mágam (*Magaon*).—Here were three houses facing, respectively, N. 3° W., N. 8° W., and N. 18° W., the walls facing in these directions had all suffered the same damage, *viz.*, the mud which was used to fill up the intervals between the pillars of unburnt bricks had fallen outwards. If we take the mean of these three directions, we obtain N. 9° W. as the direction from which the shock came.

Makahama (*Harda Maka Nana*).—At this place the walls of the mosque, which were built of bricks and mud, were uninjured; but the pillars of brick-work above the walls, which were apparently intended to support the roof, though in this case they did not reach high enough, and the weight of the roof rested on wooden supports at the sides of the pillars, were damaged. The ends of the mosque face W. 17° S. and E. 17° N., the middle pillar at the west end fell outwards and the three middle pillars on the north side also fell outwards and one pillar on the south side was tilted inwards. This indicates a shock about diagonal to the building or W. 28° N.–E. 28° S.

Sopur.—The fort situated on the right bank of the river at the end of the bridge was considerably damaged. The component materials were rubble, cemented partly with mortar and partly with mud. It was a square building with a tower at each corner, the towers being portions of octagonal pyramids built on to the corners which point N., S., E., and W., and in the middle of the S.W. side was a square gateway tower. Inside, on the ground, there were several cracks running N.E.–S.W. On the S.W. side the top of the gateway tower fell inwards; the same occurred to the south and west corner towers; on the S.E. wall a portion fell near the east tower in a S.E. direction, and the east tower fell entirely. Several portions of the N. W. wall, and a considerable portion of the N.E. wall fell. The roof of a small hut just outside the gate was thrown off to S. 13° E., bringing down the walls at the same time. All this indicates a shock from a direction somewhat to the east of south.

Chikar.—This is a fort situated above the Jhelam some distance to the south in the neighbourhood of Garhi; it is built of rubble and mud, with horizontal wooden beams at intervals of 2 feet and a mud plastering over the whole. The building is square, with portions of octagonal pyramids forming towers at the corners and in the middle of three of the sides; on the east side there is a square gateway tower. A portion of the east corner of the S.E. tower fell down towards the east and a portion of the N.W. tower fell to the west. This gives an E.–W. direction for the shock at this point.

Position of the seismic vertical.—Tabulating the above we get—

PATAN—	
Temple	E. 22° S.—W. 22° N.
SRINAGAR—	
Sher Garhi	E.—W.
Sagin Darwazi	W. 6° 30′ N.
Tashwan	E.—W.
GONDIKALLEL—	
Small mud hut	S. W.—N. E.
MOOJIGOOND—	
Stable	E.—W.
KAOSA	E.—W.
MAGAM (MAGAON)	N. 9° W.—S. 9° E.
MAKAHAMA—(HARDA MAKA NANA)	W. 28° N.—E. 28° S.
CHIKAR Fort	E.—W.
(SOPUR Fort	S., some degrees E.)

Plotting these directions on the map, we find 17 intersections within a circle of 4 miles radius round a point quarter a mile S.W. of Jampur, 12 miles from Srinagar in a westerly direction from the northern end of the city; and 21 intersections within a radius of 10 miles round the same point. Considering the class of buildings from which the observations were necessarily taken, this gives as accurate a determination of the position immediately above the seismic focus as could be expected. This position agrees sufficiently well with the results obtained at Sopur, which were not plotted owing to the indefiniteness of the indications.

Residency at Srinagar.—The walls of this building, which is situated on the right bank of the Jhelam to the east of the city, were fractured in such a way as to indicate a shock very nearly N.–S. This is possibly due to a reflection of the shock from the inlier of older rocks which lies to the east of the town; but as the fractures were mostly old ones that had been plastered up previously, they are not of a nature to give satisfactory indications.

Baramula.—At Baramula also everything tends to show that the shock was there N.–S., walls facing north and south being overthrown, and those facing east and west fractured. This also is probably due to a reflected wave from the hills to the north of Baramula.

Depth of the seismic focus.—We saw that at Srinagar the angle of emergence was 32°. Now the depth of the focus is obtained by the formula—

$$d = r \tan. e$$

where e = angle of emergence at any point, and r = distance of that point from the seismic vertical, we have therefore—

$$d = 12 \times \tan. 32^\circ$$
$$d = 7{\cdot}5 \text{ miles}.$$

which in the absence of other data from which the depth might be calculated may be taken as an approximation to the mean depth of the seismic focus.

Meizoseismal area.—The greatest damage has been done over an irregularly elliptical area, the long axis of which is 10 miles and the short axis 6 miles long, and the superficial area about 47 square miles, and nearly symmetrically disposed about the seismic vertical. Within this area, marked by a broken line (— — — —) on the maps, the destruction was very complete, whole villages being almost entirely destroyed and many lives lost. This corresponds to the meizoseismal area of Mallet.

First isoseismal.—The area outside this, corresponding to Mallet's first isoseismal, includes the area within which large portions of villages and towns were thrown down and persons killed. This is included by a line passing east of Srinagar through Magaon south of Baramula and across the Jhelam near Gingal, then passing north of Sopur and round again to the south of Srinagar. It includes an area of about 500 square miles.

Second isoseismal.—Outside is again another area of about 3,000 square miles including those places from which slight damage to buildings, &c., is reported to have occurred, but it is probable that even within this area there was some loss of life. It is indicated on the map by the broken line passing north of Gurais, from thence it passes east of Titwal on the Kishengunga river, west of Chikar, south-west of Bagh, and south of Púnch, at or near all of which some damage to buildings, chiefly forts, is reported. From Púnch to Gurais there are no reports, and the true course of the line is uncertain.

Third isoseismal.—This is a large area: including the places where the shock is reported to have been perceived by the unassisted senses, *viz.*, Peshawar, Gilgit, Simla, Sabathu, Dalhousie, Lahore, &c.

Outside the third isoseismal area is a larger area, the extent of which is quite unknown. It is that in which the shock might have been perceived by means of properly constructed instruments.

Sound accompanying the shock and preliminary tremors.—A sound, which is variously described as resembling distant thunder, a discharge of artillery, and the noise caused by blasting operations, preceded the shock, and seems to have been noticed by many who were not asleep at the time; but no preliminary tremors seem to have attracted attention.

Transit velocity of the wave.—No observations of the time at which the shock was felt were made with any instruments sufficiently accurately adjusted as to give any reliable data for calculating the transit velocity.

Velocity of the wave particle.—I was not able to find any objects overturned or projected in such a way as to give a measure of the velocity of the wave particle, but considering the class of buildings which have escaped, it cannot have been very great; for almost the whole of the buildings are either bad, ill-laid and ill-cemented masonry, or simply mud structures; and we know that a horizontal velocity of 3 to 4 feet per second is sufficient to fracture such structures.[1]

Landslips.—Several secondary effects of the earthquake were noticed.

[1] The Neapolitan Earthquake of 1857, Mallet, Vol. II, p. 346.

A large landslip occurred at Larri-dur, a place about 7 miles south of Baramula. This village was situated upon a hill lying N.W.—S.E., composed of slightly hardened Karewa [1] clays resting upon sandstone and dipping to N.E. at 5° to 10°. Above the clay is surface soil of varying thickness. The upper 30 feet of clay and surface soil has slipped along to the dip, exposing a fresh smooth surface of clay. The line of parting ran along the length of the hill, and a fissure has been formed along this line varying in width from 30 feet at the S.E. end to about 500 yards at the N.W. end, and with a length of about half a mile. To the N.E. of the narrow end of the fissure another slip has taken place from the side of the hill. The mass of clay and surface soil that has slipped is all piled up to N.E. of the hill in the little valley situated there, and all the huts that lay in its path were of course buried.

The slip was probably due to the presence of water in the clay, which must have accumulated along the plane of bedding, thus producing a soft water-saturated stratum over which the upper mass would readily slide. With the upper mass thus situated, floating as it were on a layer of slime, a slight shock might be quite sufficient to fracture it and cause it to slide by reason of its own inertia.

Fissures and sand craters.—In many places, as at Patan, Dubgaon (at the junction of the Jhelam and Pohra rivers), along the banks of the river at and above Baramula, numerous fissures were formed in the alluvial soil, of no great width (none exceeding a yard across) and all running roughly parallel to river banks or else across the slope of hills.

In the neighbourhood of many of these fissures water and fine sand were thrown out, and the villagers stated that there was a strong sulphureous smell given off from the sand for several days. This smell was probably due to sulphuretted hydrogen gas ($S. H._2$) produced by the slow decomposition of the strings of vegetable matter imbedded in the alluvial soil. In one case at Nila, near Patan, I saw an inflammable gas without odour being slowly evolved. This was probably marsh gas ($C. H_4$) or one of its homologues, produced in the same manner.

Effect on springs.—Several springs were affected by the earthquake, the flow of water being increased for periods of time ranging from a few hours to as many as eight days.

The country occupied by the meizoseismal area is entirely composed of recent alluvium, and that within the first isoseismal line is almost entirely of the same character, the Karewa beds (pleistocene alluvium) coming into the N.W. of the area in the neighbourhood of Baramula, and down the river below Baramula the alluvial deposits are underlaid at a short depth by the more indurated rocks of the Panjal system, which also appear to the east of Srinagar.

Subsequent shocks.—The slight shocks subsequent to the great one continued at intervals up to as late as August 16th, on which date there was a shock at about 7 A.M., since that time I have seen no reports, though the shocks probably continued to a much later date.

Desirability of erecting seismometers.—In a country like Kashmir, subject as it is to earthquake shocks at frequently recurring intervals, it would be highly desirable, especially in the absence of buildings suitable for seismological observa-

[1] Old lacustrine or fluviatile deposits now eroded into plateaus and terraces.

Lithographed at the Survey of India Offices, Calcutta, November 1885

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Lithographed at the Survey of India Offices, Calcutta, October 1885.

tions, to have at one or more stations seismometers erected, and should this for any reason be found impossible, it might still be practicable to erect at several points masonry pillars surrounded by a rough wooden fence and placed in charge of the headmen of the villages if necessary, which, if overthrown or fractured by an earthquake shock, would to a great extent supply the place of ordinary seismometers.

In conclusion, I would thank Colonel Sir O. St. John, K.C S.I., R.E., the officer on special duty in Kashmir, and all the officials of His Highness the late Maharaja of Kashmir and Jamu with whom I came in contact, for the assistance rendered me during my stay in Kashmir and without which it would have been almost impossible to carry on the investigations.

Notes on the results of MR. H. B. FOOTE'S *further excavations in the* Billa Surgam Caves, *by* R. BRUCE FOOTE, F.G.S., *Superintendent, Geological Survey of India.*

The further exploration of the Billa Surgam bone caves during the season 1884-85, by Lieutenant Foote, R.A., have been rewarded with a rich collection of fossil bones, together with many traces of the contemporaneous existence of man in the form of rather rude bone implements and other cut bones of great interest.

Lieutenant Foote resumed work at Billa Surgam in December last, and continued at it till the end of May. Previous to his return to military duty, he spent a few days with me, assisting me in unpacking the collections he had made, and explaining various points connected with his work. He subsequently drew up an interesting report of the work effected, much of which will be quoted further on.

With reference to the condition in which he found the caves on his return in December (1884), he reported: "I found everything just as I had left it at the end of May previous. The north-east monsoon having failed, the spoil banks were untouched, so I could not judge whether the stream which flows through the caves in wet weather is of any size."

Order in which the work was pursued.

"On first re-commencing operations, I determined to finish off the layer C c in the south corner of the Cathedral cave, and also the remaining cave earth in the Charnel House before proceeding to excavate over the whole area of the Cathedral."

"When the Charnel House cave was finished, as I had as many men at work in the Cathedral as I cared to have, I set the Charnel House gang to dig in the small cave which opens into Chapter House on the side. The results obtained will be given further on."

The Garden.

Mr. Henry Foote further examined, at my special request, the little grass-grown patch—"the garden"—on the cliffs above the north Chapel cave, as it seemed a very likely place to have been resorted to by possible cave dwellers as a strong terrace well suited for cooking and for basking, and whence they could keep a good look-out against sudden attacks from enemies. The little terrace was completely dug over down to the rock, but yielded nothing of interest. No further excavation was attempted in the Purgatory cave.

Further excavations in the Cathedral.

The second series of excavations made in the Cathedral cave was much less easy to effect than the first, as he had to contend with great masses of hard stalagmite, much of which had to be blasted, while the rest was broken up with cold chisels.

Discovery of further passages and chambers.

The excavation of the whole area of the Cathedral cave was effected to a depth of 16 feet, and in the southern corner a wide shaft was sunk to a further depth of 21 feet, making a total of 37 feet from the original surface. The sinking of this shaft revealed the existence of a passage opening from the south. This passage, to which the name of the "Corridor" was given, was followed up, and at a distance of 55 feet southward of its mouth was found to lead into another larger passage running east and west.

The Corridor.

On the south side of this east and west passage, and opposite to the mouth of the Corridor, another passage was found running south apparently, but for want of time not excavated.

The Fairy Chamber.

The east and west passage formed a domed chamber, measuring, before the excavation of its floor was commenced, 25 feet by 12 feet, with a height of 10 feet in the centre. A large fine stalactite hung from the centre, and below it was a large mass of stalagmite, the off-flow of calciferous water, from which had formed a stalagmite crust from ½ to 1 inch thick over the floor of the chamber. At the eastern extremity of the chamber the roof of the cave sloped down to about 2 feet from the floor, and here occurred "a perfect forest of most beautiful little stalactites, some forming delicate little pillars, others branching off into tree-like forms as ramified as the most elaborate corals." To this chamber Lieutenant Foote gave the name of the "Fairy Chamber" after the beautiful little cave at Caldy, in Pembrokeshire, so graphically described by Professor Boyd Dawkins in "Cave-hunting." The western end of the "Fairy Chamber" was filled with cave earth, which proved very rich in good specimens, as did also that in the "Corridor." The atmosphere in the Fairy Chamber was extremely close and steamy, and it was impossible to be in it for many seconds without being bathed in perspiration.

Section of beds in the Cathedral.

The series of beds exposed during the excavation of the Cathedral cave is given below in tabular form. The several layers in which the thicker beds were taken out, and the marks with which their fossil contents were registered, are also shown:—

9. Surface, or bat's dung, bed		C	Average thickness	3′
8. Grey sandy bed, with some bat's dung		C		3′
7. Stalagmite in irregular masses				—
6. Red sandy cave earth		C a		3′
5. Stiff red clay	excavated in three layers of 3′ each	„ b	9′	3′
		„ c		3′
		„ d		3′
4. Stiff dark marl		„ e	6′	3′
		„ f		3′

3. Dark loamy marl	C h		3′
2. Grey marl	„ i „ j	6′	3′ 3′
1. Grey marl	„ k „ l	6′	3′ 3′

Of the above formations everything down to the base of 5 (C d) was entirely removed, and the underlying formations were exposed in a wide shaft sunk in the south corner of the cave (to a depth of 37 feet from the surface); the average thickness of the mass removed over the whole area of the cave was 16 feet. The beds showed a general low dip north-westward.

With reference to the surface (bat's dung) bed, Lieutenant Foote states:

Surface bed.

"This bed varied very much in thickness, being 4 feet thick behind the high altar and only 1 foot thick on the north front of the cave, but it increased again on the south front, until behind some of the stalagmite masses in front of the high altar it attained a thickness of 6 feet. There were many small bones in it, most of which had lost their gelatine."

Of the upper bed of grey sandy cave earth (C,), he remarks it "is much infil-

Bed C.

trated in places with colouring matter, and at the top a good deal mixed with bat's dung—in fact to the presence of the latter I attribute the grey colour of the earth, which would otherwise have been nearly white from calcareous infiltration. The stratification was "very indistinct. There were very few large bones found, but plenty of small ones, which had all lost their gelatine but were not mineralized."

"Before excavating the next layer (C a), I had to remove the barrier of stalag-

Stalagmite barrier.

mite across the cave; the softer blocks I broke up with cold chisels, but the great majority had to be blasted; and in all I removed some 50 tons of rock."

"C a, as I termed the next layer of earth, was a red sandy bed about one yard

Layer C a.

thick, but in the front of the cave it was considerably thicker in places owing to the stream (flowing from the back of the cave) having scooped out channels in the underlying red clay which were filled up with the sandy bed."

"This bed partly underlies the high altar, and also contains a good many blocks of limestone—in fact in front of the altar it was entirely replaced by the basement blocks of the stalagmite barrier which here formed a regular floor. Many of these blocks of stalagmite are *in situ*, and as they are of large size, (some being 4 or 5 feet high), the underlying cave earth (C b) must be of great age, as, owing to the very dense nature of the greater part of these blocks, they must have been formed slowly."

Referring to the red clay bed $\left(C \begin{smallmatrix} b \\ c \\ d \end{smallmatrix}\right)$, Lieutenant Foote writes:—"Another

Bed C $\begin{smallmatrix} b. \\ c. \\ d. \end{smallmatrix}$

fact which points to the great age of this clay bed is that its surface is covered with a regular pavement of fallen blocks of limestone; and as most of them are small, they would seem to be rather the result of the slow breaking up of the roof owing to weathering than of any sudden disturbance of the rock by earthquakes.

Layer C c.

The layer C c of the red clay was found to be very rich in teeth in places, but very poor in front of the high altar. Like the overlying layer, this becomes much more sandy as it goes back behind the high altar; and as it becomes more sandy, so are the large bones and teeth replaced by small ones. With regard to these beds being rich in some parts in small bones, which are almost entirely absent from them in other parts, I would suggest that it is most likely owing to the bed being higher behind the high altar than elsewhere, it might therefore have been high and dry there when the other parts were under water, and consequently it would have been chosen as a resting-place by the owls, &c., which came to make their castings in the cave.

The surface of the underlying dark marl bed (C $\frac{e}{f}$) was found to have been scooped out by stream action to a depth of some 2 to 2½ feet; and where this had been the case, the overlying red clay was by so much the thicker than elsewhere. The excavation of C d brought to light the mouth of the Corridor passage leading southward into the Fairy Chamber, into both of which the red clay extended and maintained its character for richness in fossil remains.

C d yielded nearly all the important large bones found, and, excepting C b, was richest in small bones as well. Of cut bones C d yielded nearly twice as many as all the other beds together.

The several beds penetrated by the shaft sunk by Lieutenant Foote after clearing out the whole of C d and all above it, were of much less interest than the red clay above them, from the fact that they yielded but few good bones and teeth, most of the tolerably numerous fossils being fragmentary.

Bed C $\frac{e.}{f.}$

In this respect the lower half of the dark marl bed (C $\frac{e}{f}$) was better than the upper, which contained little but fragments of teeth, many being parts of molars of Rhinoceros.

Bed C h.

The underlying dark loamy bed C h was fairly rich in small bones, amongst which many belonging to different genera of birds.

Beds C $\frac{i.}{j.}$ C $\frac{k.}{l.}$

Of the remaining beds, C i and C j became increasingly poor in bones, while C k and C l are, to all intents and purposes, sterile, so much so that Lieutenant Foote does not consider them worthy of further exploration.

In the front portion of the Charnel House cave, where Lieutenant Foote had in his first exploration reached a depth of 27½ feet, he descended through 8 feet of stiff grey marl to the bottom of the cave at a total depth of 35½ feet from the original surface. No bones were found in this grey marl.

At the eastern or inner extremity of the Charnel House the passage widened out somewhat as followed eastward, and at the crossing of two master-joints in the limestone formed a star-shaped well (in plan), from which 18 feet of stiff red-clayey earth had been removed. At a depth of 27 feet the passage widened out in the cross joint and could have been entirely cleared; but as this would have involved costly timbering to shore up the sides, and the cave earth was very sterile, Lieutenant Foote judged it wiser simply to sink a pit in the centre of the cave, which was from 5 to 6 feet wide. The sinking was effected in depths of a yard each till a depth of 58 feet 6 inches was reached when the passage contracted suddenly from 5 feet to 6 inches and could be followed no further.

The results obtained by the excavation of the little cave on the south side of the Chapter House were small, the only point of real interest was that of a large human molar in a bed of red cave earth about 4 feet below the surface, the only human bone found anywhere in the true cave earth. The red cave earth was overlaid by black gravel from 1 to $1\frac{1}{2}$ foot thick.

Absence of skulls.

A remarkable fact, not easy of explanation, is the almost total absence of the skulls of the animals whose bones are met with in the caves. With the exception of two or three tolerably perfect skulls of bats which live in the cave, no entire crania or large fragments of crania were found, though many mandibles or rami of mandibles with or without their teeth were met with, from those of Rhinoceros down to those of minute shrews and rodents, &c. Teeth of many genera, especially ruminant and rodent, were obtained in considerable numbers, and mostly in excellent preservation.

A fairly large number of genera not found during the first exploration have now to be added to the preliminary list of the cave fauna, especially among minute mammals, birds, and reptiles.

The working out of the remains obtained at Billa Surgam will furnish materials for a very valuable chapter on the prehistoric fauna of South India, though the anthropological results so far obtained are rather disappointing from their negative character.

Preliminary list of fauna.

The following is a tentative preliminary list of the fauna of Billa Surgam, including some additional forms not found in the first collection made. These have an asterisk prefixed to their names.

MAMMALIA.

Presbytis (Semnopithecus) priamus ?
Macacus ? sp.
Chiroptera, several.
Sorex sp., small.
Tupaia ? sp., small.
Ursus ? sp.
Felis tigris.
 Do pardus ?
 Do. sp., medium sized.
 Do. sp., small.
Viverra zibetha ?
* Paradoxurus ?
Herpestes griseus ?
Canis sp.
Sciurus ?
Mus sp.
* Nesokia sp.
Hystrix leucurus.
Lepus sp.

Rhinoceros sp. ? javanicus. A possible second (smaller) species is suggested by difference in size and shape of posterior upper molars.

* Equus sp., large.
Do. sp. ? small.
Sus indicus.
Rusa aristotelis.
Axis maculatus.
* Cervulus aureus ?
Memimna.
Antilope bezoartica ?
* Gazella bennettii ?
Portax pictus.
Capra ?
Ovis ?
Bos sp.
Gavæus ?
* Manis pentadactyla.

AVES.

Genera belonging to the orders Grallatores, * Rasores,
* Scansores ?, * Insessores, and Raptores.

REPTILIA.

Crocodilus sp.
Varanus dracæna.
Agama ?
Lacerta ?
* Ophidia, several sp.
* Emys sp.
* Phelone sp.

AMPHIBIA.

Rana sp., small.
Ditto sp., very large.
Bufo ?

In their mode of occurrence, the bones, &c., collected during Lieutenant Foote's second season presented the same features as those of the first. Most of the bones and teeth occurred detached, and many of them had been cut or broken before being entombed in the several caves. Of the few large bones found, the most important belong to the genera Rhinoceros, Bos, and Equus.

Of the larger teeth collected, there are a fair series of Rhinoceros and Equus. Of bovine ruminants, of Sus and Hystrix many teeth were collected. Very large quantities of small bones left in the caves by birds of prey making their castings were found in almost all the layers of cave earth removed, as was the case in the earlier excavations.

No signs of continued residence of man or large animals.

As before, no traces were found of the continued residence of man or of large carnivora in any of the caves. No cooking-places of any size were found, though here and there scraps of charcoal or a little ashes occurred, nor was any pottery met with in any of the lower lying beds. Only very few calcined or charred bones were found, and they were in the superficial deposits of the Cathedral and Purgatory.

As in the Charnel House the bones found in the Cathedral were washed in from behind through passages communicating with the surface of the plateau above, and the main stream flowing through the body of the Cathedral cañon seems to have deposited only barren strata of sandy and stony character.

Of the streams which filled the Cathedral, one flowed in from the east, entering the apse close to the north side of the high altar, the other entered from the south through the Corridor. It is not improbable that another passage entered the apse of the Cathedral from the south-east, but is now hidden by the great stalagmitic mass of the high altar.

Bone implements.

Of the cut bones a considerable number are so shaped as to necessitate the conclusion that they were fashioned for special purposes; others, and they are much more numerous, though often elaborately cut, are so vaguely shaped that it is hard to conceive their having been prepared for any definite object; they rather suggest the idea that their fashioners were simply amusing themselves as they whittled them.

Nondescript cut bones.

Besides these trimmed bones most of the large bones found, and many of the smaller ones as well, show signs of man's agency in having been cut and scraped, and often to a great extent.

All the large bones had been set aside and registered as they were exhumed in the caves, also a large number of smaller bones and teeth; but a more careful examination of the numerous parcels of small bones brought from Billa Surgam, which examination could not be undertaken on the spot, has yielded many hundreds more of important bones and teeth and cut bones of medium and small sizes. There can be no doubt, however, that yet many more will reward the exhaustive examination, to which they will have to be submitted by the pal-osteologist, by whom the whole series of 'finds' is to be worked out finally.

Census of the selected specimens.

A census of the selected and registered specimens shows them to number 4,700 in round numbers, of which 3,000 are bones or teeth and the rest cut and trimmed bones. Of these latter some 200 may be considered to represent real implements prepared with a definite purpose. Of the remainder it is hard to say with what object they were trimmed into the shapes they now show.

Cuttings probably effected with stone implements.

None of the implements with which the cuttings were effected were met with in the caves, but from the peculiarity of the cut surfaces which are very scratchy, not clean and smooth, it is difficult to resist the inference that the implements used were not made of metal but of stone. The cuts show that the implements were used much more with a sawing or heavy scraping action than with a chopping one. None of the bones, so far as I have examined them, show the splitting off of chips beyond the cut which invariably accompanies the action of heavy metal implements.

Bones showing the marks of teeth of carnivora are not very numerous, nor do many show the grooved markings made by the teeth of rats and other rodents.

No stone implements found.

As stated above, no stone implements were found, though Lieutenant Foote, who is quite familiar with such antiquities, devoted very special attention to the search for them and examined personally many thousands of stones turned up during the excavations, besides exhibiting typical implements both palæolithic and neolithic to his diggers. One possible implement may be admitted in the shape of a tiny triangular flake of transparent quartz found by Lieutenant Foote during his first season at the caves. Such flakes have unquestionably been converted into drills by neolithic and other peoples.

Character of bone implements.

Among the worked bones shaped for specific purposes, the following forms appear to be recognizable :—

Awls.
Arrow heads, unbarbed.
Ditto with one barb.
Spear or harpoon heads, small.
Dagger.
Scraper knives.
Scrapers.
Chisels.
Gouge.
Wedges.
Axe heads.
Sockets, double, large and small.
Ditto, single.

The most remarkable of these implements is the gouge, already described in my second paper on the caves, and the dagger which is made of the calcaneum of some large (ruminant ?) animal. The calcaneum proper is the handle, and the narrow blade of the implement is cut out of the united fibula and tibia. It would be a formidable weapon in the hand of a strong man.

None of the supposed arrow or harpoon heads show more than one barb, which appears always to be basal, but a number of them are rudely waved as if anticipating the Malay Kriss. The supposed whistle is a digital bone, apparently of an antelope, of which the distal end has been cut off. It is not an effective whistle, and might very possibly have been intended as a handle to some small boring implement.

These cut bones are being sent to Europe together with the other cave treasures, as no collections of prehistoric bone implements exist in India with which to compare them.

A single cylindrical bead fairly well shaped, made of some dark brown material (possibly bone), was found in the upper layer of cave earth C in the Cathedral cave ; it was associated with numerous bones but no other articles of human workship. The perforation of the bead is well drilled, and the aperture at each end slightly enlarged by the use of a larger sized drill.

It is impossible to describe these implements more fully unless they were figured, which I trust they will be in the full memoir to be drawn up about the Kurnool caves.

Advisability of further exploration.

As to further explorations of the Billa Surgam caves, I think the excavations should certainly be continued so far as to remove the remainder of the red clay C d from the Corridor and Fairy Chamber. Further exploration of the Billa Surgam and other caves should be carried out by a prehistoric Archæological Survey Department, for which there is a very large field of work in the south of India.

Other caves visited.

Several other caves being known by report in other parts of the Kurnool District, of which it was desirable to have some positive information, Lieutenant Foote and I devoted the Christmas week (1884) to visiting them. The following caves were seen by us:—

1. A group of small caves lying 3 miles north of Billa Surgam, and known as the Boganpalli caves.

2. Two small caves lying south-west of Owk, in the south-western part of Koilkuntla Taluq.

3. A little cave in the centre of the village of Billam, in Banaganpalli State, and exposed at the bottom of a well.

4. A large and important cave about a mile south-west of Billam village.

5. A deep well-like chasm into which a long flight of steps descends to the sacred spring of "Nela Billam," about 6 miles north-east of Tarpatri. The two Owk caves, the little Billam cave, and the "Nela Billam" cave, are full of water in their lower passages as far as we could explore; but the great Billam cave is in wet weather a subterranean water-course traversed by a furious torrent.

Two other caves west of Gorlogunta, near Billa Surgam, were visited by Lieutenant Foote early in 1884. Of all these caves the Boganpalli group alone seems to promise good results to future explorers.

In conclusion I would remark that Lieutenant Foote carried out his work with great zeal and tact, and no little devotion to duty, for he was working in a desolate out-of-the-way valley out of reach of civilisation and all society. For, excepting myself for a few days, he saw no European for months together, which is no small trial to a young man fresh from all the gaiety and life of Bombay.

Besides the excavation work Lieutenant Foote took a number of very successful photographs of the Billla Surgam and other caves which he had not been able to do with the large wet-plate camera lent him by Government during his first season.

On the mineral hitherto known as Nepaulite, *by* F. R. MALLET, *Superintendent, Geological Survey of India.*

In 1853 a rather large collection of rocks and minerals from Nepál was presented by General Jung Bahádur to the Asiatic Society of Bengal. The greater part of these were found by Mr. H. Piddington, Curator of the Society's Museum of Economic Geology, to be of no value, but one ore attracted his attention as being unfamiliar, and was subjected by him to examination and analysis.[1] The mineral was said to have been found in considerable quantities not far from Khatmandu, and, being easily fusible, to have been used for casting into cannon balls, which, however, flew to pieces on being fired. Mr. Piddington described the mineral as a carbonate, mainly of bismuth, copper and iron, and pronouncing

[1] Jour. As. Soc. Bengal, Vol. XXIII, p. 170.

it to be a new species, gave it the name of 'Nepaulite,' from the country whence it had been sent. The analysis given by him is as follows:—

		Metallic about
Sulphur	1·60	
Silex	3·60	
Carbonate of Protoxide of Bismuth	34·80	24·6
Carbonate of Copper	22·96	14·40
Per-Carbonate of Iron	25·62	9·21
Ox: Cerium	9·40	
Lanthanum?	2·80	
	100·78	

Also traces of silver.

Mr. Piddington described the mineral as having a metallic lustre. "In external appearance it resembles exceedingly some of the varieties of granular and massive plumbago, or antimonial ores, which, at a first glance, and where the quartz matrix has no blue stain, it might well be mistaken for. The fresh fracture is of course somewhat brighter and more steely than the old surface, which like that of the plumbago ores is of a duller black, though always with a good metallic glance." But he makes no allusion to the remarkable peculiarity that 'Nepaulite' differed in this respect from all previously known native carbonates, the lustre of which is, without exception, non-metallic. This fact was in itself sufficient to cause some suspicion as to the correctness of the analysis given.

In 1866 the geological and mineralogical collections of the Society were handed over to Government, and in 1876 were transferred to the Geological Museum. During the arrangement of our economic collections I submitted the specimens in question to an examination, which, though very partial, was sufficient to prove that the ore contained a large proportion of sulphur, and also of antimony, and that the analysis quoted above could not possibly be correct. It is, however, only recently that I have been able to examine the substance more completely.

The mineral has a metallic lustre, iron-black colour, and dark brown streak slightly tinged with red. It is uncrystallised, and occurs irregularly through a somewhat translucent quartz-rock, which has a granular structure, with apparent traces of foliation, suggestive of its being a metamorphic quartzite rather than a true vein-stone. Azurite, malachite, melaconite, cervantite, smithsonite, ochre, calcite, &c., occur in association with the sulphide ore, most of them being probably results of its alteration. The sulphide is so mixed up with the gangue that it was only by laborious picking that enough could be separated for an analysis, which gave—

Sulphur	21·12
Antimony	25·17
Arsenic	1·32
Copper	38·69
Silver	traces
Lead	·30
Iron	5·33
Zinc	2·44
Calcium carbonate	1·07
Magnesium „	·13
Insoluble gangue	·68
Oxygen, carbonic acid, water & loss	3·75
	100·00

The oxygen, carbonic acid, and water are due to malachite, azurite, and melaconite, from which the sulphide ore could not be wholly freed. Cervantite was also not improbably present in small quantity, although, like the calcium carbonate, not visible to the eye. The number of minerals of apparently secondary origin in association with the sulphide, and the somewhat large proportion in which they occur, seem to indicate that the specimens were obtained from near the surface. Hence it is not unnatural that the sulphide should be in a somewhat altered condition. As an indication of the exact composition of the fresh and unchanged mineral, the analysis is therefore unsatisfactory, but it suffices to show beyond all doubt that the mineral is tetrahedrite of a common type. The above figures correspond to the formula R_4 (Sb As)$_3$ $S_6 = R_{4\frac{2}{3}}$ (Sb As)$_{2\frac{1}{3}}$ S_7, the excess of metals over the proportion required for the formula R_4 (Sb As)$_2$ S_7 being certainly in part, and probably wholly, due to the occurrence of some of them partly in an oxidised state, owing to the alteration of the mineral just alluded to.

Considering the wide discrepancy between the preceding two analyses, the idea may perhaps suggest itself that they refer to altogether different specimens. But those which I examined were handed over to Government direct from the Asiatic Society's Museum; they agree in their general outward appearance with the description given by the author quoted, and when they came into our possession the word 'Nepaulite' was found marked upon them in oil paint.

Notice of the Sabetmahet Meteorite, *by* H. B. MEDLICOTT, *Geological Survey of India.*

Sabetmahet is a small village in the Gonda district of Oudh, close to Muthuraghat on the Rapti, about 11 miles north-west of Balrampur, approximately at 82° 7′ E. Long. and 27°-35′ N. Lat. The fall occurred on the evening of the 16th of August 1885. The stone is an average oligo-siderolite, *i.e.*, having but a moderate admixture of meteoric iron, and so, under the circumstances explained in the following extracts of correspondence, there was no occasion to press the claim for surrender. The weight of the whole stone is given as 2 lbs. 13·77 ounces (1297·04 grammes). A very small portion was sent as a sample—

Larger piece	1·52	grammes.
Smaller piece	·52	"
Minute fragments, aggregating	·80	"
Total .	2·84	grammes.

The record is only worth publishing to illustrate what honour meteorites receive among our "Aryan brothers" of the period in Hindustan. The story moreover exemplifies a universal evil—the influence of priests and through them of women in dragging men to superstition: yet,

Das Ewig-Weibliche
Zieht uns hinan.

Extract of a letter from the Deputy Commissioner of Gonda, dated 5th September 1885.

"The stone was brought in from Balrampur piously wrapped in a cloth and carried by Brahmans. It was decked with flowers and it had been daily smeared all over with ghee [clarified butter] which made the smooth exterior look quite the colour of iron, and it had been subjected to frequent puja [ceremonial worship] and coatings of sandal wood powder, which latter I carefully washed off. The villagers, where it fell, had started a subscription to build a shewala over the aerolite, which was looked upon as a Mahadeo, and the Maharani with her accustomed liberality had promised money assistance for the construction of the shrine. * * * * * *

"In the present instance I can very clearly see that to take this aerolite from the superstitious villagers who have obtained possession, and who have been for days doing puja to it, would cause to them the most profound disappointment and sorrow. I believe, too, the Maharani on whose estate it fell having evinced her superstitious sympathy by giving a money subscription would with the people feel hurt if the aerolite were appropriated by the Government."

Extract from the evidence of the man who saw the stone fall and dug it out; attested by the Deputy Commissioner, dated 3rd September 1885.

"On Sunday, at a quarter after 5 P.M., I made over the stone to Gur Purshad Goria and went home. It was of a kunkur colour up to that time [no doubt from adhering clay]. Next morning people assembled, and Mahesh Pandit also came. Gur Purshad washed the stone; the Pandit then said that he (Gur Purshad) ought to worship it. A terrace was then made at the same place where the stone had fallen, and it was put on it. On Monday morning when I saw it, it was of a kunkur colour. The more it was worshipped the more it became black."

ADDITIONS TO THE MUSEUM.

FROM 1ST JULY TO 30TH SEPTEMBER 1885.

Five specimens of Eozoon Canadense, from Sir William Dawson, Montreal.
PRESENTED BY H. E. THE COUNTESS OF DUFFERIN.

A sample of fire clay from Mangrup, Meywar, Rajputana.
PRESENTED BY COLONEL C. K. M. WALTER, RESIDENT, MEYWAR.

ADDITIONS TO THE LIBRARY.

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ASHBURNER, *Charles A.*—Brief description of the Anthracite Coal-fields of Pennsylvania. 8° Pam. Philadelphia, 1884. THE AUTHOR.

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