MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

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n the Geology of the DÁRJÍLING DISTRICT *and the* WESTERN DUÁRS, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

MEMOIRS

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GEOLOGICAL SURVEY OF INDIA.

On the Geology and Mineral Resources of the DÁRJÍLING DISTRICT *and the* WESTERN DUÁRS, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

CONTENTS.

CHAPTER I.—GENERAL DESCRIPTION OF AREA AND ROCKS.

For many years the existence of coal has been rumoured from time to time in the outer range of the Sikkim Himalayas. Fragments of the mineral had frequently been observed in the hill streams, and its occurrence in larger quantity had also been reported. Amongst other places, the Sivok valley, close to the debouchure of the Tísta,* was mentioned, and so long ago as 1853 this locality was brought to Dr. Oldham's notice by Dr. Campbell, then Superintendent of Dárjíling. Specimens of the coal were also sent by him to Mr. Piddington, whose analyses of them gave very favorable results.† A brief examination of the Sivok

* The spelling in this report is on the official system, and differs from that on the maps appended, which have been photozincographed from the Revenue Survey maps of the Dárjíling and Jalpigori districts, after the addition of the geological lines.

† Journal, Asiatic Society, Bengal, Vol. XXII, p. 313, & Vol. XXIII, pp. 381, 403.

and neighbouring streams, however, by Dr. Oldham, sufficed to prove that the coal was nothing more than the fossilized stems of individual trees, such as has frequently been observed elsewhere in the same Tertiary rocks, along the base of the Himalaya, and which were economically worthless.*

To Dr. Hooker we owe the first notice of the possible existence of the true Indian coal-measures in this region. In March 1849,† when stopping at Pankabári on his way to Dárjíling, he observed in one of the streams there "carbonaceous shales, with obscure impressions of fern leaves, of *Trizygia* and *Vertebraria;* both fossils characteristic of the Burdwan coal-fields, but too imperfect to justify any conclusion as to the relation between these formations. Ascending the stream, these shales are seen *in situ,* overlain by the metamorphic clay-slate of the mountains, and dipping inward (northwards) like them. ... The carbonaceous beds dip north 60° and 70°, and run east and west; much quartz rock is intercalated with them, and soft white and pink micaceous sandstones. The coal seams are few in number, six to twelve inches thick, very confused and distorted, and full of elliptic nodules, or spheroids of quartzy slate, covered with concentric scaly layers of coal: they overlie the sandstones mentioned above. These scanty notices of superposition being collected in a country clothed with the densest tropical forest, where a geologist pursues his fatiguing investigations under disadvantages that can hardly be realized in England, will, I fear, long remain unconfirmed."‡

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* Journal, Asiatic Society, Bengal, Vol. XXIII, p. 201.

† Himalayan Journals, Vol. I, p. 402. These were not published till 1854.

‡ The following list includes all the other geological papers, &c., on the Sikkim and Bhután Himalayas with which I am acquainted:—

1848.—A few observations on the probable results of a scientific research after metalliferous deposits in the Sub-Himalayan range around Dárjíling. By R. H. Irvine, Esq., M. D.—Journal, Asiatic Society, Bengal, Vol. XVII, p. 137.

The importance of the coal-supply for the great trunk railways of India, has hitherto rendered the examination of the fields south of the Ganges more pressing, from an economic point of view, than the exploration of an out-of-the-way corner of India like Dárjíling. The connection of Calcutta with the hills by the Northern Bengal State Railway, has recently, however, given the question of the existence of coal in the Sikkim mountains a new importance. Copper mines have been

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1850.—Examination and analysis of an orange-yellow earth brought from the Sikkim Territory by Dr. Campbell, Dárjíling, and said to be used there as a cure for goitre. By Henry Piddington, Esq.—Ibid, Vol. XIX, p. 143.

1852.—Notice of graphite sent by Captain Sherwill from Karsiáng. By H. Piddington, Esq.—Ibid, Vol. XXI, p. 538.

1853.—Notes upon a tour in the Sikkim Himalaya mountains, undertaken for the purpose of ascertaining the geological formation of Kánchinjinga and of the perpetually snow-covered peaks in its vicinity. By Captain Walter Stanhope Sherwill, Revenue Surveyor.—Ibid, Vol. XXII, pp. 540, 611.

1854.—Correspondence respecting the discovery of copper ore at Pushak, near Dárjíling. Dr. A. Campbell and H. Piddington, Esq.—Ibid, Vol. XXIII, p. 206.

1854.—Examination and analysis of Dr. Campbell's specimens of copper ore obtained in the neighbourhood of Dárjíling. By H. Piddington, Esq.—Ibid, Vol. XXIII, p. 477.

1855.—Correspondence respecting Dárjíling copper ore. Dr. A. Campbell.—Ibid, Vol. XXIV, p. 706.

1856.—Geological observations in Sikkim. H. Schlagintweit, Esq.—Ibid, Vol. XXV, p. 22.

1861.—Description of a native copper mine and smelting works in the Mahanaddi Valley, Sikkim Himalaya. Communicated by H. F. Blanford, Esq.—Percy's Metallurgy, Vol. I, p. 388.

1862.—Journal of a trip undertaken to explore the glaciers of the Kanchunjinga group in the Sikkim Himalaya in November 1861. By Major J. L. Sherwill, Revenue Surveyor.—Journal, Asiatic Society, Bengal, Vol. XXXI, p. 457.

1865.—Notes on the sandstone formation, &c., near Baxa Fort, Bhután Duárs. By Captain H. H. Godwin-Austen, F. R. G. S., Surveyor, Topographical Survey.—Ibid, Vol. XXXIV, pt. 2, p. 106.

1868.—Notes on geological features of the country near foot of hills in the Western Bhután Duárs. By Captain H. H. Godwin-Austen, F. R. G. S., &c.—Ibid, Vol. XXXVII, pt. 2, p. 117.

worked for a long time past in the same region, but little has been known as to their value; and while lime has been in great demand of late for the railway works, the supply has been scanty and the cost extremely high. It having therefore been decided that an examination into the mineral resources of the Dárjíling district and the Western Duárs should be made, I was deputed to the duty at the commencement of last cold weather.

My attention was of course mainly directed to such points as bear more directly on economic questions, and my observations on some other portions of the geology were necessarily rather scanty. The area which I examined most closely is a band a few miles wide along the foot of the hills, between the Mechi and Jaldoka rivers; that in which the coal-bearing rocks occur. I left the hills to the north of this for the close of the season, and had only time to traverse them rapidly on my way to the different mines. Except at Baxa, the foot of the hills forms the British frontier all along the Western Duárs, and my observations here refer to a mere fringe of the hills immediately north of this line—all that has been topographically mapped, and that my instructions, as well as the time at my disposal, allowed me to survey.

Boundaries of Dárjíling hill territory.

The Dárjíling hill territory (including in this term the Dáling sub-division) is not marked either orographically or geologically as a region distinct in itself. It comprises an area which, as a portion of the great Himalayan range, is quite insignificant, and the limits of which have been determined by political considerations. While the Terai stretches along the base of the hills, our territory is divided from Nepál on the west by the continuation of the Singalela ridge and the Mechi river. Previous to the Bhután war the Tísta formed the eastern limit, but the annexation of the Dáling sub-division from that state has extended the frontier to the river Jaldoka. The Tísta, with its tributaries the Rang Chu and Great Rangít, and the Rammán, an affluent of the latter, form the northern limit of Dárjíling and divide it from independent Sikkim.

Dárjíling hill territory belongs to zone of Lower Himalayas.

The Himalayan range has been commonly divided into three orographical zones:—the great range of snowy peaks, which, roughly speaking, form the axis of the chain; the Lower or Outer Himalaya, forming a broad belt of mountains of inferior, but still considerable, altitude south of the snows; and thirdly, the comparatively low hills forming the Sub-Himalayan zone, either as ridges and spurs contiguous with the outer hills or separated from them by 'duns' (flat-bottomed longitudinal valleys), of which latter the Siválik hills in the North-West Provinces are the type.* These detached ridges are unrepresented along this portion of the Eastern Himalayas, where the Sub-Himalayan zone is locally even wanting altogether.

The basin of the Tísta within the hills approximates to an oblong in form, with the longer axis north and south. Near the north-western and north-eastern corners tower the giant peaks of Kánchinjinga (28,156 ft.) and Dánkia (23,189 ft.) at a distance from each other of rather less than fifty miles, and respectively about sixty and seventy miles from the plains. From Kánchinjinga the Singalela ridge runs southwards, dividing Nepál and the valley of the Támbar from Sikkim and that of the Great Rangít. It is the continuation of this ridge in a south and then south-easterly direction, by Tánglu, Senchal, and Sitáng, with its various lateral spurs, which constitutes the Dárjíling hill territory west of the Tísta. From Dánkia a lofty ridge runs southward by the Gnáream and Chola peaks, separating the basins of the Tísta and the Tursa from each other. At Gipmochi (11,518 ft.) this ridge divides into two great spurs; one running to the south-east and the other to the south-west, including between them the valley of the Jaldoka. It is the lower half of the south-western spur, with its ramifications, that constitutes the hills of the Dáling Sub-division. The hills between the Jaldoka and the

* Vol. III, pt. 2, p. 5.

Tursa belong to the south-eastern spur, while those between the Tursa and the Raidak form the termination of a great ridge running southward from Chumalári (23,944 ft.) and dividing the basins of those rivers from each other.

At Phallut, near the head of the Rammán river, where the boundaries of Nepál, Sikkim, and Dárjíling meet, the Singalela ridge has an elevation of 12,042 feet, this being the culminating point of the district. The highest eminences are nearly all situated along the continuation of the main ridge, like Tánglu (10,080), Senchal (8,606), and Maháldarám (6,000). Similarly, the highest point of the Dáling hills is where the main ridge first enters British territory, where it has an altitude of over 10,000 feet; the other principal elevations do not exceed 7,000 or 8,000.

The densely luxuriant vegetation by which these mountains are covered, ranging from the matted cane-brakes of the Terai, and the Indian rubber trees and other tropical forms of the deep valleys, to the oak and pine forests which clothe the highest ridges, has been described by Dr. Hooker in his journals. He attributes the heavy rainfall to which such luxuriance is largely due to the fact that the alluvial plain between Sikkim and the mouths of the Ganges is almost a dead level, the foot of the hills being only 300 feet above the sea. Hence the vapour-laden southerly winds from the Bay of Bengal reach the outer range of hills without impediment, while the same current, when deflected easterly to Bhután or westerly to Nepál and the north-west Himalayas, is intercepted and drained of much moisture by the Khásia and Gárro hills in the former case, and the hills of Rájmahál and Chutia Nágpur in the latter. Sikkim is hence the dampest region of the whole Himalaya. *

Drainage.

The valleys on the south-western side of the Singalela ridge are drained by the Mechi, the Bálasan, and the Mahanaddi, the last of which, after receiving the other

* Himalayan Journals, Vol. II, p. 388.

two in the plains, joins the Ganges above Rámpur Bolia. All the remainder of the Dárjíling hills is drained by the Tísta and its tributaries, except the extreme eastern end, where the superfluous water is carried off by the Jaldoka. These rivers eventually reach the Bráhmaputra south-east and east of Rangpur. Thus the Singalela ridge forms at the present time the watershed between the Ganges and the Bráhmaputra. The Mahanaddi and the Tísta flow into the plains in the debatable ground where, under sub-deltaic conditions, a constant struggle is going on between the Ganges and the Bráhmaputra, as they approach each other from the west and from the east, across the great plains to the south of the mountain range. Early in this century the Tísta was tributary to the Ganges.

Lakes.

Here, as elsewhere in the outer Himalayas, lakes are very uncommon and of insignificant dimensions. There is one such about six miles south-west of Hope Town, and another, called Rom Tál, on the Rámthi naddi, some miles east of the Tísta. The latter presents some features of interest. As measured on the map, it is 550 yards long and about 200 broad. For 30 or 40 yards from each bank in the upper part of the lake, dead stumps of trees (which are evidently *in situ*, and not large branches of sunken drift wood), appear above the surface of the water, indicating that the lake, if not formed, has at least increased considerably in depth, within the time that such timber can remain under and above water without falling to pieces. Charred piles below water are known to be capable of resisting decay for centuries, but trees in the above condition would no doubt rot much sooner. Towards the lower end vertical precipices rise from the lake, and here the water seems to be much deeper; too deep to allow of any stumps appearing above the surface. For more than a quarter of a mile above the lake there is a delta of slate shingle, which yearly encroaches on and diminishes the area of the water. The Lepchas have a tradition that three or four generations ago the whole of this delta formed a part of the lake, and from what I have seen of the transporting power of the hill streams, I can well believe that the present delta could have been formed in this time, especially as the upper Rámthi flows entirely through brittle, easily broken up, slates. The first lateral torrent above the lake on the west side contributes an immense amount of débris from a naked precipice at its source. Of course the commencement of the delta must have been synchronous with the earliest existence of the lake, and although the Lepchas' account may not be strictly true, the delta is certainly not of high antiquity.

As for the mode of formation of this sheet of water, its recent origin puts glacial action in any form out of count, even if the low altitude, about 1,000 feet above the sea, does not do so. The stream for a mile below the exit has a much greater fall (400 feet) than either further down, or above, the lake; and the bed is there filled with huge blocks of Tertiary sandstone, amongst and under which the water flows. I have nowhere, except here and below the Dohír Tál,—a similar but much smaller lakelet, about half a mile to the eastward,—seen an accumulation of this kind; and it seems most probable that both lakes and blocks are due to one or more landslips from the hills above, which have dammed up the original bed of the stream. The blocks are all of Tertiary sandstone, and hence cannot have been washed down stream, as the rocks above the lake are Damúdas and slates. For the same reason, besides those given above, they cannot be the remains of a moraine.

Hot springs.

Hot springs are known to exist in Independent Sikkim, but the only indication of such in the Dárjíling district that I could hear of, was at the Mangphu copper mines on the Tísta. About 600 feet above the river there are two or three small clefts in the slate, the air in which feels warm and moist to the hand when inserted, and 'clouds' are said to issue from them morning and evening, when no doubt the vapour is condensed by the coldness of the air. The clefts are incrusted here and there with sulphate of copper derived from the decomposition, by the moist air, of the specks of ore in the cupriferous slates. There is probably a warm spring here, the water of which trickles away through the crevices of the rock and the loose débris, without reaching the actual surface of the ground. The geographical co-ordinates are latitude 26° 58′, longitude 88° 29′ (= 88° 25½′ according to Admiralty value), elevation above the sea about 1,300 feet.

Chalybeate springs.

The 'mineral spring' about three miles east of Dárjíling is well known, and was formerly utilized for medicinal purposes, a convalescent depôt having been built near it for the convenience of the troops stationed at Jallapahár. The water, however, is not used at present, and the depôt has gone to ruin. It was also used by the hill-men for rheumatism and cutaneous diseases, the patient being placed in a rude bath made of plantain stems, the water in which had previously been heated by throwing hot stones into it; it was also taken internally. The spring rises amongst the boulders in the bed of a lateral feeder of the Rangnu, which is dry above this point (4th May), and the water, issuing at 62° F., trickles away in a little rivulet, which deposits ochre in small quantity, but has no appreciable taste or smell. It is said to have formerly had a sulphureous odour, when used for medicinal purposes: latitude 27° 2½′, longitude 88° 22′ (= 88° 18½′ according to Admiralty value), elevation 2,050 feet. This is most probably No. 23 of Schlagintweit's list of hot springs,* the temperature of which is 'unknown,' and geographical co-ordinates latitude 27° 3′, longitude 88° 15′, elevation about 1,900 feet. No *hot* spring is known in this vicinity.

Ochre-depositing springs also issue from the black pyritous slates associated with dolomite, east of Baxa, one of which at least has been used for medicinal baths by the natives in the same way as that at Dárjíling.

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* Journal, Asiatic Society, Bengal, Vol. XXXIII, p. 49.

General stratigraphy of formations.

If a section be drawn from south to north, from the Terai to the Rammán river, through Karsiáng and Dárjíling, (*vide* Map I), it will be found that the entire succession of rocks has *primá facie* the appearance of a great synclinal. In the southern part of the section, all the strata are inclined towards the north at rather high angles. Towards the centre, the dips are rolling and irregular, while between Dárjíling and the Rammán they are southerly. It is scarcely necessary to say, however, that this appearance is deceptive as far as the Tertiary rocks are concerned; their northerly dip is a constant feature along the Himalayas as far as they have been examined, and it has been usually assumed that they are faulted against the older rocks. It is more probable, however, as pointed out by Mr. H. B. Medlicott with respect to this formation as developed between the Ganges and Rávi,* that the present boundary marks an original limit of deposition against the older rocks, which has been subsequently modified by crushing and local faulting of the strata.

North of the soft massive sandstones and clunch beds which make up the Tertiaries, we come on a narrow band of Damúdas in a more or less altered condition, and including various alternations of sandstone or quartzite, shales, slates, and beds of friable anthracitic coal. Overlying these, without apparent unconformity, are some thousand feet of slates, mostly of grey and green tints, and including here and there a band of quartzite. As we ascend the hills these slates are found to pass, more or less gradually, through mica-schist into gneiss. That the gneiss should be the oldest rock, and either inverted on to the slates, and they in their turn on to the Damúdas, or else that the boundaries should be faulted ones, or finally that the relations of these formations to each other should resemble those of the Tertiaries to the Damúdas, as indicated above, is what will naturally suggest itself. Strange as it may appear,

* Vol. III, pt. 2.

however, that such thoroughly metamorphic strata should normally overlie those in a less altered condition, the evidence points to this conclusion.

From Karsiáng to Dárjíling the gneiss is continuous, verging in some places towards mica-schist. The Dárjíling gneiss generally, in fact, has a great tendency to graduate into the latter lithological type. The dips are uncertain and irregular, with several local anti- and syn-clinals, but on the whole, are northerly near Karsiáng and southerly near Dárjíling. As we descend the spurs towards the Rammán, the slates are found again underlying towards the gneiss, but, in places at least, the boundary between the two series is a faulted one. The fault may be continuous, but I believe that the throw is not very great, and that it has merely complicated a line of junction along which the slates underlie the more metamorphic strata.

If we followed the ill-marked, and often indefinite, boundary between the slates and gneiss, down the valley of the Tísta, and thence back to Karsiáng and on to the Mechi, we find that the underlie of the former is a constant feature. The same thing occurs east of the Tísta also. From the Jaldoka, by Dáling, round to Damsáng, wherever I crossed from one series to the other, the inclination is towards the gneiss. The Pre-tertiary rocks on both sides of the Tísta, may be regarded as belonging to one rather shallow synclinal (including within itself many minor folds), the axis of which is somewhat raised near the river by a secondary anticlinal at right angles to the synclinal. The lower rocks are in consequence of this elevation brought to the surface, and are more fully exposed than they otherwise would be, on account of being cut through by the deep transverse valley of the Tísta. The elevation is not sufficient to bring the Damúdas to the surface along the valley, and these rocks are consequently only exposed along the southern edge of the synclinal, where they outcrop in a narrow band varying from 200 or 300 yards to about a mile in width, and extending from

Pankabári nearly as far as Dálingkot. Here some faulting, combined with a change of strike, cuts them out, and the slates reach to the foot of the hills for several miles, but in the Mo-chu the Damúdas are found again in their old position. Some beds occur near Baxa bearing a resemblance to the same formation, but the neighbourhood of Dálingkot is the most easterly point at which indubitable Damúdas have been observed. Whether the coal-bearing series outcrops anywhere in Independent Sikkim is a question yet awaiting determination.

There is a very large development in the Duárs of variegated slates, which differ considerably in lithological characters from those of the Dárjíling district, and which, besides containing thick bands of quartzite, &c., include a band of dolomite not less than 1,500 or 2,000 feet thick. How far these two groups of slates may be distinct from each other is uncertain, but there are sufficiently strongly marked points of difference to justify one in separating them, at least provisionally. I have accordingly applied the name of 'Baxa' to one series, which is largely developed in the neighbourhood of that cantonment, and 'Dáling' to the other, as it is well seen in the neighbourhood of the old Bhutánese fortress.

The Tertiaries in the Dárjíling district, as along the Himaláyas generally, occur as a narrow band fringing the base of the hills. The existence of gaps in this fringe near Dáling and west of the Tursa river is a most unusual phenomenon; in fact, these are the only instances as yet known in which the continuity of the Tertiary band is broken, from the Brahmaputra to the Indus.*

Orography as influenced by stratigraphy.

The alternating quartzites, dolomite, and slates of the Baxa series have had a marked influence in determining the erosion of the hill ranges in the Duárs, where the two first rise into elevated ridges. In the Dárjíling district these rocks are absent; there, while the several formations as wholes differ consider-

* *Vide* Vol. IV, p. 436.

ably from each other in hardness, the rocks composing any one formation are tolerably uniform in this respect. The gneiss is as a whole considerably harder than the slates, and the latter than the Tertiaries; but, excepting some not very important bands of quartzite in the slates, there is nowhere, on a sufficiently large scale to materially affect the orography, any alternation of strata of widely different hardness in the same formation. Hence, in as far as the orography has been influenced by the geological succession of rocks, it has been mainly so by the succession of formations or series, not of minor sub-divisions. It will be seen from the map that the lower Tísta valley has been excavated through the slates, the river, south of its junction with the great Rangít, having selected for its course the axis of the transverse anticlinal alluded to above (p. 11). It seems not improbable that the Tísta between the Rang-chu and the Rangít, and the last-named river below Gok, also flow along anticlinal axes, but the country to the north has not been examined.

The gradation in hardness of the several formations as we ascend from the plains has also had a prominent influence on the elevation of the outer hills. If a view be obtained of these looking east or west, or parallel to the direction of the range, say from Pankabári bangalo across the Bálasan to the hills between that stream and the Mechi, it will generally be found that those composed of Tertiaries seldom rise more than two thousand, and often not more than a few hundred feet. From the junction of the older rocks with the newer, the hills rise more quickly to the outer limit of the gneiss, from which they, often spring rapidly to a total elevation of several thousand feet. Where the Tertiaries are absent between the Jaldoka and Lángti rivers, and the gneiss comes closer than usual to the base of the hills, the latter, rise at once to this altitude.

CHAPTER II.—DAMÚDA SERIES.

Typical Damúdas of Ráníganj.

For an account of the Damúdas as typically developed in their unaltered and comparatively undisturbed condition, as they occur in the Damúda valley for instance, I must refer to the various papers already published in these Memoirs. Mr. W. T. Blanford, in his report on the Ráníganj field, the largest and most important of these basins, and that in which the character of the rocks were first established, gives the following summary of the minor groups into which the Damúdas are divisible:—*

DAMÚDA SERIES.

			Thickness in feet.
Ráníganj Group ...	Coarse and fine sandstones, mostly false-bedded and felspathic—shales—coal-seams. The latter frequently continuous over considerable areas.	*Vertebraria; Trizygia; Glossopteris; Pecopteris; Schizoneura; Phyllotheca, &c.*: all plants.	5,000
Ironstone shales ...	Black carbonaceous shales, with numerous bands of clay-ironstone.	Fossils abundant, though not well preserved. *Glossopteris, &c.*	1,400
Lower Damúdas † ...	Coarse conglomerates, with white sandstones, numerous coal-seams of very irregular character, thinning out at short distances.	*Glossopteris; Vertebraria; Zeugophyllites? &c.*	2,000

Dárjíling Damúdas.

The Damúdas in the Eastern Himalayas occur, as already explained, along the southern side of the Dárjíling synclinal, constituting a narrow band between the Dáling slates and the Tertiaries, from Pankabári to near Dálingkot. Like all the other rock-groups, they have undergone great crushing and disturbance, and are tilted up on edge. Although subject to many minor contortions, they dip as a whole towards the north-north-west, generally at high angles, or from 40° to 90°. As might be expected, they have not been subjected to such disturbance without great change in their lithological characters. Frequently the sandstones have been converted into

* Vol. III, p. 31. † Now called Barákars.

quartzites, the shales into splintery slates, and the carbonaceous shales into carbonaceous or even graphitic schists; while the coal has lost a large proportion of its volatile matter, so as to approach to anthracite in composition. Thus while the assays of samples from seventeen seams in the Ráníganj field* show an average composition of carbon 51·09, volatile matter 32·64, ash 16·27, the mean result from five Dárjíling seams gives carbon 70·66, volatile matter 9·20, ash 20·14. At the same time, the crushing to which the seams have been subjected, has squeezed them so that they vary greatly in thickness within a few yards, and has induced a flaky structure in the coal which renders it so friable that it can be crumbled into powder between the fingers with the greatest ease. This flakiness is in fact true cleavage, and the mineral may in one sense be regarded as a 'coal slate.'

The coal seams being the least strongly coherent of the Damúda rocks, faults would be most likely to occur along them when nearly vertical. Hence, perhaps, in some cases the rapid variations in the thicknesses of the seams, and the crushed state of the coal, it having been ground between the two sides of the fault. I cannot bring forward any instances in which faulting can be shown to have acted in this way; it is probable, however, that they exist, although in the great majority of cases, simple crushing without actual dislocation has reduced the seams to their present condition.

The amount of metamorphism in the Damúdas is by no means constant: generally the beds are more or less altered, and not unfrequently highly so, but sometimes there is no alteration whatever, and the rocks closely resemble the typical ones of the Ráníganj field. The coal is an exception, as it everywhere has acquired the above flaky structure, even when the beds accompanying it have undergone no appreciable change.

The vegetable mould and clay beneath the dense jungle by which the hills are covered, render good outcrops rare, except in the beds of the

* Vol. III, p. 189.

mountain streams, and the only practicable way of obtaining anything like continuous sections is by wading and scrambling up these. The boundaries, as laid down on the map, were obtained by doing so, and connecting the junctions observed in one stream with those visible in the next; hence the band of Damúda rocks seems to have a greater degree of regularity than it probably possesses in reality. An exhaustive survey would probably bring to light cross-faults and other features which have escaped detection.

No Damúdas west of the Bálasan.

No Damúdas are visible between the Méchi and the Bálasan. In the Manjha, the Chenga, and the Dudhia streams the Tertiaries are seen close up to, or near, the slates. The Damúdas seem to have been denuded away before the Tertiary epoch. It is, however, not unlikely that the band is found further west in Nepál.

Damúdas near Pankabári.

In some of the small watercourses between the Bálasan and the road at Kelabári, the Damúdas are just seen at the very base of the hills, with clay slates above them. They are chiefly shaly sandstones, with a seam or two of coal two or three inches thick; in the most westerly of these ravines both rocks dip north 25 west at 80°. No Damúdas are visible in the Bissarbátti stream, but the space they ought to occupy (below the bridge between Kelabári and Pankabári) is blank; and there is but little doubt that they are present there. A three-feet bed of carbonaceous shale, dipping at a low angle to north-west, outcrops in a watercourse just west of Pankabári dák bangalo. It is by no means easy to separate the Damúdas from the Dálings near this, as some of the beds in the coal-series are as good clay slate as any in the Dálings.

A small ravine joins the Bissarbátti stream a little below the bridge above-mentioned. Ascending this, Tertiary sandstones are first met; a short way from the mouth these abut against a two-feet bed of carbonaceous shale, above which is rather indurated quartzo-felspathic sandstone with a few specks of mica. The quartz is white and the felspathic element buff, giving the rock itself a pale buff color; occasionally there are some thin pebbly layers, the pebbles being of white and red quartz. Besides these beds there are soft shaly micaceous sandstones, with faint vegetable impressions, and dark-grey micaceous shales, in which tolerably well-preserved plant-remains occur, the commonest being *glossopteris.* Four or five carbonaceous beds outcrop in the ravine: firstly, that above mentioned; then one of 18 inches, which includes two layers of coal; this is separated by a few feet from a bed of carbonaceous shale, 3 or 4 feet thick, containing a 9-inch seam of coal. Some distance further up there is a fourth carbonaceous bed, including some strings of coal. The strata in this section dip mostly to north-west at an angle of from 40° to 70°, 60° being about the average.

Rángichang naddi.

The Damúdas in the Rángichang dip mostly towards the north-west at an angle of from 40° to 90°. Some coaly layers are visible, but the best is only 12 inches thick and contorted on a small scale, as well as broken up by closely contiguous slips, of a few feet in throw. The beds, hereabouts, are little altered, but higher up stream they are in their most metamorphic condition, comprising hard quartzites dark-colored slates and graphitic schists. The last is a truly foliated rock, composed of lenticular laminæ of quartz included between the foliæ of impure graphitic matter. It has probably resulted from the alteration of carbonaceous shale, the carbonaceous matter in which has been partially changed to graphite. One of these bands in the Rángichang is 15 or 20 feet thick. Higher still up stream, silvery clay slates come in, which are included with the Dáling rocks.

Rakti naddi.

The Damúdas are well exposed in the Rakti naddi. The contortions of the beds render it difficult to measure the section accurately, but the following is close enough to give a good idea of the general succession of strata. In the lower part of the gorge the stream flows through Tertiary sandstones;

then there is a blank, the next rock visible being hard massive sandstone with little bedding. After another considerable blank we come to—

	Ft.	In.
Carbonaceous shale*	1	0
Sandstone	3	0
Blank	5	0
Brown shale	0	6
Coal	2	6
Sandstone	1	0
Blank	4	0
Brown shale	1	0
Coal (dipping W. 30° S. at 70°)	5	6
Sandstone	4	0
Shale and shaly sandstone	5	0
Carbonaceous shale with some *coaly* layers and sandstone	8	0
Blank	6	0
Carbonaceous shale	4	0
Sandstone	6	0
Coal	0	6
Sandstone	8	0
Carbonaceous shale	1	6
Sandstone	1	0
Coal	1	0
Carbonaceous shale	1	6
Sandstone	10	0
Blank	15	0
Sandstone	1	6
Brown and carbonaceous shales	4	0
Sandstone	2	0
Carbonaceous shale and sandstone	4	0
Sandstone	1	0
Coal (part of thickness concealed by a large block of sandstone), seen	1	4
Sandstone	0	2
Coal	0	5
Blank	4	0
Sandstone with carbonaceous layers (dipping W. 10° N. at 70°)	7	0

* This and the other Damúda sections are given as the strata are met in ascending the streams, and in ascending geological order.

	Ft.	In.
Blank	300	0
Carbonaceous shale	1	6
Brown shale	1	0
Carbonaceous shale	0	3
Brown and dark-grey shale	3	0
Carbonaceous shale	1	0
Sandstone with some shale	10	0
Blank	100	0
Sandstone	10	0
Brown shale	2	0
Sandstone	1	6
Carbonaceous shale	1	6
Blank	6	0
Sandstone	1	0
Dark grey shale	0	8
Sandstone	0	6
Blank	20	0
Sandstone and carbonaceous shale	8	0
Blank	400	0
Sandstone	6	0
Brown shale	15	0
Sandstone	10	0
Sandstone and carbonaceous shale	2	0
Sandstone	4	0
Carbonaceous shale	2	0
Sandstone	1	0
Blank	200	0
Sandstone	15	0
Coal (varies in thickness from 4" to 16" within a couple of feet, from crushing; dipping N. 10° W. at 60°)	0	8
Sandstone	1	6
Dark-grey and brown shale	4	0
Buff and greenish-grey massive sandstone with little bedding; contains some carbonaceous markings	100	0
Shale	2	0
Sandstone	20	0
Coal	0	4

* This, and the other large blanks, are the horizontal distances in which rock is obscured, not the thickness of missing strata. There is of course the possibility of good seams of coal being concealed in these positions.

	Ft.	In.
Sandstone (dipping N. 20° W. at 70°)	7	0
Shale and shaly sandstone	21	0
Coal	0	6
Shale and shaly sandstone	7	0
Coal (dipping S. 15° W. at 70°)	1	0
Sandstone	0	10
Brown shale	0	3
Sandstone	3	0
Dark-grey and brown shale	8	0
Shaly sandstone	6	0
Sandstone (dipping N. 15° E. at 80°)	30	0
Alternations of sandstone and dark-grey shale ...	6	0
Sandstone	5	0
Brown shale	4	0
Coal	0	4
Shale; some parts carbonaceous	6	0
Blank	8	0
Hard greenish-grey massive sandstone; but little bedding (dipping N. at 50°)	27	0
Dark-grey shale	6	0
Shaly sandstone	2	6
Dark-grey shale	4	0
Sandstone	0	10
Coal	0	4
Sandstone	2	0
Blank	6	0
Sandstone; some parts shaly	14	0
Coal	0	10
Shale	0	6
Blank	300	0

Then there is perhaps 100 feet of grey slate, and, after a short blank, some hundred feet of similar slate, greatly cut up by jointing. These beds, which I believe form the base of the Dáling rocks, rest on greatly crushed sandstone, with a few crumpled coaly layers. The junction is well marked, but without sensible unconformity.

In the Chochi naddi and in the western branch of the Chírangkhola, sections are obtainable. The beds exposed in the latter are mostly dark-grey micaceous shales, with rather thin-bedded sandstones and some carbonaceous layers.

Chírangkhola naddi.

At the head of the main, or eastern, branch of the Chírangkhola, the Damúdas are well exposed, dipping mostly north-west to north-north-west at 20°—70°, and including buff and grey sandstones, dark-grey and black shales, and several seams of coal, some of which, however, are greatly crushed and disturbed by small, but violent, contortions, which have affected all the seams more or less. The best seam exposed, and adjacent beds, have the following section :—

	Ft.	In.
Dark-grey shale and sandstone, containing abundance of *vertebraria* without other remains—		
Interbanded coal and carbonaceous shale	1	0
Coal with one or two thin partings of carbonaceous shale 5′ 4″ to	7	0
Grey shaly sandstone and dark-grey shale without *vertebraria.*		

The seam dips north-west at 55°, and has a thickness of 5′ 4″, at the level of the stream on the west side; on the east side (20 feet distant) it is 6′ 6″ to 7′ 0″. Here it is traceable for 45 feet up the bank with a nearly constant dip, but far from constant thickness. At 33 feet it is reduced to 2′ 6″, and 12 feet higher (where it seems to be faulted against shaly beds) it is again expanded to 5′ 0″. In the last two spots it is much impurer than below, containing more carbonaceous shale than coal. There is a seam of interbanded black shale and coal lower down the naddi —possibly the same as the above, brought in again by folding, but more probably different—which is 8 feet thick on one side of the stream and only 2 on the other. Another thinner seam is folded sharply back on itself by a small contortion.

Cart road.

The pagdandi (path) south-east of Selim Hill cuts through a 2-feet bed of coal, and a fine section is laid bare along the cart road at the 'Gumpti' below Chunbatti. The rocks are here in their least altered condition, and not much twisted, the dip being tolerably steady throughout the section.

The beds in immediate contact with the Tertiaries are somewhat obscured, and the first recognizable beds are—

	Ft.	In.
Sandstone	5	0
Coal (dipping W. N. W. at 85°, about)	1	0
Sandstone	1	6
Coal	0	2
Sandstone	5	0
Coal, about	1	0
Iron-stained quartzitic sandstone	6	0
Sandstone	3	0
Coal, about	0	6
Sandstone with some coal, much crushed, seen for 20 yards along the road.		
Blank for 20 yards along the road.		
Coal-outcrop with sandstone.		
Sandstone seen at intervals for 70 yards along the road.		
Dark-grey shale,* with one or two carbonaceous layers ...	5	6
Coal	0	9
Dark-grey shale	1	0
Coal (dipping W. 30 N. at 40°)	3	6
Dark-grey shale	0	9
Carbonaceous shale	1	6
Ditto, mixed with dark-grey shale ...	3	0
Coal	0	9
Dark-grey shale	4	0
Sandstone	6	0
Dark-grey shale	8	0
Sandstone	10	0
Dark-grey shale	15	0
Sandstone	1	0
Dark-grey shale	1	0
Coal, about	2	0
Dark-grey shale	3	0
Coal, about	0	9
Sandstone	1	0
Alternations of *coal* and dark-grey shale	5	0
Dark-grey shale	1	0
Carbonaceous shale	0	9

* The dark-grey shales, so common in the Damúdas, are, like those in this section, generally micaceous.

	Ft.	In.
Dark-grey shale	6	0
Thin-bedded sandstone	4	0
Dark-grey shale	10	0
Sandstone (dipping N. N. W. at 30°) about... ...	25	0
Nearly blank for 150 yards along the road; occasional glimpses of shale and sandstone.		
Greenish thick-bedded sandstone...	17	0
Grey shale	0	9
Coal (dipping N. N. W. at 30°)	0	9
Greenish thick-bedded sandstone...	30	0
There seems to be a fault here.		
Grey shale	3	0
Coal	0	6
Shaly sandstone	2	0
Dark-grey shale	0	6
Sandstone	8	6
Fault here.		
Sandstone	5	0
Dark-grey shale	3	0
Coal (dipping N. N. W. at 30°), 1′ 0″ to 3′ 6″ ...	2	0
Sandstone	5	0
Sandstone, seen at intervals	20	0
Sandstone	25	0
Dark-grey shale	1	0
Coal (dipping N. 30°W. at 50°), 2″ to 14″	0	8
Thick-bedded sandstone	17	0
Dark-grey shale	3	0
Coal (dipping N. 20°W. at 45°)	3	6
Dark-grey shale	1	0
Carbonaceous shale	1	0
Grey shale	3	0
Dark-grey shale	2	0
Coal 2′ 6″ to 3′ 6″	3	0
Sandstone	1	0
Blank for 40 yards along the road.		
Dark-grey shale	2	0
Coal	1	6
Carbonaceous shale	0	3
Coal (dipping N. at 30°)	4	6

This coal is nearly in the strike of the last, and is not improbably the same.

	Ft.	In.
Sandstone	8	0
Blank for 150 yards along the road.		
Sandstone	5	0
Grey shale	2	0
Coal 1′ 0″ to 2′·6″—may be one of the above beds; it is nearly in the same strike	1	6
Sandstone (dipping N. 15 W. at 35°)	5	0
Grey shale	0	6
Sandstone	0	8
Grey shale	0	5
Sandstone	4	0

Less than 100 yards further on some greenish slate is seen, and a little beyond that some beds of Damúda sandstone, with one or two thin coal seams. Beyond that again the Dáling slates come in finally.

Tindharia ravine.

In the ravine, which runs just south of Mr. Partridge's bangalo at Tíndharia, the finest coal seam yet found occurs. In the bed of the stream it dips west 15° north at 80°, and has a thickness of 11 feet, with shale below it and sandstone above. This is one of the seams which I recommended for exploration by horizontal drifts. The latest result shows that at 40 feet in from the outcrop the thickness is reduced to 6 feet; but as such variations are, in the main at least, due to crushing, not to thinning out of the seam, it is very probable that as the drift progresses further the thickness will again increase, and the seam may be found continuous for a long distance, although subject throughout to similar variations.

Lower down stream indications of two or three other outcrops occur. One of these, a couple of hundred yards below the 11-feet seam, was opened out by Mr. Montfort, who found a seam of about 6 feet, dipping west-north-west at a high angle. It is to be remembered in dealing with seams of such uncertain thickness and subject to so much disturbance, in ground where the strata are only exposed at intervals, that several outcrops may in reality only indicate one or two seams.

The paths through Mr. Partridge's tea gardens expose several layers of coal and carbonaceous shale, but I observed none of any considerable thickness.

Síbakhola river.

In the Síbakhola the Damúdas are mostly in a highly altered condition, the sandstone being converted into felspathic quartzite with strings of vein quartz through it, and the shales into dark grey slate breaking into sharp-edged splinters. No good seams of coal are exposed, although there are several thin ones.

Mahánaddi river.

The Mahánaddi also cuts through several thin layers, and one with a minimum thickness of 4 feet; the rest of the outcrop is hidden behind a large boulder. The strata dip mostly to north-north-west at 50°—80°, and are indurated as in the Síbakhola.

Mána river.

The Damúdas are very badly exposed in the Mána, and no good seams of coal are visible.

Kuhi naddi.

Where the central and eastern branches of the Kuhi naddi join, there is a cross-fault which shifts the Damúda-Tertiary boundary to the north on the east side. Ascending the central branch, Damúdas, including several thin carbonaceous layers, are found, dipping towards the north at high angles (60°—90°); a little higher up stream the dip is only 5°, and beyond this on the brow of Látpanchor are Dáling slates, having the same inclination. One of the very few cases of igneous intrusion that I have observed amongst the rocks of the Dárjíling Himalayas occurs in the Damúdas here, which are penetrated by a 7-feet dyke of micaceous greenstone running vertically to east 10° north—west 10° south. The walls of the dyke are sharply defined, and the Damúdas close to it do not show any additional alteration.

Sivok naddi.

The Tertiaries and Dáling beds are seen within two or three hundred yards of each other at the head of the Sivok naddi. The intermediate space is nearly blank, but in one or two spots doubtful Damúda sandstone, dipping nearly vertically, is seen. Even if the whole space be occupied by Damúdas, the band is greatly reduced in breadth here.

Tísta river.

In the Tísta, however, it is again expanded, and attains its maximum breadth of a mile. The strata are considerably contorted. For the last few hundred yards of its course, the Ríyem flows along the crest of an anticlinal, the beds dipping away at either side at angles of 60° — 80.° Ascending the Tísta dips are found to north at 60°, east at 80°, west at 80°, and finally west at 60°, close to the junction with the Dálings. Crushed coal-seams a few inches thick are numerous in both rivers, and at the mouth of the Ríyem there is a bed of coal 3 feet 6 inches thick mixed with carbonaceous shale and sandstone, and dipping north-north-west at 70°. Some of the Damúda sandstones here, as well as in other sections, are more or less calcareous; sufficiently so to give rise to deposits of tufa under favourable circumstances.

Lesu river.

The only rocks seen between the Tertiaries and Dálings in the Lesu are indurated crushed massive sandstone obscurely bedded, the junction of which is not seen with either of the above.

Rumtek naddi.

Near the head of the Rumtek, a small feeder of the Lesu, which it joins from the east side, the stream cuts through an 18-inch coal-seam, dipping north 15° west, at 80°. On the hill side, above a small watercourse, there is a seam of pure coal 7 feet thick, dipping north-north-west at about 20°, and in another ravine close-by the following section is visible. The beds are unaltered (except the coal, which is as flaky as usual) and remind one of the typical rocks of Rániganj :—

	Ft.	In.
Felspathic sandstone	8	0
Coal (dipping N. 15°, W. at 70°)	2	0
Carbonaceous shale, with a few nodules of ironstone ...	0	9
Clunchy shale	0	9
Shaly sandstone	1	0
Grey arenaceous shale	4	0
Coal	0	1
Felspathic sandstone, with black (carbonaceous) specks through it, and the faces of the beds in the lower part blackened by carbonaceous matter	9	0
Grey shale	0	4
Felspathic sandstone...	1	3
Coal (dipping N. 20, W. at 80°)...	0	3
Carbonaceous shale	1	0
Grey shale	1	6

Blocks of greenstone, evidently derived from one or more dykes, are brought down by the stream.

Rámthi naddi.

But little of the Damúda rocks is seen in the Rámthi, as that portion of its course is mainly occupied by the shingle delta above Rom Tál. In a side jhora an 18-inch seam of coal outcrops with a dip of 50° to west 30° north. At the head of the delta the Damúdas are made up principally of indurated sandstone and dark-grey slates, dipping north-west at 60°.

Ghísh river.

The last Tertiaries seen in the Ghísh are massive sandstones dipping north 30° west, at 30°. Twenty yards higher up stream, one or two coal outcrops are obscurely seen in a little lateral watercourse, and the rainwash brings down pieces of Damúda sandstone and dark-grey micaceous shale containing abundance of *vertebraria.* Beyond this there is some sandstone, dipping west 30° north, at 60° ; and just below the mouth of the stream which joins the Ghísh from Songchonlu are dark-grey slaty beds and slaty sandstone, with carbonaceous partings here and there. A few yards higher up, these give place to light-green (Dáling) slates, no unconformity being apparent.

Lehtí naddi.

Just north of the Tertiary-Damúda boundary in the Lehtí, a thin seam of greatly crushed coal, underlying coarse quartzose sandstone, is visible. About half a mile in a straight line higher up stream, there is a deep gully on the south side of the naddi, in which a very fine section is exposed. The strata are inverted, the Damúdas overlying the Dálings, and both inclining to the south at about 30°; although the dip of the Damúdas is tolerably steady on the large scale, small, but sharp, contortions occur. The strata are here in their most altered condition, the sandstones having been converted into a well-foliated schist, in which the laminæ of quartz are divided from each other by carbonaceous or by chloritic matter, and minute cubes of pyrites are often sprinkled through the rock.

Ranjang naddi.

The Tertiaries appear to be cut off by a fault near the debouchure of the Lehtí, and no remnant of them is found to the eastward for several miles. The Damúdas are met with for some distance along the left bank of the Ranjang, dipping easterly at low angles, and covered, at a varying height above the stream not exceeding 100 feet, by the Dáling slates. They here consist chiefly of coarse quartzose and quartzo-felspathic sandstone, including specks of carbonaceous matter and of silvery mica. There are also some shaly beds, and a few nodules of ironstone, and numerous thin layers of coal, besides one seam of 3 feet 6 inches, dipping north-east at 15°.

Pugo naddi.

The Damúdas are found again in the Pugo naddi, consisting chiefly of crushed sandstones with some shale and thin seams of coal. They dip mostly to north 30° east, at 50°—70°, and are covered on the north-east by the Dáling slates, which on the west are brought against them by a fault.

Mo-chu.

The change of strike of the Damúdas in the Pugo, to south-east or thereabouts, soon brings the Damúda-Dáling boundary to the edge of the Terai, and for several miles east of the Chel the latter rocks extend to the very foot of the hills.

The next point at which I caught the coal-bearing rocks was in the Mo-chu,* at the mouth of the Ruka naddi, where, however, only the highest beds just below the Dálings are exposed, dipping north-east at 60°. They include coarse and fine sandstones, shaly and slaty beds, and two or three coal-seams of a foot thick and less. Lower down stream the older rocks are entirely obscured by recent deposits, and the extension of the Damúdas between the Neora and the Mo is merely conjectural.

Ma-chu.

In the Ma-chu some beds, including carbonaceous layers, are obscurely seen close to, and, unless faulted against, underlying strata which I have referred to the Baxa series. I took these to be Damúda at the time, but as there are some bands of carbonaceous schist included in the Baxa rocks near Baxa itself, the above point, which I shall refer to again, is very doubtful.

No rocks identifiable as Damúdas were met beyond the Jaldoka, and they cannot be considered to have been satisfactorily traced further than the Chel.

Dárjíling Damúdas represent the Ráníganj group. (?)

It will be seen from the preceding details that there are no beds in the Dárjíling district corresponding in any degree with the 'ironstone shale' or middle group of the Damúdas in the Ráníganj field, and the question arises whether it is feasible to correlate our rocks with the Ráníganj or with the Barákar group. It is possible that both are present; as their separation, after the alteration the rocks have undergone, and without the intervening

* Chu is the Tibetan word for river.

and strongly contrasting ironstone shales, would not be easy: it is, however, more likely that only one group is represented. The fossils as yet found in the Dárjíling rocks comprise *Glossopteris* of two species (one of which is *Browniana*, the other undetermined), *Vertebraria, Phyllotheca* and *Trizygia (Annularia)*. Of these, all, except the last, are common in both groups as typically developed, whilst *Trizygia* has only been found in the Ráníganj. It is, however, so rare even in these beds, that Mr. Blanford* does not seem to consider its not having been yet found in the Barákars as conclusive evidence of its non-existence there. Further, Dr. Hooker's observation of *Trizygia* in the Dárjíling beds, which he himself speaks of doubtfully, has not been since confirmed. At the same time there is a "plant allied to *Schizoneura*," abundant and generally distributed through the Ráníganj group* of the type field, that has not been as yet observed in the beds in question; but the fossil collections made are too small to allow of satisfactory inferences from this fact.

The lithology of the Dárjíling beds seems to approximate in some respects to that of the Ráníganj group. Mr. Blanford says of the latter, that "the sandstones are generally finer in texture, and are massed in beds of greater thickness, than those below the ironstones; the coarse, white, felspathic sandstone and conglomerates are almost entirely wanting. Nodular hard calcareous bands are frequent; the coal is more regular, of more even quality, and not so frequently a mixture of coal and shale, and the seams have a uniform thickness over considerable areas. Pebbles are scarcely ever seen; shales are common." † In the Dárjíling beds, the sandstones, as a rule, are rather fine-grained; they sometimes occur in thick masses, and coarse, white, felspathic sandstones of the Barákar type are not common; they are not unfrequently somewhat calcareous, and conglomerates are absent. No comparison can be made between the coal-seams in the two localities, owing to the crushed state of

* Vol. III, pt. 1, p. 44.
† Ibid, p. 40.

the Dárjíling beds, and the impossibility of tracing the outcrops for any distance.

It has been found in tracing the Damúdas westward from Ráníganj up the valley of the Damúda, and into Ríwa, that the ironstone shales and Ráníganj groups gradually change in lithological characters. The ironstone shales, as such lithologically, become extinct, and the supposed equivalents of the Ráníganj beds contain no coal. It is quite possible that the series may change its character to the north also. But if it does not do so, and if I am right in correlating the Dárjíling Damúdas with the Ráníganj beds, the lower groups must have been denuded away along the southern face of the Himalayas, after the whole had been tilted up on edge, and before the deposition of the Tertiaries; or more improbably, dropped down by a fault. In either case they would be still present under ground, and may one day or other be found outcropping in some hitherto unexplored part of the mountains. The leading alternative suppositions are, that the Dárjíling Damúdas represent the Barákars, and that the upper groups die out to the north, or else change in lithological character. In the latter case they would be represented in a sub-metamorphosed condition by the lower Dáling beds.

No Damúdas folded up with Dáling beds or gneiss in British territory.

Not often, but still occasionally, one meets with seams of carbonaceous or graphitic schist amongst the Dáling beds; there is a layer of this kind, 2 feet thick, exposed by the Pankabári and Karsiáng road a few hundred yards below Kodabári, and another, some 30 feet thick, on the cart road, a little south of the road location at Karjang.

These, however, are clearly true Dáling beds (and in the above cases near the top of the series) and not Damúdas brought up again to the surface by foldings of the strata on a bold scale. The Damúdas in their most altered condition, as they are seen in the Lehtí naddi for instance (p. 28), have been metamorphosed quite as much as the Dáling beds generally are; yet the alternations of foliated quartzites, slates, carbonaceous and graphitic schists, and crushed seams of coal, are easily recognizable as Damúdas by any one accustomed to the Dárjíling rocks, and are quite unlike anything met with in the Dálings. The Dáling graphitic schists occur but rarely, and in isolated beds, generally of trifling thickness. They only contain a few per cent. of carbon, and have clearly been formed out of some variety of carbonaceous shale, not out of coal. I have never observed anything like true coal in the upper series.

The same remark applies to the rocks coloured as gneiss, in which I nowhere observed any beds that I had reason to suspect were still-further-altered Damúdas. The secondary folds of the main synclinal (p. 10) are not on a sufficiently grand scale to bring the lower rocks to the surface.

It is not impossible that beyond this synclinal, in Independent Sikkim, where the foldings of the strata are comparatively unknown, outcrops of the Damúda series may yet be found. Neither Hooker nor Sherwill, however, in the journals of their travels in that country, describe any rocks recognizable as such.

Probable existence of Damúdas beneath Gangetic alluvium.

The occurrence of Damúdas in the Dárjíling Himalayas adds a wide expanse to the area within which these rocks are known to have been deposited, at least in patches. It is fairly inferable that such was the case over the country now occupied by the alluvial plains of the Ganges between Rájmahál and the foot of the Dárjíling hills, and extending for an unknown distance to east and west; and it is further probable that there still exist beneath those plains, coal-fields equal, perhaps, in value to those which now supply Bengal with fuel.

The difficulties in the way of finding such are, however, manifest: 1*stly*, the unknown depth of the Gangetic alluvium, which is certainly sufficient to make boring extremely expensive, and may be so great as to render mining impracticable; 2*ndly*, the small proportion of the total area which, judging from our experience of the known coal-fields, the Damúda rocks might fairly be expected to occupy. There are indeed some reasons, founded on the connection observable in the position of the fields between Rániganj and the river Koel, with the present lines of drainage, for supposing that the Damúdas were more largely deposited in the main Gangetic valley than in the higher lateral ones.* Probably also the geographical position and geological features of the known coal-fields, would furnish a clue pointing to some portions of the southern part of the plains as more promising than others. At the best, however, the work would be mainly haphazard, and entirely so beyond a limited distance from the edge of the plains. The first borehole *might* strike a field equal to the Rániganj, and *per contra,* lákhs of rupís might be spent with no return whatever. It may be safely predicted that for many decades no attempt will be made in this direction; but at some future epoch in the History of India, when her manufacturing industries shall have been fully developed, when the demand for coal shall have enormously increased, and the fields of the Damúda valley begun to show signs of exhaustion, it is quite conceivable that the winding engine and the cage will be seen in the midst of the alluvial plains of Bengal, where an unbroken expanse of rice-fields now stretches to the horizon.

CHAPTER III.—*Baxa Series.*

Lithology and stratigraphy.

There is a series of rocks some thousand feet thick, comprising variegated slates, schists, quartzites, and dolomite, which is largely developed in the Western Duárs, but has not been recognized in the Dárjíling territory, except at the extreme eastern end. In the Duárs these strata, like those of the other formations, dip mainly in to the mountain range or more or less truly

* This question is, however, complicated by considerations as to whether the main valley may not have been too deep for the formation of coal-producing beds of vegetable matter, and by the want of knowledge as to how far the rocks have been subsequently denuded.

north, the inclination of the Baxas being generally high; there are of course many minor rolls by which the dip is locally reversed or altered.

The most prominent, and, economically considered, the most important member of the series, is a magnificent band of dolomite which is traceable from the Rehti naddi to the Tursa, and again for some miles east of Baxa. The rocks above and below it being comparatively soft slates, &c., the dolomite rises into a boldly outlined ridge, sometimes as much as 3,000 feet high. The rock is very massive as a rule, with little bedding discernible, but not unfrequently it is shaly, and passes into dark-grey slate. It has a saccharoid structure and light-grey color, but the impure shaly parts are darker; there is an exceptional variety that is finely granular and almost pure white. Nests of more largely crystalline calcite, and little drusy cavities lined by crystals of the same mineral, are often profusely scattered through it. Mr. Tween's analyses of specimens from the Títí naddi, show that it contains about 60 per cent. carbonate of lime to 38 carbonate of magnesia, and it is probably a normal dolomite (= carbonate of lime 54·35, carbonate of magnesia 45·65), owing its excess of lime to the crystals of calcite which are disseminated through it. These crystals represent the calcareous excess in the original matter from which the rock was formed.

The entire thickness of the Baxa beds is uncertain, as the base of them is nowhere seen. A section is visible on the right side of the Pagli naddi, near the frontier, the lowest strata in which are very brittle, flaggy, silicious beds, with impure calcareous layers interbanded, dipping north-north-east at 30°. These are covered by a few feet of green and white talc schist, and then by slaty, granular quartzite. Beyond is blank for some distance, and then dipping north at 60° are light green and red slates with thin calcareous layers, covered by some hundred feet of white slaty quartzite or quartz schist. Large blocks of the dolomite are brought down stream from the north, showing that that rock is still higher in the series.

A fine section is well exposed in the Títí naddi, which includes (ascending as usual)—

	Feet.
(a).—Green and red slates	500
(b).—Slates with flaggy silicious and calcareous layers ...	800
(c).—White quartzite, including bands of quartz flags and quartz schist	1,000
(d).—Green, black, and red slates, with bands of flaggy quartzite; also of chloritic schist, and flaggy calcareous beds near the top	1,500
(e).—Dolomite, with interbanded layers of dark-grey slate ...	1,500
(f).—Dark-grey slates; pyritous and rusty in places ...	300

The thicknesses given are merely eye-estimates: throughout there is a tolerably steady dip between north and north 30° east, at about 60°.

Hauri hill is formed of the main quartzite (c), and that to the north of it of the dolomite. Near Londoin hill the last mentioned rock is thrown to the south-east by a fault, and thence forms a lofty rocky ridge as far as the Tursa, but no trace of the dolomite is visible on the east side of the river. There may be a fault, as suggested by Major Godwin-Austen,* but I am more inclined to think that the dolomite band turns sharply round at the end of the ridge, from south-west—north-east to north—south, and thus disappears below the alluvium.

The rocks on the left side of the river, are green and red slates with layers of quartzite and calcareous flags, &c., and some of dark-grey, slaty rock, in which the surfaces of the beds are blackened by carbonaceous matter. The Bhutánese Súbah of Balla sent a man, who pointed out the locality from which the steatite mentioned by Major Godwin-Austen† came. It was, I was told, obtained loose in the ravine at Balla, but none is found now, and the rock had never been traced *in situ*. It is no

* Journal, Asiatic Society of Bengal, Vol. XXVII, p. 122.

† Journal, Asiatic Society of Bengal, Vol. XXVII, p. 122.

doubt a bed intercalated in the slates, like the talc schist of the Pagli naddi.

Impure, thin-bedded limestone, covered by flaggy quartzite, is exposed at the mouth of the Basra gorge; and in the Alaikuri there are green and dark-grey slates, passing into, and interbanded with, flaggy quartzite. Near the head of the river a thick band of quartzite is crossed twice; whether the same repeated is uncertain. It is coarsely cleaved at a high angle to the bedding. Blocks of a conglomerate, composed of flat rolled pebbles lying parallel to the bedding, mostly of white quartzite in a purple arenaceous matrix, are common in the Alaikuri, as in some other streams to the west, but I did not see the rock *in situ*: it comes, however, from near the head of the gorge. Blocks of gneiss and mica schist form most of the *débris* above the 38th boundary mark, coming down from the Gechijo ridge.

There is a rock sometimes met with (as in the Raimatáng naddi) amongst the impure calcareous beds of the series, which consists of interbanded layers of dolomite, varying in color from dirty white to dark red,* red jasper, and thin seams of micaceous iron, and including besides, irregular seam-like nests of quartz mixed with chlorite. The rock varies from one in which the dolomite and jasper are interbanded in irregular layers of ¼ or ½ inch thick or more, to an impure dolomite merely containing seams and nests of jasper, &c. The alternations show well the sharp foldings on a small scale, which are common in the Baxas. The rock is a subordinate one, and has no connection with the great dolomite band. Large blocks of hornblende rock are also brought down by the Raimatáng.

None of the streams west of Baxa bring down boulders from the dolomite band, which, however, re-appears in full force in the Jángti. The stream flows in this part of its course, through a narrow rocky gorge encumbered with huge blocks of stone fallen from the sides, down which

* The color-giving iron is in the state of peroxide, and hence the rock is a ferruginous dolomite, not a true ankerite.

the lime-charged water trickles over large masses of tufa. The outcrop of the dolomite, as laid down on the map, is half a mile wide; the average dip being about 60°. This indicates a thickness of dolomite (with some interbanded pyritous black slate) of 2,300 feet, if none of the beds are repeated by contortions or faulting. It seems that the dolomite has been shifted to the south by a cross-fault east of Baxa, and after being much denuded, covered up by the Tertiaries, beneath which and the alluvium it probably runs as far as the Tursa. Near the upper end of the Jángti gorge, quartzite dipping at 20° is faulted against the dolomite, whilst it is underlaid by flaggy quartzite at the lower end. Next the latter rock, is some quartzite or quartzitic sandstone, of which the faces of the beds are blackened by carbonaceous matter, and below this the Tertiaries come in.

The dolomite has been traced as far east as Jainti Hill, but not beyond; it is probably either cut off by a fault here, or trends northwards towards Sachaphu Hill.

Just north of the Tertiaries on the left bank of the Raidak, a section is exposed of a steep anticlinal with east-west axis. The beds in the centre, or the lowest, are purplish-red slates, interstratified with reddish quartzite; over these is 60 or 80 feet of quartzite (of which the surfaces of the beds are frequently blackened by carbonaceous matter), with some layers of graphitic schist, or perhaps graphitic quartz-schist would be a more correct term, as the amount of carbon does not exceed 10 per cent. or so. These beds are covered by yellowish shattery quartzite. Between the Raidak and the Chengti black-looking rocks, no doubt the above graphitic schists are exposed high up on the mountain side, in two or three places, by landslips; but I observed no trace of them in the Rhekua naddi, where the first rocks north of the Tertiaries are red slates and quartzites.

Relations to Dáling beds and Damúdas.

The Damúdas and the Dáling series (as far as the area examined is concerned) being almost exclusively confined to the Dárjíling territory, and the Baxa beds to the Duárs, whilst there is a *terra incognita* between the Jaldoka and the Daina, where the base of the hills retreats several miles beyond the British frontier, sections are almost entirely wanting to show the relations of the Baxa beds to the other series. In ascending the Ma-chu, next to the beds containing carbonaceous layers, mentioned at page 29, are very brittle silicious flags, with pink calcareous layers, and a few of red shale, dipping north-north-west at 50°; these are quite similar to some of the Baxa beds in the Pagli and Títí sections (p. 34). Beyond these, and apparently overlying them, are green slates of the Dáling type. The slates in the Lángti are also Dáling, and these seem to overlie those further south which are Baxa. Such appears to be the normal position of the two series, and it is on the strength of this that I have coloured the area north of Baxa as Dáling. The only place where I actually penetrated sufficiently far into the hills to examine this area, was in the Alaikuri, the slates in the upper part of which are of an undecided type which might belong to either series. Unless, however, there be a fault between the gneiss and the Baxa beds, it is difficult to see how the Dáling series can be wanting.

The main difficulty is, however, with respect to the relations of the Baxas and Damúdas. I cannot think that the strata, including graphitic schists, seen in the Raidak, are Damúdas, as they are interstratified with beds totally different from anything associated with the latter rocks west of the Jaldoka; and, as I have previously shown, such carbonaceous schists occur here and there in the Dáling beds, where they certainly have nothing to do with the coal-bearing series. The Raidak beds contain no coal, dark-grey shale, or other characteristic Damúda rock. It is not easy to see how the Baxas can be younger than the Damúdas; as, in the Dárjíling territory, the latter rocks immediately underlie the Dálings without sensible unconformity. On the other hand, if they be older, where are the Damúdas in the Ma-chu section, unless, indeed, they are dropped down by a fault? Judging from the Dárjíling and Bhután ground alone, I should say the Baxas were the oldest beds of all; but, on the other hand, one cannot but be struck by some points of resemblance between the latter rocks and those included in Mr. Medlicott's 'Krol group' at the top of his Himalayan series of the north-west.

Chapter IV.—*Dáling and Dárjíling* Series.*

Sections are frequently obtainable, showing the junction of the Damúdas and Dáling series. In every case which came under my notice, the two series are sensibly conformable to each other, although generally there is a very marked and sudden lithological change.

Relations of Dáling beds to Damúdas.

Thus, in a deep gully which joins the Lehtí naddi from the south (p. 28) the strata dip to the south at about 30° and are inverted, the Dáling slates being underneath. The last-mentioned rocks, of which three or four hundred feet is included in the section, consist of alternating light green and dark greenish-grey, slightly greasy slate, the latter variety looking black at a little distance. Some of these alternations are 50 or 80 feet thick; others only an inch or two, and they prove that, here at least, the fissile planes coincide with the bedding. Resting on these beds, at a clearly defined horizon, is slaty Damúda sandstone. The thin alternations of variegated slates at the junction do not bring to light the least unconformity; and the Damúdas include one or two thin layers of light green slate, similar to that below, at a few inches from the base. Above this there is some hundred feet of highly altered Damúdas, comprising foliated quartzose schists, thin seams of coal, and beds of carbonaceous schist, &c., whilst carbonaceous matter is completely absent from the slates below.

Sections are obtainable on the southern face of Látpanchor, and in the Ranjang naddi, where the Damúdas dip at 5° and 15°, and in

* The gneiss above the Dáling beds is called 'Sikkim gneiss' on the map, but 'Dárjíling' is a preferable name, as the gneiss of Kánchinjinga in Independent Sikkim may be of a different age.

each case they are covered by Dáling slates dipping at the same angle, but the absolute junction is not visible. In the Pugo, again, the older series consists chiefly of crushed sandstones, with some shale and thin seams of coal. The highest beds are graphitic schists, with thin layers of grey quartzite, dipping north 30° east, at 60°. Immediately covering these, with similar dip, are alternating dark greenish-grey and light green, slightly greasy slates, which may be traced for at least some hundred yards up stream. The junction is perfectly sharp, and the slates do not contain any carbonaceous matter.

In the Mahánaddi, indurated Damúdas of the usual character, with coal seams, &c., are visible for about three quarters of a mile. The last beds, in ascending the stream, are of crushed massive dark-grey sandstone, within 6 feet of which are light green slates dipping at 80° to north-north-west. These continue for over a mile and a half up stream, with a remarkably constant lithological character, until they begin to graduate into mica schist and gneiss. Throughout the entire distance I did not observe a trace of carbonaceous matter.

In some other sections the junction is not so perfectly sharply marked as in the above. In the Tísta, for instance, Damúda sandstone and light green slate are interbanded for some yards, and in the neighbourhood of Pankabári the junction is sometimes difficult to determine. Between Rání Hát and the cart road, there is a band of slaty conglomerate at the base of the Dálings, of insignificant thickness, which dies out to east and west.

Lithology.

The light green slightly greasy slates, sometimes interbanded with a dark greenish-grey kind, mentioned in some of the above sections, are the most prominent variety of rock for some distance north of the Damúda outcrop. In many places they are thinly fissile, but there is a system of divisional planes (sometimes more than one), generally at an angle of 30° or 40° to the planes of fissility, which causes the slate to break across into small pieces. Not unfrequently the rock contains thin laminæ of white quartz parallel to the fissile planes, showing that the latter are due to foliation, not to cleavage. These slates pass insensibly into ordinary clay slates, more or less earthy or silvery according to the degree of alteration they have undergone. There are also bands of quartzite and quartz flags, and occasionally some of hornblende schist. The latter are sometimes slightly calcareous, or composed of actinolite with magnesian carbonate of lime between the crystals, and this rock even passes into impure dolomite containing much actinolite. Such beds are, however, very rare and insignificant. The almost complete absence of lime in the Dáling beds is one of the most prominent lithological distinctions between them and the Baxas; another is the rarity of brilliantly-coloured alternations of slate, like those in the Tĭtĭ naddi section, the colours of the Dáling slates being less variegated and more sombre.

The sections west of the Mahánaddi do not show much of the light green slate, so prominent to the east of that river; along the cart road, for instance, they are more earthy and arenaceous. I am inclined to think that this is merely due to a difference in metamorphism, combined perhaps with lateral change in lithological characters; it may, however, be of more importance, and connected with the disappearance to the east of the slaty conglomerate which forms the base of the Dáling series in the neighbourhood of Selim Hill.

Dáling beds underlie the gneissose.

I have said that the Dáling beds everywhere underlie towards the gneiss. Along the outer face of the hills there is not much difficulty in drawing a line between the two, for although there is always a passage from one rock to the other, this passage is comparatively rapid. But as we ascend the valley of the Tĭsta towards the interior of the hills, the lower beds become more altered, and frequently changed into mica schist and even gneiss, whilst the gneiss of the upper strata is often of an indefinite character with much mica schist. The rocks colored blue about Kálingpung and Damsáng, and west of the Tĭsta, frequently include bands which are quite as much, or more, altered than others in the area colored pink.

All that can be done is to divide the less from the more altered strata on the large scale, and it must be remembered that this is merely a provisional separation of convenience, as there is no evidence of any stratigraphical break. The same difficulties were experienced by Mr. H. B. Medlicott in the north-western Himalayas,* by whom at least a portion of the metamorphic rocks were shown to be on the horizon of some groups of his slate and limestone series.

The slates appear to be faulted against the gneiss in the Little Rangít and on the Takvor spur; and the fault may extend to the eastward. I nowhere, however, elsewhere observed any indications of faulting along the junction, nor of pseudo-faulting, from deposition of one series against a steep pre-existing cliff of the older rocks. It is beyond dispute that the Dáling beds do underlie the gneiss, and it is, I consider, equally certain that they do so normally and not from inversion. The latter hypothesis would involve nothing less than the complete inversion of all the pre-tertiary rocks over the greater part, if not the whole, of the Dárjíling district. It would imply in fact that inversion is, so to speak, the normal order of things; for the facts cannot be explained by mere local inversion along the lines of contact. Such superposition of fully metamorphosed rocks on those in a less highly altered condition is a phenomenon by no means confined to the Dárjíling hills. It has been described by Mr. Medlicott † as the usual order of things in the north-western Himalayas, amongst the strata of his Himalayan series, with which, there can be little doubt, the slate and gneiss rocks of Dárjíling correspond more or less completely ‡.

* Vol. III, pt. 2, and Panjáb Gazetteer, article Geology.

† Vol. III, pt. 2, and Panjáb Gazetteer, article Geology.

‡ In this connection I would refer to Mr. R. Mallet's recent paper on volcanic energy (Philosophical Transactions of the Royal Society, vol. 163, page 147), in which the author shows (page 168) that if several horizontal beds or layers of rock, of different compressibilities, be subjected to tangential pressure, the work of compression will be greatest in the layers of least compressibility, and consequently the heat evolved greatest also. If the upper of two layers be the less compressible, it will be the hotter, and we may therefore reasonably conclude, the more highly metamorphosed, if the elevation of temperature be sufficient to induce such action. The extent to which the Himalayan rocks have been subjected to tangential pressure is abundantly shown by their disturbed and folded condition.

Lithology of gneiss.

The greater portion of the area coloured pink is occupied by true gneiss, but the rock very frequently passes into mica-schist, or into a variety intermediate between the two; a felspathic mica-schist or gneissose schist. Bands of quartzite occur but rarely, and hornblendic rocks are extremely uncommon and in beds of insignificant thickness. The actual gneiss itself is generally composed of translucent, colorless or grey quartz, white opaque felspar, and dark brown and silvery mica; it varies in texture from a fine-grained to a moderately coarse rock, lenticular layers of different degrees of coarseness being commonly interbanded. Almost the only accessory minerals are kyanite, schorl and garnet, the last mentioned of which is sometimes disseminated through the mica-schist in coarse crystals of considerable size. The gneiss is always well foliated, and the layers are not unfrequently wavy, the length of the waves varying from a few inches to as many feet. This is the incipient stage of the sharp crumplings on a small scale, which are also common, by which the layers are folded completely back on each other.

Absence of granite.

I have not observed any granite in the Dárjíling district, but Dr. Hooker describes the gneiss further north, near Kánchinjinga, as penetrated by numerous veins, the intrusive rock being sometimes fine-grained, in other cases largely crystallized and composed of "pearly white prisms of felspar, glassy quartz, and milk-white flat plates of mica, with occasional large crystals of tourmaline."* This gneiss may be different from that of Dárjíling, and correspond with Dr. Stoliczka's 'central gneiss' of the north-western Himalayas, which is penetrated by innumerable granite veins, and which he considers to be the oldest formation of that area and of pre-silurian age.

Dáling and Dárjíling series post-Damúda.

I have shown that the junction of the Dáling beds and the Damúdas is a natural one. It follows from this and the above considerations respecting the superposition

* Himalayan Journals, Vol. I, p. 251.

of the Dárjíling gneiss, that both it and the Dáling beds must be younger than the coal-bearing rocks. It would be useless, however, in the present state of our knowledge, to attempt to correlate them with the known post-Damúda rocks south of the Ganges; as, owing to their altered condition, we are without reliable lithological, as well as without fossil, evidence to base our conclusions on.

Dárjíling gneiss distinct from that of Bengal.

It is scarcely necessary to add that the Dárjíling gneiss must be vastly younger than that of Bengal*, which was fully metamorphosed and enormously contorted and denuded before the Damúdas were deposited on it. The Dárjíling gneiss presents several points of difference lithologically. It is more quartzose and the older rock more felspathic; the felspar is, I believe, always white in the Dárjíling rock, while it is very frequently red in the other. Again, the bands of dense tough hornblende rock which are so common in the older formation, are absent in the newer, or only represented by insignificant layers, and, as far as my examination goes, there is no limestone or dolomite in the hill gneiss. The latter, at least in the Dárjíling district, is never granitoid as the Bengal gneiss so frequently is, and it has a greater tendency to pass into, and contains more, mica-schist.

Bengal gneiss.

Proceeding up the left bank of the Raidak river, the first rock met with is hornblende schist in thick beds dipping north 10° west at 50°, and forming a low eminence; only a small thickness is seen. Beyond this is blank for a couple of hundred yards, and then Tertiaries come in, dipping locally to north at 80°. There can hardly be a doubt that this rock belongs to the gneiss which forms most of the hills that are scattered over the alluvial valley of the Brahmaputra, and which, according to Mr. Medlicott, there is no reason to suppose is distinct from that of Bengal. The southerly trend of the Tertiary hills both east and west from the debouchure of the Raidak make it probable that the Tertiaries are not faulted against, but

* The gneiss south of the Ganges is generally spoken of as the 'Bengal gneiss.'

overlie the gneissose rocks. The above outcrop is the one solitary point at which the Assâm gneiss has been observed at the foot of the hills between Nepâl and the Goalpâra district.

CHAPTER V.—TERTIARIES.

Lithology.

The Tertiaries fringe the older rocks continuously from close to the Mechi eastward nearly as far as Dâlingkot. They are made up mainly of soft massive sandstones and clunchy beds. The most prominent variety of sandstone is a rather soft, highly felspathic and slightly micaceous, white rock of medium fineness, with black specks; a pepper and salt-coloured rock. There are also light buff-coloured sandstones varying in texture from rather coarse to rather finegrained, and passing into fine earthy beds. Well-rounded pebbles, mostly of white quartz, but sometimes of gneiss and schists, are very commonly scattered through the sandstones. Near the bottom of the series they generally contain merely a stray pebble here and there, but higher up, the pebbles increase in number, and towards the top, layers and bands of conglomeratic sandstones are frequent. The pebbles are generally under 2 or 3 inches diameter and never approach in size to boulders. The sandstones are usually thick and often very massively-bedded, and false-bedding is common. They sometimes contain rounded concretionary masses of clunch which have much the appearance of rolled pieces of foreign rock. The clunchy beds are grey, greenish-grey or greenish, often micaceous and generally somewhat calcareous. Usually the calcareous matter is equally diffused through the rock, but sometimes it is aggregated in nodules resembling potatoes in form and size. In a few instances there are layers of impure light grey limestone mixed up with the clunchy beds. The latter also become bedded in places and pass into grey, slightly calcareous shale. There are also dark grey shales not unlike unaltered Damúda. The above varieties are generally mixed up in frequent alternations, but great thicknesses of soft massive sandstone unmixed with other rocks also occur, especially towards the upper part of the group; the clunch and shaly beds are most abundant towards the lower part.

Fossil stems : lignite.

Fossil stems are frequent in the sandstone. They occur up to a foot or so in diameter and 10 or 15 feet long, being generally more or less flattened by pressure. In most of them the original woody part is replaced by carbonaceous sandstone, while the bark is represented by brittle jetty lignite, breaking with conchoidal fracture. In some, however, carbonaceous sandstone and lignite are interbanded with each other throughout the entire thickness of the stem, in very irregular layers parallel to the structure of the wood. Occasionally the stem consists entirely of lignite, and is then generally squeezed quite flat. Besides such recognizable stems, little irregular masses and strings of lignite are often met with in the sandstone, but never of any size, the largest I ever saw containing less than 2 cubic feet.

Coal.

There are, however, a few beds of coal in the Tertiaries; not jetty lignite with conchoidal fracture, but soft and flaky, very much resembling the Damúda coal in outward appearance. The possibility of its being Damúda caught up in the Tertiaries suggested itself to me, but further examination convinced me that it is not so. At least two such beds are met with on the cart road, one of which is a lenticular mass 6 feet thick, but only extending for a few yards laterally; it may represent a local accumulation of drifted vegetable matter. The other varies, where exposed, from 9 to 2 inches in thickness, and what is possibly the same bed is exposed at two or three points lower down the winding road. An assay of the coal from the second bed shows that it contains 43·2 carbon, 19·6 volatile matter, and 37·2 ash, or nearly half as much volatile matter as carbon. The highest percentage of volatile matter in the Damúda coal is less than a fourth that of the carbon, and the average only one-eighth. These Tertiary coal beds are by no means common, not more than half a dozen outcrops having been observed altogether, none of which showed any reasonable promise of commercial value.

Ferruginous beds.

I shall allude to the ferruginous beds of Lohárgarh when describing the iron ores of the district. I may here, however, point out the similarity in geological position of the Lohárgarh rock, occurring as it does towards the base of the group, with the well-known ores of Káládhúngí and Déh-chaurí below Naini Tál. The latter are found in the clays at the base of the lignite-sandstone, and are represented at intervals along this zone as far as the Nahan group of the north-west has been traced.* The occurrence of the Lohárgarh rock renders it probable that the ferruginous band is represented along the entire length of Nepal also, or from the Satlej to the Mechi.

Thickness.

A fine section of these Tertiary rocks is exposed in the Mahánaddi; where they dip with considerable steadiness towards the north-north-west, or up stream, at angles the mean of which is probably about 35°. The entire length of section is three miles and three quarters, indicating, if all the beds passed over represent true vertical thickness, and excluding possible faults, a total of over 11,000 feet.

Dr. Hooker was therefore in error in supposing that these strata are represented to but a trifling extent in the Dárjíling district, and that they rise to but a few hundred feet above the sea there.† It is true that they do so in the neighbourhood of Pankabári, where they were examined by him, but east of the Mahánaddi many of the Tertiary hills are over 2,000 feet high.

Line of boundary.

The relations of these rocks to the older formations, along the line of junction in our present area, seem to resemble exactly those in the north-western Himalayas which have been described so fully by Mr. Medlicott. He believes "that

* Vol. III, pt. 2, p. 178.

† Himalayan Journals, Vol. I, p. 403.

the junction is primarily a line of original contact, possibly modified by subsequent faulting,"*—that the original limit of deposition of these rocks was a steeply escarped coast line, against which the sands and mud were banked. By subsequent tangential pressure the consolidated strata were crushed up so as to present a pseudo-underlie towards the older formations; whilst the steep original contact gives the junction the appearance of being a faulted one. The direction of such an escarpment as the above, in highly inclined strata, would generally be determined by the strike of the bedding; and in the Dárjíling district, the persistent parallelism of the Tertiary-Damúda and Damúda-Dáling boundaries would seem to indicate that such an escarpment may have been determined by the outcrop of the upturned Damúdas.

Break in the continuity of the Tertiary fringe.

The Tertiaries are wanting for some miles eastward of the Lehtí naddi; they occur again in the Ma-chu, but are again absent for forty miles eastward of the Jaldoka. Their absence along this part of the lower hills was first pointed out by Major Gowdin-Austen; and, as observed by Mr. Medlicott,† it is the only known instance of the kind from the Indus to the Bráma Khund. With respect to the question whether their absence is due to denudation or to their never having been deposited along this portion of the hills, I think the former is decidedly the more probable explanation. The thickness of strata exposed in the Ghísh river is as great as anywhere to the west; the group does not show any sign of diminishing thickness; yet three miles further east it has entirely disappeared. The older formations do certainly stretch further south here, owing mainly to a change of strike, and it is possible that they originally ran still further south as a promontory in the Tertiary basin of deposition. There is, however, no evidence that they did so; and it is more difficult to explain the removal of such a promontory, than it is to explain the removal of the softer Tertiary rocks on the alternative supposition.

* Vol. III, pt. 2, p. 102.

† Vol. IV, p. 436.

Recent boulder deposits.

Between the Chel and the Langti there are enormous recent boulder deposits,* which become finer to the south, and eventually graduate into the ordinary alluvium of the plains. They form cliffs of three and four hundred feet high about the debouchures of some of the rivers, like the Jaldoka. Remembering the difficulty frequently expressed by Mr. Medlicott, of separating the true Sivalik strata of the north-western Himalayas from the recent deposits of the Duns, it struck me as possible that some of the deposits in question might represent the Sivalik group. I did not observe anything, however, tending to prove that such is the case, or leading me to make any separation in them. The deposits, which occur all along the base of the hills, may not in reality perhaps be more largely developed here than elsewhere, but they are cut through much more deeply by the rivers; and it is to be noted that this feature occurs in a portion of the strip where the Sub-Himalayan hills and rocks are absent.

Tertiaries near Baxa.

The latter reappear some miles east of the Tursa, and are thence found continuously as far east as the Sankos river, which was the furthest point I reached. At the debouchure of the Raimatáng, there is at the base of the Tertiaries some two or three hundred feet of soft, dark-red, slightly micaceous, earthy sandstone and sandy clays mottled red and light greenish. Above them are soft massive sandstones of the ordinary type. The passage beds are exposed at the debouchure of the Jángti; ascending the stream, we have, dipping at 70° to north—

	Ft.
Soft white sandstone with black specks	40
Sandy clay or clunch; red, mottled with light green ...	30
Grey clunch	2
Light greenish clunch mottled with red	10
Sandstone like the first-mentioned	5

* *Vide* Major Godwin-Austen's paper, Journal, Asiatic Society, Bengal, Vol. XXVII, pt. 2, p. 117.

Then a blank, beyond which the ordinary sandstones, &c., come in. These beds remind us of the mottled red clays, &c., which Mr. Medlicott describes at the base of the Nahan group.

Conglomerate beds are more largely developed in the Baxa Tertiaries than in those of Dárjíling; as usual, they occur near the top of the group. In the ravine below and immediately west of the right picket at Baxa there is a considerable thickness of them—rolled pebbles of sizes up to 6 inches diameter in an arenaceous matrix. Similar bands are found in the Rhekua naddi, which flows into the Sankos.

Tertiaries represent Nahan group.

A comparison of the above lithological characters with those given by Mr. Medlicott for his Nahan group of the north-western Himalayas * shows the strong similarity between that group and these Dárjíling beds. The Nahans are essentially the 'lignite-sandstones' of the North-West; and our rocks further agree in the occurrence of ferruginous beds and of red clays and sandstones near the base, as well as of conglomeratic bands near the top. Mr. Medlicott felt satisfied from his examination of the Tertiaries further east, in Upper Assam, that they there represent the Nahan group; and he further pronounces my specimens from the Dárjíling country to be of a decidedly Nahan type.

* Vol. III, pt. 2, p. 114.

ECONOMIC GEOLOGY.

CHAPTER VI.—*Coal—Graphite.*

COAL.

I have mentioned all the coal out-crops as yet found, when describing the Damúdas, but it may be well to give here a list of the more important ones, or excluding those under 2 feet thick. Proceeding from east to west, we have—

Principal known out-crops.

		Thickness of coal at out-crop. Ft.	In.	Dip.
Rakti naddi		2	6	70°
Ditto		5	6	70°
Ditto (part of thickness concealed) seen ...		1	4	70°
Chirankhola naddi	5′ 4″ to	7	0	55°
Ditto	2′ 0″ to	8	0	
Pagdandi, south-east of Selim Hill		2	0	
Cart road		3	6	40°
Ditto		2	0	
Ditto	1′ 0″ to	3	6	30°
Ditto		3	6	45°
Ditto	2′ 6″ to	3	6	45°
Ditto		6	0	30°
Ditto		2	6	35°
Tíndharia ravine		11	0	80°
Ditto		6	0	
Mahánaddi river (part of thickness concealed) seen		4	0	70°
Ríyem naddi		3	6	70°
Rumtek naddi		7	0	20°
Ditto		2	0	70°
Ranjang naddi		3	6	15°

I have spoken of the above as out-crops, not as seams, because the vegetable mould and clay beneath the dense jungle render it impossible to trace the seams for any distance. They are seldom visible except in the very beds of the streams, nor can a seam be recognised in a second out-crop with any certainty on account of its rapid variations in dip and strike, and still more in thickness. The sections are seldom sufficiently good to trace the seams by means of the associated beds. Thus the same seams almost certainly out-crop more than once on the cart-road, and the 6-feet Tindharia seam may be the same as the 11-feet one.

Rapid variations in thicknesses of seams.

I have included all out-crops of 2 feet and upwards in the list, not on the supposition that a 2-feet seam of coal would pay to work, but, as I have previously explained, the seams vary greatly in thickness within a few yards. Thus, one of those in the Chirankhola is 8 feet on one side of the stream and only 2 on the other, and another on the cart road varies from 1 foot to 3 feet 6 inches in the short distance along which the out-crop is visible. A thickness of 2 feet at the out-crop may be the *minimum* thickness of the seam.

There can be no question that these rapid variations are due mainly, or almost entirely, to the crushing which the rocks have undergone; but to some extent they may be caused by variations in the thickness of the bed as it was originally formed. How much should be attributed to the latter cause is a most important element in the question of working the coal, and it was partly to gain information on this point that I recommended horizontal trial drifts to be driven into a couple of the more promising seams, namely, the 11-feet seam in the Tíndharia ravine and the 7-feet one in the Chirankhola. Mr. Tyndall, Executive Engineer of the Dárjíling and Jalpigori Divisions, under whom the work was put, was unable to break ground at the latter during the rains. The drift into the Tíndharia seam had been driven 40 feet in from the out-crop, at the commencement of the rains, and the seam was reduced to 6 feet. It is, however, very probable that it again increases in thickness further in; and with a view to ascertaining the mean thickness of the bed here, and whether it maintains that thickness for some distance, or dies out partially or altogether, as well as to gain information as to the constancy or otherwise of the dip and strike, and whether the seam has been faulted or not, I recommended that the drift should be continued to a length of 300 or 400 feet into the hill side. Mr. Tyndall thought he would be able to do this, although progress is not easy with ordinary kulis unaccustomed to mining work. Mr. Blanford states that in the Ráníganj field, the coal of the Ráníganj group is more regular and of more even quality than that of the Barákars, and the seams have a uniform thickness over considerable areas.* If then, as seems not improbable, the Dárjíling beds represent the Ráníganj group, it may be inferred with some probability that the seams possess a considerable degree of persistency.

Amount of coal.

With respect to the amount of coal existent, I have already alluded to the difficulty of determining the number of actual seams. The above list of out-crops is not a long one, but the time at my disposal only allowed of my going up the principal streams. An exhaustive search in all the smaller streams would undoubtedly increase it considerably. On the other hand, in some rivers, like the Tísta, where the rocks are fairly exposed, while seams of a few inches thick are numerous, not one of importance is visible.

Crushed condition of coal.

The crushing to which the coal has been subjected has induced a flaky structure, which renders it so friable that it can be crumbled into a flaky powder between the fingers with the greatest ease. It was simply dug out of the Tíndharia drift with kodális, and a large proportion was extracted in powder, whilst what remained in lumps crumbled down on the application of the least violence; if handled roughly, or let fall a few inches, the lumps fell to pieces. The coal is not quite homogeneous in this respect; some samples from the Tíndharia drift were a little firmer than others, but the difference was trifling, and the coal at the end of the drift, 40 feet from the original out-crop, was as soft and flaky as at the surface. This proves beyond question that the flakiness is due entirely to crushing and not in any

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* Vol. III, pt. 1, p. 40.

degree to surface weathering. Hence no material improvement in the firmness of the coal can be expected as the drift progresses, and there is every reason to suppose that the seams everywhere will, like this one, prove as crumbly in the interior as at the surface.

Composition.

The following assays made by Mr. Tween illustrate the composition of the coal; the specimens were first dried at 212°:—

Darjíling-Damúda coals.	Free carbon.	Volatile matter.	Ash.
Rakti naddi, 5′ 6″ seam	79·3	7·6	13·1
Cart-road, 6′ 0″ seam	74·1	9·0	16·9
Chirankhola naddi, 7′ 0″ seam	69·6	5·2	25·2
Tíndharia ravine, 11′ 0″ seam	66·3	12·4	21·3
Ravine south of Pankabâri, 0′ 9″ seam ...	64·0	11·8	24·2
Average ...	70·66	9·20	20·14

The samples were all taken at the out-crop, within a foot or two of the surface, but the coal seems to be little altered by exposure. The following assays are of samples taken at intervals of 10 feet in the Tíndharia drift:—

Tíndharia ravine, 11′ 0″ seam.	Free carbon.	Volatile matter.	Ash.
At surface	66·3	12·4	21·3
10 ft. from surface	66·8	11·4	21·8
20 " "	67·5	14·4	18·1
30 " "	64·4	10·4	25·2

The coal in many seams has a brilliant sub-metallic lustre; in others it is duller. The former variety is more friable than the latter. The mineral is an 'anthracitic coal;' not a true anthracite, the volatile matter in which does not exceed 5 or 6 per cent.; that of the 11-feet Tíndharia seam, which contains 12 per cent. or so of volatile matter, cakes to a slight degree in the fire. A qualitative analysis of the ash of this coal proved the absence of both sulphur and phosphorus, a most important advantage in the manufacture of iron.

Mr. Blanford gives assays of coal from seventeen of the Rániganj mines.* The mean of these shows an average composition of free carbon 51·09, volatile matter 32·64, ash 16·27. If we assume, as we fairly may, that the Dárjíling coal, in its undisturbed state, had about the same composition as the Rániganj, it follows that during and since the elevation and contortion of the former, and its associated beds, the coal has lost on an average more than two-thirds of its volatile matter. The percentages of free carbon and ash are thereby of course increased.†

Mining.

The question of whether the Dárjíling coal can be profitably delivered at the terminus of the Northern Bengal State Railway, say at Sukna, may be conveniently discussed under three heads, *viz.*, mining, conveyance of the coal to the foot of the hills, and conversion into a usable form of fuel.

The high inclination of most of the seams, as well as the softness of the coal, would necessitate a method of mining altogether different

* Vol. III, pt. 1, p. 189.

† A similar change has been shewn by Prof. H. D. Rogers to have taken place in the coal of the Appalachian field, where the strata are folded up in the Alleghany Mountains. In the western part of the field, where the bedding is level and unbroken, the percentage of volatile matter ranges from 40 to 50 per cent. "Eastward of this, on the Monongahela, it still approaches 40 per cent., where the strata begin to experience some gentle flexures. On entering the Alleghany Mountains, where the distinct anticlinal axes begin to show themselves, but before the dislocations are considerable, the volatile matter is generally in the proportion of 18 or 20 per cent. At length, when we arrive at some insulated coal-fields associated with some of the boldest flexures of the Appalachian chain, where the strata have been actually turned over, as near Pottsville, we find the coal to contain only from 6 to 12 per cent. of bitumen, thus becoming a genuine anthracite." (Lyell's Elements of Geology, sixth edition, p. 499.—Coal containing as much as 12 per cent. of volatile matter can scarcely be considered a true anthracite).

from that pursued in the Ránígaṇj collieries, where the greatest dip of the worked seams does not, as I am informed by Mr. Hughes, exceed ten or twelve degrees. Coal mining in highly inclined strata is always more difficult than in horizontal ones, but in many European fields, like those of Belgium, Westphalia, and some of those in England, fuel is profitably extracted from highly contorted seams. Where the folds of the strata are on a sufficiently large scale, so that the dip is tolerably constant for some distance, the coal can be worked at any inclination. But when, in addition to such larger curves, the seams are further crumpled up by other contortions on a minor scale, the difficulties are vastly increased, and may become so great as to render the coal valueless. Now, in the previous part of this report, I noticed several instances in which the Dárjíling seams are affected in this way, or where they are crushed into small and violent contortions, and even doubled back sharply on themselves. This is decidedly the most unfavourable feature present. The coal in many places will be unworkable in consequence, and it is even possible that this condition may be so prevalent as to prevent any portion being worked to a profit. The rapid variations in the thicknesses of the seams, a consequence of the same crushing, is another element to be taken into consideration, although of much less importance than the contortions. The crushing has, further, more or less shattered the sandstone and shale beds, or their equivalents where metamorphosed, so that these rocks cannot be expected to furnish as firm a roof as the same strata where undisturbed. The existence of faults and minor slips is also to be expected, and if of frequent occurrence, these would add another grave difficulty to working the coal. When describing the Damúdas, I noted some instances of the occurrence of such slips.

In the more highly inclined seams, the coal itself would form the roof of the galleries, and as it is far too soft to be self-supporting, there would be a heavy item of expense for timbering; an item which does not exist in the Ránígaṇj mines worked on the post and stall system, where the roof is of sandstone or shale supported on stout pillars of coal. It is also to be remembered that the further a level is driven into the hill side, the greater will be the depth of superincumbent rock, and consequently the greater the expense for stronger timbering to withstand the increased pressure.

On the other hand, should the above difficulties not prove insurmountable, the coal could be mined, for a considerable time at least, by levels driven into the hill sides from the out-crops of the seams. The advantages of this would be important. The preliminary cost of shaft-sinking through unproductive rock would be saved, and also the expense of winding-gear to raise the coal, including the capital sunk in machinery, and the consumption of coal for winding-engines, such as are necessary in mines worked by shafts. The coal need merely be run out to the surface on tramways laid along the main levels. Further, pumping machinery and engine-power therefor, which form an important item of expense in shaft mines, would not be required, as the mines would drain themselves. The soft, friable state of the coal, and the high dips, would lead one to expect a considerable percolation of water from the surface. The Tíndharia drift, however, was quite dry in the interior, although a rivulet of water was trickling down the hill side directly above it. The surface clay no doubt protects the out-crop, and it would probably do so in many other cases also. In a thoroughly wet mine, it is to be feared that the water would render the already soft coal so yielding that the difficulty of keeping up the roof would be considerably increased.

The softness of the coal, although so disadvantageous in other respects, has at least this in its favor, that the work of 'getting' the coal would be easier. Instead of the laborious 'holing under', and subsequent breaking down by wedges or blasting, that is employed in most mines, nothing is requisite but to dig the coal out with kodálís and picks, as was done in the Tíndhariá drift.

It may be confidently asserted that no risk is to be apprehended from fire-damp within any distance from the surface that the mines are likely to attain. As such is practically unknown in the Damúda coal of the Ránίganj mines,* there is little to fear from the same coal after it has lost two-thirds or three-quarters of its volatile matter, from the disengagement of which the fire-damp originates. It is no doubt possible that some of this disengaged gas may still remain stored up at a considerable depth, but it is highly improbable, taking into account the disintegrated state of the coal and the disturbed condition of the beds it occurs in.

Another point in favor of the Dárjíling coal is the almost total absence of trappean intrusions, which do great injury to the seams in some of the fields south of the Ganges.†

Carriage.

If the results of the trial drifts should prove sufficiently encouraging to warrant an attempt to work the coal on a commercial scale, the neighbourhood of Selim Hill would be the most favorable place at which to begin operations. Out-crops of fair thickness occur more plentifully there than along most other parts of the Damúda band, and the Chirankhola and Tíndharia seams, which are amongst the thickest yet known, are close to the cart-road, although several hundred feet below it. As a temporary measure, the coal could be brought up to the road on mules or cattle, along paths which would cost a very trifling sum, and then carted down to Sukna. The distance along the road, from the place where the Damúda band crosses it to the foot of the hills, is eight miles, and the difference of level, as measured by aneroid, 1,800 feet. The distance in a straight line is only three miles. If, subsequently, the out-turn should be sufficiently large, it would of course be necessary to make more complete arrangements, the plans which strike one as the simplest being either a tramway along the side of the road or a direct wire-tramway.

* Vol. III, pt. 1, p. 174.

† Vol. III, pt. 1, p. 146.

I observed no good seams near Ráni Hát, but a closer search might discover such. Their absence, indeed, would be another point against the coal, as showing that the seams near Selim Hill are not continuous for two miles to the eastward. If found, the coal could be taken down the easy gradient of the diluvial Ráni valley, and thence across the Terai to Sukna, a distance altogether of about six miles.

To bring the coal away from the neighbourhood of the Mahánaddi, it would be necessary to construct a road or tramway down the gorge of that river—about three miles measured along the bed of the stream, the distance from the debouchure to Sukna being three more. But this of course would not be undertaken until after mines had been opened near Selim Hill, and unless they turned out well.

Conversion into usable fuel.

The coal, as extracted from the mine, being in powder, or, at best, in lumps which crumble into powder on the application of the least violence, it manifestly cannot be used in its natural state.* It must be artificially compacted before it can be utilized as fuel for locomotive purposes.

Two ways of doing this present themselves—namely, coking and conversion into patent fuel. The Government of Bengal has directed one hundred máns to be sent to Calcutta for trial by both methods, but this has not yet arrived. Meantime, I may give the results of some experiments on a small scale which have been made.

* A small quantity of coal from the Tíndharia 11-feet seam was raised by Mr. Partridge, the owner of the Tíndharia estate, before the drift was opened, and an endeavour made to use it, in its natural state, for working the steam-engine which drives the tea-rolling machines. I am indebted to Mr. Montfort for an opportunity of witnessing an experiment of this kind. The furnace was being stoked with wood, and the engine working at 25℔s. pressure, when the coal was added in fragile lumps and powder, a good deal of which fell at once between the fire-bars into the ash-pit. The coal caked slightly, so as to admit, after a short time, of being gently stirred and broken up, but being mostly in powder when shovelled in, the fire was too much choked to allow sufficient draft, and the pressure soon sank from 25 to 15℔s.

Of the coals mentioned at p. 54, the Tíndharia, which contains about 12 per cent. of volatile matter, and which cakes slightly in the open fire, yields a firm hard coke when the powder is ignited in a covered crucible. Coal from the Rakti and Pankabári seams does not coke at all, although the assay of the latter agrees closely with that of the Tíndharia. It is a well-known fact that the coking property of coal does not depend solely on the percentage of volatile matter, although a certain amount of such is indispensable. Much of the Dárjíling coal is too near anthracite to give promise of being convertible into a good coke, and the above experiments seem to indicate that some of it will not coke at all. The following table shows the amount of free carbon and ash, after the elimination of the volatile matter, in the coals mentioned at p. 54.

		Carbon.	Ash.
Rakti naddi	5′ 6″ seam	85·8	14·2
Cart road	6′ 0″ „	81·4	18·6
Chirankhola naddi	7′ 0″ „	73·4	26·6
Tíndharia ravine	11′ 0″ „	75·7	24·3
Ravine south of Pankabári	0′ 9″ „	72·5	27·5
	AVERAGE ...	77·8	22·2

As artificial fuel the coal promises to turn out well. Mr. J. Grant of Barákar, who has had the management of patent fuel works at Ránígani, was kind enough to experiment on a few pounds of dust-coal from the Rakti naddi 5′ 6″ seam. The ingredients used were in the following proportions:—

Dust-coal	... ...	1 ton.
Starch, composed of	Flour	12 to 16 lbs.
	Water	30 to 35 gals.
Crude carbolic acid	... ...	1 pint.

After being well mixed, the composition was pressed, by hand merely, into small cylindrical vessels, and the cakes subsequently allowed to dry. They were then almost as firm as average patent fuel; and Mr. Grant is of opinion that, when pressed by machinery, the bricks could be turned out as hard as ordinary Indian coal in the block. A couple of the cakes were broken up and tried by Mr. Hughes on a smith's hearth at the Mint. The fuel burned clearly, with little flame, and afforded a strong welding heat. It stood the blast without crumbling, and left but little clinker. It should be remarked, however, that the Rakti naddi coal has the best composition of any as yet assayed. The amount of ash in the Dárjíling coal is greater than that in Rániganj, but the higher percentage of carbon fully compensates for this. The assays indicate that the heating power of average Dárjíling coal is above that of average Ráníganj, and nearly equal to that of the very best seams. The best Dárjíling is superior to the best Ráníganj.*

Mr. Grant estimates the approximate cost of making the coal into artificial fuel as follows:—

	Rs.	A.
Disintegrating the smalls with Parr's patent machine, about ...	0	2
Flour (say rice)	0	8
Crude carbolic acid	0	4
Moulding	0	2
Drying	0	1
Engine-power	0	1
Total per ton ...	1	2

The first item would not be necessary in the case of most, at least, of the Dárjíling coal, as it is already in a sufficiently disintegrated state. Ample water-power could be supplied at Sukna by an aqueduct from the Mahánaddi, thereby saving the consumption of coal for engine-power.

* *Vide* Records of the Geological Survey of India, Vol. VII, pt. 1, p. 20, for assays of the best Ráníganj coals.

The cost of manufacture may therefore be taken at one rupí a ton, or perhaps rather less.*

Relative cost of Rániganj and Dárjíling coal.

The question of the profitable workability of the Dárjíling coal of course depends on whether it can be delivered for use at Sukna, and the northern part of the railway, as cheaply as Ránígan coal; in other words, whether the expenses of mining the highly inclined and much contorted Dárjíling seams, carrying the coal to Sukna, and converting it into usable fuel, will not exceed the cost of the easily mined Ránígan coal, plus carriage to the same place. I am indebted to Mr. Prestage, Agent of the Eastern Bengal Railway, for the following estimate of the cost of Ránígan coal delivered at Sukna *viá* the East Indian and Eastern Bengal Railways:—

	Rs.	A.
Cost per ton of Ránígan coal delivered at Sámnaggar on the Eastern Bengal Railway	7	12
Loading at Sámnaggar	0	4
Carriage to Kushtia	3	8
Unloading at Kushtia	0	4
Ferry across Ganges to southern terminus of Northern Bengal State Railway	0	14
	12	10
Carriage by Northern Bengal State Railway to Sukna, 200 miles (actual cost)	3	0
Cost per ton at Sukna	15	10

This route includes carriage from Ránígan to Biddabatti (106 miles) by the East Indian Railway, transport across the Húglí to Sámnaggar, carriage from Sámnaggar to Kushtia (95 miles) by the Eastern Bengal Railway, and transport across and up the Ganges (about 20 miles) to the Northern Bengal State Railway terminus, or in all 201

* This is exclusive of the cost of machinery and plant, which Mr. Grant estimates at about £900, for a daily outturn of 50 tons.

miles of railway carriage and two ferries. The two main alternative routes are—*1st*, from Ránígauj to Rájmahál by rail (173 miles), and thence down the Ganges for about 130 miles; and, *2nd*, from Giridi (Karharbári) to Manghír by rail (137 miles), and thence down the Ganges for about 260 miles. Both these routes have the advantage of involving only one shipment into boats. The following are approximate estimates of the cost of transporting coal by them:—

Viâ *Rájmahál.*	Rs.	A.
Cost of coal at Ránígauj per ton	3	8
Loading at Ránígauj	0	4
Carriage by rail to Rájmahál	6	12
Shipping at Rájmahál	0	4
Carriage by boat to terminus of Northern Bengal State Railway	1	4
	12	0
Carriage by rail to Sukna	3	0
Cost per ton at Sukna	15	0

Viâ *Manghír.*	Rs.	A.
Cost of coal at Giridi	3	8
Loading at Giridi	0	4
Carriage by rail to Manghír	5	11
Shipping at Manghír	0	4
Carriage by boat to terminus of Northern Bengal State Railway	2	8
	12	3
Carriage by rail to Sukna	3	0
Cost per ton at Sukna	15	3

Thus it appears that Ránígauj or Karharbári coal cannot be delivered at Sukna under about Rs. 15 a ton. The actual cost of raising the coal at Ránígauj is, as I am informed by Mr. Hughes, about Rs. 1-4 on an average, or, including cost of management, rather less than Rs. 2 a ton.

The cost of carrying the Dárjíling coal to the foot of the hills by tramway, would probably not exceed a few annas a ton. Allowing, however, Rs. 3 for carriage in the first instance by carts, we have roughly—

	Rs.	A.
Carriage to foot of hills	3	0
Conversion into patent fuel	1	0
Cost, exclusive of mining, at Sukna	4	0
Carriage by rail to southern terminus of the Northern Bengal State Railway	3	0
Cost, exclusive of mining, at southern terminus of Northern Bengal State Railway	7	0

as compared to Rs. 15 a ton at Sukna and Rs. 12 at the southern terminus for Ránígan̄j coal. This leaves a margin of Rs. 11 in the former case, and Rs. 5 in the latter, for the cost of mining the Dárjíling coal. If, therefore, the difficulties of mining the latter could be overcome at over double the expense of raising the Ránígan̄j coal, the Dárjíling coal would pay at the southern terminus, and it would pay at Sukna if it could be brought to bank at over five times the expense of raising the Ránígan̄j coal.* If we allow, say, 8 annas a ton for carrying the coal to Sukna by tramway, the margin for mining will be still larger. Serious, therefore, as are the difficulties to be encountered—difficulties which, it is not to be concealed, may prove insurmountable—the Dárjíling seams are clearly well worth a fair trial; and I would decidedly recommend that the experimental drifts be carried on.

GRAPHITE.

I have already explained that the carbonaceous shales of the Damúdas are, in their most highly altered condition, converted more or less into a graphitic schist, and that similar beds are occasionally met with in the Dáling beds. The change, however, of the carbon from the

* This is on the assumption that the coals are of equal heating power; as I have shown, the Dárjíling has some advantage in this respect.

amorphous to the graphitic condition is, as far as my observations go, never complete, and is generally very partial indeed. The following assays* of semi-graphitic Damúda schist from the Rakti naddi, and of so-called graphite collected by Captain Sherwill, and now in the Geological Survey museum, show how small the percentage of carbon is:—

	Ash.
Rakti naddi	92·0
Near Pankabári (Sherwill)	83·8
Near Karsiáng (Sherwill)	84·6

The ash consists mainly of quartz and other silicious matter. It is scarcely necessary to say, that even if all the carbon were true graphite, a mineral containing 85 per cent. of ash is commercially worthless. It is no doubt possible that purer layers may exist; fair specimens of graphite have been obtained in the North-Western Himalayas† from strata similar to the Dáling beds, and possibly including Damúda rocks. I have never seen such, however, from the Dárjíling hills, and it is not probable that any really valuable masses of the mineral will be found. Specimens of the Kumáon graphite even, which have been sent to England for the opinion of manufacturers, have been pronounced by them as useless, or, at best, as not worth more than £5 a ton.‡

Chapter VII.—*Iron—Copper—Lead.*

Iron.

Lohárgarh.

There is a strong ferruginous band included in the Tertiary sandstones of Lohárgarh.§ The out-crop runs along the southern brow of the hill, with a thickness near the centre of perhaps 40 yards. The length of the out-crop being about a mile from east to west, or between the points where the band disap-

* Made by Mr. Hughes.

† Vol. III, pt. 2, p. 180.

‡ Jour., As. Soc., Bengal, Vol. XXIV, p. 203.

§ Dr. Hooker erroneously states (Himalayan Journals, Vol. I, p. 402), that the iron ore is wholly superficial.

pears below the alluvium, there is clearly an almost unlimited supply of ore. It is, however, of poor quality, the better portions containing only about 30 per cent. of iron, as shewn by Mr. Tween's assays—

No. of assay.				Percentage of iron.
1	...	...	...	30·8
2	...	...	...	28·7
3	...	...	...	32·3

The ore varies from a strongly ferruginous clay to an impure brown hematite, and has frequently a pseudo-brecciated aspect. It is not smelted by the natives, although there are vague traditions of its having been once worked, and of hammers still to be seen on the hill, so heavy that no one can lift them! The Chenga naddi brings down lumps of ore, an assay of one of which gave 39·6 per cent. of iron, but the lumps which stand such water-transport are the tougher and purer, or less clayey, portions.

Taking into account the poorness of the ore, and the facts that there is no considerable supply of limestone within 60 miles (unless in the unexplored country of Nepál to the westward), and that the Dárjíling coal, if practically workable, will certainly be more expensive at the mines than Ránígaṇj coal at the pit's mouth; also that wood is already growing scarcer and dearer in the hills west of the Tísta, owing to the demand for tea-making, there is little reason to suppose that iron works could ever be profitably established at Lohárgarh. In other parts of the country, more centrally situated, cheap coal and good ore are found together.

Síkbhar.

A valuable bed of iron-ore was discovered four years ago, about a mile east-south-east of Síkbhar. It is two or three hundred feet above the bed of the Rer, and some three thousand feet above the sea. It has, as yet, only been worked at two spots, about two hundred yards apart. The section at the eastern digging includes actinolite rock, with some quartz- and talc-schist containing octahedrons of magnetite; this is covered by the band

Copper.

The method of copper-mining adopted in Dárjíling is very similar to that generally pursued in India in most native mining operations. The mines greatly resemble magnified rabbit-holes; meandering passages are excavated with little or no system; and although some precaution is taken to support the roof in the more shaky places by timber props, the number of galleries fallen in show how inefficiently this is done.

Method of mining.

The passages average about a yard in height and width; but where the rock has not yielded a paying proportion of ore, they are contracted to a size barely sufficient to admit a man's body. Access to the interior of the mines, therefore, is gained by crawling on 'all fours,' and in the narrowest parts, by lying flat on the face and progressing after the manner of serpents. As a natural consequence of such a primitive system, the excavations cannot be carried beyond a very trifling depth, as compared to European mines; although taking the actual risks incurred into count, and imaginary dangers, which the stillness and darkness within the bowels of the earth are not calculated to dispel from the minds of a simple, superstitious race, no little courage is shown by the miners in excavating as far as they often do.

The tools generally used are an iron hammer and a round pointed chisel, which is held by a strip of split bamboo twisted round it. Small picks are also sometimes employed.* The lights used are thin strips of dry bamboo, a bundle of which the miners take to work with them; they say that the smoke is less irritating to the eyes than that from other kinds of wood. They are, I believe, all Nepális: the Lepchas never engage in such occupations.

The ore, which is copper pyrites, is brought from the mines in small bamboo baskets of an elongated form, so as to be readily taken along the narrow passages.

Dressing of the ore.

* Illustrations of these tools and of the smelting furnace are given in Percy's Metallurgy (Vol. I, p. 388). Mr. Blanford mentions that in the Mahánaddi mine, the rock was loosened by lighting fires against it.

After a preliminary breaking-up of the larger pieces and rejection of the refuse, the picked ore is broken up small on flat stones, with hammers formed of suitably-shaped pieces of quartzite, or other hard rock, tied into forked sticks. Subsequently it is pounded to a coarse powder with heavier hammers of the same kind.

The powder is washed in troughs made of rough planks fixed on the ground, one forming the bottom, which has a slight incline, and the others fixed on edge. In form and size the troughs resemble small coffins, but the top and lower end are open. A small stream of water flows though, which is regulated in quantity by a dam of clay at the upper end. A hollow is made in the dam to allow a sufficient stream to flow into the trough, while the surplus water runs off by another channel. The ore is continually agitated by hand, or with a small basket-work shovel, and moved towards the upper end of the trough, by which means the larger fragments of copper pyrites, and of mundic if the ore be contaminated with it, are collected there, and the lighter residue carried lower down. This residue, which still contains some ore, is ground in hand-mills similar to those used in India for grinding corn, with grinding surfaces formed of slabs of gneiss. It is then re-washed in the same way as before, and the same operations sometimes repeated on the residue. The ore from the different washings is mixed together, and is ready for smelting. Most of the dressing operations are done by women.

Smelting.

The smelting-furnace is generally built with some neatness, of refractory clay; but in its ruder form consists merely of a hole dug in the ground, with a low clay rim along the sides and front, and a higher one, or a flat stone, at the back; the inside is plastered with refractory clay if that of the ground itself be not sufficiently infusible. The furnace is about 18 inches deep, a foot square at the top, and tapering a good deal towards the bottom. When it is dry, small charcoal is filled in to a depth of about a foot, and beaten down by a wooden rammer till a saucer-shaped floor of coarsely powdered charcoal is formed, sufficiently compact to prevent the products of the smeltings sinking into it. These protect it from the blast, and it is besides too compact to burn easily. There is no orifice in the lower part of the furnace. Two clay tuyeres dip nearly vertically about 3 inches into it from the top, and are respectively connected with skin bellows by horizontal tubes about a yard long. The tubes are formed of clay mixed with chopped straw, and are moulded on a straight stick, which is subsequently withdrawn.

The furnace thus prepared is lighted up with charcoal and the bellows at each side worked alternately. When at its full heat, the powdered ore is sprinkled in at short intervals, until a sufficient amount of regulus, or 'cheku' as it is called by the smelters, has collected at the bottom of the furnace, covered by the lighter slag. The charcoal is then raked away, and the surface of the slag cooled with a whisp of wet straw tied to a stick. The solidified cake is removed and the fresh surface cooled; in this way the slag is taken off in two or three successive cakes, leaving the heavier and more perfectly fluid regulus behind, which is afterwards cooled and extracted.

The regulus (which contains some metallic copper disseminated through it, especially in the form of filiform crystals lining the cavities of the vesicular mass) is pounded and ground, mixed with an equal amount of cow-dung, and made into balls about the size of oranges. After drying, a quantity of these are spread on a layer of charcoal in a place surrounded by stones, and covered by more charcoal. The whole is then ignited, and the regulus thus roasted with free access of air. The roasted balls are subsequently crumbled down and ground, and the powder sprinkled into the furnace in the same way as the original ore. The slag, when the operation is finished, is cooled and removed in cakes, leaving a fluid mass of metallic copper at the bottom of the furnace. The copper is sold in this state at the rate of Rs. 2-8 per three sírs, which is equal to about 10*d.* a pound. It is still vesicular and brittle, and is re-fused before being wrought into manufactured articles, the refined copper amounting, it is said, to 13 chatáks per sír ($\frac{13}{16}$ths) of the crude.*

Mode of occurrence of the ore.

Altogether there are over a dozen localities in the Dárjíling territory and the Western Duárs where indications of copper have been observed. The examination of these leads to some important generalizations. *1st.*—With the exception of some copper near Baxa in the rocks of the Baxa Series, all the known copper-bearing localities are in the Dáling beds. Some are, it is true, situated in the transition rocks between the Dálings and the gneiss, but none in the genuine gneiss itself. *2nd.*—The ore in all is copper pyrites, often accompanied by mundic. Sulphate, carbonate and oxide of copper are frequent as results of alteration of the pyrites, but they occur merely in traces. *3rd.*—The ore occurs disseminated through the slates and schists themselves and not in true lodes.†

Copper localities. Pankabári.

Mr. Piddington describes specimens of hornblende rock containing iron pyrites with a trace of copper from the neighbourhood of Pankabári.‡ I obtained a lump of clay-slate containing similar pyrites from the bed of the Bissarbatti stream.

Ráni Hát (1).

In the bank of the Ráni naddi, rather more than a mile above Ráni Hát, a couple of trial excavations have been made about twenty yards apart. One is in quartz-schist, dipping north 15° west at 40°, through two or three layers of which, of

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Bisman, the lessee of the Mangphu copper mine on the Tísta, informed me that the yield from the various operations at his mine were about as follows:—1 mán (maund) of picked ore yields 6 or 7 sírs of washed ore; 7 sírs of washed ore yields 4 of regulus; 4 sírs of regulus yields 1$\frac{3}{4}$ sírs of copper, or about 3$\frac{3}{4}$ to 4$\frac{1}{2}$ per cent. of copper from the picked ore. Eight or 9 sírs of regulus are obtained at one operation in about six hours, and 3 or 4 sirs of copper in about three hours. These figures are not altogether reliable.

† Mr. Taylor, a practical miner who examined a mine in the Mahánaddi valley when it was at work, and whose report thereon is given in the appendix, speaks of the 'lode' there. I believe, however, he must have used the word merely to express a metalliferous band of rock, without reference to its mode of origin.

‡ Journal, Asiatic Society, Bengal, Vol. XXIII, p. 479.

half an inch or an inch in thickness, iron pyrites with a trace of copper is disseminated. The other is in hornblende schist, and the pyrites here is even less plentiful than in the first. The excavations were not sufficiently promising to induce the miners to continue them beyond a few feet.

Ráni Hát (2).

About half a mile to the east of the above locality, and perhaps in the same stratum, copper has been worked rather extensively. The spot is a mile north of, and 1,100 feet above Ráni Hát, near the head of the Chochi stream. The rock is quartz with some hornblende-schist dipping north at about 35°. The copper-bearing stratum averages about 18 inches in thickness. Here and there throughout it copper pyrites is disseminated in little layers parallel to the bedding. These layers are not solid ore, but throughout them the pyrites is more or less thickly disseminated, while elsewhere in the cupriferous stratum the ore is absent or only visible in specks.

There are six galleries now visible, the roof in five of which has fallen in within 30 feet or less from the mouth. The remaining passage is still open, and extends to a length of over 90 feet. It, like all the others as far as they are open to inspection, is driven from end to end through the same stratum; and thus, as the passages run more or less nearly with the dip of the beds, they descend at an angle of about 35°. Although there had been an inch of rain a day or two before my visit the mine was quite dry. As the hill-side here is very steep, and the mine is near the watershed between two watercourses, there is naturally but little water to drain in. The mine was worked for a month or two last year, but is now abandoned for the time being.

Mahánaddi.

There is an old mine several hundred feet above the Mahánaddi on the west side, near the mouth of the Baffupáni, which has been deserted for many years, and all the openings have fallen in, so that very little can now be seen. The gangue is hornblende-schist with quartz- and chlorite-schist dipping north 40°

west at from 30° to 40°. The main cupriferous stratum seems to be about 2 feet thick, throughout which the ore, with mundic and traces of blende, is disseminated, as in the Ráni mine, in little strings or clustered particles and in specks. Several openings have been made into this stratum; and 6 or 8 feet above it, where the rock is also slightly cupriferous, there is a trial opening, which, however, was not carried beyond a yard or two.

It will be observed that the last three copper-bearing localities are situated a little south of the gneiss in the transition beds between it and the Dálings, and that the rock is all quartzose hornblende-schist, on the same horizon. It is not improbable that all belong to one cupriferous stratum extending at least from north of Ráni Hát to the Mahánaddi, and it is along this line that any further search for copper in the neighbourhood should be made.

No one with me in the field knew of any mine in the Mahánaddi valley but the above. It would appear, however, from Mr. Taylor's report, given in the appendix, that more than one mine was worked there some twenty years ago. The mine he examined was probably different from the above, as he says the 'lode' dips north at 30°; it was very probably in the same stratum however, as his description agrees closely with my observations in other respects.

Mr. H. F. Blanford also visited one of these mines about the same time as Mr. Taylor; he describes the cupriferous stratum as small, and the ore as very poor with a large admixture of mundic.*

Mangwa.

Mr. Piddington mentions iron pyrites with a trace of copper from Mangwa, a village near the next mentioned locality,† but no mine appears to have ever existed there.

* Percy's Metallurgy, Vol. I, p. 388.

† Journal, Asiatic Society, Bengal, Vol. XXIII, p. 479.

Pashok.

The principal Pashok mine is on the hill-side above the Rangiák stream. It was worked in Dr. Campbell's time by a man named Rájman, who is said to have lost heavily by it; afterwards by Bhotu, and lastly by another Rájman, by whom it was abandoned three years ago after the discovery of the Mangphu mine. The cupriferous stratum is quartzose hornblende-schist, dipping south-west at 15°, through which the ore, with mundic, is very sparsely disseminated. Mr. Piddington's assay of a sample from this locality yielded only 1¾ per cent. of copper.* There is another older mine, close to the bank of the Rangiák, which has entirely fallen in.

The Pashok and Mangwa copper localities appear to be on the same horizon as the Mahánaddi and Ráni Hát.

Rangbong naddi.

Copper is said to have been recently found near the head of the Rangbong, west of Pashok, but I did not hear of it until after I had left the neighbourhood.

Rattu.

The Rattu mine is in Independent Sikkim, but I visited it as it was being worked at the time. The rock is grey clay-slate with interbanded lenticular layers of quartz, through both of which the ore occurs, but chiefly in the latter. The strata dip at high angles, and vertically, with an irregular strike from north-east—south-west to north—south. The mine is in a ravine which runs nearly parallel to the direction of the strike, so that the entrances cut across the bedding, but inside there are also drifts ramifying parallel to it. The mine is extremely wet, with rivulets of water running down some of the passages. The men are therefore unable to sink below the level of the stream outside into which the water drains.

The ore here is the best I have seen, and occurs in considerable quantity, as evidenced by the extent of the excavations. Several heaps of good picked ore, very free from mundic, were lying about; a care-

* Journal, Asiatic Society, Bengal, Vol. XXIII, p. 477.

fully selected average sample contained 9·1 per cent. of copper. A sample taken from a heap of pounded ore ready for washing gave 7·8 per cent. when assayed by Mr. Tween.

Kálingpung.

The mine about two miles north-east of Kálingpung is in wrinkled and wavy clay-slate dipping south-east at 60°, and containing irregular, more or less lenticular little seams of quartz parallel to the bedding, and interbanded layers of very hard and tough light grey quartzite. It is in this rock and in the quartz seams that the ore (with a little magnetic pyrites) mainly occurs, although a little is also visible in the slate itself. The proportion, even in the quartzite, is very small. The mine was worked a couple of years ago, but was given up on account of the hardness of the rock. There are two openings near each other, the larger of which extends about 40 feet along the strike of the beds, with a maximum depth of 10 or 12 feet.

Re Ung.

About a quarter of a mile above the mouth of the Re Ung a trial drift has been made some 20 feet above the bed of the stream. The rock, which is clay-slate with interbanded layers of quartzite, dipping north 30° east at 40°, contains copper pyrites disseminated through it, but in such small quantity that the drift was abandoned after a few feet of progress. This station is nearly on the same horizon as the Mangphu cupriferous beds.

Mangphu.

The Mangphu copper mine on the Tísta is the only one in Dárjíling territory that is worked at present. It was, as I was informed, first opened about four years ago, and it has the reputation of being the best mine in the district. The lessee last year was a Nepálí named Bisman; his lease expired on the 15th of November, and had not been renewed at the time of my visit in January, so that mining was temporarily suspended, and the men were engaged in smelting the small remainder of ore on hand.

The mines are on the hill-side on the left bank of the Tísta. The latest worked, which are said to have been the most productive, are about 500 feet above the river. The rock is a light green and greenish-grey clay-slate containing irregular layers of a grey fine-grained slaty sandstone, and dipping north to north-east at from 30° to 40°. The ore, with which there is little or no mundic, occurs in both varieties of rock. Throughout the entire thickness cut through in the galleries (some 3 feet), cupriferous layers occur here and there, while in the intervals the ore only occurs very sparingly or in specks. The lenticular cupriferous layers, which are parallel to the bedding, vary in thickness up to several inches, or even occasionally, as Bisman told me, up to a foot. Throughout these the ore is more or less abundantly disseminated, and little nests or short irregular layers of the pure mineral sometimes occur as much as half an inch, or an inch thick. The main passages descend with the dip of the beds from the out-crop, the deepest being 46 feet in length. There are three others close to this, one of which has fallen in. They were perfectly dry in January.

Five feet below these galleries there is an abandoned trial opening, and another about 100 feet higher up, from both of which copper in small, but not paying, quantity was obtained. Seven hundred feet above the river there are several openings throughout a thickness of 20 or 30 feet of strata, which have been abandoned, and nearly all of which have fallen in. It appears then that throughout a thickness of at least 200 feet, these slaty rocks contain cupriferous bands at intervals, and that a few of these are moderately productive. But out of fifteen or sixteen galleries opened, the majority have been abandoned and allowed to fall in. Bisman informed me that only three had paid. As lessee of the mines, however, he would not be likely to unduly magnify their value, and it is possible that some of the abandoned galleries were given up from their having been driven as far as the miners thought it safe to go. If the information Bisman gave me be correct, the average yield of copper from the picked ore is about 4 per cent. He told me he had made 72 máns of copper (of 40 paka sírs) during his year's tenure of the mine.

Sampthar.

In a lateral ravine which joins the Lesu south of Sampthar, some indications of copper have been exposed by a landslip, and the out-crop was cleared for my inspection. The rock is clay-slate, with occasional lenticular layers of quartz, in which most of the copper pyrites, associated with mundic, occurs. These layers contain a considerable proportion of ore, but there were only two or three of them exposed, varying in thickness from 2 inches downwards. The dip of the beds is west 20° north at 30°.

Ravine west of Chel river.

Four years ago a small quantity of ore was extracted from a ravine west of the Chel by the same men who worked the next-mentioned mine. The slates here dip north at 40°; and Arjun described the seam as only 1 or 2 inches thick.

Chel river.

This mine, the mouth of which is on a level with the stream, is now completely filled with stones and water, so that nothing can be seen, except that it is driven into clay-slate dipping east of north at 30°. It is on the western bank of the Chel at a point where the river, which flows in two channels above, again joins into one. Arjun, a Nepálí, who was sent to show me the place, and who had worked in the mine, told me that the locality was indicated to him and others who were searching for copper about four years ago by some fishermen on the Chel, who had observed what they thought looked like ore. After much labor the miners succeeded in turning all the water to the eastern side of the channel, thus leaving the western bank dry. The mine was carried to some 20 feet from the surface, following the dip of the beds, the seam varying from about 4 inches to a foot in thickness, and Arjun described it as having been solid ore with little or no gangue (?). Twenty máns of copper was smelted during four months' work. The hot-weather had then set in, and seven men died of fever. Jangbir, the lessee of the mine, who had gone towards Dárjíling to sell the copper, also died, and hence the mine was abandoned. The seam, however, still maintained its full thickness, but its value is greatly diminished by its position. There is no high ground near, so that it must be worked below the level of the stream, and in such slates the influx of water would undoubtedly be very great.

Chamurchí.

Copper is said to exist near Chamurchí in Bhután, and several years ago, as I was told by the headman of the place, some Nepálís made a commencement of working it, but were driven away by sickness. The headman did not know the exact locality, but said it was a short way up the river from his village. I found a piece of quartzite in the bed of the stream containing copper and iron pyrites disseminated through it.

Baxa.

About half a mile west of Baxa there is a spot on the hill-side where copper has been found, but not worked. The rock is greenish slate with quartzose layers, the latter especially containing mundic with some copper pyrites, and the surface débris at the spot is cemented into a gossany breccia. The proportion of mundic is greater than that of ore.

Mr. Beckett, when Deputy Commissioner of Jalpigori, gave permission to some Nepálís to work copper ore near Baxa, but I have no information as to whether they actually did so.

Summary of copper localities.

The localities in British Territory where copper is known to exist may be grouped thus :—

Mine now worked	Mangphu.
Mines abandoned, but still partially open ...	Ráni Hát. Pashok (1). Kálingpung.
Mines abandoned and wholly fallen in or choked up	Mahánaddi, Pashok (2). Ravine west of Chel river. Chel river.
Localities where trial openings have been made and abandoned	Pankabári. Ráni Hát. Mangwa. Re Ung.
Localities recently discovered and not yet tried beyond merely clearing the outcrop	Rangbong. Sampthar. Baxa.

It appears then that out of the above fourteen localities four have been tried by the native miners, but have not been considered sufficiently promising to induce them to go on. Of the mines now wholly fallen in or choked, Arjun spoke of that west of the Chel as very poor and unimportant, but he described the seam in the Chel itself as decidedly rich, compared to most of the others. I cannot say what degree of reliance can be placed on his account. Mr. Taylor describes the 'lode' he reported on in the Mahánaddi valley as 2½ feet thick, and estimates the yield "in places" at 12 to 16 per cent. of ore, which is equal to 4 to 5½ per cent. of copper. Mr. Blanford describes the ore from this or a neighbouring mine as very poor, with a large admixture of mundic. My own opinion of the mine near the mouth of the Buffapáni, judging from the little still visible, was not more favorable.

The proportion of ore now apparent in the Ráni Hát and Pashok mines is very small, but this cannot be considered a fair criterion of their value, as the miners would not be likely to abandon them if there were any tempting layers of ore exposed at the time. The same seam probably varies much in productiveness, and a mine would most probably be abandoned when the seam was least productive, although the percentage of ore might again increase if the work were carried on further. No very reliable opinion can therefore be formed as to the value of these mines in their present state, but there seems no reason to suppose that they were ever more than fairly productive to the native miners, if even always that. I think the Ráni is the better of the two. Mr. Piddington's assay of ore from the Pashok mine gave only 1¾ per cent. of copper. The proportion of ore at Kálingpung is about equal to that at Ráni Hát, but the rock is extremely hard and tough.

Work at the Mangphu mine had been suspended for a couple of months at the time I visited it, and the only ore yet unsmelted was some which had been powdered, and left uncovered exposed to the wash of the rain. I was therefore unable to get any average samples from considerable heaps. The proportion of ore, however, exposed in the newest galleries was considerably greater than in any of the deserted mines, but several galleries and trial drifts had been abandoned. According to Bisman, the lessee, the average yield of copper from the picked ore is about $3\frac{3}{4}$ to $4\frac{1}{2}$ per cent. This is equal to poor Cornish picked ore.

The Rattu mine in Independent Sikkim is, as I have said, the best I have seen, the picked ore there containing 8 or 9 per cent. of copper, which is slightly above the average yield of Cornish ore.

The exposure of the outcrops did not lead me to suppose that the Sampthar and Baxa seams would turn out above the average of those elsewhere.

It appears then that the best seams are fairly productive, while the working of others does not seem to have much more than covered expenses, and some have resulted in a loss. The miners have not a thriving look about them, and the number of deserted mines is in itself suggestive that copper smelting in the Dárjíling hills is not a very lucrative employment.

Conditions not encouraging to European enterprise.

The prospect cannot be considered very encouraging towards any attempt to work these mines systematically. No doubt the native miners make a living out of them, barbarous as their way of mining is. The chief disadvantages of that system, however, lie in the injury to the seam and the wastefulness by which the greater part of it is left behind in the mine, while the latter can only be carried to a trifling depth from the surface. The system is perhaps not greatly more expensive with regard to what ore *is* obtained than a more civilized method of procedure, as long as the mines are shallow. The miners may locate themselves at some likely-looking spot and make a profit if they gain sufficient ore to smelt a few mans of copper. If a venture does not turn out well, or when a locality is beginning not to pay, they have merely to pack up their skin bellows and a few tools and remove elsewhere, leaving behind them the remains of their clay furnaces and a few huts made of branches.

Lodes equal to the better Dárjíling seams would no doubt be sufficiently attractive in Cornwall to tempt speculation; but the conditions in an old mining country, where the requisite *personnel* and *materiel* are both at hand, can scarcely be compared to those in the Himalaya mountains. Metal mining under the most favorable circumstances must always be a speculative undertaking, as the rapid fluctuations in the value of mining shares and the long lists of non-dividend-paying mines in England abundantly shows. It cannot be asserted that an attempt to work some of the Dárjíling seams must end in loss, but the conditions are not such that one can feel very sanguine of success.

If any such attempt should be made, it ought to be confined at first exclusively to mining, and no expense incurred in preparations for dressing and smelting until it has been shown that there is a prospect of the mine yielding a fair return.* The ore brought to grass meantime could be dressed in the native method, and sold to the native smelters, or sent to England, if it should be found advisable in the end to give up the project. It would, of course, be absolutely necessary that the work should be put under the superintendence of a skilled European miner. The workability or otherwise of the Damúda coal will have important influence on the expense of copper-*smelting* in the Dárjíling hills.

Leases.

I do not think the natives can be easily induced to adopt a better system of mining. It is that which they and their fathers before them have always practised; they have no one to teach them a better, nor capital, or perhaps inclination, to adopt it if they were taught. One step, however, in this direction might, I believe, be taken—by granting longer leases of the mines. The present system is to put up the leases to auction yearly; one which must foster a hand-to-mouth mode of working, as the lessee's interest is to get as much as possible out of the mine at the time, careless of what becomes of it afterwards. If he were sure of possession for a term of years, it would be more worth his while to attempt some degree of system. No doubt he can always retain possession by bidding highest, but he has no guarantee that the bidding may not go above the real value of the mine. I think that if permission were given to work any of the deserted mines free for a year, so as to allow the miners fairly to test their value, and after that leases were granted for a term of years by tender or auction, men would be found willing to reopen some of them.

Lead.

I have no information of lead having ever been worked anywhere in the present area. I observed, however, an indication of the metal in the Sakkam river, in the shape of a boulder composed of garnet and hornblende, containing some galena, with pyrites and magnetite disseminated through it. The boulder, of course, was washed from the upper part of the stream.

Chapter VIII.—*Lime—Building stone—Slate—Clay—Steatite—Salt-licks.*

Lime.

There are three sources from which lime is procurable in the area under discussion, namely, from the dolomite of the Baxa series, from the impure limestone beds of the Tertiaries, and from calcareous tufa. It is the last rock only that is, or, I believe, ever has been, burned for lime.

Dolomite.

Mr. Tween's analyses of the dolomite from the Títí naddi are as follows :—

	Light grey saccharoid.	White, almost crypto-crystalline.
Carbonate of lime	59·7 ...	60·5
„ „ magnesia	37·8 ...	38·7
Oxide of iron and alumina ...	1·0 ...	} ·3
Insoluble	·8 ...	
	99·3 ...	99·5

The rock, therefore, contains an excess of lime over that in normal dolomite, and is almost quite free from impurity. A high range of hills is entirely formed of it, so that the supply is inexhaustible; but the dolomite hills west of the Tursa are just beyond the British boundary in Bhután, the authorities of which would no doubt demand a royalty for working the mineral. For the supply of Jalpigori the most advantageous locality is a ravine a little east of the Rekti naddi (north of the 21st boundary mark). The rock in the lower part is black slate, above which is dolomite, forming a naked precipice at the head of the ravine, from which numberless large and small blocks are washed down every rains, so that there is no necessity to quarry. A considerable quantity of gravel, and small lumps of a convenient size for burning, is washed across the frontier.

The dolomite east of Baxa is within the British boundary.

Tertiary limestone.

The clunch beds of the Náhan group are very frequently more or less calcareous. Sometimes the calcareous matter is segregated into nodules, and these even pass into short irregular beds of impure grey or yellowish limestone. Mr. Dejoux, Executive Engineer in charge of the Sealdah experimental cement works, has kindly analysed some rock of this kind from the Chirankhola naddi with the following result:—

Carbonate of lime	68·7
" " magnesia	1·7
Oxide of iron and alumina	1·3
Clay	27·4
Sand	·6
Loss	·3
	100·0

Mr. Dejoux is of opinion that the stone would yield a kind of natural cement, more especially a kind containing rather more clay than the above. The beds, however, are thin, not very frequent, and irregularly scattered through the clunch, so that no quarries, beyond perhaps some small pits, could be opened. Considerable quantities of calcareous boulders are washed down by some of the streams, but they vary in composition from a rock like the above, containing 70 per cent. or so of carbonate of lime, to a merely calcareous clunch, so that it would be difficult to obtain a stone for cement purposes having a uniform composition. A rough approximation to the composition can be gleaned from the fracture, which is rough and uneven in the calcareous clunch; both becomes finer as the proportion of lime increases, until in a rock like that of which the analysis is given it is smooth and conchoidal.

One or two of the thickest beds of limestone have been marked on the map; but even these do not exceed a few feet.

Calcareous tufa.

The lime used in the Dárjíling district is derived entirely from calcareous tufa. In the Rumtek naddi, where a quarry is at present worked by a Lepcha, I had an opportunity of observing the way in which it is burned.

The kilns, which are over 15 feet in internal diameter, consist each of a circular wall about 10 feet high and 2 feet thick, built of flattish stones from the bed of the adjacent stream. The interstices on the inside are luted with clay, and at the bottom at opposite sides are two orifices, about 3 feet high by 2 feet broad, for the admission of air, and from one of which the lime is withdrawn. There is a rough shed close to the orifice, under which the lime is stored.

The kiln is filled to within 2 feet of the top with logs of wood, and then the tufa, in pieces averaging 2 to 4 inches long, is thrown in and piled up into a low cone, the edge of which is on a level with the top of the wall, and the apex some feet above it. After being lighted, the kiln burns for about a week, and when tolerably cool, the lime is extracted from below and slaked with water, in which state it is sold. The uppermost part of the heap of tufa, which is exposed to the air, and which merely acts as a blanket to keep that nearer the fire hot, is scarcely burned at all, and is returned to the kiln at the next firing. The system of adding the fuel and limestone in alternate layers, and keeping the kiln continuously fed, seems to be unknown. I was told that the average yield per kiln at one operation is about 300 máns, and that the sub-contractor who burns the lime receives 8 annas a mán for it on the spot from the lessee of the quarry. The actual cost of lime-burning in the Dárjíling district (including quarrying the tufa, cutting wood, &c.,) seems to be about 6 annas à mán, but owing to the expense of carriage it was selling this year at Pankabári at Rs. 3 a mán and at Jallapahár at Rs. 2-6. The lime in the latter case came from a place in Sikkim, some miles across the boundary, at an elevation of 3,500 or 4,000 feet. From thence it had to be carried to over 7,000 feet at Jallapahár across the valley of the Rammán, where the elevation is only 1,600 feet.

The tufa is always nearly pure carbonate of lime, even when the rock from which it is derived is dolomite. Thus analyses of that from the Títí naddi gave the following results :—

	Ordinary porous tufa.	Crystalline tufa.
Carbonate of lime	98·10	98·50
„ „ magnesia	1·30	1·50
Oxide of iron, alumina, and insoluble matter...	·80	·06
	100·20	100·06

Both carbonates of the dolomite are converted into bicarbonates and dissolved by water holding carbonic acid in solution ; but the bicarbonate of lime being the less stable compound is decomposed first, with deposition of tufa, while the bicarbonate of magnesia is carried off in the water.

The tufa is nearly always porous, the crystalline variety being rare. There is a peculiar species of moss often seen growing on it, which the natives assert turns into, and is in fact the origin of, the tufa. I observed what probably gives rise to this idea in the ravine above mentioned east of the Rehti naddi. The water of the stream is so charged with calcareous matter that the dead leaves and twigs in the bed are thickly encrusted with it. Deposits of tufa have been formed at every little cascade, on which the moss grows out more or less horizontally, and along the sprays which point downwards the water trickles from root to apex and then drips off. Thus little stalactites are formed, each of which encloses a spray of moss in the centre, and which gradually encroaches on the root; while the plant keeps pace in its growth at the other end, and crowns each stalactite with a living rosette.

The calcareous matter forming these deposits is derived from various sources; from the dolomite of the Baxas, the calcareous clunches and impure limestones of the Tertiaries, the calcareous sandstones of the Damúdas, and the occasional calcareous bands in the Dáling beds.

Tufa in Western Duárs.

As might be expected, the largest masses are found along the base of the dolomite hills; where there is what I believe may be considered, an inexhaustible supply of lime from this source, independent of the dolomite itself. At the Bandapáni waterfall (within the British boundary), where there is a series of rapids and cascades of perhaps 50 feet, the stream flows continuously on a tufa for at least two or three hundred yards, the thickness of the deposit, where seen at the lower end, being 7 or 8 feet. There is a thick deposit near the 20th boundary mark, which cements the talus at the foot of the hill into a coarse breccia. Close to the Tursa river there are masses of tufa at the foot of the hills, forming cliffs 30 feet high; and there are numerous masses where the Jángti naddi cuts through the dolomite. These are some of the localities in which I have observed deposits of the kind, but they are no doubt to be found in almost every ravine and watercourse.

The magnesian and pure lime from the dolomite hills is therefore well worth attention. It might be burned either close to the Tursa (a stream which is navigable for the largest dug-outs to the foot of the hills, and for larger boats to within a few miles of them), and thence taken down to the Bráhmaputra, or in the vicinity of Jainti Hill, east of Baxa. The latter locality is, however, less favorably situated, as it is some miles from the Raidak, which is a smaller stream than the Tursa. When the Northern Bengal Railway is complete, the lime could also be burned at the western end of the range, carted to Jalpigori, and then taken by rail either to the foot of the hills at Sukna, or down country. By one or other of these routes it might compete with the Sylhet lime from Chátak over a considerable part of Lower Bengal, if not in Calcutta itself.

Tufa, derived probably from calcareous Tertiary beds, has been worked in a ravine off the Déma naddi for the supply of Baxa with lime. The deposit has recently, however, been buried by a landslip.

Tufa in Dárjíling district.

The tufa deposits in the Dárjíling district, which are derived, not from large masses of limestone, but from rocks generally containing only a small percentage of calcareous matter, are on a much smaller scale than those in the Duárs. It is from them, however, or from similar deposits in Sikkim that the lime used in the district is procured. Tufaceous masses seem to be more common along the Tertiary-Damúda boundary than elsewhere, probably on account of the issue of springs there.

The following list includes all the localities with which I am acquainted:—

1. West of Pankabári, in a watercourse 500 or 600 feet above the Bálasan, formerly worked, but now exhausted.

2. In the neighbourhood of the cart road, tufa is found in several of the watercourses a few miles from the plains; generally it does not exceed a few inches in thickness, covering the rocks in the beds of the nallas and giving them a rounded appearance as if all solid tufa.* Sometimes there are thicker accumulations. The bed of one steep watercourse I ascended was lined with it for 30 or 40 yards, the tufa hanging down here and there in stalactites. It is derived in this neighbourhood from Tertiary calcareous clunch, and has been worked in several places.

It is generally very difficult to estimate the thickness of a tufa deposit unless a section is exposed by quarrying or natural fracture.

3. At the east side of the Mahánaddi, just north of the Damúda-Dáling boundary, tufa occurs in small quantity.

4. Tufa was formerly worked near the end of the spur at the junction of the Sibakhola and Mahánaddi.

5. A small deposit is said to have been found within the last few months on the hill side a little below the mouth of the Kuhi naddi.

6. Near the head of the Kuhi there is a deposit from which lime has been rather extensively burned within the last year or two.

7. Tufa occurs in small quantity near the head of the Sivok naddi.

8. It is found in considerable quantity in some of the ravines which join the Riyem near the mouth of the latter, but has not been worked as yet. The Tertiary rocks here are more than usually calcareous.

9. It was formerly worked at Pashok, but the locality is now exhausted.

10. Tufa is said to have been lately found near the head of the Rangbong naddi (west of Pashok).

11. There are two abandoned quarries near the head of the Sím naddi (north-east of Takda). The rock from which the tufa has been derived is a calcareous actinolite rock. By following the strike of this, other deposits would no doubt be found.

12. In the Sambúl naddi (west of Damsáng) there is a mass of tufa some 80 feet long and 20 high, with a thickness varying up to 2 feet or so. It was worked some years ago when Major Lance's bangalo at Damsáng was being built. There is a smaller deposit about 150 yards higher up stream.

13. Near the left bank of the Lesu, a little above the Fing or Thaffing naddi, there is a mass of tufa through and over which a spring of water issues. It seems to be more than a foot thick in places.

14. In the Rumtek naddi (a small tributary of the Lesu) tufa was being quarried this year from by far the largest deposit I have seen in the district. Part of it is concealed by surface soil, but the portion visible is about 150 feet long by 30 or 40 broad, with a thickness at the side, where it was being quarried, of 8 feet. A little higher up stream there is smaller deposit, and near the head of the naddi some of the watercourses are lined with tufa.

BUILDING STONE.

There is little demand for other building stone than rubble; which is generally procurable from the rocks nearest at hand: coarse slate from the Dáling beds; gneiss, which usually is easily split into conveniently sized pieces; and, near the foot of the hills, the harder Tertiary beds—are the varieties of stone mostly used for such purposes.

Freestone in blocks of any size could be procured from the Tertiary sandstones; but unless carefully selected its durability would be open to question. There is comparatively little stone from which good ashlar can be obtained in the older formations. The Dáling beds are mainly slaty. Good-sized blocks can be quarried from the gneiss in places, but generally it is too schistose to furnish such. A few of the Damúda beds of sandstone are also capable of being worked.

Slate.

Shortly after my arrival in the district, my attention was directed to a reported discovery of roofing slate. On examination of the locality, however, I found that the slate was in no way superior to that frequently found amongst the Dáling beds elsewhere. From the best slate I have seen, slabs cannot be procured more than a few inches across, with a thickness of a quarter of an inch, and these are too brittle to trim well on the edges. Flagstones, for flooring purposes, could, however, probably be worked in some places.

Clay.

The gneiss decomposes superficially into a light brown, very plastic clay. Both it and the clay resulting from the decomposition of the Dálings are used throughout the Dárjíling district for making bricks. Some of the Dáling slates decompose into a white clay which might be used for pottery. There is a quantity of this material near the right bank of the stream at the debouchure of the Sakkam. I am told that similar stuff is used in Sikkim for whitewashing.

Steatite.

I have already (p. 35) alluded to the steatite found amongst the Baxa beds at the debouchure of the Tursa; which, Major Godwin-Austen states, has been used by the Bhutias for making cups, &c. The locality is across the boundary in Bhután.

Salt-licks.

So-called salt-licks are frequent along the outcrop of the Damúda rocks. They occur chiefly where there are seams of coal interstratified with sandstone, &c., and are resorted to by the wild animals of the jungle for the sake of the saline matter which effloresces to a slight extent on the surface of the beds. The ground is trodden down into a black mud by the feet of deer, rhinoceros, and elephants, the last of which dig out the coal with their tusks to a depth of several feet. The efflorescence is not of common salt, but of sulphate of soda which is probably formed by the oxidation of a trace of pyrites in the coal, and the reaction of the resulting sulphate of iron on soda washed out of the felspar which sometimes forms an ingredient of the sandstones.

APPENDIX.

From Captain H. C. James, *Officiating Superintendent of Darjeeling, to* W. Grey, Esq., *Secretary to the Government of Bengal, Fort William,*—(*No.* 301, *dated the* 23*rd June* 1856.)

The Lieutenant-Governor is, I believe, aware that Mr. Hunt, the Railway Contractor of Mirzapore, stated, when in Calcutta, his willingness to send a practical miner in his employ, to ascertain the value of the copper veins in the vicinity of Darjeeling. Captain Taylor, the miner, arrived here in April, and I at once rendered him every assistance to enable him to visit the copper localities: the pathway to the principal mine was in such a bad state that I had it put in order, and erected a small shed for Captain Taylor to reside in during his stay at the mine.

2. I now beg to enclose Captain Taylor's Report, which, I regret to say, is not of a very favorable character. I have had much conversation with Captain Taylor since his return from the mine, and I learn from him that he does not think there is a chance of any richer ore being met with, unless a "level" is driven from or near the river on to the course of the lode which is now being worked; to do this would, I understand, cost at least two or three thousand rupees, and it is even then uncertain whether richer ore would be found. I presume that it is not the intention of the Government to undertake the working of this vein; we must wait therefore till some one comes forward with more capital than the man who at present rents the mine possesses, before so expensive an experiment can be undertaken.

3. From Captain Taylor's report it appears that only from 12 to 15 per cent. of metal* is obtainable from the ore, and though this quantity does and will pay the natives working in their primitive and inexpensive method, no capitalist would think of laying out money on so unpromising a speculation.

4. Captain Taylor visited some others of the localities at which copper ore has lately been discovered, but he informed me that the indications at the surface were not sufficiently favorable to induce him to make further investigations, and, the rains coming on, he was obliged to leave many places unexplored.

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* Captain Taylor says the lode will yield in places 12 to 16 per cent., and it is clear from his data that he meant that percentage of *ore*, not of copper.—F. R. M.

5. I have lately seen some very rich copper ores from a mine in Nepâl, situated a short distance from this, where in some of the veins the pure metal is found; and as the same range of hills runs through the Darjeeling territory, I feel confident that much richer lodes are to be, and will be, here met with: the very thick jungle is the great impediment to these discoveries, as during the greater part of the year the surface of the ground is invisible owing to the dense foliage which covers it.

6. The balance of the amount of Rs. 180, placed at the disposal of the Superintendent of Darjeeling for the purpose of searching for ores, has been laid out on that account, and I am glad to report that copper ore has been discovered in four other localities. In clearing the jungle around the mine, and in making the road to it passable, I was obliged to expend more money than I then had in hand, and I have now the honor to request that the Lieutenant-Governor will sanction the extra outlay, *viz.*, Rs. 48-10-9. I also beg that I may be allowed to spend Rs. 100 during the ensuing cold weather in making further search for copper ore and coal, and which search I shall be able personally to superintend.

7. I have delayed the transmission of Captain Taylor's report, in the hope that two Assistants in the Geological Survey, the Messrs. Blanford, who are daily expected, would be here and able to give their opinion on the other localities where copper ore has been discovered; but as they have not yet arrived, I have thought it best at once to despatch the report.

8. Considering that this report on the vein now worked is not of a very satisfactory nature, I have to request that the Lieutenant-Governor will allow me to rent it to the present tenant till the 30th April 1857, at the annual sum now paid by him, namely, Rs. 100; for under present circumstances I do not anticipate a higher offer.

From CAPTAIN T. TAYLOR, *to* CAPTAIN H. C. JAMES, *Officiating Superintendent, Darjeeling,—(dated* 12*th May* 1856.*)*

Having during the past month examined the copper works and the neighbouring hills agreeably to your request, I beg to hand a report thereof. These works are situated near the Manunda river and about nine miles from the plains. Only one lode, or vein, is opened and wrought on to any extent; the hill in which this lode is discovered is running at about right angles from the river, and the working is carried on about 500 feet from the base. From the great declivity of the hill I suppose the rains have washed down the superincumbent earth, showing the back or top of the lode in an easterly and westerly direction with a dip or incline or underlay north of 30° from the horizon.

2. This lode is about $2\frac{1}{2}$ feet wide, with well-defined walls imbedded in gneiss or mica-schist. The component parts are chiefly quartz, iron pyrites, prian, blende chlorite, and gossan intermixed throughout with copper pyrites (some of which I

herewith send), which is frequently termed peacock-ore, from the gorgeous play of iridescent hues on the faces, angles, &c. Also, a little carbonate of copper with some spots of black copper ore. At present the lode will yield in places about 1 ton per fathom, and produce from 12 to 16 *per cent.**

3. The extent of these workings is about 80 fathoms in length and 20 fathoms in depth, or "on the course of the incline," at the furthermost point. The men have no regular system of working, but have burrowed in wherever the best spots of ore appeared. The superincumbent earth and rock is supported on props of timber 3 feet high: I never saw such holes before; but the continual sitting on their hams gives the hip and knee joints that suppleness which allows them to work in low places with ease.

4. The character of the lode throughout indicates that good deposits may be found at a greater depth; it much resembles many productive lodes I have seen in Cornwall,† especially the Caradon lodes near Liskeord, with the exception of the underlie, which I attribute to the great declivity of the hill, and no doubt it will be found greater as the works deepen. The average dip or inclination of the Cornish lodes is about 55° or 60° from the horizon; but frequently reckoned from the vertical as 2 or 3 feet in one fathom.

5. I have traced this lode for a considerable distance. At one point about four or five miles *west*, it was formerly worked on to a small extent, and some ore smelted. The matrix is a little harder. The component parts as aforedescribed, producing some good stones of ore, are, I think, of a little richer quality. I have also found three other lodes, only one showing any good indications at the surface, which is about six miles south-east from the present workings: I opened on it a little, and broke some stones containing good copper pyrites; but the immense jungle is the great impediment to making a minute investigation. In visiting the coal locality, which is near the plains on the Manunda river, I found three small veins imbedded in a compact sandstone, two of which are within a space of 40 feet. The river had undermined a large hill causing a portion to fall, thereby showing a section 100 feet in height and length. I do not put much stress on these small beds of coals, but others of importance may exist. The place is densely covered with jungle, but boring may be resorted to during the dry season. Finding coals would be essential for smelting purposes, transporting the ore would be ruinous. The Manunda river is by no means navigable.

6. Their present mode of dressing or cleaning, smelting, &c., is rude in the extreme. The first part of their process is to break or crush down the ore on a large stone, which serves for an anvil, and a stick attached to another stone for a hammer or

---

* Equal to 4 to 5½ per cent. of copper.—F. R. M.

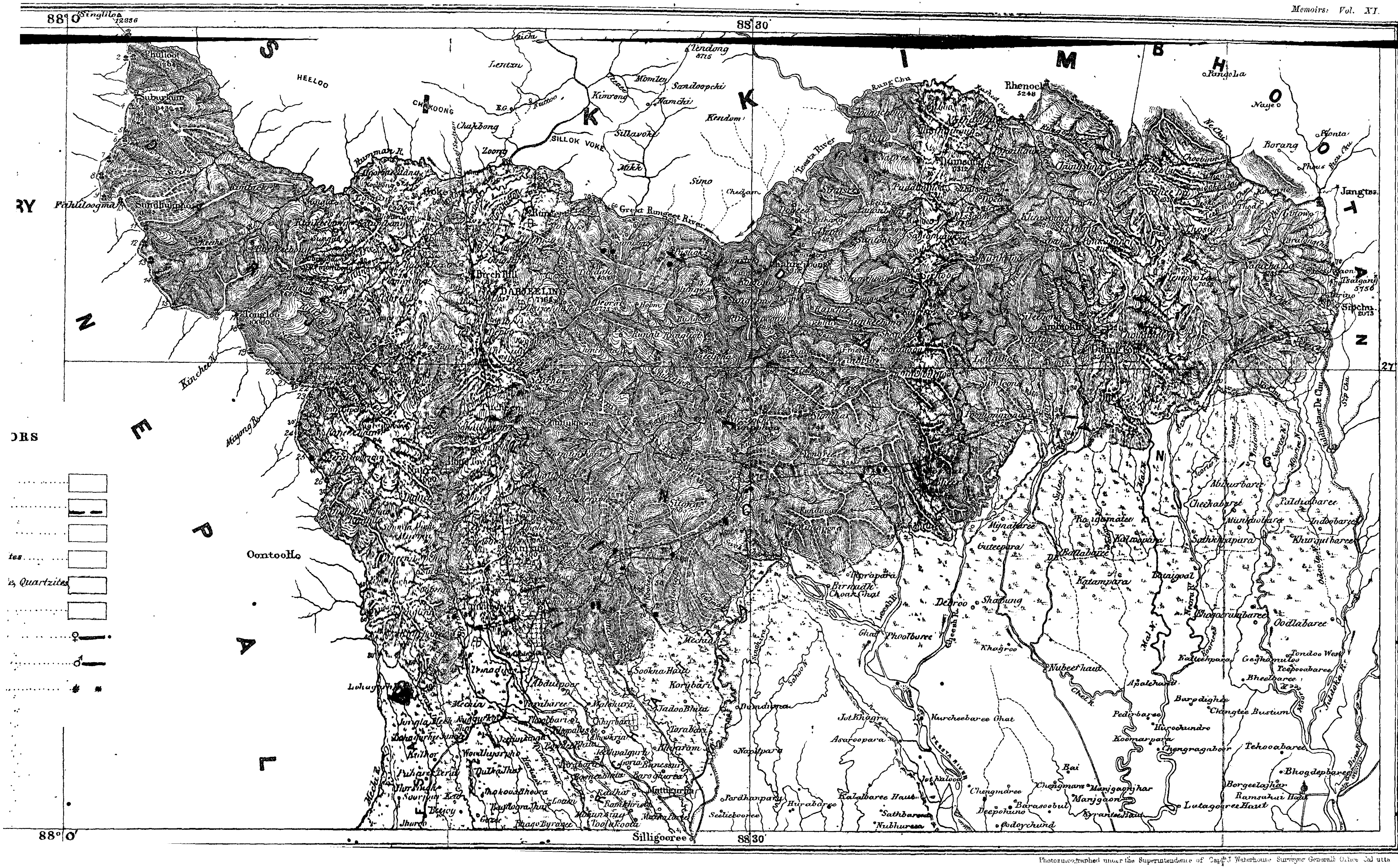
† No trustworthy comparison can be drawn between metalliferous *beds* of rock and true lodes like those in Cornwall.—F. R. M.

sledge. When so reduced that the whole would pass through what we term "a three-hole," or a sieve having nine holes in a square inch, they carry it to a strake, or small incline, made with planks about 8 feet long $1\frac{1}{2}$ feet wide, having two sides and head-boards; and then wash off a great part of the impurities, which constitutes their dressing department. The produce they make of the copper ore is about 10 *per cent.* They then take the cleaned ore and put it with charcoal into a furnace, and two men keep up a continual blast until the whole is melted to a regal or lump.

2ndly.—They bruise down the lump and mix it with cow-dung, then put it in a slow fire for two days; and for refining they again put it in the furnace with more cow-dung and charcoal, and give it a strong heat until the whole is smelted or converted to a fluid, the copper, being the heaviest, settles to the bottom. They work the pure copper into cooking utensils, which they sell at about one rupee per seer.

7. Their mining operations from the first to the last stands open to great improvement, instead of working in the side of the hill as they now are, with the disadvantage of the lode underlaying in the hill, and, if I may be allowed the term, pulling the ore out "by the hair of the head."

I should recommend a level to be driven from or near the river on the course of the lode, which would not only gain a good back or top, but prove to a fair depth the intrinsic worth of the lode. Generally speaking, the copper lodes are found the most productive, from 30 to 70 fathoms below the surface; and, as it cannot be expected that one yellow copper ore lode of 2 or 3 feet wide can yield ore enough to compensate any adventure for the outlay required in India, in fact such instances are rare in England. Therefore I should recommend levels to be driven to intersect other lodes; points for driving could with little difficulty be marked out with bearings during the dry season. As to the machinery required, it would depend greatly on the condition the *ore* would be found in, also whether above or below the adit level; but at all seasons of the year there is ample water power to work all machinery required. A crushing mill from 20 to 24 in *diameter* would be absolutely necessary. If coals can be procured for smelting purposes, charcoal would be of but little moment. I suppose with coals it would take fifteen parts to produce one part metal, allowing the ore to produce 15 *per cent.* Then I should judge from the copper produced and indications of the lode opened, as well as from the general appearance of the neighbouring hills, that such explorations would in time prove the district to be a dividend-paying mining locality.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BHOOTAN
NEPAL
88° 0'
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DARJEELING
Great Rungeet River
Teesta River
Rhenock
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Indoobaree
Chengmaree
Manjgaon
Jalpaigoori
Naxalbaree
Rangamatee
Ballabaree
Katampara
Guteepara
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Sathbaree
Nubhuresa
Deepohuno
Barasoobul
Boyrant Haut
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Ramsuhai Haut
Lohagarh
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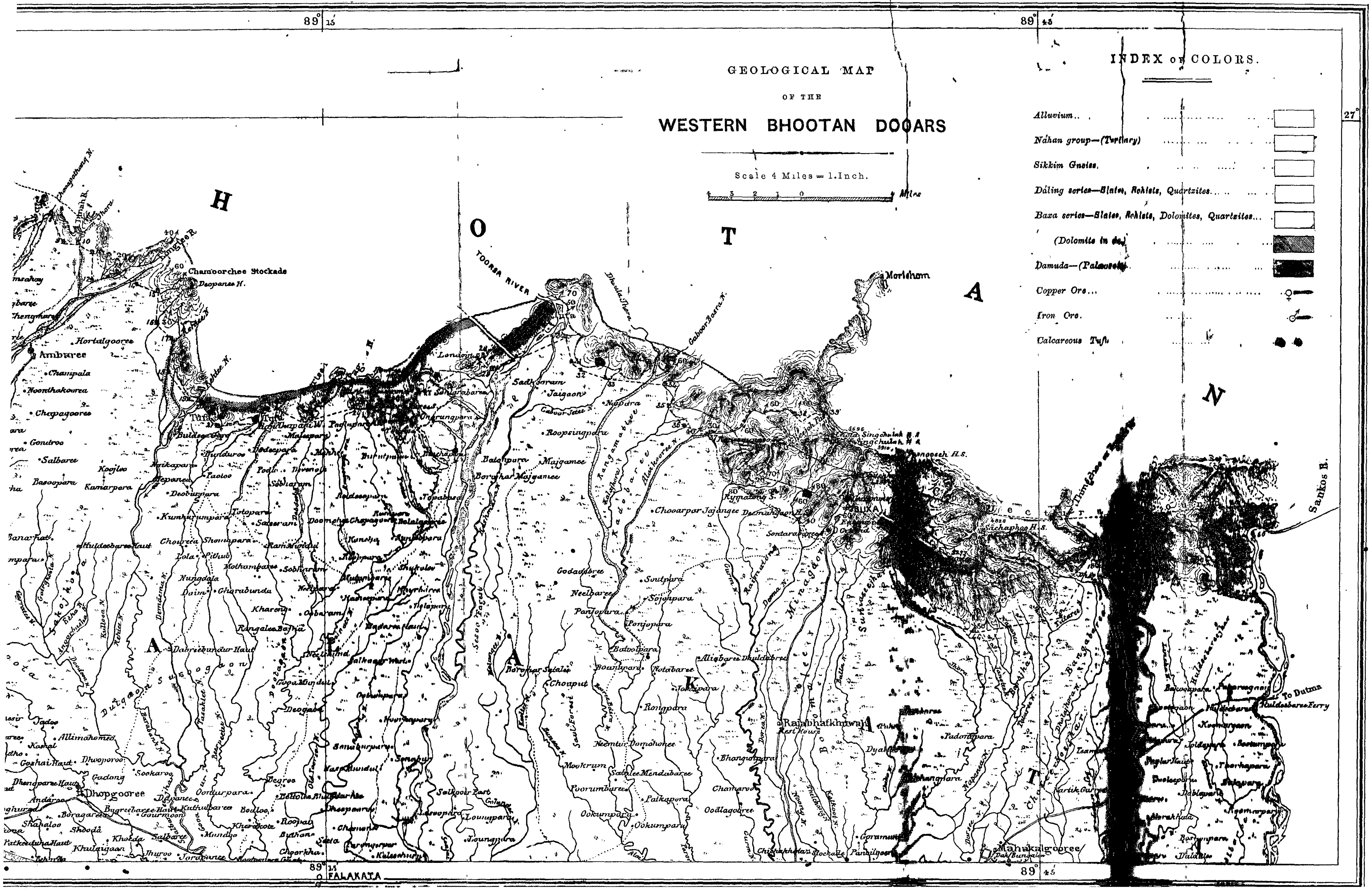
GEOLOGICAL MAP
OF THE
WESTERN BHOOTAN DOOARS
Scale 4 Miles = 1 Inch.
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Daling series—Slates, Schists, Quartzites
Baxa series—Slates, Schists, Dolomites, Quartzites
(Dolomite in do.)
Damuda—(Palæozoic)
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Calcareous Tufa
B H O O T A N
TOORSA RIVER
Chamoorchee Stockade
Morisham
Sankos R.
Rajabhatkhawah
Mahakalgooree
Dhopgooree
Ambaree
FALAKATA
To Dhubri
Huldeebaree Ferry
89° 15
89° 45
27°

RECORDS

OF

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VOLUME XXIII.

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ERRATA.

MEMOIRS OF THE GEOLOGICAL SURVEY OF INDIA, VOL. XXIV, PART 2.

Page 12, 12th line from top, *for* Adatoda *read* Adhatoda.
" " 21st " " " " is *read* are.
" 14, in the marginal section, *for* Nahan. Sandstone *read* Nahan Sandstone.
" 29, 8th line from top, *for* canno *read* cannot.
" 138, 4th line " bottom, *for* quantitive *read* quantitative.
" " " " " " " o *read* of.
" IV of Index, *for* Read *read* Reade.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1890. [November.

Geological sketch *of* Naini Tal; *with some remarks on the* natural conditions *governing* mountain slopes, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.* (With a map and plate.)

PRELIMINARY REMARKS.

Absence of fossiliferous rocks.

The geology of Naini Tal, in its purer scientific aspects, is neither very attractive nor very instructive. The absence of all fossiliferous deposits in the vicinity older than late tertiary makes it impossible to assign to the rocks their absolute geological age, as well as takes away all scope for the fossil-hunter, and all that vivid interest which centres round the petrified remains of an earlier life on the earth: we cannot speak familiarly of a "Carboniferous limestone," nor of "Silurian slates," neither can we wander forth with hammer and chisel to any well-known locality whence a harvest of palæontological specimens may be gathered.

No mineral wealth.

Besides this, there are no mines of economical wealth to be disclosed. There is neither gold in the streams, nor copper nor lead in the limestone: there is a dearth of useful minerals, with a trifling exception, as there is a dearth of fossils.

At first sight, then, it is difficult to imagine what the geologist can find to say of a district so barren and unfruitful; and I must caution the reader at the outset that here will be found no idyllic geological romance. If he wishes to know what is concealed beneath the bright verdure of young mountain grass, dotted with the sombre oak, rhododendron, and cypress, he must sit down to a mental exercise such as chess or a mathematical problem.

General objects of the paper defined.

Nearly every visitor to Naini Tal knows that, roughly speaking, there is a difference between the rock forming each side of the lake; that there is limestone on the rugged Ayarpata side and slate (locally called shale) on the gently sloping Government

House side. A little more inquiry would teach him that this broad distinction is not everywhere carried out. A certain amount of slate will be found associated with the limestone on the south-west side, whilst a few outlying patches of limestone will be found covering the slate on the north-east side. Without going into details here as to certain other variations which occur, I may briefly state that there is a definite geological pattern, more or less concealed at the surface, set out before us as our study, the salient points of which are represented in the geological map of the settlement. It is this pattern—this inlaid-work of different rocks—that we must understand, and if the reader has the patience to accompany me in a few rambles over these hills with other objects than picnicking, I hope at the conclusion to make him as familiar with the mechanism of the earth's crust here, as a watch-maker is familiar with that of a time-piece. He will be able to see faulted boundaries and natural boundaries as clearly portrayed on the surface of the earth as if the hill-sides themselves were painted different colours, and thus he will find that the chaotic rock pattern of the hills is not accidental, but has a real meaning in the growth and development of the mountain area.

In this country, where the lamp of pure science burns feebly, or not at all, there are perhaps but few who on coming to Naini Tal are able to look upon the landscape with a geological eye, but few who see in the surrounding hills and valleys any harmony of composition and structure other than that of a pictorial kind. For the rest, Deopata is one peak and Ayarpata another, whilst the different glens, valleys, and tarns are each themselves and nothing more. All latent bonds of structure and origin, all the hidden processes of constant change that are ever altering the face of the scene, are, I am afraid, as unnoticed to-day as if Sir Charles Lyell had never lived or written his "Principles of Geology." I hope in the following sketch to draw some little attention to this fairly interesting theme: perchance here and there may be found some few disciples of this last-born of the sciences for whom the matter may not be unpalatable.

Coming to the practical question as to what geology has to say regarding the safety and permanence of the station and its communications, I hope to be better understood; though on such a subject one is necessarily tongue-tied to a considerable extent. Ever since the disastrous landslips of 1880, the Naini Tal public has been somewhat agitated as to the probability of further landslips, whilst considerable confusion has been introduced into the subject by small slips having occurred now on this side, and now on that side of the lake, and apparently of slate and limestone irrespectively. Now it would not do for me to blacken a house-holder's prospects by proscribing as dangerous any particular site in Naini Tal. However much I might be able to do so, I should bring a shower of abuse upon myself were I to colour a map of the station shewing all the dangerous localities. And yet there would be very little difficulty in so doing. It is merely a problem involving a few factors such as composition of the rock, its whole or shattered condition, the angle of the hill slope, the angle of dip or cleavage, and the relations these four factors hold to one another.

Nevertheless, I shall later on point out broadly the difference between a safe slope and a dangerous slope; and give a few general principles whereby each resident may be able to see for himself whether his site is safe or not.

GEOLOGY.

Section from Kathgodam to Naini Tal.

Bhábar deposits.

In addressing myself to the geology of Naini Tal—the foundations of the subject so to speak—I think it will be well to describe actual excursions along definite directions in and around Naini Tal. We will begin therefore, as all must who come to this summer resort, with the line of country between Kathgodam, the terminus of the Rohilkund and Kumaon Railway, and Náini Tal. Even before reaching Kathgodam there is much to be learnt regarding the features of the country. We may know by the peculiar labouring of the railway carriages that we are not crossing what looks like a vast plain, but are really ascending an incline of about 50 feet a mile, which is abruptly terminated as we can see from the carriage windows by the long blue and purple line of the Himalaya rising sheer and steeply out of it. This incline, over which the line runs, is known as the Bhábar. It is a very gently sloping deposit of gravels, with occasional sand and clay beds, the outpouring during recent times of the various rivers and streams which drain southwards from the Himalayan range. Year by year as the annual monsoon bursts upon the steep slopes of the hills, more and more detrital material is carried down by the uniting of rills, torrents, streams and rivers, and is deposited at the foot of the hills when the speed of the streams and rivers is slackened by the gentle slope of the country. Perhaps nowhere in the world can we get a better insight into the processes by which geological strata are accumulated than along the mountain-foot of the Himalaya. This elevated belt of Bhábar gravels which girdles the whole length of the southern foot of the Himalaya is the great spoil-bank, the result of the disintegration of the mountains by water action. As we get a nearer view of these mountains, we see great rifts in their sides, that is to say, the gorges and ravines, whence the excavations have been made by the water to supply the gravels of this Bhábar zone. Having once realised this aspect of change and instability in the geological features before us, and seen how the Bhábar zone is enriched with material at the expense of the Himalaya, we shall be in a position to understand what a powerful agent of change denudation is in this elevated mountainous tract subject to about 100 inches of rainfall every year.

But in most cases this denudation, except when viewed in this large way, is almost invisible to us. Nearly all the glens whose mouths open towards the plains are covered densely with a forest of Sál and other trees. Only very seldom do bare hill-sides scored by rainfall and torrents meet our view. One such case is, however, very noticeable, a little east of Kathgodam as we begin the journey up to Naini Tal. A very rapid weathering of the edges of the strata is there taking place so that vegetation can keep no hold on the slope, and undergrowth and forest alike have had to fall. At the base of this wound in the face of the hill, we may see a yearly accumulating detrital fan, which, in a semi-liquid condition, moves during the rains like a glacier over the flatter country to the south, and is a source of much damage to the canals in the vicinity. Other places near Naini Tal where the individual processes of denudation can be studied, especially during the monsoon, will be mentioned in their place in this paper. I here wish merely to draw attention to the act that immense denudation of these Sub-Himalaya takes place, as evinced by the

Bhábar deposits and their ever-changing conditions, without, save in rare cases, leaving palpable traces behind them on the parent hills, whose rounded forms, covered with luxuriant forest, undoubtedly at first sight suggest that rest, strength, and fixity proverbially but erroneously ascribed to all mountains.

It is certainly the case that very much more erosion takes place in these Sub-Himalaya, than in the outer Himalaya, and still more than takes place in the regions of perpetual snow; but the impression on any one visiting these parts is the very reverse. Bare precipices and jagged rock are the rule of course, when the limit of vegetation is passed at about 12,000 feet above the sea, while day and night from different causes the hill-sides resound with the crash of falling blocks as they crumble from tottering pinnacles or charge down the terminal moraine of a melting glacier. This antagonism of impression and fact is not introduced here as a paradox, but rather as an illustration of the magnitude and importance of those generally noiseless and invisible forces—denudation by water action—as compared with the more striking phenomena effected by frost and snow.

With these general remarks on the Bhábar deposits, let us turn our attention to the section before us. A noticeable orographical feature of the Sub-Himalayan rocks on which we first tread is the absence of that subsidiary and distinct range of hills, which commonly first breaks the monotony of the plains, namely, the Siwaliks, and which is characteristically displayed south of the Dehra Dun. As we journey from Kathgodam to Naini Tal, we cross no such range of hills running parallel to a still higher range; nor are there any other well-marked surface features distinguishing the younger tertiary rocks from the older slates and limestone of Naini Tal proper. All is welded into one nearly homogeneous range with secondary spurs running out to the plains. This is an unfortunate accident so far as our section is concerned, from an illustrative point of view, and it will therefore be necessary to diverge in imagination from the line of our section in order to understand the typical aspect of the Sub-Himalayan zone.

Sub-Himalayan rocks:

Away west, along the edge of the hills, in the neighbourhood of Rámnagar and Kálágarh, we first begin to see a longitudinal subsidiary range to which the name Siwalik may be given geologically, though no such name is known to the natives. As soon as this range begins to set in, we see that it is the accompaniment of two younger rock-stages of the Sub-Himalayan system, namely, the Upper Siwalik conglomerate and the middle Siwalik sand-rock stages. As I have written fully on this subject in a memoir just published,[1] I shall only make a passing reference to it here, in order to bring out the connection between the present Bhábar deposits and the older Sub-Himalayan deposits of our section.

The meaning of the word Siwalik—the track of Siva, the destroyer—shews that even by the natives of this country in a former age the aspect of disturbance and contortion visible in the rocks of that range had been vividly apprehended. And this is the first aspect it is necessary to notice here, for in this respect, and in this only, does its geological structure differ from that of the Bhábar zone. At a comparatively late geological time, but before man's appearance on the earth, the Siwalik conglomerate lay flat and undisturbed at the foot of a Himalayan land almost precisely the same

[1] Memoirs G. S of I., Vol. XXIV, pt. 2.

in its general features as that which now exists. The Siwalik conglomerate was then in fact the Bhábar deposits of its day; since which time it has been elevated and marked off from a newer Bhábar that at once began to form, and has acquired those corrugations of its strata in lines parallel to the higher hills, which by superstition were credited to the action of Siva, and by science are recognised as due to the lateral crumpling of the earth's crust.

The Nahan sandstone.

But the section before us, between Kathgodam and Naini Tal, is devoid of these two rock stages of the Sub-Himalaya. The whole of the labyrinthine tract of Sál-covered hills, between the Bhábar zone and the neighbourhood of Douglas Dale, is composed of the lowest member of the Siwalik series, namely, the Nahan sandstone. It takes its name from the town of Nahan, where our pioneer of systematic geological work in the Himalaya, Mr. Medlicott, first described it; and when once seen, in its full thickness of several thousand feet, its massiveness, its freedom from local variations, and its general character as a rather soft but eminently workable micaceous sandstone, of ochre or greenish-brown tints, there is no possibility of mistaking it, not only from one end of the Himalaya to the other, which is no mean distance, but even further, as it circles round about our north-west frontier on the one hand, or Burma on the other.

Notwithstanding its great thickness, and the majestic fold bent back upon itself into which it is thrown, as illustrated in section I, I have shewn elsewhere in my memoir that its apparent oneness with the greater Himalaya is misleading. Though now as much a part of the Naini Tal range (geographically) as it is possible to conceive, it is really but a comparatively modern addition to the Himalaya as a whole. To be clear in our conception of it we must regard it as once having lain flat and monotonous, as the country around Bareilly, at the foot of a Himalayan range not very different in its main features from what we now see; and as having then been hardened by age and superincumbent strata, and synchronously upheaved and welded to form but one piece with the range of older hills.

Thus just as the Siwalik conglomerate found west of our section is but an ancient Bhábar country that has been upheaved folded and incorporated with the parent Himalaya to the north, so the Nahan sandstone and shales are but a still more ancient Taraí country that has suffered in a like manner save that its incorporation is more complete and assured.

Our first excursion therefore, whether by tonga road or by bridle path, takes us inevitably across this Nahan zone, the history of which I have briefly summed up. For more complete information I refer the reader to my memoir.

The main-boundary fault.

At Joli Kot, a little south of Douglas dale, where the cart-road, after a divergence up the Nalena R., emerges to a full view of the white houses of Naini Tal, the Nahan zone is left behind. In a moment we cross the great master-fault of the south edge of the Himalaya, called the main-boundary fault, which divides these Nahans from the older rocks; but the actual line of this hiatus in the geological structure of the country is not marked by any prominent surface feature. This line is one that can only be found with great care and patience, and we must not expect the moss-covered rocks in the cuttings to tell their tale uninvited; for indeed a very practised eye and hand are requisite to determine where the Nahan rocks end, and the older Himalayan rocks begin.

Trap.

For a considerable distance, the rock north of the main-boundary is a very much decomposed trap, is decomposed on the surface of the road as to greatly resemble the Nahan sandstone.[1] Nothing but a specimen dug from the very heart of the cuttings and subjected to microscopical examination will fully reveal that we have crossed the rubicon and that we are now on Himalayan as distinguished from Sub-Himalayan formations.

Limestone and slates.

For a little over a mile this trap continues, and we then enter on the purple, grey, and sometimes carbonaceous slates, which, with the superincumbent dark blue-grey limestone, occupy so much of the nearer ranges in this and other parts of the Himalaya, and here too the mystery of these azoic formations must begin to strike us. Not a trace of a fossil has ever been found in them. Were we in Wales, or some of the western counties of England, we could well imagine these slates, grits, and calcareous bands to contain trilolites, graptolites, or mollusca, such as are so familiar there in the great Silurian and Cambrian systems. And as for the massive limestone, we should certainly be tempted to regard it as the mountain-limestone of the northern counties and be prepared to find it crowded with marine fossils. In this aspect, then, the contrast between these Himalayan rocks and those in England of a similar composition is very noticeable. There is no room for doubt that both sets of strata were accumulated slowly in a fairly deep sea, at some period in the world's history: indeed geology would be no science at all were it possible to call this conclusion in question. That being so, there are three courses of belief open to us; we may believe that they represent deposits formed before the dawn of life on the earth, or that they were formed under some conditions fatal or distasteful to living beings, or that they once contained these remains and that subsequent slow chemical and mechanical changes in the rock have obliterated all traces of them. Each of these theories is however beset with difficulties, and Himalayan geology has waited long, and must still wait before one or other theory can be adopted with any semblance of truth.

Waiving this somewhat transcendental question, let us see what can be learnt as to the structural history of these formations in the building of the Himalaya. On our line of section up from Joli Kot to the lake there is a general dip of the slates at angles between 25° and 30° (though often-varying) in a northerly direction. About $\frac{3}{4}$ mile south of the outlet of the lake the massive limestone, with some few hard purple grit bands, normally succeeds the slates. It is nevertheless certain that this though true is not the whole truth. At more than one point along the two or three miles occupied by the slates, there must be repetition by reduplication. This is shown by the fact of the recurrence of outliers of the massive limestone at a much lower elevation; and further south than that at the lower end of the lake. The village of Naikana, due west about a mile from Douglas dale, is built on one of these outliers, whilst there is another small one south-east of Manora. Still more west at Balnekhan the same limestone is exposed, and again at Jagueda, south of Khurpa Tal, there is a continuous exposure of the limestone of full thickness and dipping steeply south-south-west. The horizontal section (Section I) will illustrate better than words the folding and faulting that has supervened and brought about the present state of things.

[1] In the accompanying plate, Section I does not cross the trap.

We must not forget to notice the true cleavage possessed by these slates. This is liable to be overlooked, and indeed has been overlooked by many observers in the Himalaya, from the fact that it generally coincides with the bedding. The reversed folding and faulting has tended to turn all the individual beds of the slate series so as to dip towards the north, which is the dip of the cleavage in this locality. A little patience will easily reveal the fact that this is not by any means universal; whilst in some of the steeper parts of the Balia ravine, due east of the old Gurkha barracks, fragments of slate may be picked up where the cleavage planes alone are well-developed, the bedding being feebly indicated by different tints of grey. A remarkable condition of the slate all over Naini Tal, and indeed in most parts of the Lower Himalaya, is its utter worthlessness for roofing purposes: there is no durability in it, as may be seen by the way it breaks up and crumbles anywhere near the surface of the ground. This seems to be due in the first place to the fact that it is never very pure; we nearly always see the colour of the rock changing rapidly through various shades of grey, or purple and green, and its texture altering from a smooth, satiny-surfaced slate to an impure irregularly-cleaved rock indicating sandy admixture. Every here and there bands of strong grit or quartzite are interbedded, which have still further tended to prevent the rock from assuming the perfectly parallel folia so desirable for economical purposes. But above all, the decidedly cataclastic nature of the rock is what tells most against it. The cleaving forces that first made the rock into a slate have, in this greatly crushed region of the Himalaya, overdone their work; and the rock besides becoming cleaved has also been sheared, that is to say, the particles of the rock have not only re-arranged themselves parallel to one another to form a slate, but this not having given sufficient relief to the crushing forces, there followed a bodily movement along closely packed planes of shear, and these planes of movement crossing the cleavage have rendered the rock liable to break up into splinters.

Cleavage in the slates.

So far as I have seen, slates are never used by the hill people for roofing purposes, and they assuredly would be, could they be found to take the place of the thatch or wooden roofs in this very rainy region. In those parts of the Himalaya where the older micaceous schists prevail, we constantly meet with the châlets of the villagers roofed with inch-thick slabs of glistening schist, which circumstance shews that slate would be used for the same purpose could it be found.

As we ascend the last steep climb towards the lake, we find the massive limestone gradually asserting itself, first in isolated blocks covered with fern and moss, which have slipped down from above, and then in larger, craggy platforms cut up by deep, damp fissures. None of the limestone so far is actually *in situ*, and all of it possesses a tilt downwards in the direction of the hill-slope. On getting near the lower bazar, the massive limestone sets in with more intensity, and associated with it are some thick, dark, purple sandstone bands outcropping from Fairy Hall to Springdale. Much of the latter rock may be noticed built into the retaining walls and pavements as we pass through the bazar. But the limestone is all round us, of a dark indigo colour outside, and a paler blue-grey when freshly broken. It is impossible to overlook it, for directly or indirectly much of the beauty of Naini Tal, and many of its most impressive features, owe themselves to it. In the first place it constitutes the floor of the dam that keeps back the water of the lake; secondly, all the more rugged

The massive limestone south of the lake.

peaks and precipices west of the lower bazar may be seen to be constituted of it; whilst lastly, its rough and honey-combed exterior, and the soil and moisture that it forms or attracts, have enticed a luxuriant growth of plants, shrubs and trees to take up their abode on it.

We have now arrived in the cool and shady valley of Naini Tal, amid a keener and lighter air, amid a more temperate flora of fir, oak, and rhododendron, as contrasted with the heavy hot sub-tropical climate of the sál-covered Sub-Himalayan tract; we have gained these time-worn slopes composed of rocks that have a wide distribution all over the outer Himalaya, and we shall now proceed to take a few smaller excursions along such lines in and around the station as will best illustrate our purpose.

Section from the Lower Bazar to Giwalikhet and Ayarpata.

View across the valley.

This line of country is well known to picnickers on their way to the "landslips" as they are called. After passing through the lower bazar, where geological observations are hampered considerably by the usual accompaniments to an Indian native town, and by the noxious smells of the sulphur spring which issues from the rock at the lower end of the lake, we get a good view opposite of the southern spur of Sher-ka-danda as we ascend by the Tarat district office. We see the uniform slopes about Stoneleigh composed of the slate series, with a large number of loose blocks of the massive limestone still clinging to the surface, as remnants of a skin or covering of the limestone that has not yet all been denuded away. Many of these blocks at first suggest the idea that they have at some period come bounding down the hill-side from the larger masses of the same limestone higher up near the crest of the ridge, three of which are very distinctly seen between the highest point of Sher-ka-danda and the Bleak house slip. This appearance is however in a measure deceptive, like a great many others which geology presents to us. These blocks have probably never travelled at any great pace down the hill-slope, but have gradually, inch by inch, worked their way down as the underlying rock became eaten away by weathering.

Swallow holes.

Above the Tarai district office the massive limestone is interbedded with much purple grit with subsidiary slate. At the bend in the road marked 6,627 feet bar. the purer beds of massive limestone are met with again, but they shew no good evidence of dip. The country from this point on to Giwalikhet is very irregular and uneven, full of small hollows, and with hillocks of limestone thrown about as it were in a fantastic manner. These hollows suggest ancient "swallow holes" on a small scale, and recall many of the aspects of the mountain limestone country in England. In the rains the depressions become filled with water which cannot easily escape on account of a superficial soil of tenacious clay, very slippery to the feet, which clothes this part of the hill. At Giwalikhet itself there is a larger wooded hollow also filled in the rains by a small lake. I am inclined to think that it also is of the nature of a "swallow hole," which has had its underground channel filled up by mud and clay to the larger extent.

The landslips.

At the south-west end of this tarn there is a slight rise as we approach the very awe-inspiring precipices which have received the name of the "landslips." Directly beneath our feet we look down a cliff or scarp descending 1,000 feet, sheer, at an angle of 60° or 65°. Above us in the direction of the 7,468 feet hill we see another 1,000 feet of sheer rock at a somewhat lower angle. We have thorefore before us in profile what seems a perpendicular cliff, 2,000 feet high, composed of bare beds of limestone with some interbedded slates and grits dipping about 30° north.

This view down the landslips is very fine in any weather, but more especially in the rains when innumerable rills of water are actively at work tearing down fresh debris from the high naked scarp, and hurling it out of sight far below us through clouds of mist, to eventually repose a heterogeneous assortment of fragments on the low ground at the head of the Nehal N. There it accumulates, and will continue to do so until Ayarpata with its riven sides is no more, or until some change in the drainage causes it to be swept away by torrents more quickly than is the case at present.

Scree material.

This scree material at the base of the scarps is well worth a visit on its own account, if time and space permitted; for there may be seen, in those great gathered heaps, 100 feet or more in thickness, the half-way stage in the forming of a new deposit from the wreck of an older one. It has not been sufficiently sorted and rolled as to its constituents to be left in a horizontal accumulation of gravel and sand, but it lies in any plane on which it happens to fall, clothing the hill-sides in an amorphous mass of angular fragments, and burying completely out of sight all the rock formations which are *in situ* beneath. Of course it is a transitional, and therefore a very unstable formation, and will doubtless never be preserved in the future geological record of this part of the earth. Its ultimate destiny is to be much more sorted and rolled as it is carried further and further down the Nehal line of drainage to the plains. Every step it takes in this direction will tend to select out the coarser and the finer material to make the pebbles more worn and rounded, or to split and wear them down to powder, until finally they lie in very nearly horizontal layers of alternating sands, conglomerates, and clays as a new addition to the Bhábar deposits.

Calcareous tufa and Gypsum.

A small amount of calcareous tufa is forming in and among this scree material, and often lines the water channels, giving a home to a miniature forest of maiden-hair fern in which one may walk ankle deep. Besides calcareous tufa, gypsum in small quantities is also being laid down, sometimes in the lower parts of the precipices themselves, but more often among the scree material. Below the site of the old Nehalpur bridge there are more extensive beds of it which I have described elsewhere.[1]

Ayarpata.

Mounting from the wooded hollow of Giwalikhet by a long-since disused and scarcely distinguishable path, we zig-zag our way up to the picnic ground near the top of Ayarpata. On the way we cross a bed of trap apparently insinuated among the bedding, and above it a set of rocks containing a fairly large amount of slate of grey and purple colour, also dark grey grits or quartzites, besides the ordinary massive limestone. At the picnic ground we can see these rocks striking (with a dip of 60°) almost due east towards 6,969 feet bar. But a much better section of these same rocks is to be obtained by returning from the picnic ground along the ridge running south-west to the 7,468

[1] Records G. S. of I., Vol. XXII, p. 137.

feet peak, half a mile south of Ayarpata. The band of trap in particular may be well-studied along its outcrop just north of this peak. It may be seen to be a truly intrusive dyke although apparently so parallel to the bedding; for, near a steep little pinnacle of rock, there is a vein of the dark trap distinctly intruded in the limestone, and brecciating it. In a westerly direction this thin band of trap may be traced with a little difficulty as far as the Khurpa Tal road. It is well exposed on the new mall between the Khurpa Tal road and Ayarpata, where it stands out as a harder mass among the softer slates and limestone. Wherever it is clearly seen it may be noticed to be slightly coarser grained within than at the sides.

Trap.

Returning to the picnic ground, and ascending to the north summit of Ayarpata (7,721 feet), we find the ridge forming this summit to be composed of the limestone beds dipping south instead of north, that is to say, we have crossed a synclinal (see Section II). Bearing in mind the fact that the dip hitherto has been steadily to the north, through a vertical height of about 2,000 feet in the limestone series, it is evident that the thickness of this series must slightly exceed that amount at least. Furthermore, from evidence gleaned here and there on the hill-sides, it may be made out, as shewn in the section, that the northern limb of the synclinal is rapidly inverted, though we cannot trace this inversion everywhere on the steep ringal-covered slopes north of Ayarpata. The inversion is the precursor of the fold-fault which marks the boundary between the limestone and the slates, the latter appearing when the slope of the hill-side slackens in the neighbourhood of Aubrey Villa and Emily Cottage. These slates, although appearing to overlie the limestone, can be recognized as really the same as those we have already examined coming definitely beneath the limestone in the section between Kathgodam and Naini Tal. They agree with them in every respect petrologically, and their apparently abnormal position is really perfectly natural when we consider the manner in which the strata have been folded and faulted as exhibited in the section.

Synclinal with inverted northern limb.

We will call this fault the Ayarpata fold-fault for the sake of future reference. Calculating its "throw" from the relative thickness of the beds on each side of the synclinal we find that it averages at least 3,000 feet.

Ayarpata reversed fault.

So far in our ascents and descents; since leaving Giwalikhet we have been traversing over a block of strata possessing dips of various amounts but with a practically uniform strike. As may be seen on the map, the arrows indicating the dip are all turned towards or from one general direction and the amounts of dip are large, that is to say, from 40° to 60° with transitional dips near the Ayarpata fault of all angles between those amounts, and inverted dips of from 60° to 40°. On the bazar side of Giwalikhet, including the country about Sherwood, Rock-house, and the hill-sides south and west of Clarke's Bay, the strata on the contrary are practically horizontal, or with a rolling dip that does not accumulate much (see Section I). The line of division is necessarily a fault, and its direction is very well marked by a prominent line of gaps and hollows, extending from the hollow of Giwalikhet up the stream to the north-east between the Rock-house ridge and the eastern slopes of Ayar-

Country about Sherwood, Rock-house, and the hill-sides south and west of Clarke's Bay.

Giwalikhet cross-fault.

pata, thence to the gap near 6,969 bar., where there is a prominent change in the direction of the ridge lines, and thence across the lake to the Khairna road gorge. The effect of the fault is greatest to the south-west, and scarcely marked at all on the north-east side of the lake. For some distance the band of trap seen on the way up to Ayarpata follows the fault, then vanishes a little west of Rock-house, and does not again appear until a little west of St. Loo on the opposite side of the lake among slates. This fault we may call the Giwalikhet fault.

Ayarpata to Deopata and China.

Butcher's hill and Handi-Bandi hill.

Beginning our traverse where we left off in our last excursion, we descend by the landslip road, as it is called on the map, and notice the difference in soil and vegetation as we cross over the Ayarpata fold-fault, and enter on the slate series. On getting down to about the 7,000 feet level we turn through the gap in the ridge south of Butcher's hill, and find ourselves once more on the limestone formation. Moreover, we can see that from Butcher's hill along the north-west side of Sleepy Hollow, towards the quarries, there is a regular outcrop of limestone cutting by a cross-fault, over the strike of the slates to the east. Between Butcher's hill and Deopata comes Handi-Bandi hill, almost inaccessible on most of its sides, on account of the great masses of riven rock and tangled undergrowth which encumber the slopes. Nevertheless we can see that both Butcher's and Handi-Bandi hills are but miniature Deopatas, their general structure being almost exactly the same, especially on their southern slopes.

Deopata.

We proceed on towards Deopata, and find that the fold into which the rocks are thrown corresponds exactly to the similar fold remarked on the top of Ayarpata. The precipitous southern face is a dip slope of 55°, the dip steepening slightly towards the summit and then becoming vertical, and inverted at the great fold-fault which goes north of Ardwell and south of the Church. This great fold-fault is parallel to, and in its nature identical with, the Ayarpata fault, and both were doubtless produced together by one and the same earth movement. We will call this fault the Deopata fold-fault and the cross-fault the Sleepy Hollow cross-fault.

Oolitic limestone.

Some of the limestone forming the summit of Deopata is oolitic, the large grains at first suggesting fossils. The limestone is, however, perfectly unfossiliferous, so far as all investigations have gone. Looking down from the cairn along the line of fault we see, by reason of the vertical depth of the valley, how trenchant and important this fold-fault is, cutting as it does, clearly and sharply through hill and hollow alike.

China.

North of the Deopata fault, along the ridge towards China, we cross over very slightly inclined beds which express in their comparatively flat arrangement the great relief to the strata which accrued from the fault. There is a thin capping of massive limestone on the top of the ridge as far as the gap, where the road goes to Kilberry, and beneath it a regular and unbroken sequence of the slate series. Continuing straight up the ridge to China, there is much the same thing, slates beneath dipping 10° west-south-west or thereabouts, and a thin capping of massive limestone catching one point of the ridge only.

There is, however, another band of limestone of slightly different aspect coming among the slates, and some way beneath the main portion of the massive limestone. This thin band is exposed from the south China peak to the north China peak, in one line of outcrop. It is remarkable as at first appearing to be made up of very finely pulverised shells. Having subjected a portion of this to the microscope, I am able to state that this appearance is unfounded, there being not the slightest trace of any structure such as a shell in what is really a finely crystalline rock The same band of rock is also exposed at intervals along the south-west side of China, and indicates that a complete layer of it truncates the topmost part of the mountain, though the precipitous nature of the south-east side prevents identification of it in that position.

Decaying scarp of China.

There are many points of analogy between China and the "landslips" inasmuch as each consists of a steep scarp of bedded rocks dipping at low angles and rapidly resolving into scree-material. The weather-worn face of China pared down and cut into by water-channels with only here and there a portion left sufficiently overgrown to give lodgment to a few cypresses, is throughout the rainy season in a constant state of disintegration. The outer crust of the precipice after becoming rotten by the soaking it has sustained crumbles away at irregular intervals, and becomes deposited as a talus at the bottom of the steeper part: Not seldom these small falls of rubbish from the high scarps may be heard many times repeated during the day. Last year (1889) a larger accumulation than usual took place along a line of cataclastic slate at the northern end of the lake fault, and in falling caused no small consternation to some of the residents in the vicinity. A scarp of this kind, however, can never become very dangerous. The constant shedding of small pieces of the outer crust affords the necessary relief which prevents the surface from working up for a great land-slip properly so called.

"Cirque" at the head of the Naini Tal valley.

The head of the Naini Tal valley from its amphitheatre-like aspect, doubtless merits the name of "cirque," since it is walled in on three sides by the Handi-Bandi hills, Deopata and China. From what I have described above with regard to the denudation here going on by streamlets it may be inferred that they have been sufficient to cause the cirque without calling in the aid of glaciers, or of underground springs.[1]

China to the Bleak House Spur.

Change of dip.

Leaving China behind us, and continuing down towards the ridge on which Government House stands, we find the slate series constantly with us. As we approach Fairlight Hall, there is to be noticed a gradual change in the direction and amount of the dip of the slates. Instead of being nearly west at low angles it becomes more south-west at 30° and 40°, reaching 60° locally. This change produces a necessary change in the sculpturing of the hill-sides. The scarps die out and dip-slopes begin to take their place (see Section II), some of which, south of Fairlight Hall, are very steep and with a convex outline.

[1] See Ball, Rec. G. S. of I., Vol. XI, p. 176.

Trap.

At Alma Lodge, in the gap south of Alma Hill, there appears a bed of trap of the same constitution as that found on Ayarpata. It is 20 yards thick, and dips with the slates 35° south-south-west. Near the junction with the slates it is somewhat slickensided. Most probably it is intruded along the bedding as in the case of the trap of Ayarpata. Since microscope sections reveal the identity of the two rocks, the fact of apparent bedding in the two distinct sets of strata is of itself sufficient to prove that the rock is not truly interbedded, but intrusive along the dip planes.

Extension of the trap.

As can be seen from the map, the trap dyke, as we may now call it, extends for a considerable distance in a north-westerly direction, keeping throughout its range in the map to a uniform aspect and thickness. A short distance south-east of Alma Lodge the Sleepy-Hollow cross-fault shifts the outcrop of the trap to the south-east face of the hill-side, where it may be traced only with difficulty for about ½ mile on account of the soil and vegetation which clothe the slope to a large extent. It then either vanishes according to the nature of its intrusion, or it is cut off by the Deopata fold-fault. Whether there is a subterranean connection between this final appearance of it on this side of the lake and its appearance on the other side it is impossible to say.

Microscopical structure of the trap.

Microscopically the trap[1] is made up of plagioclase felspar, and augite, with alteration products hornblende and quartz, the latter filling the spaces between the other minerals. There are besides magnetite and a little apatite. The rock is holo-crystalline, and the felspars in regular crystalline forms, which are, however, changed into a grey, dusty-looking mineral, through which the twinning and polarisation colours can only be seen indistinctly. The augite is of very pale pellucid brownish-yellow colour, separated into irregular groups by the invading crystals of felspar. It therefore is without crystallographic outline. It is much cut up by widely open cleavage cracks parallel to the faces of the rhombic prism. Sometimes there are fairly distinct pinnacoidal cleavages visible. The augite is altered here and there into a bright green hornblendic or chloritic mineral faintly dichroic. The secondary quartz has been formed by alteration of the felspar, appearing sometimes interwoven with the felspar prisms at one side or end, though it also fills in spaces between the crystals. The rock very much resembles the Limeri rock[2] No. $\frac{7}{786}$, and also one from the Bhim Tal stream ¾ mile north of the Gola R.[3] No. $\frac{8}{357}$.

If the latter resemblance indicates contemporaneity, then the intrusive position of the trap in the limestone of Naini Tal indicates that the basic traps so extensively developed in the neighbourhood of Bhuwali and Bhim Tal are also of later age than the Naini Tal limestone—a point that was left uncertain in my last paper.[4]

Dip slope in the slates.

The rest of the way along the hill-slope towards the Bleak House spur is over slates exposed with a slightly rolling dip averaging 30° down the hill-side. Thus the whole of this part of Naini Tal containing a great number of houses is built upon a dip slope which is so pecu-

[1] The rock sections here described were sliced by the Rev. T. D. Gray, M.A., Chaplain of Naini Tal, and kindly lent me for description.

[2] Records G. S. of I., Vol. XXI, p. 18.

[3] Ditto Vol. XXIII, p. 36.

[4] Ditto ditto p. 30.

liar in respect of the clean sweep that the hill-side makes down to the lake, as to have suggested to Mr. H. F. Blanford that it was due to the friction of a glacier. Later on, in this paper I shall shew reason for discarding the hypothesis that glaciers ever had anything to do with shaping the topography of this neighbourhood. A simpler explanation of this feature is to be found in the circumstance that isolated patches of the massive limestone are still left clinging to the surface of this dip slope, one at Sher-ka-danda, two more on the ridge between there and the Bleak House spur, and a great number of small ones (too numerous to be represented except diagramatically on the map) in the vicinity of the Bleak House spur. For a strong-bedded formation like that of the massive limestone which, judging from these isolated fragments, once extended probably in a rugged rocky mass over the surface of these slates, necessarily crumbled away under the action of alternate heat and cold and weathering, and eventually left an almost clean swept surface behind.

Convex slope of debris.

I have previously in this paper referred to the cleavage in these slates, and the smashed condition in which they are frequently found. On one part of the hill there is a great cake of superficial rubbish slightly cohering because of the calcareous tufa which is deposited among it, but which still, in the rains, sometimes partially breaks up and scatters fragments of limestone and slate down the hill slope. The surface of the slope here has become convex owing to this accumulation of debris, half arrested by the cementing influence of the carbonate of lime. It does not require the gift of prophecy to recognise this as the site of the next land-slip that Naini Tál will have to chronicle. For obvious reasons I do not mention the place more definitely.

Bleak House spur.

The Bleak House spur for many years has been the bug-bear of Naini Tal communications. It will be seen by the map to be in close proximity to the lake fault, and therefore within the sphere of the grinding and crushing which the softer rocks along the line of that fault have sustained. The rock, in fact, forming the Bleak House spur, has "gone into pi"; and partly owing to that circumstance, partly to the dip of the slate being down the slope, and partly to the slope being a junction slope for the massive limestone and the slate, it has been always in a state of collapse kept constant by the undermining action of the Balia stream carrying away the fallen talus. Hence the roadway round it can never be stable in the rainy months.

The outfall of the lake.

Many statements have been hazarded at different times regarding the material forming the dam at the outlet of the lake; and as a consequence a halo of mystery has unwarrantably gathered round the subject. Some authorities have stated that this dam consists of boulders and clay, the stranded moraine of a departed glacier; others, that it is the rubbish of an old landslip, which descended from the slopes to the east; whilst others have thrown out still wilder theories on the subject. But it is not of much moment to examine these different errors, the result chiefly of guess-work. The fact of the matter is, that beneath what is but a mere veneer of tumbled blocks in the bed of the stream, the material is what we should naturally expect, namely the rock *in situ*, normally continued from that which forms the foundations of the lower bazar. As coloured on the map, this rock is the hard massive limestone. It crosses the head of the Balia ravine, and is then separated by the lake fault from the slate series of Bleak House spur.

GENERAL REMARKS.

Faults and disturbance of the strata.

Let us now try to group together some of the scattered facts brought to light by our different excursions in and around Naini Tal. And first, as regards the faults, they may be divided up as follows:—

1. The Deopata and Ayarpata reversed fold-faults, with an east and west strike.
2. The Sleepy Hollow and Giwalikhet cross-faults, with a north-east or north-north-east strike.
3. The Lake fault.

Doubtless in and around the limestone hills there are a great many more minor faults that could never be properly recognised, but those enumerated above are the only ones which have had any structural part to play in the architecture of this part of the earth's crust. Secondly, as regards the contortion and folding of the strata (which are intimately connected with the faulting), we see that the whole of the area north of the Deopata fault, north-east of the lake fault, and south-east of the Giwalikhet fault is chiefly remarkable for the absence of any very striking folds. The lateral pressure exerted on the rocks here seems to have spent itself partly in the production of small irregular contortions in them and partly in cleaving them. In the vicinity of China, the general dip is very gentle indeed, seldom exceeding 10°; whilst all the part north-east of the lake and south-east of the Giwalikhet fault has also one gentle inclination not exceeding 30°; and usually in a south-west of west-south-west direction. A slight exception occurs near the south edge of the limestone crags at Manora and Hill View, where there is a dip to the north at low angles. This area of gentle inclination of the dip planes is very markedly in contrast to the two remaining areas of Ayarpata and Deopata, which have their strata dipping often at angles of as much as 60° with a steep and reversed synclinal near the Deopata and Ayarpata reversed faults respectively.

This seems to mean that instead of the whole of the Naini Tal area yielding alike to the influence of the lateral crushing to which the Himalaya have been subjected, and bending in regular folds of anticlinal and synclinal, there has been violent movement only in the Ayarpata and Deopata area, whilst the rest of Naini Tal has remained practically quiescent. It is plain that the great synclinal fold which must have been initiated somewhere about the centre of these two areas was, in the first place, prevented from carrying the strata on the east side of the Giwalikhet fault with it by reason of that fault. In other words the Giwalikhet fault represents the line of division between the violently moving strata to the west and the more quiescent strata to the east. In the second place it is equally evident that the synclinal fold was again broken along the Sleepy-hollow fault, one portion of the wave going further north and resting in the position of Deopata, and the other part remaining behind in the position of Ayarpata. The final condition then came about by the northern limb of the great synclinal (now divided into two by the Sleepy-hollow fault) becoming vertical, then inverted slightly, and then tearing a little north of the axis of the synclinal producing the Deopata reversed fault on one side and the Ayarpata fault on the other.

The connection of the lake fault with these movements is not however at all manifest.. It presents certain difficulties which cannot be entered into fully here, but I may mention that on the whole the balance of evidence seems to shew that it is the tail-end of a lateral displacement, due to a later earth-movement than any of the previous ones which we have considered. In my map of the Sub-Himalaya[1] it will be seen there is a great lateral fault running down the Balia ravine, and cutting the Gola River at Ranibagh. It is almost certain that the Lake fault and this lateral displacement are the effect of one movement, and most probably that movement was connected with the upheaval of the Nahan zone of rocks at a later epoch than that at which the other earth-movements which we have considered took place.

Viewing the folds and dislocations of the Naini Tal area in a still more general light, it is apparent that they represent an effort on the part of the strata to take up less horizontal room not only in a north and south direction, but also to a less degree in an east and west direction: that, in fact, there is a point situated about the position of the upper bazar towards which, as towards a centre, the waves of earth-movement have set in from north-east, south-east, and south directions. These efforts were not equal in all directions, the north and south effort was the most important as evidenced by the two east and west gigantic reversed faults. The south-west to north-east effort was less important, but is seen in the gentle dip south-west of the slate series on the north-east side of the lake, and on the two cross faults of Sleepy Hollow and Giwalikhet, whilst the south-east to north-west effort is seen in the general north-west dip at the edge of the limestone cliff south of Stone-Cross.

Origin of the lake.

Doubtless many a visitor to Naini Tal wonders how the lake itself came here, for lakes in the Himalaya are not numerous; the little cluster of the Kumaun Lakes, including, besides Naini Tal, Bhim Tal, Sath Tal, Naukuchia, and Malwa Tal, being a striking and peculiar feature of this part of the mountains. Ordinary ingenuity in such cases generally exhausts itself in an appeal either to fire or frost as a cause of the phenomenon. The deep little hollows in the hills are either attributed to the extinct craters of a volcano, or to the work of a glacier. The first of these however will most certainly not apply to Naini Tal, for none of the rocks in the vicinity are volcanic, nor are there any traces whatever that ashes, scoriæ, or lava were ever thrown up or exuded from its placid rim.

The glacier theory boasts more staunch adherents, and has been advocated by Mr. H. F. Blanford. It is a plausible enough theory on the face of it, but I have never been able to find a single fact to support it, neither moraines, nor *roches moutonaées*, and no trace of boulder clays or transported blocks.

Professor V. Ball in his paper "On the origin of the Kumaun lakes[2]" was similarly unable to find any proof of the glacier theory. It must be noticed, however, that his disbelief is largely centered on what he thought was a fact, namely, that the oultet of the lake was not solid, but made up of debris, such as a landslip might have heaped together. In other words, he thought there was no *rock-basin* such as could be attributed to a glacier. Mr. H. F. Blanford, on the contrary, saw the remnants of a moraine in the debris which he supposed filled up the outlet of the lake and held to the glacier explanation on that account.

I have shewn earlier on in this paper that there is undoubtedly solid limestone

[1] Memoirs, G. S. of I., Vol. XXIV, pt. 2.
[2] Rec. G. S. of I., Vol. XI, p. 174.

in situ at the outlet, that in fact there is a rock basin in a sense here, but still I am unable on that account alone to lend support to the glacier hypothesis.

I may perhaps mention here a few scratched stones set in a tough clay which I found at one point on the cart-road. At first sight they had a great resemblance to those in a true boulder-clay. Close examination shewed them to be mere imitations due to the movement of soil-cap over them; for the stones were only scratched on their upper surfaces, parallel to the exposed slope of clay, and the scratches and striæ were all directed down hill. On pointing them out to Mr. R. D. Oldham, he, though struck with the remarkable way they mimicked ice scratches, was perfectly convinced of their superficial origin due to the movement of soil-cap.

Fascinating, therefore, as are the volcanic and glacier hypotheses, I am afraid they must be relegated to that large limbo of plausible guesses which have not come true.

But now, having thrown aside fable, is there any more ordinary means by which the lake could have come into being.[1] And we must here realize that any gently-flowing stream in a valley would be converted into a lake by a raising of the lower, or a sinking of the more central, portion of a given area. Now the lower portion may be elevated in a variety of ways—by land-slips, by slow "creeping" of the soil-cap, or by earth-movements originating in a deeper cause. Also it must not be lost sight of that these three causes may merge into each other by gradations. A land-slip may be so slow as to become a "creep," and a "creep" so large and important as to merit the name of an earth-movement. The fault represented on the map east of the Balia ravine indicates a relative movement of the rocks, bringing about a broken up, cataclastic condition of them along the fault, although, so far as the limestone is concerned, the resulting slightly displaced masses of it are big enough and sufficiently held together in irregular stratified layers, as to still form a rock barrier that will stand long after the protective works constructed at that point have crumbled to dust.

Again, the more central portion of a flat valley may be deepened in a variety of ways—by eddies, by springs from beneath, by the breaking up of swallow-holes, or by earth-movements of an opposite tendency to those just referred to.

Let us now look at a few analogous lakes and tarns; there are Khurpa Tal and the two little lakes on the east side of the Balia ravine below the brewery, plainly stopped up by debris from above. They were once little valleys whose mouths have been stopped up by the great rush of fragments brought down to them by cross-drainage. It does not appear, however, that Naini Tal owed its formation to any such cause as that.

On the other hand, in and around Naini Tal, on the limestone, there are numerous little hollows which become lakes in wet weather. They are genuine basins in the solid rock, which have become lined with a nearly impervious clay. There can be little doubt, I think, that these at any rate, as I have before mentioned, owe their existence, first to swallow-holes, or subterranean cavities, which the rainfall of centuries has gradually made for itself by trickling down the joints or other fissures of the limestone. These might go on enlarging themselves perhaps for a considerable time, but sooner or later a smash would occur at the bottom of the hollow, and the passage would become partly choked up. Let us imagine it again and again being

[1] I pass over all details regarding the shape, depth, &c., of the lake as they have already been given by Prof. V. Ball in the paper alluded to.

enlarged, and again and again broken down, whilst all the time the drainage area was also gradually but surely enlarging itself, and we see that more and more clay would mingle with the limestone debris at the bottom of the hollow; until some day after a re-settlement there would be a complete stoppage of the water channel, or it would remain smaller than was able to carry off all the water entering it. We should then have a lake formed, which rising up to the lowest edge of the hollow would overflow, resulting in a condition similar to that of Naini Tal.

I see nothing preposterous in imagining some such origin as this for Naini Tal. There is well-known to be a subterranean outlet above the Bull and Basin indicating that some water at least escapes from the lake at the present day by means of a fissure or swallow-hole. This escape may once have been the only outlet, which later had its channel broken in, or choked up, sufficient to allow the water to rise to its present level.

In the same way I might take the theory of differential earth-movements, and shew that they may not unreasonably have had a good deal to do with the formation of the lake. The lines of faults, which are numerous near the lake, are all lines of movement, on one side of which the strata have gone up and on the other side down. A little more movement at one point either up or down would bring about the required effect; not to mention the probability that these lines of fracture, once started, would be made use of by water, and enlarged so as to become the starting points of swallow-holes.

Looking at the lines of faults more closely, we see that there is a point mid-way between Sukha Tal and the Upper Bazar, and another point a quarter of a mile north-west of Smuggler's Rock, from each of which three directions of fissuring cross one another at pretty nearly equal angles, making two stars of fracture. The centre of each star may well indicate a focus of movement, or point at which the main direction of tearing of the strata became altered and dispersed in this radiate manner. Such focuses would almost certainly be taken advantage of by subterranean waters, producing under-ground erosion and subsequent falling in, sufficient to account for the hollow now occupied by the lake.[1]

To pursue the matter further would be unwise. The origin of lake basins in nearly every part of the world in which they occur has long been recognised as a *crux*. To my mind the difficulty is not to account for the presence of lakes in among the hills, but to account for their absence over such large areas where some favourable opportunity one would think ought to have presented itself.

CONDITIONS GOVERNING MOUNTAIN SLOPES.

Difference between plateau country and true mountains.

In considering the natural dangers to which a hill-station may be subject in consequence of the action of geological agencies, we may dismiss everything applicable to plateau country, where the strata are generally inclined but a few degrees from the horizontal, and concern ourselves solely with such phenomena as may occur in an area of true mountains, where the inclination of the strata is generally severe, and where foldings, inversions, faulting, and crushing along

[1] In a foot-note (p. 181), Prof. V. Ball suggests that the basin of Naini Tal may possibly be connected with some local faulting, the existence of which is implied by the sulphur spring at the outfall.

lines of movement are common accompaniments. In such country there are no long stretches of level ground with intervening deep ravines and winding scarps; but there are a number of culminating points, from which main-ridges, side-ridges, and side-spurs, with intervening streams, streamlets, and water-courses grow from one another like the branches of a tree.

A hill-station must largely occupy slopes.

It necessarily comes about that in a hill-station the great majority of the houses must be built on hill-slopes, whilst but a few can be accommodated on the ridges, and still fewer on the comparatively rare, flat "cirques" or bottoms at the valley heads. We have therefore to consider the safety or otherwise of *slopes* from a geological stand-point.

Slopes of 40° and over.

Every one who has had much practical experience of mountain climbing knows by an unerring instinct when the critical angle of about 40° has been reached in ascending a hill slope. It is that angle at which he must begin to climb cautiously and guard against a slip of the foot. It is also the angle at which large fragments of fallen rock lie in so unstable a position, that a touch will destroy their equilibrium and set them in rapid motion downwards. The terminal moraine of an actively shedding glacier is generally fixed at about this angle in its upper part, the huddled and jagged blocks being in a most precarious position. Scree material or talus, at the foot of a precipitous scarp that is in a state of rapid disintegration by frost, generally begins at this angle, and then lowers gradually. A slope, with an angle of 40° therefore, or anything above it, must be considered a dangerous one under any circumstances, and should never be built on unless it be but a few yards in height and forming part of a much gentler slope.

As a matter of fact few such slopes are ever built on, as, when not too steep, they are seldom clear of freshly-fallen blocks, uncovered by soil or vegetable growth; but for the sake of safety, the angle of 35° may very well be taken as the limiting angle subject to other conditions noted below.

Slopes of 25° and under.

In the other direction every slope below 25° may be considered safe, no matter what the structure or condition of the rocks, with perhaps a few rare exceptions.

Slopes at the debatable angles between 35° and 25°.

We have therefore by this simple elimination arrived at the debatable angles ranging between 35° and 25°. These are sometimes quite safe and sometimes dangerous; and they are those most frequently found in hill-stations in the Himalaya.[1]

Geological conditions of slopes.

The safety or not of these slopes depend on the following:—(1) *composition* of the rock; (2) its *condition* whether whole or shattered; (3) direction and inclination of the *divisional planes* which penetrate through the rock. Let us take these three in order.

Rock composition.

The composition of the rock is perhaps of least importance, and at all events can least be avoided, since the hill-station must make the best of the material on which it is built. By far the best and most lasting hill-sides in the Himalaya are those composed of the gneissose-granite and micaceous schists, so familiar at Ranikhet, Almora, and Kalandanda (Kalogarhi).

[1] Nothing is more deceptive to any one unaccustomed to deal with angles than the apparent inclination of slopes. Slopes of 60° are very often described as "quite vertical," and those of 70° or 80° as "overhanging". An instrument must always be used for determination.

From many points of view hill-stations on these rocks possess several advantages; for the rock, though stable and tough, is soft when first worked; roads and sites for houses can be cut quite readily in it; whilst the more fissile varieties afford abundance of excellent stone for such rough and ready buildings as are required. The soft sandstones of Nahan age, and all similar sandstones, such as the Murree sandstones, and the sandstones and shales of Kasauli and Dagshai come next in order of merit, but as they seldom rise about 5,000 feet they are not often likely to come within the sphere of a hill station.[1] Next in stability is the massive limestone formation, and all similar thick-bedded limestones and traps, which often afford very safe though rugged slopes. The rock as building material is, however, difficult to work, very absorbent of water, and sombre and unlovely to look upon. Last in order come all slates, shales and fissile varieties of quartzite and trap. These very seldom form good and trustworthy slopes, the material itself being very generally rotten, liable to rapid disintegration by the action of the atmosphere, and prone to become cut-back and to form those convex forms of slopes which are the most dangerous. In my wanderings in the Himalaya I have frequently seen old and new landslips of far greater size and destructiveness than that which occurred at Naini Tal in 1880, but I have always noticed that the slipped rock has been some form of slate or cleaved variety of trap.

Condition of the rock, its whole or shattered state.

In previous papers on the geology of the Himalaya, I have at several times drawn attention to the violent nature of those lateral thrusts and intense foldings of the strata, the concomitants of the upheaval of the mountain area. It is owing to these thrusts and foldings that lines of movement, or thrust-planes, have been started in rocks of all kinds, but more especially in slates and fissile rocks, along which a brecciating, shattering, or grinding up of the rock constituents has taken place. The rock in the vicinity of such lines is often reduced to a powder, or to an aggregation of fine fragments dispersed in a pasty matrix. When water gains access to these planes of weakness the rock returns to its original form of soft clay marl, sand, or gravel; it loses coherence with itself, and with the surrounding rock, and some form of slipping is inevitable. A very instructive set of local examples of this kind is to be seen in the neighbourhood of the Lake fault. Along this line intense grinding and crushing of the rock sides has taken place; as witness the condition of the rock at Bleak House spur, the subsidence of the cart-road below the Cemetery; the falls of limestone which have taken place near the Smuggler's Rock, in part also the slip near the Temples and that of China which took place in 1889.

All these points are points of weakness, more or less along the line of fracture of the lake fault, as can be seen by a glance at the map.

Crushing and shattering of a rock are however not always due to a fault. They frequently make their appearance in a thin-bedded or less rigid stratum in proximity to a very hard, thick-bedded stratum. The state at the position of the old Naini Tal landslip (1880) is of that character, partly due to the neighbourhood of the once superincumbent limestone, fragments of which may still be seen in one or two places on the hill-side not far away, and partly to the layer of hard trap beneath.

[1] As an exception to this, the associated purple shales or clays when obliquely exposed with a dip down hill are liable to cause some trouble from the soft miry condition into which they get after heavy rain.

The third is the most important of the three factors which go to make the slopes of between 25° and 35° safe or unsafe. The divisional planes cutting through a rock may be either directed down the slope, or in towards the hill, or in a direction between the two. As a general rule, however, on a slope of any importance, the dip is either down the slope or in towards the hill.

Direction and inclination of the divisional planes in the rock.

Figs. I, II, and III are examples of dip down the slope, and fig. IV is an example of dip in towards the hill. The two first are those to be avoided, as likely to prove unstable and prone to slip. Of the two, the combination of dip and slope as seen in fig. I where the angle of dip is slightly lower than that of the slope is the more dangerous. This is easily seen to be due to the fact that in it the beds or layers of cleaved rock are cut away below, leaving a free edge which allows an upper bed to slide down over a lower; whereas in the case depicted in fig. II, a similar set of beds is shewn cut away above, leaving each bed with a firm basis of rock below it on which to rest. The third example (fig. III) shews a combination of a steep angle of dip coinciding in direction with the slope. Here the hill-side may be considered structurally much safer than that of fig. II. Finally, in fig. IV, the dip is shewn in the opposite direction or in towards the hill. This is the safest arrangement for all slopes fixed at the debatable angles of between 35° and 25°.

In the diagram fig. V, *a b* represents the slope of the hill, and the radiating lines represent the different angles of dip. The thin lines shew the amounts of dip which in combination with the slope of the hill are dangerous, whilst the thick lines shew the safe amounts.

From this we see that dips between 15° and 45° in the direction of the slope constitute an unsafe hill-side. This may be expressed differently by saying that when the dip varies within 15° on one side or other of the angle of slope (taken at 30°), it must be considered dangerous; and it is more dangerous when the angles of dip within the prescribed limits of 15° are less than those of the angle of slope, and less dangerous when they are greater.

When the inclination of a slope varies in amount, we have one or more convex or concave surfaces presented. The concave slopes, as a whole, are better than the convex ones. In the former the lower part of the slope and in the latter the upper part are relatively the safer.

Varying forms of slopes.

It is somewhat beside the scope of this paper to consider all the dynamical and physical conditions which are brought about in consequence of a given geological structure. Still it may be briefly pointed out that water plays a very active part in the actual starting of a landslip, and that the accumulation of surface debris, which often loads a hill-side with an unstable, heterogeneous mass of rubbish, is attended with much danger. Both these mediate causes are but the secondary results of an ultimate geological structure. For instance, a safe slope, as already defined, where the dip of the strata is in towards the hill, is obviously one on which water can have little to say, in consequence of the latter being drained away towards the centre of the base of the hill; whereas an unsafe slope, as already defined, in which the dip is down hill, is on the other hand one on which water will either emerge and form lines of springs, lubricating the under-surfaces of the strata (when the angle of dip is less

Mediate and proximate causes of slipping.

than that of the hill slope), or else will establish a hydrostatical pressure on the layers of rock and tend to wedge them off (when the angle of dip is slightly greater than that of the slope). In the same way, surface accumulation of debris, though taking place more or less on all slopes, seldom accumulates largely on a slope with the dip towards the hill, save when the angle of slope is very low, and therefore safe on that account. But it accumulates with dire effect on a dip slope, becoming a terrible menace to the safety of the hill-side, when eventually, through gradual "creeping" down the slope, or through cutting back of the hill-foot, it gives a bulged appearance to the slope such as Mr. R. D. Oldham[1] has described as the forerunner of the disaster of 1880.

Falling blocks.

It merely remains to mention cases in which falling blocks from a high precipice or scarp may become dangerous on account of the momentum they acquire on their downward journey. These are not generally of much account, and can easily be guarded against by flat terraces built above the houses, or trenches dug to receive them. Still a safe slope considered on the previous lines of argument may sometimes become dangerous on the above account, and it is well to keep in mind, therefore, that the distance to which falling blocks will travel is proportional (among other conditions) to the height from which they come and the angle of slope. Practically, it may be laid down that a block detached at a point on a precipice will be at rest before reaching a point on the slope below, such that a line joining the two makes no greater angle with the horizontal than 35°.

Application of the above principles to Naini Tal.

The following categorical summary has special reference to Naini Tal, and may be found of some practical use:—

(1) The limestone formation, as a whole, (other things being equal) is safer than the slate formation.

(2) The chief danger to apprehend on the limestone is the falling of loose blocks, or pinnacles of rock, during the rainy months. By blasting or knocking away any such loose blocks on slopes or precipices exceeding 40° they may always be rendered innocuous.

(3) Even when the hill-slope approximates to 35°, if the dip is in towards the hill, a limestone slope is less dangerous than one of 25°—30° in the slate formation when the dip is down hill.

(4) On the north-east side of the lake where the dip and cleavage of the slates is often coincident with the slopes, both being at about 30°, more danger is to be apprehended from slipping than anywhere else in the station. Still, even on general slopes of this kind, there may be found plenty of local slopes of no greater angle than 25°, and these may generally be pronounced safe so long as the following warnings are attended to:—

(*a*) Never to build at the top of a concave, or bottom of a convex slope.

(*b*) To avoid lines of springs when the slope exceeds 25°.

(*c*) To avoid places where a brecciation, or great smashing of the strata has taken place along a fault or elsewhere.

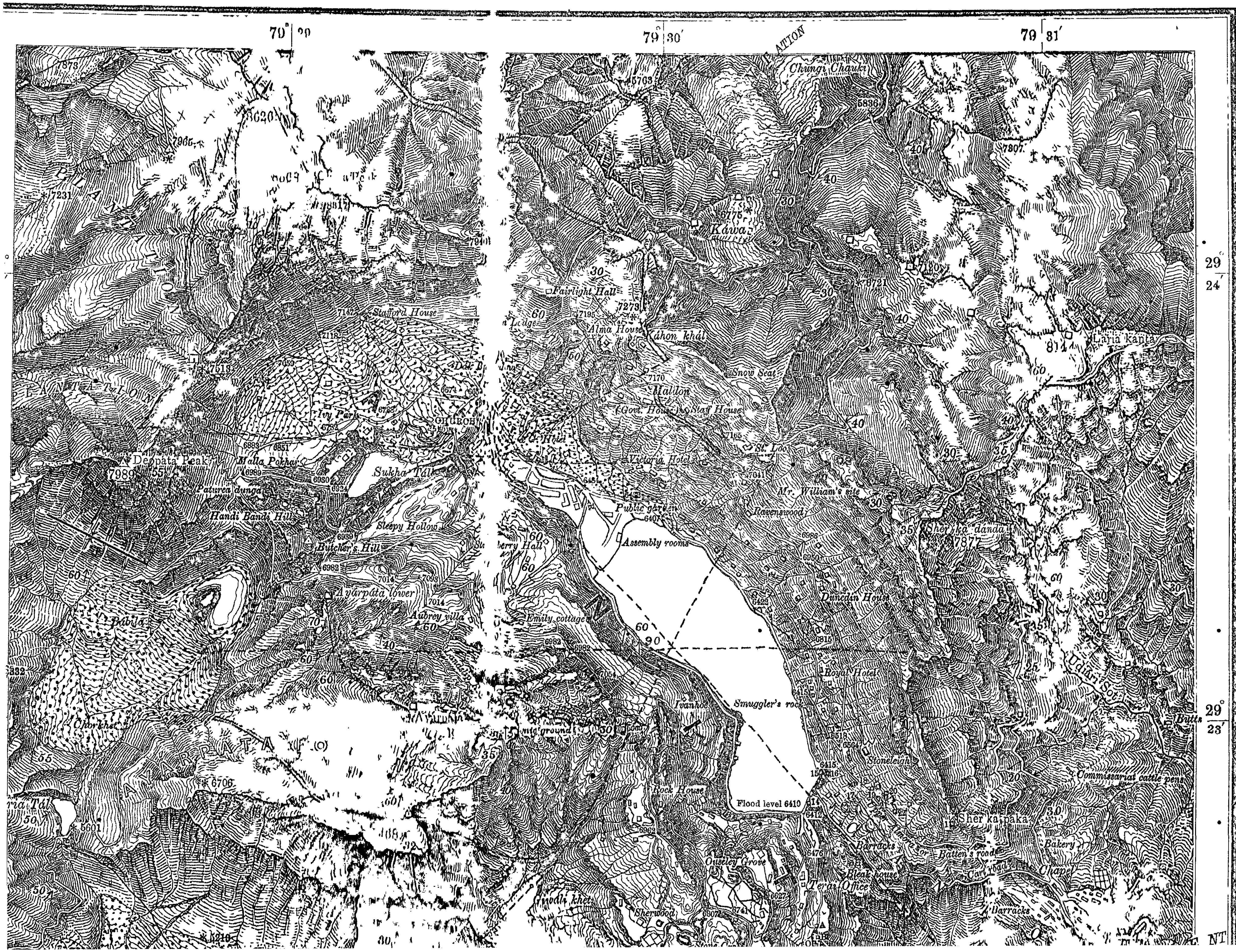
(*d*) To avoid as a consequence of (*c*) places where accumulations of surface material are tending to give a bulge to the hill-side.

[1] See Rec. G. S. of I., Vol. XIII, p. 277.

GEOLOGICAL MAP

of

NAINI TAL



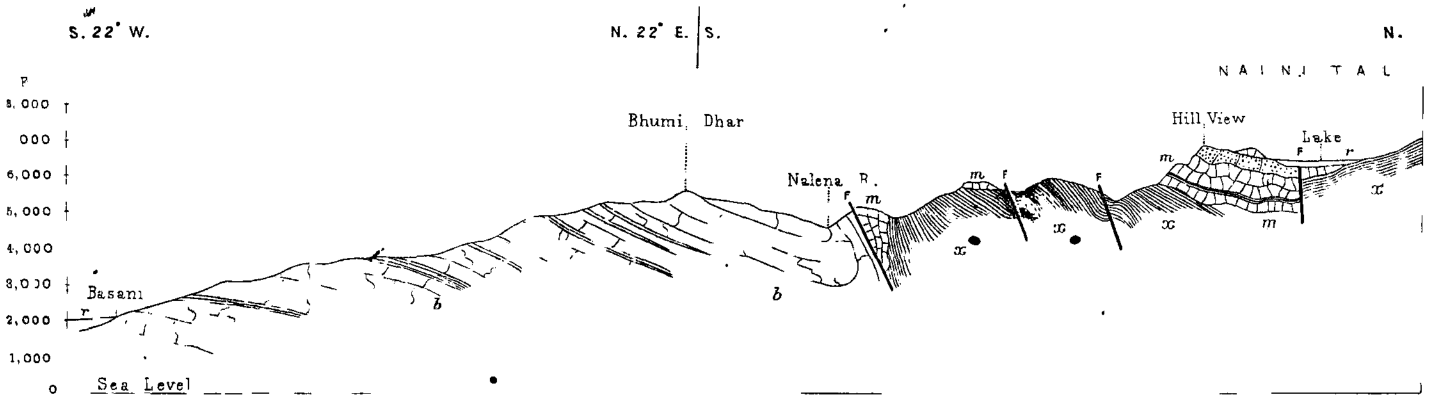
INDEX

Allurium (Recent)........	
Scree material do............	
Massive Limestone series (Age unknown).....	
Purple Slate series...........do...	
Trap (Intrusive)........	

Direction and amount of dip thus .... ↙30

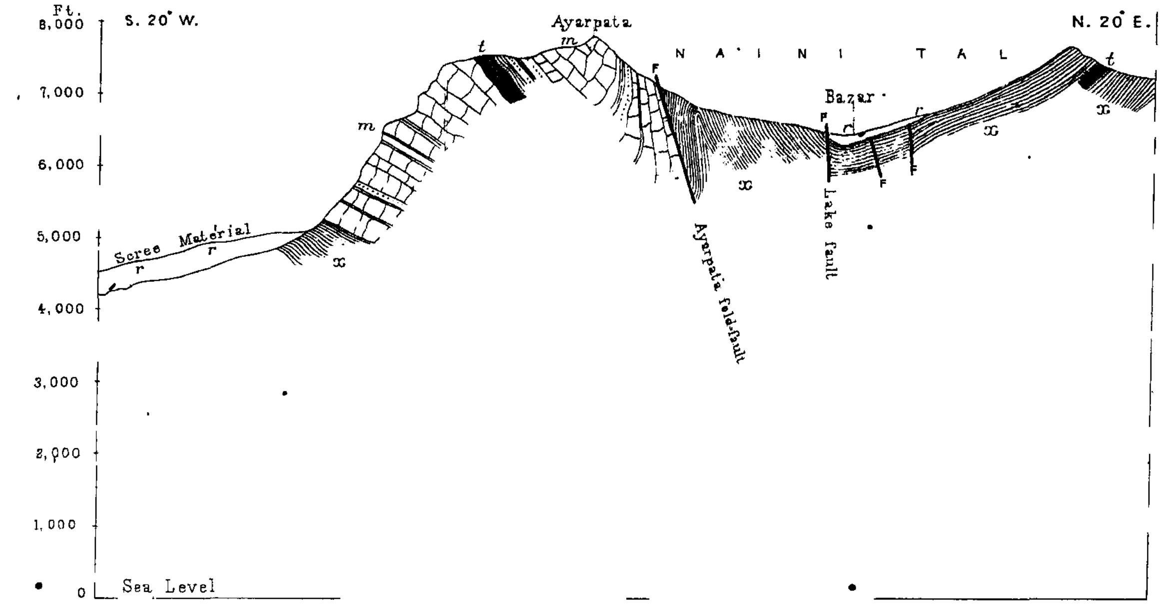
Faults are represented by broken lines thus ------

Middlem



SECTION. I.

Horizontal & Vertical Scales, I Inch = I Mile.



SECTION. II.

Horizontal & Vertical Scales, 2 Inches = I Mile.

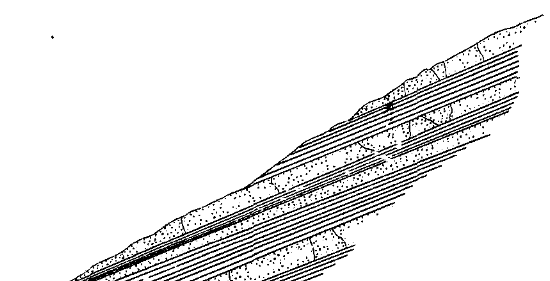


FIG. I.

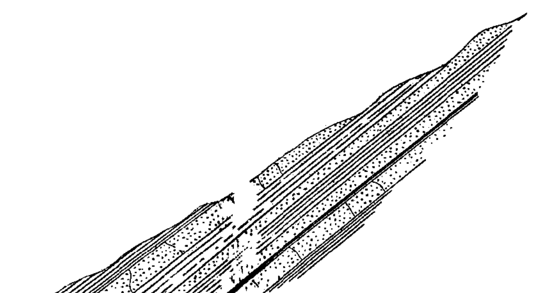


FIG. II.

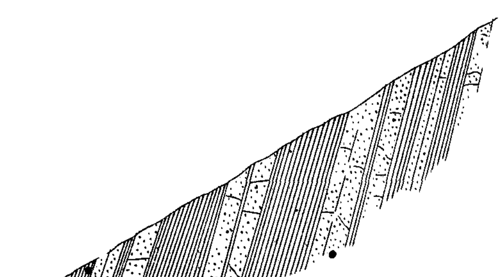


FIG. III.

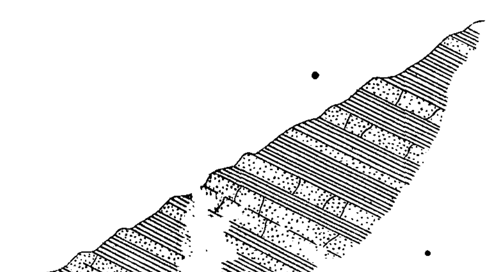


FIG. IV.

INDEX TO SECTIONS

r = *Recent*

b = *Nahan Sandstone*

m = *Massive Limestone*

x = *Purple, Grey & Carbonaceous Slates*

t = *Trap Dykes*

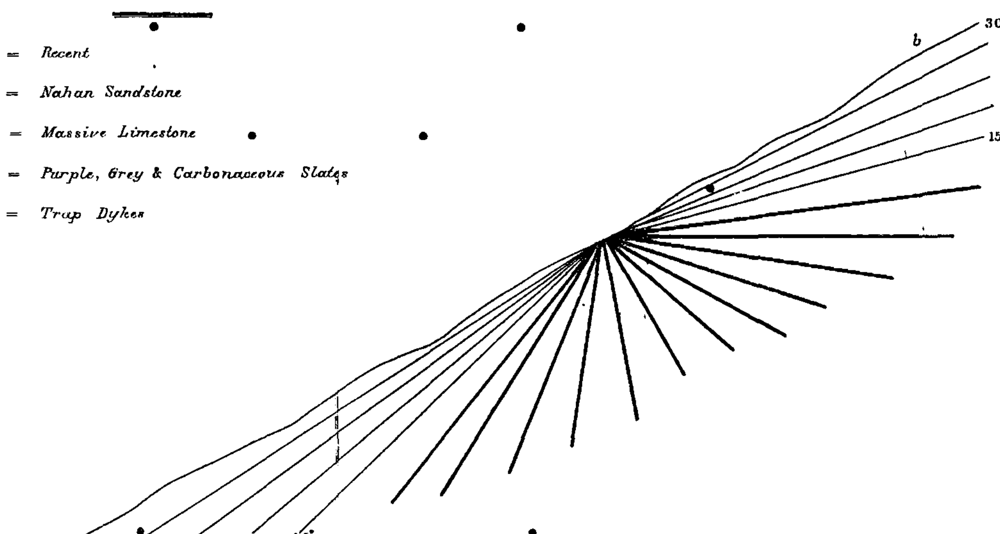


FIG. V.

Note on some Fossil Indian Bird Bones, *by* R. LYDEKKER, B.A.

During a recent examination of the small series of Siwalik Bird bones preserved in the British Museum, I have been enabled to determine two specimens which have been hitherto unnamed. These are respectively the distal extremity of the right femur, and the proximal extremity of the corresponding bone of the opposite side, of a species of Pelican, which from their size I refer to *Pelecanus cautleyi*.[1] In woodcut 1 these two fragments are drawn alongside of the complete left femur of the existing *Pelecanus mitratus*, the proximal fossil fragment being reversed. It will

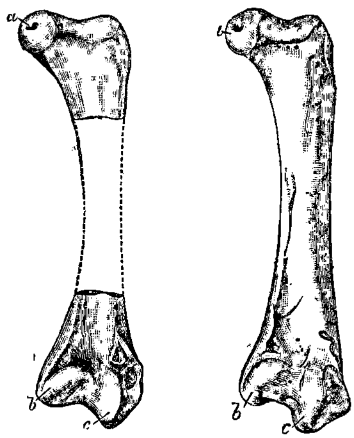


Fig. 1. Posterior aspect of the right femur of *Pelecanus mitratus*, and portions of the corresponding bone of *P. cautleyi*. ½. *a*, head; *b*, tibial condyle; *c*, fibular do.

be seen from the figures that the fossil fragments correspond so exactly with the recent bone, as to render it impossible to draw any good specific distinctions between the two. The distinctive characters of this species must, therefore, continue to rest upon the well-marked features afforded by the type fragment of the ulna.

The specimen on which the smaller Siwalik Pelican described by Mr. Davies,[2] as *P. sivalensis* was founded, having never been figured, I have remedied this omission by giving a full-sized figure in woodcut 2, in juxtaposition with the corresponding

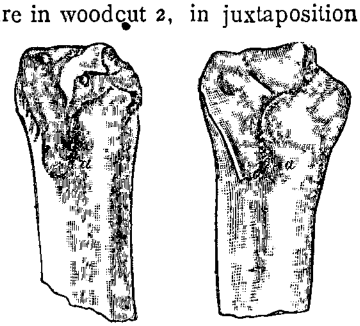


Fig. 2. Palmar aspect of the distal extremity of the right ulna of *Pelecanus sivalensis*, and corresponding portion of the homologous bone of *P. mitratus*. 1/1. *a*, palmar trochlear depression.

[1] See Pal. Ind. Ser. 10, vol. iii, p. 137.
[2] See Pal. Ind. *loc. cit.*

portion of the ulna of the recent *P. mitratus*. As stated in the original description, this specimen differs from the distal extremity of the ulna of *P. cautleyi* by its inferior dimensions, the shallowness and shortness of the palmar trochlear depression (*a*), as well as in some minor points. The close general resemblance to the larger ulna of *P. mitratus* is sufficiently apparent from the figures.

Among the Bird bones obtained from the Karnul caves, I described and figured[1] some imperfect specimens of the tibio-tarsus and tarso-metatarsus under the name of *Ibis melanocephala*. From a re-examination of some of these specimens presented to the British Museum, I find that this determination is incorrect, and that

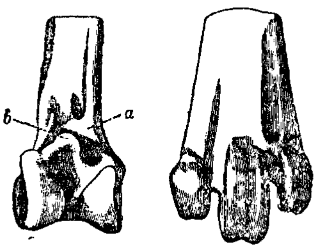


Fig. 3. Anterior aspect of the distal extremities of the right tibio-tarsus and the left tarso-metatarsus of *Pseudotantalus leucocephalus*. $\frac{1}{1}$. *a*, bridge over groove for extensor tendons; *b*, tubercle on same.

they really belong to *Pseudotantalus leucocephalus*. In figure 3, the distal extremities of the tibio-tarsus and tarso-metatarsus of a recent skeleton of this species are given for comparison with the figure of the fossil bones. The resemblance between the recent and fossil tarso-metatarsus is very close, but the latter being immature is rather smaller than the former. The figured tibio-tarsus indicates a considerably larger bird than the fossil tibio tarsus; the smaller fossil specimens of this bone described in the text agree, however, very closely with the figured recent bone, and the larger size of the figured fossil does not appear sufficient to indicate its specific distinctness.

[1] Pal. Ind. Ser. 3, vol. iv, pp. 53, 54.

The Darjiling Coal *between the* Lisu *and the* Ramthi Rivers, *explored during season 1889-90, by* P. N. BOSE, B.SC., F.G.S., *Deputy Superintendent, Geological Survey of India.* (*With a map.*)

I.—PRELIMINARY.

In March, 1849, Dr. (now Sir Joseph) Hooker noticed near Pankabari some coal seams "six to twelve inches thick, very confused and distorted," and carbonaceous shales with plant fossils "characteristic of the Burdwan coal-fields." No notice was taken of these coal-bearing rocks until 1873, when the completion of the Northern Bengal State Railway gave to them a new importance. Mr. F. R. Mallet of the Geological Survey was in that year deputed to examine the coal and other mineral resources of the Darjiling Hill Territory. Mr. Mallet's survey brought to light a narrow band of coal-bearing rocks in the Sub-Himalayan range stretching from Pankabari to Dalingkot. In the "Memoirs of the Geological Survey," Volume XI, Part I, Mr. Mallet fully discusses the workability of the coal seams he came across. The decision arrived at by him, which is very forcibly expressed in a later paper in the "Records of the Geological Survey,"[1] is decidedly against the workability of the coal, so very decidedly, indeed, that, coming from one of the most careful observers the Survey has ever had, it was considered final.

Mr. Mallet rightly pointed out that owing to its flakiness the coal could not be utilised in its natural state,[2] and that this friable condition was due not to weathering, but to "crushing during the period of elevation of the Damuda rocks," so that no improvement can be expected at a distance from the surface. The Darjiling coal must, therefore, be artificially compacted before it can be used as fuel. This can be done in one of two ways, coking or conversion into *briquettes*.[3] Mr. Mallet's experiments with regard to the coking properties of the Darjiling coal were not at all hopeful. With regard to the conversion of the coal into patent fuel, his

[1] *Op. cit.* X, p. 143.

[2] Some of the Lisu valley coal was tried in its natural state by Mr. North of the Bagrakot Tea Estate, who says in a letter to me :—

" . . . . It burnt very well with wood, but alone it did not. This of course I put down to its being wet, and think better results would have been got if my furnace had not been so large; besides which the fire-bars were too far apart, and the coal went through."

With closely set fire-bars the coal may be used in its natural condition, but, I think, only to a limited extent, and at a short distance from the coal-field, where there will be little risk of repeated rough handling.

[3] The result of my experiments with regard to coke-making will appear in the sequel. With regard to *briquettes*, Messrs. Burn & Co, very generously lent me a small Boomer press originally intended for pressing tea-bricks. The coal-dust with which was mixed a little *bhutta* gruel (in the proportion of 1 maund to a ton of coal) was pressed into hard bricks. But they stuck firmly to the sides of the moulds; and as these were not hinged, the bricks could not be taken out without being broken. With proper moulds, the bricks, I have no doubt, could be got out undamaged.

experiments showed that it would probably be remunerative. They were, however, on a small scale, and "it yet remains to be proved," remarks Mr. Mallet, "whether this plan would answer on a commercial scale."

So the Darjiling coal was given up as hopeless. On the data before him, Mr. Mallet could have come to no other conclusion than what he arrived at. But Mr. Mallet's survey was very general. He had time only to go up some of the principal streams and notice the outcrops of coal that presented themselves as it were to him. It is possible that some important ones lay hidden in the intervening areas between the principal streams. Indeed, when it is remembered how thick the jungle is where they occur, and how obscure the sections are as a rule, such a thing appears highly probable. It was this probability, and the immense economic importance of the Darjiling coal, that led to my deputation to re-examine it last cold season. I made a general examination of the area between the Jít and the Tístá, and a fairly detailed one of that between the Lisu and the Ramthi, where the coal seams gave the best promise of success.

I must say, when I started work, I had but little hope of finding workable coal. The find, however, of thick seams of cakable coal in the Churanthi valley early in December appeared very promising, and it was considered desirable to ascertain their extent and thickness by excavations. The Government of Bengal was applied to for a grant of R2,000 for the purpose, which they sanctioned in March.

The coal-ground[1] being almost entirely in the Reserved Forest, is covered by very thick, nearly impenetrable, trackless jungle. The exuberant undergrowth of creepers, and the low, matted, dark scrub jungle, especially of cane, presented the most serious obstruction to vision and locomotion. The emanations from decomposed vegetation were at times almost intolerable. I had literally to cut down nearly every foot of my way; and clambering up the innumerable streamlets and watercourses was equally slow and tedious work. To add to these natural difficulties, the Revenue Survey Map of the area, though on a sufficiently large scale (2 inches to the mile), is neither accurate nor detailed enough for close work. Many streams are not marked; those that are, it is difficult to say if they are all correctly laid down; several do not certainly appear to be so. Scarcely any landmark was available. One bridle-road passes through the explored area, along the watershed between the Lisu and the Churanthi. But it is not on the map; very likely it was not in existence when the survey was made. There are a few scattered hamlets north and west of the coal area; but they are not on the map, as they must have sprung up since its construction. So a new map had to be made, which is presented with this report. It is, I believe, fairly correct, and is on a sufficiently large scale to admit of details.

The great difficulty experienced in the supply of labour, the almost absolute want of trained assistance, and the early setting in of the rains (about the middle of April), were amongst the other hindrances to the exploration. My progress would have been still slower, but for the cordial help which I received from Mr. A. W. Paul, Deputy Commissioner of Darjiling. My grateful acknowledgments are due to him and to the neighbouring planters, especially to Mr. J. L. Lister of the Nimbang Cinchona Plantation, for smoothing away many of my difficulties.

[1] I have made a number of bridle-paths which are practicable for ponies, though not without difficulty at places.

II.—PHYSICAL GEOGRAPHY.

Rivers and their tributaries.

The coal area explored in detail is two and three-quarters of a mile in length and about three-eighths of a mile in breadth. It is situated in the Sub-Himalayan range, about three to four miles from its foot. The Ramthi forms the eastern, and the Lisu the western boundary. The former joins the Jit, a short distance beyond its debouchure into the plains, together forming the Ghish river, a tributary of the Tístá. The Lisu, better known as the Lísh in the Duars, falls into the Tístá above Phulbári. Between the Lisu and the Ramthi, there is a third river called the Churanthi. It carries a good volume of water in the hills, but is barely traceable in the plains. All these rivers run in a general north-south direction across the strike of the rocks which usually varies between W.N.W.-E.S.E. and E.N.E-W.S.W.

The rivers are parted from one another by narrow spurs running roughly parallel to them. Thus we have a spur, separating the Lisu from the Churanthi which may be called the Chankiang spur, after the nearest village, and the Nunmáti spur forms the watershed between the Churanthi and the Ramthi.

The streams tributary to the three rivers mentioned above run in a general east-west direction, being parallel to the strike, or cutting it obliquely. Of such streams, the most important is the Ramtek Jhora. It is also called Chunkhola,[1] as lime used to be made here some years ago. The other streams having mostly no local names have, for convenience of reference, been denominated A, B, C, &c.

Configuration of the ground.

The coal-bearing rocks (the Damudas), consisting mostly of rather soft fine-grained sandstones and slaty shales, form a sort of depression between high escarpments of hard quartzitic beds belonging to an older system (the Dalings) on the north side and those of massive conglomeratic, Tertiary strata on the south side. Indeed, the configuration of the Damudas may almost be followed with the eye. In the Damudas, again, spurs have been left where sandy beds prevail over the shaly, and as the coal is usually associated with the latter, one could tell by standing at a convenient position, not only how the Damudas run, but also where large seams of coal may be expected to occur, and where unproductive rocks preponderate most.

The depression between the Dalings and the Tertiaries in which the Damudas occur is roughly parallel to the strike of the rocks which, as has been mentioned before, usually varies between E.N.E.-W.S.W. and W.N.W.-E.S.E. The depression varies greatly in depth, the Chunkhola being the deepest in the explored area. The height of the Chunkhola near the ruined lime-kiln was found to be about 700 feet above the sea-level, and that of the spurs on either side of it about 2,500 feet. The coal outcrops occur at heights varying from about 700 to about 1,200 feet.

A consequence of the comparative softness of the Damudas is the widening of the rivers as they enter these rocks. The Romtal in the Ramthi is the best instance of such expansion. When Mr. Mallet saw the "lake" (16 years ago), it was very deep at its lower end. It has since entirely silted up; and a white mass of sand and shingle occupies the place of a once fine sheet of water.

[1] Strictly speaking, *khola* signifies valley, so that *chunkhola* would mean the entire valley of the Ramtek river.

As might be expected from the nature of the rocks, the rivers run through deep gorges in the massive Tertiary conglomeratic sandstones. Vertical precipices of these rocks, sometimes no less than 1,500 feet in height, tower majestically on either side of the rivers in awe-inspiring silence.

Fall of the rivers, &c.

The Damudas, as a consequence of their comparative softness, are cut through by anastomosing streams, streamlets, and watercourses, which is a distinct advantage in the tracing of the coal outcrops. This advantage is, however, to a very great extent neutralised by the covering up of the Damudas by detritus from the Dalings and the Tertiaries. The fall of the rivers, streams, and streamlets increases in the order they are named, that of the minor streams being the greatest. The streamlet C, for instance, a tributary of the Ramtek Jhora or Chunkhola, which has its source just below my head-quarters camp, measures about half a mile in length. Within this length the fall is from about 2,500 feet to about 750 feet, that is to say, about 1 foot in 1½ feet.

As a consequence of this immense fall, huge slips take place during the rains; to such an extent, indeed, that it is often difficult to say where the rock is *in situ*, and where not. Consequently, the exact demarcation of the different systems of rocks is a matter of the greatest difficulty. The sections in the streams are seldom continuous for any considerable distance being hidden by talus; good outcrops of coal are never exposed in them. The rivers bring down huge masses of rock, some measuring 20 feet or more across, from long distances. Thus we have big "boulders" of gneiss in the Lisu and the Jít (a river a mile east of the Ramthi) very nearly down to their debouchure into the plains, at a distance of some eight miles from the parent rock. Immense "boulders" carried from longer distances are met with in the larger Himalayan rivers, such as the Tístá and the Rangit. The "boulders" are transported not so much, I believe, by the force of the current, as by the cutting away of the ground under them, so that they topple over and are rolled down.

Climate.

With regard to climate, the rainfall of the area is very heavy. The average of seven years from 1883 to 1889 at Nimbang just north of the coal-area is 194·87 inches, which is considerably greater than that of Darjiling. Last year the rainfall at Nimbang was 245·83 inches. The following details have been kindly supplied by Mr. J. L. Lister of the Nimbang Cinchona Plantation :—

Rainfall in inches.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	TOTAL.
1885 .	0·43	0·13	2·66	2·92	10·71	30·92	70·64	43·04	35·19	5·68	0	1·15	203·47
1886 .	0	0·11	4·02	0·91	11·88	38·13	47·12	60·71	24·58	5·78	0·44	0·64	194·32
1887 .	5·04	0	1·60	5·12	21·02	44·13	34·26	47·48	29·43	7·87	0·15	0	196·10
1888 .	0·88	0·50	2·82	4·69	7·35	35·56	51·05	30·78	25·51	2·36	0·48	0	161·98
1889 .	2·85	3·82	0·05	4·43	11·93	60·82	80·66	45·99	23·95	9·33	2	0	245·83
1890 .	2·02	0	0·30	5·58	6·21 (up to the 28th).								

The temperature decreases, and the salubrity of the climate increases with altitude. From the middle of April to about the end of May, I had my head-quarters camp on the highest peak of the Chankiang spur north of the Chunkhola, at an elevation of about 2,600 feet. Within that period, the temperature seldom rose above 80°. But, the place being exposed on all sides, and the weather rather showery, the changes of temperature were sudden and great. For permanent quarters, more sheltered sites will be found on either side of the spur.

III.—GEOLOGY.

For detailed information on the geology of the district, the reader is referred to Mr. Mallet's comprehensive memoir. I shall here chiefly refer to such facts as have been brought to light by the excavations.

The Damudas: sandstones and shales.

The coal-bearing rocks (the Damudus) consist essentially of sandstones and shales, the former predominating. The sandstones are greyish, rather soft, massive-bedded, medium-grained, felspathic, and occasionally calcareous. They are never pebbly; and this constitutes the most important point of difference between them and the adjacent Tertiary sandstones. False-bedding is common. Along bedding and joint planes, they are not unoften seen to be thinly crusted over with carbonaceous matter; but the vegetable impressions are never very distinct. The shales, as has been already mentioned, are subordinate to the sandstones. They are sometimes coarse, being sandy and micaceous, when reddish tints prevail; sometimes very fine and black, breaking with conchoidal fracture. They are, as a rule, more or less carbonaceous, the black shales being most so; and it is in association with these that coal seams occur.

Mica Trap.

Igneous rocks occur; indeed, would appear to be rather common. Like those which I have described from Barakar and Raniganj,[1] they abound in mica (biotite), and are "mica traps."[2] That they are intrusive is shewn by the hardening of the sandstones, shales, or coal in contact. The contact coal, as at Barakar, usually occurs in columns, which are dull in colour, and rudely hexagonal; sometimes it is found to be hard and peculiarly lustrous. A good intrusive sheet of "mica trap" is seen in the stream D, 7 feet in thickness, just below pit No. 9. It is traceable for a short distance dipping with the associated coal and following the change of strike. Other thick outcrops of "mica trap" were observed near pit No. 11, west of the Nimbang-Bagrakot road, in the Churanthi, and in the Nunmati stream between the Churanthi and the Ramthi. From the nature of the associated strata and their lie, all these outcrops appear to belong to the same sheet as that in the stream D, near pit No. 9. If so, they mark a good horizon. The coal beds in contact with the "mica trap" are pervaded by anastomosing veins of a reddish or brownish rock. It has a "felsitic" look, but the specimens obtained being all much decomposed, its petrography is at present unascertainable; and owing to the extreme obscurity of sections, I am doubtful about its relation to the thick sheets of "mica trap." I may note that I nowhere saw the "mica trap" cut distinctly through the sedimentary strata. But,

[1] Rec., Vol. XXI, pt. 4, p. 163.

[2] The felspar being much decomposed, it is difficult to say whether the mica trap is Minette or Kersanton.

owing to the smallness of the explored area, and the wretchedness of the exposures, not much reliance can be placed on this negative fact.

Age of the Mica Trap.

With regard to the age of the "mica trap," it must have been posterior to the deposition of the coal-bearing rocks, at least the greater portion of them, and anterior to the disturbances they underwent, as well as to the deposition of the adjacent tertiary rocks. For the mica trap, or, indeed, any other igneous rock, was nowhere found among the last-named rocks; and, as has been observed before, the intrusive sheets dip with the associated coal and sedimentary strata, and follow their strike.

Dip, strike, &c.

All the rocks have been greatly disturbed. The dip is usually very high, from 45° to near verticality; it is seldom lower than 30°. The strike is very inconstant. In the explored area, the usual strike ranges between E.N.E.-W.S.W. and W.N.W.-E S.E., the dips pointing from N.N.W. to N.N.E. But, sometimes, as in the Chunkhola, near the junction of the stream F, and in the Lisu valley at pit 1, the strike is nearly N.—S. Sharp twists in the strike were observed at diverse places. There is also faulting to a great extent; but owing to the ground being much covered up, the faults were nowhere well seen, except in the case of some small ones exposed by excavations; and the course of the faults as given on the map must be taken as more or less conjectural.

As a consequence of the disturbance which the beds have undergone, the rocks have been greatly crushed, the crushing effect being specially noticeable in the shales and the coal. The former have been converted into extremely fragile, splintery slates, which break in all conceivable directions; and a flakiness has been induced in the coal, so that with the least violence it is as a rule reduced to small bits, if not to absolute dust.

Age of the coal-bearing rocks.

Mr. Mallet is inclined to correlate the Sub-Himalayan coal-bearing rocks with the Raniganj stage of the Damuda series. I have nothing to add to his discussion on this point.[1] On account of the great crushing which the beds have undergone, the plant-fossils have been very badly preserved. I could collect anything like a respectable number of them from only one place, pit No. 2 in the Lisu valley. They appear, however, to belong mostly to one genus—*Vertebraria.*

Tertiary rocks.

On the south side, the Damudas are in contact with the Tertiary rocks. These consist chiefly of micaceous, felspathic sandstones and conglomerates. The conglomerates are coarse, sometimes very much so. They are best developed near the junction of the Tertiary and Damuda beds. The sandstones have usually a brownish hue: they are, sometimes, though rarely, highly ferruginous. The sandstones and conglomerates are as a rule very thick-bedded. Clay beds, sometimes highly ferruginous, occur, but are quite subordinate. These and the sandstones are met with below the conglomerates, that is to say, at the base of the Tertiary system. Small pockets of coal[2] and

[1] *Op. cit.* p. 29, *et seq.*

[2] A specimen of this coal was analysed and found to contain moisture 17·52, volatile matter exclusive of moisture 31·88, fixed carbon 49·28, and ash 1·32. It is noteworthy that the analysis of this coal agrees very closely with that of fragments found in 1837, during some boring operations, in Fort William, at a depth of 392 feet (see Man. Geol. of India, Vol. III, p. 77). There can be scarcely any doubt that these fragments were derived from the Tertiary coal of the Sub-Himalayan range.

lignite are found in the sandstones, as in the Ramthi and the Jít. But no workable seam of either has been found anywhere; nor is any such seam ever likely to be found.[1] No fossils beyond unrecognisable vegetable remains have been found in these rocks. But from their lithological characters, and from the presence amongst them of lignite sandstones, Messrs. Medlicott and Mallet concluded that they represent the Nahan stage of the Siwalik series.[2]

The Tertiary strata have a general north-western dip. Their strike is more constant than that of the Damudas, and the dip also (except sometimes at their junction with the latter rocks) lower and more uniform, seldom exceeding 30°, and seldom deviating much from N.N.W. The sál-clad massive sandstones and conglomerates forming craggy ridges are beautifully seen to slope with the dip, and can be followed with the eye to long distances.

The Damuda—Tertiary boundary.

The Tertiary and Damuda strata both having as a rule northerly dips, the former, though more recent, appear to underlie the latter. Good contact sections are rare. As the relation of the two sets of rocks is of immense practical as well as theoretical importance, I shall here give in detail some facts bearing upon it.

Commencing with the westernmost part of the explored area, near streamlet L, a tributary of the Ramtek Jhora, a wall-like bed of massive tertiary conglomerate, is in contact with Damuda shales[3] and coal. The dip of both is high, about 70°, and points north-westward; so that the tertiary conglomerate appears to underlie the Damuda shales. I had a pit dug at the junction, pit No. 20. It went down to some 20 feet, the conglomerate and the coal-bearing rocks being found all the way in contact as at the surface. Here we have very likely a reversed fault.

There is nothing particularly noteworthy about the boundary between the streams L and F. Near the junction of the latter stream with the Ramtek Jhora, the boundary line becomes tortuous; and there is also discrepancy in strike, the coal-bearing rocks at and south of pit No. 65 striking very nearly N.-S., whereas no such change of strike was observable in the abutting Tertiary strata to the south. East of pit No. 65, the boundary line runs fairly straight nearly as far as the Bagrakot-Nimbang road. The junction along a portion of it, south and south-west of, pit No. 11, is well exposed. Here the Tertiary strata have been much crushed; and they abut against the coal-bearing rocks in a manner which, coupled with the straightness of boundary, gives rise to a strong suspicion of faulting. I am inclined to think that we have a reversed fault here.

Between the Bagrakot-Nimbang road and the Churanthi river, the boundary line is far from straight, and the facts as revealed by excavations do not favour the idea of faulting. Just east of the road the Damudas bay into the Tertiaries. Further east, the coal of pit No. 7, at the junction of streams D and D[1], distinctly passes under Tertiary conglomerates and sandstones. The pit between Nos. 7 and 39 went through some 30 feet of the latter rocks; below these coal was struck, which, I have hardly any doubt, belongs to the same seam as that exposed in pit No. 7. The seam,

[1] It is necessary to emphasize this. Owing probably to the proximity of the Tertiaries to the Duars and the Terai, more notice has I find been taken by the planters of these pockets of Tertiary lignite than of the seams of Damuda coal.

[2] "Mem.," Vol. XI, pt. 1, p. 50.

[3] I must say, no fossils were found here. But the shales and the associated coal have an unmistakably Damuda facies.

which is exposed by a number of pits between 75 and 41, passes, when traced southward, at 39, under Tertiary conglomerates. There is just a skin of these about 39; but they increase rapidly in thickness southward. From the sections in the pit 39 and that between it and 7, the Tertiaries are seen to rest upon a very uneven surface of the coal-beds; the latter had been denuded out into hollows before the former were deposited. There would also appear to be diversity of strike. The sections here suggest simple unconformable superposition. East of 39, the boundary line runs fairly straight as far as the Churanthi river. Here the Damudas bay into the Tertiary beds in such a manner as to leave little doubt concerning the unconformable superposition of the latter. Some coal of rather good quality was obtained by digging through the Tertiary sandstones by the side of the stream M (a feeder of the Churanthi), which I am inclined to think belongs to the seam exposed in pit No. 7, or to that just north-east of it. The Tertiary conglomerates and conglomeratic sandstones in the intervening area were found too thick and too hard to settle this important point by diggings. Two or three borings here will be of great practical and theoretical interest. The ground east of the Churanthi was not explored in such detail as that to the west of it; and the boundary line being more or less conjectural is drawn fairly straight as far as the Ramthi. I have no doubt that, with more detailed exploration, the Damudas will be found to bay into the Tertiaries at places.

It will be seen, from what has been said above, that the boundary line between the Tertiaries and the Damudas, though it appears fairly straight on a small scale map, is sometimes very crooked. There is faulting at places; but the facts noted above do not favour the idea of the entire boundary being a fault. This conclusion appears to be in accordance with that arrived at by Mr. Medlicott in the North-Western Himalayas, who believes the junction between the Tertiaries and the older rocks there to be "primarily a line of original contact."

The Dalings.

On the north side the Damudas are in contact with the Dalings. The junction is much covered up, more so than that with the Tertiaries just treated of; and the boundary line being for the greater part more or less conjectural may not be quite so straight as shewn on the map. In the Chunkhola the junction is fairly well seen in the streams B, C, D. Close to it the Dalings consist of impure limestones and of slates which are partly ferruginous and partly carbonaceous. The latter have a small percentage of carbon, one of the samples analysed shewing only 5·2 per cent. of fixed carbon. The carbonaceous slates occur in association with thin foliæ of white quartz; and the rock may be called carbonaceous quartz schist. This schist is usually well developed near the junction. Further north, silvery slates, quartzites, &c., occur. The limestone mentioned above occurs just at the junction. It is poor in lime, as the following analysis by Mr. P. Lake will shew:—

$Si\ O_2$ and insolubles	53·10
$Fe_2\ O_2$ and $Al_2\ O_3$	2·45
Ca O	23·77
M O	·70
C O_3	18·65
H_3 O	·58
	99·2

The Damuda-Daling boundary.

The Damudas and the Dalings both dipping northward, the former, though more recent, have the appearance of underlying the latter. This appearance is rendered the more deceptive owing to the uniformity of dip (both in amount and direction) presented by both of these series, and owing to the occasional lithological similarity of some of their constituents. As a rule, however, and especially away from the junction, the petrological contrast between the two series is marked, and when the boundary is not covered by talus, it is not difficult to demarcate it. The Dalings are, as a rule, far more advanced in metamorphism than the Damudas.

With regard to the boundary between the Damudas and the Dalings, it may be partly, like the Damuda-Tertiary boundary, a reversed fault. As, however, but few excavations were made along the former, the observations regarding it are not of such a satisfactory character as those relating to the latter.

Conditions of deposition.

The presence of carbonaceous beds in the Dalings probably indicates that estuarine and terrestrial conditions had already set in during the Daling epoch. These conditions certainly prevailed during the Damuda epoch and the Tertiary period, when there were laid down carbonaceous shales, coal, and false-bedded sandstones in the former, and coarse conglomerates, lignitiferous sandstones, &c., in the latter. Indeed, the same conditions appear to have lasted up to the present day.

IV.—ECONOMIC GEOLOGY.

§*1. Principal Coal Seams.*

The ground immediately to the east of the Kalimpong-Bagrakot road was explored in greater detail than any other portion of the Damuda area. I shall, therefore, start with a description of it.

The Churanthi Valley.

At pit No. 7, there is exposed a good seam of coal 16 feet in thickness. It has a high north-eastern dip amounting to 70°. It rests upon fine micaceous, more or less carbonaceous, arenaceous shales about 8 feet in thickness. Below these shales, a thick outcrop of coal is exposed in the streamlet D^1. I at first took it to belong to a distinct seam; but by diggings it was found to be only the 16 feet seam sharply twisted back. On the north side, this seam is faulted against another, about 6 feet in thickness, resting upon shales about 4 feet thick, and dipping nearly vertical in a south-western direction. Eastward, a pit along the strike (between Nos. 7 and 39) disclosed what I believe to be the 16 feet seam coal under some 30 feet of conglomeratic Tertiary sandstones. Further east, these sandstones were found too thick to attempt diggings. The 6 feet seam which is faulted against the 16 feet seam in pit 7 was traced by diggings for a short distance westward, after which its course in that direction was found to be cut off by a fault.

Sixty-two feet north of the seam last mentioned there is a thick seam resting upon sandstones. It was traced through pits 75, 60, 43, 42, 41, and 39, almost continuously for about 340 feet. From the sections in pits 41, 42, and 43, it is found to be about 24 feet in thickness. The dip is north-eastern and varies from 40° to 45°. Near 75, the strike takes a twist and changes from nearly N.W.-S.E.

to N.E.-S.W. The seam is traced down to the stream D, near which there is in all likelihood a minor fault. South of the stream D, we have a good seam exposed by pits 22 and 6. In pit 6, it is about 17 feet in thickness and rests upon shales with inter-bedded thin coal. The dip varies from 40° to 55° in amount, and from N.N.W. to N.W. in direction. I believe the seam is identical with the 75-39 seam.[1] The former was traced to pit No. 87. Proceeding south-west along the strike, we have a good seam exposed by pits 38 and 51. The trench at 38 cutting the strike very obliquely, the thickness of the seam is doubtful. It cannot, however, be much less than 25 feet; and, like the seam 6-87, I believe it is identical with 75-39, in which case, we have got this seam traced for a distance of some 800 feet, without any diminution of its thickness.

The last-mentioned seam is superposed by sandstones which are fairly well seen in the stream D. Several minor coal seams and sheets of "mica trap" are found in these. Just below pit 9, a thick sheet of the mica trap is met with. It is overlaid by coal which extends with but little interruption to pit No. 8 for a distance of about 80 feet. Of this coal, that in immediate contact with the mica trap is worthless as fuel being very hard and columnar; further beyond, in pits 9, 21, and 8 a seam of coal of inferior quality is exposed, averaging about 18 feet in thickness. Similar coal is exposed in pits 10, 45, and 27 by the stream DD[1]; it is very likely the continuation of the 8-9 seam. In fact, I believe, it is continued to the Churanthi as shewn on the map.

The coal of No. 9 is parted from a seam of good coal (pit 104) by a few feet of shales. This coal is about 5 feet in thickness, dips N.W. 45°, and is overlaid by sandstones. There can be scarcely any doubt that it is this coal which is caught in pit No. 46, where the thickness is about 7 feet. It is probably continued through pit 28 to the Churanthi (pit 105). In the last-named pit, however, the coal is of inconsiderable thickness.

A seam of good coal is exposed in pits 47, 48, and 49, of which the thickness in pit 48 is 8 feet, and in pit 49 is 9 feet. It would probably be found to run parallel with the last-mentioned seam at least to some distance westward.

The coal of pit No. 7 as well as of the seam 75—39, traced along the strike eastward, passes under thick Tertiary rocks. By the stream M, close to its junction with the Churanthi, there was disclosed some good coal in pit 95, which, I am inclined to think, is identical either with the coal of pit No. 7, or with that of the seam 75—39. The Tertiary rocks in the intervening ground were found too thick to attempt any excavations: two or three borings would settle the question of the identity satisfactorily. In the meantime I may give the reasons which led me to believe in it.

First.—There is a thick outcrop of mica trap, 300 feet north of pit No. 95, which seems to be the same as that found in the stream D below pit 9; for it is overlaid by altered coal and other rocks similar to those superposed on it in the stream just named. The relative position of the coal of No. 7 or of No. 75 with regard to the mica trap is the same as that of No. 95.

Secondly.—The strike which all these rocks have when last seen near pit No. 39 would bring them to the position occupied by them between the stream M and the Churanthi.

[1] That is to say, the seam lying between pits 75 and 39. For the sake of brevity, I shall refer to seams in this way.

The Ramthi Valley.

Between the Churanthi and the Nunmati stream, the ground is much covered up and was not explored in detail. Some diggings were made by the last-mentioned stream. A trench at 93 exposed the following section in descending order :—

8′ anthricitised hard *coal*—Dip N. 50°.
4′ intrusive sheet of mica trap (?)
6′ altered hard *coal*.
12′ good *coal*.
11′ *coal*, partly altered, partly shaly.
Shales more or less carbonaceous.

As the strike between the Churanthi and the Nunmati stream (a feeder of the Ramthi river) is very steady, being E.—W., I am inclined to believe that the coal of No. 93 is the same as that of 95 by the stream M.

Further up the Nunmati stream, several seams of coal, more or less worthless as fuel, and intrusive sheets of mica trap (?) are met with, until near pit 91, where thick sandstones are met with. At pit 91, there is a seam of good coal about 6 feet in thickness, dipping N.—10—E. 45°.

East of the Nunmati stream the trend of the strike changes from nearly E.—W. to E.N.E.—W.S.W. by the stream E, and to nearly N.—S. by the stream P, where the dip at pit 33 is westerly. This pit exposes a seam of rather good coal 10 feet thick dipping 70° W. Below it there is another seam of indifferent coal (pit 32) about 7 feet in thickness. In pit 30, by the Ramthi, there are two seams, of which the upper is 10 feet in thickness, and the lower varies from 2 to 5 feet. The dip is western.

The Chunkhola.

Going back to the Bagrakot-Kalimpong road, we find about 160 feet west of it, near pit 11, a thick sheet of mica trap overlaid by columnar and otherwise altered coal. I am strongly inclined to think that it is identical with the thick sheet mentioned above as occurring in the stream D below pit 9. There are indications here of the mica trap being faulted against the Tertiary conglomerates.

Proceeding along the strike westward, the mica trap is traceable for a short distance south-west of pit 62. Further beyond, the ground near the junction is much covered up, and there is nothing specially noteworthy south of the Ramtek stream until we come to pit 65. The section here in descending order is as follows :—

Micaceous sandy shales.
27′ good *coal*. } Dip E.N.E. 30°.
25′ sandy shales. }
30′ good *coal*.
Sandstones. Dip E.N.E. 85°.

Taking the average dip of the lower seam, which is higher than that of the upper, at 50°, we get its thickness to be 22·8 feet. The thickness of the upper seam, if the dip (30°) of the underlying shales be taken, is $13\frac{1}{2}$ feet. Both of these seams were traced northward to the Ramtek river where they are lost, probably cut off by a fault. Southward they were traced to the stream F, where they either pass under, or are faulted against, the Tertiary rocks, the question being left unsettled owing to the difficulty of sinking pits in these. The actual length over which the seams are traced is 340 feet.

The sandstones underlying the lower of the two seams just mentioned have a very high eastern dip bordering upon verticality. They are seen for a short distance west of the coke-kiln where they are faulted against coal-seams, carbonaceous shales, &c., running with a very different strike (nearly E.-W.). The ground is much covered up by debris of Tertiary conglomerates, and is, besides, confused by faulting and contortion. By ripping it open several thick seams of excellent coal were exposed. Just by the stream F, at pit 25, a very thick seam is exposed. In a trench dug nearly across the strike its outcrop measured no less than 40 feet. Taking the average dip at 50°, its thickness would be 30 feet. Westward, the ground was not sufficiently well opened up to enable me to say with certainty how it ran in that direction; and its relation to the seam just north-west of it is very doubtful. Possibly the two seams are identical, one being slightly shifted from the other by faulting. Eastward, the seam of pit 25 is faulted against the sandstones underlying the bottom coal of pit 65.

A trench across strike at pit 36 exposed the following section in descending order:—

> 22′ good *coal* (lower part somewhat stony). Dip N.-10-E. to N.-10-W., 40°.
> 16′ shales.
> 29′ good *coal*. Dip N. 45°.
> Shales.

The thickness of the upper of these two seams is about 15 feet, and that of the lower seam about 20 feet.

Both of these seams agree very closely with those exposed east of the coke-kiln in thickness and quality as well as in the fact of their being parted by shales. I think it highly probable that the seams of pit 65 have been brought to the position they occupy in section 36, first by a twist in the strike south of the stream F, and then by faulting.

The upper seam of pit 36 is much covered up by debris of Tertiary rocks. Digging through these to a depth of some 20 feet, it was seen to be apparently faulted against another seam of excellent coal, which at pit 56 dips E.S.E. 50°. The thickness of the latter seam is about 17 feet. It is continued westward to pit 35, where a twist in the strike takes place, the dip changing to E.N.E. 55°. The thickness as measured here is slightly greater amounting to about 20 feet. It is apparently faulted against another seam of hard, altered coal, below which we have some excellent coal, about 13 feet thick, resting upon sandstones and dipping E.S.E. This coal is, I believe, continued to pit 13 at the junction of the stream F and the Chunkhola.

The ground just described (containing pits 65, 25, 36, 56, 35, and 13) is very rich in excellent coal-seams. On the data available, any attempt to identify them with the seams exposed between the Kalimpong-Bagrakot road and the Churanthi would lead to too much speculation, which I have tried to avoid. I may, however, just observe that a thick outcrop of mica trap occurs between pit 54 and the junction of the stream K with the Ramtek river. If it be permissible to identify it with the mica trap near pit 11 by the Bagrakot-Kalimpong road, then the seams exposed tin pit 65 may be identical with the coal-seam in pit 38.

South-west of the stream F, there is nothing specially noteworthy until we get to the stream L. Between its junction with the Ramtek river and pit 20, there were found indications of good coal-seams. This ground, however, was not explored in sufficient detail.

Going back to the Bagrakot-Kalimpong road, we find some 400 feet west of the Kuli huts a rather promising seam exposed by pit 5. It is about 14 feet in thickness, and dips E.—10—N. Southward, the ground being much covered up, it could be traced but for a short distance. There are indications of coal near pit 61, but none of respectable thickness was encountered. The dip here is also eastern. But at pits 62 and 11 the beds of altered coal (mostly columnar) are inclined N.N.W. I am inclined to think that a line of fault runs between pits 61 and 62, and extends to some distance westward, probably as far as the junction of the stream H with the Chunkhola. There is very likely another line of fault running along the spur, dividing Chunkhola from the Churanthi valley; for the rocks on either side of it present great discordance both as regards strike and lithology. On the Bagrakot-Kalimpong road and east of it the dip is north-western; whereas west of the road it varies from E—18—N to N.E.: and the seams occurring west of the road—that of pit 5, for instance—are not to be found east of it.

Proceeding westward from pits 5 and 61 we have in pits 68 and 34 indications of good coal. Further west there occurs in pit 29 an excellent seam. The section here is as follows (in descending order):—

Shales.
2′ good *coal.*
9″ shales.
14′ 3″ good *coal.*
Blackish carbonaceous shales.

The dip is E.N.E. 45°. Taking this dip, the thickness of the lower seam comes to about 10½ feet. Lower down the streamlet in which pit 29 lies, another seam of good coal was exposed by diggings (pit No. 53). It has a thickness of about 6 feet, and strikes nearly E.—W.

Proceeding westward, some very good coal was exposed by diggings by the stream G (pits 69 and 59). A cross cut at 69 exposed the following section (in descending order):—

1′ *coal.*
1′ 3″ shales.
38′ 9″ *coal,* dip N. to N.—10—W. 65°.
4′ carbonaceous black shales.
3′ grey sandy shales.
3′ carbonaceous, oily, black shales, Dip N 80°.
Sandstones.

If the amount of the dip be reliable, the thickness of the main seam comes to no less than 35 feet. As regards the quality of the coal, it has a very strong resemblance to that of pit 29; and the strike which the latter has would bring it to the position occupied by the former.

Just west of the junction of the stream G, with the Ramtek river, there is an outcrop of good coal (pit 55) about 14 feet in thickness, resting upon thin, splintery carbonaceous shales, with interbedded thin seams of coal, dipping N. 45°. The seam was traced for a short distance westward. Higher up the stream G, north of pit 69, there is a thin seam of good coal (3′ 6″) resting upon shales, and dipping about 50° N.—6—W.

By the stream H, and the footpath just east of it, there are indications of several promising seams. But the ground is so extremely covered up that they could not be traced far on either side of it. The section by the stream exposed by a cross cut, pit 85 (*i.e.*, a trench across strike), is as follows (in descending order):—

a. 10′ *coal,* dip 45°.
27′ sandstones.
8′ black carbonaceous shales.
b. 4′ good *coal.* }
8′ shales. } Dip 45° N. to N.—10—W.
c. 11′ good *coal.* }
Shales.
80′ shales, sandstones, and coal, not well exposed.
d. 1·1′ *coal.*

From the steadiness of the strike between the streams G and H, I have but little doubt that the seams *b* and *c* of the above sections with some of the associated carbonaceous shales represent the thick seam of pit 69; and that the seam *a* represents the thin seam above pit 69, though the former is immensely thicker than the latter.

At pit 99 by the footpath just east of the stream H, a good seam about 8 feet thick is exposed, which I am inclined to connect with the coal of pit 100 presently to be mentioned.

The strike continues very steady for some distance westward. By the footpath just east of the stream C, there are several exposures of good coal. At pit No. 90, we have the following section:—

9′ *coal.*
1′ shales.
2′ *coal.*

Below pit 90 occur shales with thin seams of coal until we come to pit 100, where there is a rather promising seam of which the exposed thickness is no less than 10 feet. I am inclined to consider the latter as identical with the coal of pit 99 east of the stream H.

With regard to the coal of pit 90, it very likely represents the seam *d* of the section at pit 85. The higher seams of this section are, I believe, caught in pit 79 further west by a footpath east of the stream B. Here the section is as follows (in descending order):—

97′ reddish sandy shales with thin *coal.*
a. 19′ *coal.*
4′ shales.
b. 28′ good *coal.*
Hard reddish shales.

The dip varies in amount from 35° to 55°, and in direction from N. to N.N.W. The thickness of the seam *b* in this section, taking the average dip at 45°, is found to be 19·8 feet. Together with seam *a* its thickness would be very nearly that of the thick seam of the stream G (pit 69), with which I am strongly inclined to identify it.

Proceeding further west along the strike, some seams were exposed by excavation by the stream A. None of them appears to be very promising, and if they represent any of the seams mentioned above (as from the strike they appear to do, at least in part), they must do so in a considerably attenuated form.

The Lisu Valley.

At the forest boundary dividing Chunkhola from the Lisu valley the ground is much covered up. The few outcrops seen here are all of worthless coal. West of the forest boundary, indications of good coal were found by the stream N. at pit 14 and the one above it. In the former, the seam is 7 feet thick, dipping N.—15—W., and in the latter, the seam is 7 feet 6 inches in thickness, dipping 35° N.—10—W. The strike of these as well as of the outcrops at pits 15 and 16, is the same as that prevailing east of the forest boundary in pits 70, 74, &c.

Further west, the strike changes probably by a twist, the dip in the pits 4, 82, 17, and 18 west of the stream R being north-eastern. The section exposed by pit 4 is as follows (in descending order):—

Carbonaceous shales with thin seams of coal.
4' *coal.* }
1' carbonaceous shales. } Dip 25° E.N.E.
4' *coal.* }
Sandstones.

The seam exposed by pit 18 is 5 feet 6 inches in thickness; and the coal appears to be very good. The seams in pits 17 and 82 were not well exposed; and their thickness is doubtful. From the strike it seems to me probable that the coal of the pits 4, 82, 17, and 18 represents respectively that of the pits 14, 107, 15, and 16.

Further west, the ground is so covered up by detritus from the Dalings, that very little rock is seen *in situ*. There are, however, indications of excellent coal in pits 1, 2, and 3. The section exposed by pit 1 (in descending order) is as follows:—

a.—5' 9" good *coal.*
3' 3" black carbonaceous shales.
4' sandstone.
5' black carbonaceous shales.
b.—1' 10" *coal.*
5' 3" black carbonaceous shale.

The dip is high about 65° to 80°, pointing E. to E.N.E. The seam *a* was traced for some 100 feet northward, where a fault appears to separate it from the seams of pits 2 and 3. In pit 2, a seam of excellent coal, 3 feet 6 inches in thickness, is observed interbedded with micaceous, sandy shales, which yielded a large number of fairly-preserved fossils mostly belonging, however, to one genus, *vertebraria*. The seam in pit 3 is about 2 feet 9 inches in thickness; it is very likely identical with that of pit 2. The dip of both is high (about 50°) N. W. to N.N.W.

Tabular Summary.

The following is a tabular summary of the principal coal-seams not less than 5 feet in thickness, leaving out those which have been too highly altered by contact with igneous rocks :—

Seam (indicated by pits).	Dip.	Average thickness in feet.	Length of seam actually traced in feet.	REMARKS.
(I)—SUPERIOR COAL (CLASSES A AND B).[1]				
I.—Churanthi and Ramthi Valleys.				
(1) 39—41—42—43—60—75—6—38—51	40° to 55° N. E. to N.W.	22	800	This seam is very likely continued to next pit under Tertiary conglomeratic sandstones which cover the intervening ground.
(2) Near pit 95 (close to junction of stream M with the Churanthi) . .	N. N.E.	?	...	This coal is probably continued to next pit.
(3) 93	50° N.	17·5	...	Part of this coal is of inferior quality. This seam is possibly continued to seam 4.
(3*a*) 91	45° N.—10—E	6	...	Probably identical with seam (5 *b*).
(4) 33—(Stream P, a feeder of the Ramthi) .	70° W.	9·4	...	
(5) 7—(Two seams faulted) .	70°N.N.E.to N.E. (16 feet seam) S.W. (6 feet seam).	22 (total thickness)	200	Very likely continued to near pit 95.
(5*a*) 104—46—28—105 . .	45° N.W. to N.N.E.	5 ?	1,650	
(5*b*) 47—48—49 . . .	35° to 50° N. to N.N.E.	8·5	825	
II.—Chunkhola.				
(6) 65—(Upper seam) .	30° E.N.E.	13·5	340	These seams are possibly identical with those next named.
(7) 65—(Lower seam) .	50° E.N.E	22·8		
(8) 25	50° N.	30 ?	...	This is probably identical with lower seam of next pit.
(9) 36 (Upper seam) . .	40° N. 10 E. to N. 10 W.	15	300	
(10) 36 (Lower seam) . .	45° N.	20		
(11) 56—35	50° E.S.E. to 55° E.N.E.	18·5	55	This seam is faulted against the one next named.
(12) 35	E. S. E.	13	250	
(13) 5	E. to N.	14	165	Possibly identical with the next seam, but shifted by a fault.
(14) 29	45° E. N. E.	12	660 ?	Probably continued to next seam. The thickness given here is the aggregate thickness of two seams parted by 9 inches of shales.
(15) 59—69—85—79 (?) .	45° to 65° N. to N. N. W.	27 (?)	1,815	
(16) 101 (Stream G, above 69)—85 (uppermost seam) . . .	45° to 50° N. to N. N. W.	5 ?	500	

[1] *Vide infra*, pp. 17—18.

Seam (indicated by pits).	Dip.	Average thickness in feet.	Length of seam actually traced in feet.	REMARKS.
(17) 34—68—53—55—64—102	45° N. N. E. to N.N.W.	8	1,000	
(18) 99—100. . . .	45° N.N.E. to N.N.W.	9	700	
III.—Lisu Valley.				
(19) 14—4	35° N. 10 W. to 25° E.N.E.	5·25	750(?)	
(20) 1	65° to 80° E. to E.N.E.	5·5	...	
(II)—INFERIOR COAL (CLASS C).[1]				
I.—Churanthi and Ramthi Valley.				
(21) 8—21—9—10—40—45—27—103 . . .	50° to 85° N.W. N.N.E. N. 10 E.	15 ?	1,800	The seam is very thick between pits 40 and 45. It is very likely continued to next pit.
(22) 97 (Nunmati stream) .	N.N.W.	...	...	Seam of 32 is probably identical with the upper one of 30.
(23) 32	W.	7	...	
(24) 30 (Two seams) . .	W.	13 (total thickness).	...	
II.—Chunkholá.				
(25) 11—45	N.N.W.	8	...	

§ 2. *Quality of the Coal.*

With regard to quality, the coal may be classed under three heads as follows:[2]—

Class A.—Cakes strongly. Percentage of ash not exceeding 16.

	Pit No. 3 (Lisu Valley).		Pit No. 1 (Lisu Valley).	Pit No. 1.
Moisture	14·54	Percentage minus the moisture.	4·72	3·28
Volatile matter (exclusive of moisture)	8·86	10·37	22·16	20·60
Fixed carbon	63·96	74·84	60·24	60·12
Ash	12·64	14·79	12·88	16·00
Colour of ash	Gray. Cakes strongly, and forms a light tumid cake.			

Three samples from pits Nos. 1, 2, 3 in the Lisu valley were found to contain respectively 10·64, 8·88, and 16·12 percentage of ash. These samples as well as those from pit No. 1, of which the analyses are given above, were from the surface, and were found either not to cake or only to sinter slightly. From a depth of 5 or 6 feet from the surface, the coal from all these pits was found to coke strongly, like the sample from pit No. 3, the analysis of which is given above.

As far as I could judge from appearance, the coal from pits Nos. 29, 59, and 69 belongs to this class.

From the analyses given above, the average percentage of ash is found to be 12·23, and the average percentage of fixed carbon, 61·44.

[1] *Vide, infra*, p. 19.

[2] The analyses were made in the Survey Laboratory.

Class B.—Cakes strongly. Percentage of ash between 16 and 22.

	Pit No. 7, Churanthi Valley, depth 9 feet.		Pit No. 25, Chunkhola or Ramtek River, depth 7 feet.		Pit No. 7, Churanthi Valley, surface.	Pit No. 7, surface.	Pit No. 7, surface.	REMARKS.
Moisture	4·21	Percentage minus the moisture.	16·10	Percentage minus the moisture.	20·80	21·48	17·20	From a comparison of the analyses of the different samples from pit No. 7, the caking power is found to increase, and the percentage of ash to decrease, with depth.
Volatile matter (exclusive of moisture).	14·09	14·71	15·47	18·44				
Fixed carbon	62·56	65·31	51·85	61·80	57·92	56·52	63·28	
Ash	19·14	19·98	16·58	19·76	21·28	22·00	19·52	
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	
Colour of ash	Pale brown . .		Reddish gray .		Dark red .	Dark red .	Dark red .	
	Cakes strongly .		Cakes strongly .		Cakes, but not very strongly.	Sinters slightly.	Cakes, but not very strongly	

The coal of the pits 39, 41, 42, 43, 6, 38, 65, 36, 35, 56, 13, 55, 100, &c., in fact the greater portion of the coal described above, appears to belong to this class.

Class C. Does not cake. Percentage of ash between 22 and 33.

	Pit 30, Ramthi Valley. (Surface.)	Pit 30, Ramthi Valley. (Surface.)	Pit 9, Churanthi Valley.
Moisture	·80	1·60	5·76
Volatile matter, exclusive of moisture	7·88	10·40	
Fixed carbon	58·12	61·76	69·84
Ash	33·20	26·24	24·40
	100·00	100·00	100·00
Colour of ash	Dark brown.	Light red.	Dark brown.

To this class belongs the coal of pits 8, 21, 10, 45, 40, 27, 103, in the Churanthi valley; 97, 32 in the Ramthi valley; 11, 12, 54 in the Chunkhola.

In the following table the Darjiling coal (Class A and B) is compared with the Rániganj coal:—

	Fixed carbon.	Volatile matter (including moisture).	Ash.
Darjiling, average of 8 assays	59·56	22·94	17·42
Raniganj, average of 31 assays	53·2	30·63	16·17

The utilisation of the Darjiling coal depending to a great extent upon its caking property, care was taken to test it in the field in earthen *kalsis*, as well as on a larger scale in kilns. Three kilns were put up, one on the saddle separating the Churanthi valley from the Chunkhola, another in the Chunkhola, and the third in the Leeshkhola (Lisu valley). Coal from pit 7 was tried in the first, from pit 25 in the second, and from pits 1 and 3 in the third. All of the kilns turned out good coke which has been pronounced by a competent authority to be quite up to any made at Barakar. A sample of the coke assayed in the Survey Laboratory was found to contain only 0·62 per cent. of sulphur (0·58 per cent. as sulphide, and 0·04 per cent. as sulphate).

The fact that so many of the outcrops have yielded good coke is the most hopeful feature about the explored coal.

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§ 3. *Quantity of immediately available good coal in the central portion of the explored area.*

With regard to the quantity of the coal, I shall attempt a calculation of it only for the central portion of the explored area (marked *a*, *b*, *c*, *d* on map), which was opened up in greater detail than any other portion. This area measures only 97 acres, or about three-twentieth of a square mile. Within this small area, I shall, to be on the safe side, restrict myself to those seams or portions of seams which have been actually traced by me. Further, I shall neglect all coal which contains more than 22 per cent. of ash, and all seams less than 5 feet in thickness.

I shall put the limit of workable depth at 1,000 feet. In Europe there are coal mines of more than treble this depth in rocks quite as highly disturbed as those we are dealing with. But, in India, no coal mine has, I believe, yet reached the depth of 500 feet; and in taking the limit of workable depth at a thousand feet, I hope I am not transgressing the bounds of Indian probabilities.

For facility of calculation, I shall assume an uniform average inclination of 45° for all the seams. From an inspection of the table of principal seams, it will be seen that this average is well warranted by facts.

Seam.	Available quantity of coal in tons.
(1)[1]	746,592
(5)	186,648
(5a)	349,965
(5b)	279,972
(6)—(7)	519,214
(8)—(10)	509,040
(11)—(12)	328,755
(13)—(15)	1,903,809
(16)	106,050
(17)	395,354
(18)	267,246
	5,592,645

In round numbers we have 5½ millions of tons of almost immediately available good coal belonging to classes A and B within an area of not more than 97 acres. The whole of this coal will, I believe, be found to be convertible into good coke. For the entire explored area, which measures a little over one square mile, the amount must be much greater though not proportionately, as the seams appear to suffer attenuation eastward as well as westward. Twenty millions will not, I think, be an over-estimate for the whole of the explored area. If we take coal of class C into account, we would probably have some ten millions of tons more.

§ 4.—*Carriage; mineral resources; labour; mining.*

Carriage.

The coal-field is situated at a distance of 2½ miles (as the crow flies) from the Duars. There is only one made road in the explored area, the Kalimpong-Bagrakot road. It passes along the water-shed between the Lisu and the Churanthi and is practicable for ponies. Running as it does through the central and apparently the richest portion of the coal-field, its importance, if widened into a cart-road, would be great. There is a path which runs along the Lisu river to Asabari at the foot of the hills, where a *hát* is held every Sunday. It could be made into a cart-road; but the expense will, I think, be greater than in the case of the Kalimpong-Bagrakot road, as several bridges will be required.

[1] These numbers refer to the seams tabulated before, see pp. 16—17. Strike faults may reduce the estimated quantity to some extent.

From the foot of the hills there is a cart-road to Silliguri, a distance of about 18 miles. The only river it crosses is the Tístá. At present tea from the plantations just at the foot of the hills is carried to Silliguri at a charge of about 5 annas or so per maund. If the cart-road be extended to the coal-field, carriage by cart to Silliguri would cost 6 annas per maund. If a tramway be made, the cost would be much reduced.[1] The proposed Duars Tramway will pass at a distance of about 10 miles from the coal-field, and a branch to it is well worth the consideration of the Tramway Company. Besides the coal, the branch line would tap several flourishing tea plantations, such as Bagrakot, Phulbari, and Asabari. I must say, however, that traffic on this line would have to be suspended for three months and a half, from June to the middle of September; for the rivers which the proposed branch line would cross swell to large proportions during the rains, though almost dry for the remainder of the year.

Mineral resources in the vicinity of the coal.

With regard to mineral resources, the coal-field is advantageously situated. Seven miles to the north of it, at the head of the Rere Ung, there are some excellent iron-ores.[2] There are two kinds of ore, of which one is described by Mr. Mallet to be in places pure magnetite, but more usually including a varying proportion of actinolite; the other is a "schist composed of magnetite, micaceous hematite, actinolite, and talc, irregularly interbanded; the last three also including octahedrons of magnetite." Specimens of both kinds of ore have been assayed with the following results:—

	Percentage of iron.
Magnetite	71·50
Micaceous hematite	59·89

Neither contain any phosphorus or sulphur.

Mr. Mallet who examined the ores observes: "the deposit is a valuable one; as will have been seen from the assays, the ore is extremely rich, and the quantity appears to be considerable, while the iron produced is of the best quality."

There is copper ore two miles north-west of the coal-field on Yongri Hill. Mr. Mallet who examined it in 1882 observes:[3]

. . . . The Yongri seam, like all the other known cupriferous seams in the Darjiling district, (1stly) occurs in the rocks of the Daling series, (2ndly) is a bed, not a true lode, and (3rdly) that the ore is copper pyrites.

"As is commonly the case in the Darjiling mines, the seam is not of constant thickness, expanding in some places, as I was informed by the miners, to a foot or so, and in others thinning to only 1 or 2 inches. A sample of the ore, as it was being brought out from the mine, yielded on assay 1·5 per cent. of copper, while a sample of picked ore gave 6·6 per cent.

"Taking the general strike of the rocks into account, it is not impossible, perhaps not improbable, that the Yongri cupriferous band is on the same horizon as the metalliferous strata at Mangphu. The chance is at least sufficiently great to suggest a somewhat promising clue towards the discovery of new outcrops, between the two positions, to any one with sufficient geological knowledge to apprehend the bearing of the facts."

[1] Carriage by the Tístá to Jalpiguri, if practicable, would be cheap. I hear tea from some of the plantations near the coal-field is conveyed in boats down this river. The coal could be carried down to the foot of the hills by wire-tramway; and this mode of conveyance may prove cheaper than an ordinary tramway.

[2] *Vide* Mem., XI, p. 67.

[3] Rec., XV, pp. 56—57.

[The Mangphu copper ore on the Tístá, referred to in the above extract, is not very far from the coal-field, about 6 miles to the north-west.]

A mile and a half north-east from the Yongri mine, on the western flank of Sampthar hill, Mr. Mallet encountered a metalliferous band, which was found to contain "arsenical pyrites with a somewhat considerable proportion of mundic and a little copper pyrites." "As white arsenic and orpiment (arsenious acid and arsenious sulphide)," says Mr. Mallet, "are both easily prepared from arsenical pyrites, and orpiment is used to a considerable extent in India in connection with the preparation of hides, it seems likely that if some of the copper miners were to learn the way of making the above-mentioned products, they could profitably work the Sampthar ore, especially as some copper could be subsequently extracted from the spent pyrites." [1]

There are deposits of tufaceous limestone in the Chunkhola, from which lime used to be made at one time. But the supply from this source will never be plentiful; it will certainly not meet the demand for the manufacture of iron on a large scale. There are beds of limestone belonging to the Daling series in the Chunkhola; but the limestone appears to be poor.[2] I could, however, but pay little attention to it. Very likely with closer search more promising outcrops will be found. We have good coke, and an abundance of rich iron-ores: with good flux, we may expect to have iron manufactories at no distant date in the Darjiling District.

Labour-supply.

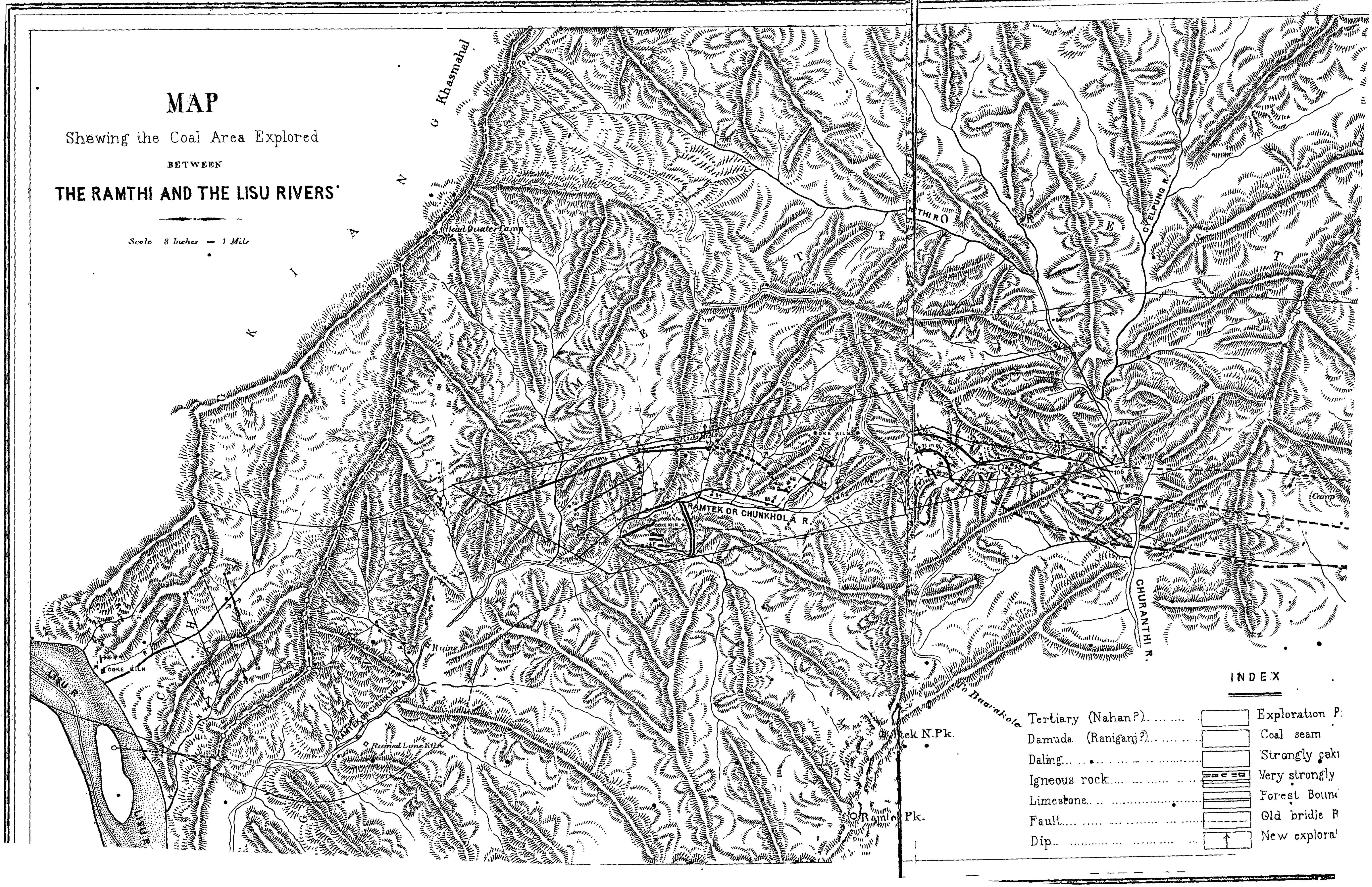
There are a few villages north and north-west of the coal-field. But they are scantily populated; and land is so cheap that every tenant has got more of it than he can well attend to. Consequently labourers as a class do not exist; and great difficulty was felt by me in procuring local labour. If the coal be worked, Nepalese labourers will have to be got. In the neighbouring cinchona plantation at Nimbang they work at R5-8 to R4 per month; and there is no reason why they should not be available for the coal mines at the same wages, *provided that suitable land for them to settle on be found.* Every family of labourers requires a small plot of land to grow *bhutta* on; in fact, the low wages mentioned above are conditional upon such land being granted rent-free. Within the coal area, there are not many good sites for settlements; and should the coal be worked on an extensive scale, a fringe of cultivable land to the north and west of the coal-field at Chankiang and Makum would be required.

Mining.

With regard to mining, some of the conditions appear to be distinctly in favour of the coal, while others are quite as distinctly against it. The disturbance which the coal and associated rocks have suffered is by no means an unmixed evil. Owing to its crushed condition it can be easily dug out with picks and *kodalis*, so that the cost of extraction would be much less than in the Raniganj and Giridih mines. On account of its high dip, the Darjiling coal has been brought to the surface; consequently, it will not, as a rule, be necessary to sink shafts through unproductive rocks, and a very heavy item of expense will thus be saved. The powdery condition of the coal is favourable for coke-making; and water for the kilns or ovens could be brought down from a higher level than these in bamboo or iron pipes at a comparatively trifling cost. On the other hand, owing to the crushing which the coal and the associated rocks have undergone, these (especially the shales) are not likely to afford a firm roof in deep mining, and extensive timbering will be necessary. There being reserved forest, however, on all sides, timber will be cheap.

[1] *Op. cit.*, p. 58.

[2] *Vide ante*, p. 8.


MAP
Shewing the Coal Area Explored
BETWEEN
THE RAMTHI AND THE LISU RIVERS
Scale 8 Inches = 1 Mile
Khasmahal
Head Quarter Camp
RAMTEK OR CHUNKHOLA R.
CHURANTHI R.
COKE KILN
Ruins
Ruined Lime Kiln
LISU R.
Camp
INDEX
Tertiary (Nahan?)
Damuda (Raniganj?)
Daling
Igneous rock
Limestone
Fault
Dip
Coal seam

The Basic Eruptive Rocks *of the* Kadapah Area, *by* PHILIP LAKE, B.A., F.G.S., *Geological Survey of India.*

In Southern India there were at least two great periods of eruption of basic rock before the time of the Deccan trap. The first eruption took place in the Dharwar and the second in the Kadapah epoch. Before Dharwar times, and also between the Dharwar and Kadapah epochs, there were many dykes injected into the crystalline and schistose rocks of the country, but they are at present unconnected with any contemporaneous flows, and may never have reached the surface.

The contemporaneous traps of the Kadapahs are all found in the Poolumpett beds of the Cheyair group. In the rocks below these there are many intrusive dykes but no flows, while above the Cheyair group no traps of any kind are found among the Kadapah rocks. A full account of the relations of these traps to the beds in which they occur is given by Dr. King in his Memoir on the Kadapah and Karnul rocks.[1]

The chief of the contemporaneous flows are those of Jootoor and Palamodu.

Jootoor trap.[3]

Adopting Mr. Teall's classification,[2] the Jootoor trap is an olivine-dolerite, or olivine-gabbro. It is a fine-grained holocrystalline rock composed chiefly of olivine, augite, and plagioclase felspar, but containing also "opacite" (probably magnetite) and a little mica. The specific gravity is 2·9, and the percentage of silica is 45·59.

The olivine, which seems to have crystallised out before the augite and felspar, occurs in rounded grains, which are frequently clouded at the edges. Along the cleavage cracks opacite has been developed in great quantity, but there is no sign of alteration into serpentine. The olivine granules are sometimes included in the augite and felspar.

The augite generally forms large ophitic masses, but occasionally occurs in fairly well-defined prisms. It is of a very pale brown colour. The cleavage is generally irregular. One section of a twinned prism which shows the prismatic cleavages, making an angle of 89° with each other, also shows a striation parallel to the trace of the twin-plane, *i.e.*, to the orthopinacoid (100). In this it resembles diallage, but the striation is not very marked. Opacite is developed along this lamination, and also along irregular cracks which cross most of the sections of augite.

The felspar is not abundant, and there are not enough crystals for the determination of the species. It is twinned on the albite plan.

A little brown dichroic mica is also found. Opacite is sometimes developed along its cleavage planes.

The opacite, as already mentioned, occurs along the cracks and cleavage planes of the ferro-magnesian constituents, especially the olivine. It is mostly in the form of a fine dust, but occasionally forms little needle-shaped crystallites. It is probably magnetite, and has evidently been formed by the alteration of the olivine, &c.

Greenish chloritic matter also occurs in the rock, but is not abundant.

[1] King. Mem. G. S. of I., VIII.—The specimens on which the descriptions in this paper are based were collected by Dr. King, and are now in the Indian Museum.

[2] British Petrography, p. 70.

[3] Mem. G. S. of I., VIII, p. 196.

Palamodu trap.[1]

The Palamodu trap is a dolerite without olivine. It consists chiefly of augite in an earthy base. The base has evidently been formed by the alteration of felspar, and remnants of plagioclase crystals are seen in it. Besides the augite, there is also a serpentinous mineral which seems to have been formed by the alteration of the augite. The specific gravity of the rock is 2·9.

The augite occurs in crystalline masses without crystalline outlines. Very often the plagioclase crystals, or the earthy pseudomorphs of these, penetrate the augite, and it is clear that the augite crystallised out after the felspar. The rock is, therefore, ophitic (diabasisch-körnig of Rosenbusch). Besides the prismatic cleavages, there are shown in some of the augite sections sets of dark lines parallel to the planes, 100 and 010. These are not always easily distinguished from the prismatic cleavage; but in one section which shows the two sets of dark lines at right angles to each other (and in convergent polarised light gives an optic axis a little outside of the field), the extinction is parallel to these lines, and the lines are therefore not parallel to the prism (110). The development of planes parallel to the pinacoids suggests that the augite may be rhombic; but this is not the case. In sections out of the zone 100,010 (with the cleavages parallel) the extinction is not always paralle to the cleavage; and when it is parallel, the section shows an optic axis in convergent polarised light. The augite is therefore monoclinic. Its double refraction is positive and strong.

It is probable that the dark lines are generally developed, parallel to only one of the planes 100, 010; for in most of the sections only one set of these lines is visible.

The augite, separated as well as possible from the other components of the rock, was found by Behrens' microchemical methods to contain Ca, Mg, and some Al.[2] The amount of Al found was small, and it may have come from the other materials of the rock, which could hardly be completely separated from the augite. The augite is not highly aluminous.

In many cases the augite is partly altered into a fibrous-looking earthy substance, the fibres apparently lying nearly at right angles to the vertical axis.

The final product of alteration of the augite is a fibrous-looking mineral penetrated by little veins of what appears to be the same mineral oriented differently. The colour is greenish yellow, and the mineral shows a feeble pleochroism. The extinction is parallel to the fibres or cleavage. In convergent polarised light, the mineral is found to be bi-axial; and as the extinction is straight, it must be rhombic. It is probably bastite.

The felspar is almost entirely decomposed, and the species cannot be determined. There are besides the plagioclase, a few grains of clear felspar without any definite form and without any twining. This is probably of secondary origin. There is also a little quartz, which may have been set free during the alteration of the felspar.

[1] Mem. G. S. of I., VIII, p. 198.

[2] Being unable to procure any cæsium chloride, I was obliged to use rubidium chloride instead as a test for Al. For suggesting the use of rubidium chloride I am indebted to Mr. P. Brühl of the Civil Engineering College, who kindly gave me a specimen. 100 parts of water at 17° dissolve 0·619 parts of cæsium alum or 2·27 parts of rubidium alum (Watt's *Dictionary of Chemistry*, after Redtenbacher), so that the test with cæsium is about 3·7 times as delicate as that with rubidium. With cæsium 0·01 milligrammes of $Al_2 O_3$ can be clearly proved, and therefore with rubidium 0·37 milligrammes can be detected. In the present case the drop of liquid was allowed to evaporate slowly, almost to dryness.

At Betumcheru, in Karnul District, is another mass of trap, which also appears to be contemporaneous and of Poolumpett age. This rock is composed chiefly of plagioclase and augite. There are two specimens in the Museum, one obtained at Betumcheru, and the other three miles W. S. W. of Betumcheru. The former is fine-grained and holocrystalline (Sp. gr. 3·0), while the latter is compact and contains amygdaloids (Sp. gr. 2·7).

Betumcheru trap.

In the first specimen the augite very much resembles that of the Jootoor trap. It has crystallised after the felspar, and forms ophitic plates. The felspar crystals frequently penetrate it. It is often partly decomposed into a clouded greenish substance which is dichroic.

The plagioclase occurs in long lath-shaped sections with numerous twin-lamellæ. The maximum extinction found in the zone 100,001, referred to the trace of the plane 010, was about 29°, and the plagioclose is therefore labradorite, or possibly a more basic felspar.

Magnetite is scattered through the rock in nests.

The second specimen (3m. W. S. W. of Betumcheru) is very finely crystalline. Almost all the augite appears to have been converted into chlorite, and the rock is practically composed of plagioclose microliths in a chloritic base. Magnetite is scattered through the rock in small grains and in skeleton crystals. A few grains of a brownish granular substance fill up the interstices of the rock, and there is also a little hæmatite present.

The amygdaloids are composed of quartz, or quartz and chalcedony, in alternate layers. In some cases chlorite fills up the spaces between the quartz crystals.

From these descriptions it will be seen that the Kadapah traps are essentially plagioclase-augite rocks. The Jootoor trap contains olivine, and in parts of the Betumcheru mass the augite has been converted into chloritic or, possibly, serpentinous matter. But this does not alter the character of the rock.

The augite appears to be non-aluminous or but slightly aluminous, and is allied to diallage. The felspar is basic, and in parts of the Betumcheru trap, and probably in the other traps also, is allied to labradorite or bytownite.

The occurrence of these highly magnesian traps in the Kadapahs is interesting in connection with the presence of serpentinous and steatitic rocks in the Paupugnee beds, which lie below the horizon of the contemporaneous traps. Dr. King[1] shows that where the Paupugnee limestones and slates are in contact with trap, they are frequently seamed and veined with serpentine. Steatite also is abundant in places. The Paupugnee traps are intrusive, and there can be little doubt that they are of the same age and character as the Cheyair traps; and the serpentine and steatite are evidently derived from the augite and olivine forming so large a part of them.

The Deep Boring at Lucknow, *by* R. D. OLDHAM, A.R.S.M., *Deputy Superintendent, Geological Survey of India.*

An experiment of considerable practical and scientific importance has lately been carried out by the Municipality of Lucknow, which has put down a boring, 1,300 feet in depth, in search of an artesian water-supply. A section of this boring, received from the President of the Municipal Board, is here published and deserves some comment.

[1] *Loc. cit.*, pp. 164—166.

Our late Director, Mr. H. B. Medlicott, always maintained that artesian water could be obtained by deep borings in the Gangetic plains, the failure of those put down as yet being due to their unfavourable situation. Though it is extremely improbable that the Gangetic alluvium has that structure which would have been most favourable for the production of an abundant supply of artesian water, and was at one time believed by Mr. Medlicott to be the actual structure, yet it has been recognized that the analogy of previous experience in other alluvial plains justified the hope that water would be obtained under sufficient pressure to rise to the surface; the only difference of opinion being as to the probable abundance of the supply.

It will be seen from the record that, as the boring progressed, water steadily rose in the bore hole till, between 1,189 and 1,202 feet, a bed of quicksand was passed through, from which 10 gallons per minute flowed from the top of the bore hole. This is of course a miserable supply to be obtained from so expensive a venture, but does not by any means represent the true capacity of the bed, owing to the want of judgment shown in the selection of the points at which the size of the casing was reduced. I find that the bottom of the 12″ pipe is at 408′ 8″ in "fine sandy silt;" of the 10″ pipe at 798′ 1″ in "quicksand with abundance of mica," and the 8″ pipe ends at 898′ in "kankar, hard, with a little sand." All these are permeable beds, one freely so, in which the water had not sufficient pressure to rise to the surface; at all these junctions there must have been leakage, and the 10 gallons a minute, barely flowing at the surface, do not truly represent either the pressure or the discharge of the 4″ pipe at the bottom of the well.

In the current newspapers this boring has been stigmatised as a failure; such it doubtless is if regarded as a source of water-supply, but as an experiment it has been conspicuously successful. It has established the fact that at 1,200 feet there is water under sufficient pressure to flow at the surface; it is probable the succeeding water-bearing strata, which would be struck by a deeper well, would yield water at a higher pressure; and, even if the pressure and supply so obtained be insufficient, an abundant supply of pure water will be obtainable by pumping.

In sinking a fresh well, as has been decided on, it will be necessary to start with a larger size of bore hole, and to show greater judgment in selecting the points at which the casing is reduced in size. The boring just abandoned appears to have been made with an ordinary chisel bit, and the casing driven close behind the head of the boring till it would go no further; but, in such stuff as was passed through, there seems no reason why an expanding bit should not be used, thereby reducing the friction against the outside of the casing and increasing the distance to which each separate size could be driven.

There are two points of theoretical interest connected with this boring. They are (1) whether the head of water comes from the northern or southern margin of the plains, and (2) whether the bore hole has not nearly reached the base of the alluvium.

With reference to the first. It has now been established that the formation of the depression, now occupied by the Gangetic alluvium, has proceeded *pari passu* with the elevation of the Himalayas, and that it has extended southwards by the gradual subsidence of the northern limit of the peninsula rock area. On its northern boundary the history has been different: the deposits formed at the foot of the Himalayas during the Siwalik period, which were originally part of the Gangetic plain, have been compressed, elevated and cut off from their continuation under the, at present, undisturbed deposits at the foot of the hills. There is consequently no reason for supposing that the gravel and sand deposits of the *bhábar* continue under the alluvium; on the contrary, there is every reason to suppose that they have been deposited over a comparatively impervious deposit of clay and silt with occasional beds of sand. Yet, owing to the want of continuity of individual beds, their lenticular shape and their great horizontal extension as compared with their vertical thickness, it is possible that the water would find an easier, if tortuous, underground passage in a direction parallel to the bedding than transverse to it, and so the head might be derived from the northern margin of the plains.

On the other hand, the manner of the southward extension of the alluvium through subsidence of the surface would lead to the formation of a zone of coarse-grained sand, and possibly gravel deposits, overlaid by finer-grained impervious clays. This structure would be particularly favourable for artesian conditions, although the elevation of the southern margin of the plains is much less than that of the northern.

As things stand then, we have a greater effective head to the north, but a more tortuous passage for the underground water, and consequently a greater loss of head; to the south the effective head is less, but, if the bore hole has reached nearly to the base of the alluvium, a more direct passage for the water and less loss of head by friction. The single boring put down is insufficient to decide between these two alternatives.

As regards the second point, whether there is any great thickness of alluvium below the bottom of the bore hole, this may be decided by the next boring, which, it is to be hoped, will be carried to a greater depth than the present one. At present the question is more or less one of conjecture, but the frequent reference to "coarse sand," in the lower part of the boring, points to a closer proximity of the margin of the alluvium than is at present the case, and consequently to an approach to the base of the alluvium. If my supposition is correct, the total thickness of the alluvium under Lucknow would not be more than 2,000 feet at the outside, and probably some hundreds less than this.

Record of the Lucknow Artesian Well.

DESCRIPTION OF SOIL.	Colour.	Thickness of stratum.	Total depth.
Made earth, Old Fort embankment	Brown	24	24
Sandy clay	Yellowish brown	17½	41½
Kankar, mixed with clay	Bluish gray	6½	48
Sand and clay, alternate thin layers	Brown	2	50
Quicksand, micaceous	Gray	14	64
Sandy clay	Brown	2	66
Clay, with a little fine sand	Yellow	19	85
Sand, with a very little clay	Gray	5	90
Quicksand, fine	Yellow	14	104
Clay	Whitish	5	109
Clay, with scattering kankar nodules	Bluish brown	7	116
Kankar	Bluish gray	6½	116½
Sandy clay	Yellow	1½	118
Kankar and clay, mixed	Bluish gray	1	119
Sandy clay	Yellowish	2	121

Record of the Lucknow Artesian Well—continued.

Description of soil.	Colour.	Thickness of stratum.	Total depth.
Sand, clean	Gray	3	124
Sandy clay	Brown	24	148
Quicksand	Gray	4	152
Silt, fine	Yellowish brown	6	158
Quicksand, fine . . . *water 61 ft.*	Yellowish brown	5	163
Sand, with a little clay	Yellow	6	169
Clay and silt mixed	Yellow	9	178
Clay carrying abundance of nodules	Yellowish (light)	8	186
Sandy clay	Yellow	4	190
Quicksand, very fine . . . *water 42 ft.*	Yellowish (light)	6	196
Quicksand, coarse	Gray	13	209
Clay	Whitish	6	215
Silt, fine	Brown	4	219
Sand clay, hard	Brown	7	226
Clay and sand, mixed	Yellow	7	233
Sand, free and hard	Gray	4	237
Sand, with a little clay, soft	Brown	1	238
Sand, free and hard	Gray	1	239
Sand, soft	Gray	2	241
Sand, free and medium hard	Gray	1	242
Sand, quite hard	Gray	2	244
Sand, coarse and nearly as hard as rock	Gray	2	246
Sand, medium, hard	Gray	10	256
Sand, fine	Brown	6	262
Sand, medium, hard	Gray	5	267
Sand, soft	Brown	4	271
Clay and silt, fine	Light yellow	4	275
Sand, coarse and very hard	Gray	2	277
Sand, do. medium hard	Gray	2	279
Sand, coarse and hard	Gray	2	281
Sand, coarse, alternate hard and soft layers	Gray	9	290
Sand, carrying abundance of nodules, hard	Gray	21	311
Sand and silt, fine	Light yellow	8	319
Sand, medium, hard	Gray	3	322
Sand, very hard, coarse	Gray	9	331
Clay and silt, fine	Yellow	7	338
Sand, coarse	Gray	3	341
Sand, coarse . . . *water 24 ft.*	Yellow	17	358
Sand, hard	Gray	2	360
Sand with a little clay, fine	Yellow	5	365
Sand, hard	Gray	4	369
Silt, fine	Brown	4	373
Silt, fine, with occasional nodules	Brown	6	379
Sand, fine and hard	Gray	2	381
Sand, fine and medium hard	Gray	2	383
Silt, fine	Gray	21	404
Silt, with abundance of nodules	Gray	4	408
Sandy silt, fine	Yellow	2	410
Clayey silt, fine	Reddish brown	20	430
Clayey silt, fine	Yellow	32	462
Sand, coarse and hard	Gray	1	463
Sand, with a little clay, rather coarse	Gray	7	470
Sand, fine and very hard	Gray	2	472
Sand, fine and medium hard	Brown	8	480
Sand, coarse and medium hard	Brown	9	489
Silt, fine	Brown	2	491
Sand, hard	Gray	2	493

Record of the Lucknow Artesian Well—continued.

Description of soil.	Colour.	Thickness of stratum.	Total depth.
Sand, with a little clay	Gray	9	502
Sand, very hard (like rock)	Gray	1	503
Sand, with occasional very hard thin layers	Gray	7	510
Sand, free and medium hard	Gray	6	516
Sand, fine and soft	Gray	3	519
Sand, medium hard, free	Gray	3	522
Sandy silt, fine	Yellow	14	536
Sand, fine and hard, with a little clay	Gray	12	548
Sand, fine and hard, free	Gray	36	584
Sand, medium hard, free	Yellow	9	593
Clayey silt, very fine	Light yellow	12	605
Sand, medium hard, free	Gray	4	609
Silt, fine and soft	Yellow	13	622
Sand, fine and hard	Brown	2	624
Sand, very hard, like rock	Brown	2	626
Sand, hard and free	Brown	14	640
Sand, medium hard, free	Brown	4	644
Sand, very hard, like rock	Brown	1	645
Sand, medium hard, free	Brown	18	663
Sand, micaceous, with kankar nodules	Yellow	8	671
Sand, fine and medium hard, free	Yellow	4	675
Sand, coarse, with hard layers	Gray	8	683
Sand, coarse and very hard, like rock	Gray	2	685
Sand, extremely hard and fine, rock	Yellow	5	690
Sand, fine, with abundance of kankar	Brown	10	700
Sand, fine, with very many hard kankar nodules	Brown	10	710
Sand, rather coarse, medium hard, with some kankar	Brown	25	735
Sandy silt	Brown	15	750
Sand, medium hard, free. *water 13 ft.*	Yellow	17	767
Kankar, hard	Bluish gray	1	768
Sand, with layers of kankar nodules	Yellow	10	778
Sandy silt, with abundance of mica	Gray	5	783
Sand, with occasional kankar nodules *water 9 ft.*	Yellow	9	792
Quicksand, with abundance of mica	Gray	6	798
Kankar, hard, with a little sand	Light gray	6	804
Sand, softish and free	Gray	2	806
Sand, with abundance of nodules	Brown	8	814
Silt, very tenaceous	Brown	8	822
Kankar, very hard	Bluish gray	1	823
Sand, softish, carrying some mica	Yellow	32	855
Clayey silt, very tenaceous	Yellow	7	862
Kankar, hard, with thin streaks of sand	Bluish gray	3	865
Sand, hard, and free	Yellow	5	870
Sand, midium, hard	Yellow	7	877
Kankar, hard, with a little sand	Bluish gray	3	880
Sand, medium, hard, with streaks of silt	Yellow	14	894
Kankar, hard, with a little sand	Bluish gray	6	900
Sand, fine, medium hard, with a little silt and some nodules	Yellow	27	927
Kankar, solid bed, hard as rock	Bluish gray	2	929
Sandy silt, very fine	Brown	7	936
Limestone, medium hard	Gray	5	941
Sand and limestone, alternate thin layers	Gray	6	947
Sandy silt, very fine	Yellow	13	960
Sand, coarse . *water 2 ft.*	Gray	15	975
Sand, coarse, abundance of kankar, some mica	Gray	15	990
Quicksand, coarse . *water 5 ft.*	Gray	27	1,017
Sand, coarse, abundance of kankar nodu'es	Gray	23	1,040
Sand, coarse and free . *water 5 ft.*	Gray	15	1,055

Record of the Lucknow Artesian Well—concluded.

DESCRIPTION OF SOIL.	Colour.	Thickness of stratum.	Total depth.
Kankar, solid bed, very hard	Bluish gray	2	1,057
Limestone, soft, commonly called rotten limestone	Gray	7	1,264
Rotten limestone, frequent hard streaks, some nodules	Gray	16	1,080
Limey silt, *i.e.*, limey clay with a little fine sand	Yellowish brown	27	1,107
Kankar, solid bed, very hard	Bluish gray	2	1,109
Limey silt, with occasional hard nodules	Yellow	24	1,133
Limestone, medium, hard	Gray	2	1,135
Limey silt, alternate hard and soft thin layers	Yellow	3	1,138
Kankar, solid bed, very hard	Bluish gray	3	1,141
Limey silt, hard and soft layers, some nodules, *water 1½ ft.*	Grayish brown	7	1,148
Limey silt, with occasional hard streaks	Yellow	13	1,161
Quicksand, coarse, with abundance of mica	Yellow	5	1,168*
Sand, coarse, medium hard, with nodules	Gray	23	1,189
Quicksand, coarse, with abundance of mica—*water. flowed 10 gals. per minute at surface*	Gray	13	1,202
Sand, coarse, in hard and soft layers	Gray	19	1,221
Sand, fine, rather hard, with streaks of silt	Brown	19	1,240
Clayey silt, very fine, compact and uniform	Grayish brown	96	1,336

C. A. B. OLIVER,
Secretary, Municipal Board,
LUCKNOW.

* Sic in origin.

SUPPLEMENTARY NOTE.

Since the above article was sent to press, I have had an opportunity of visiting the works at Lucknow. No decision has been come to as yet about making a second boring; but the fact of a sheet of rising water having been struck certainly warrants a second and deeper trial, if only on the general ground of its possibly placing the province in a more hopeful condition of tapping water at places within an ascertainable range of the Lucknow level, or in the lower extent of the Gangetic plain. The cutting of the strata in the bore hole was so severe that the samples brought up have been reduced to great fineness; but it does not seem that any very coarse sands were met with: and thus it is not at all clear that the boring has touched anything like the lowest beds of the Gangetic alluvium.

Mr. Trowbridge, the Engineer in charge of the well-works, has explained away Mr. Oldham's doubts as to the proper enlargement of the hole at foot of tube; and apparent want of judgment in selecting points for insertion of tubes of decreasing diameter. There is a steel cutting shoe at the foot of the tubing which is quite powerful enough to cut out space for the descent of tube; while the larger tubes or drive pipes having been driven as far as possible, insertion of smaller tubing became necessary when the usual precautions as to sufficiency of overlap were observed, simple enough problems in well-boring, with so certified and experienced a specialist as Mr. Trowbridge.—*Editor.*

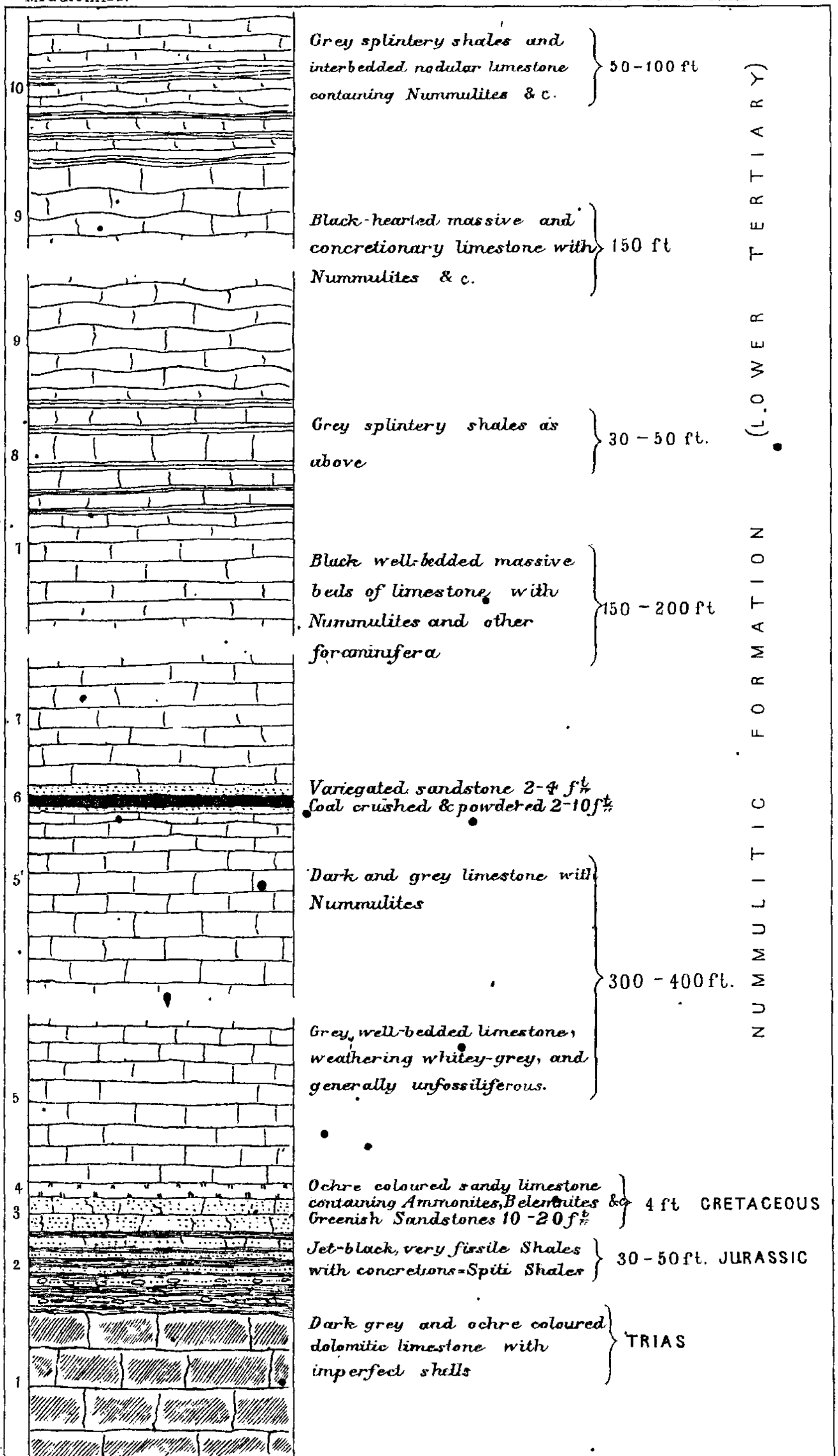
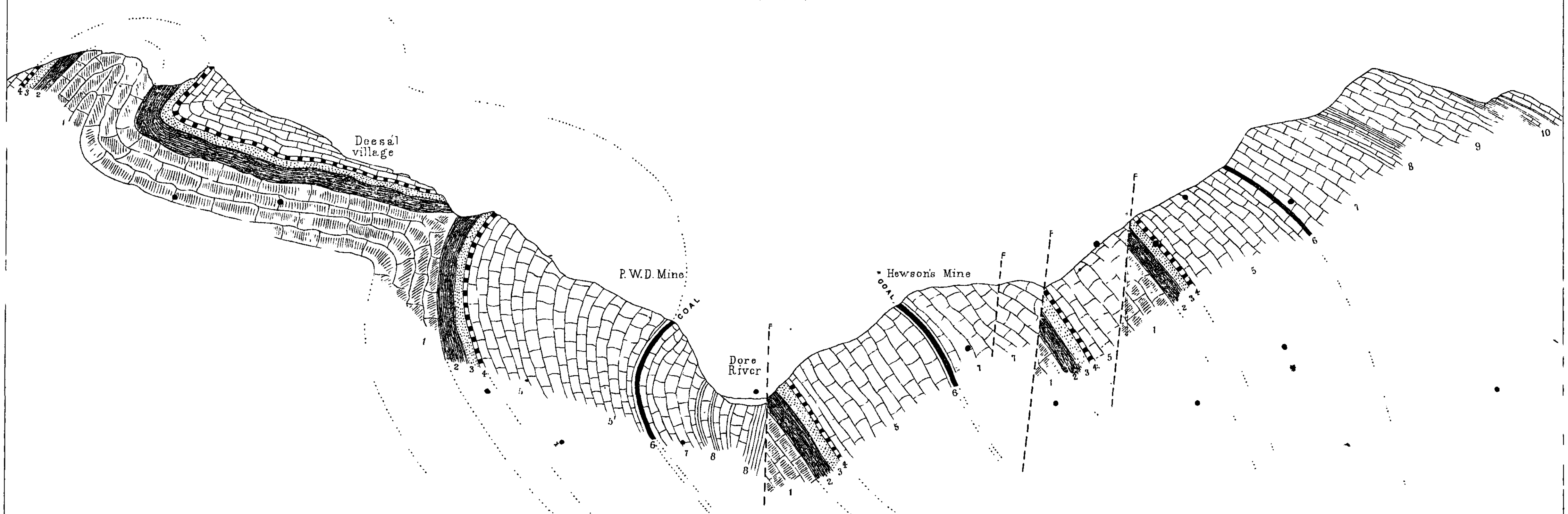


FIG. I VERTICAL SECTION, DORE RIVER.

FIG. 2. SKETCH – SECTION ACROSS DORE RIVER

N. B. For number references (1,2,3, etc.) see vertical section.



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Preliminary Note on the Coal Seam *of the* Dore Ravine, Hazara, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.* (With two plates.)

MR. D. MORRIS, Executive Engineer in charge of Coal Mines, North-Western Railway, and Mr. C. Jones, Assistant Engineer, Hazara Sub-division, have each described the occurrence of the coal in the Dore ravine as lying with the adjacent limestones in the form of an anticlinal arch cut through by the river action. This is a very pardonable mistake; for the first view up the valley as we go east from Dhamtour certainly gives one this wrong impression. On the north side of the river we see a dip to the north or north-west, and on the south side a dip to the south-east—facts which easily lend themselves to the above conclusion.

Previous experience of Himalayan sections had prepared me for putting but slight faith in an apparently simple condition such as this; but before I could get to work to unravel even the circumscribed area embraced in this note, it was necessary to become thoroughly acquainted with the normal lie and sequence of the strata. This was not so easy a task as I expected: I was delayed by many slight mistakes and imperfect representations of the rocks in Mr. Wynne's unfinished map of the district, and by the inclement season of the year, which made hill-traversing difficult.

Being now in a position to lay bare the essential points in the rock-structure of the Dore ravine near Hewson's and the Public Works Department mines, I take the opportunity of this short note to state the case as briefly as possible, leaving all detailed remarks, and the purely scientific aspect of the questions involved, for a subsequent finished report.

Round about the Dore valley and neighbourhood there are very many exposures of carbonaceous shales, with associated sandstones, which from fossil evidence have been assigned by Dr. Waagen to the Jurassic epoch, and as the probable equivalents of the Spiti shales. It is necessary once for all to state that these black and coaly-looking strata have nothing to do with the Dore coal. Their horizon is much lower in the natural chronological sequence of the rocks. The real coal-bearing stratum, as exposed in Hewson's mine, the Public Works Department mine, and in other localities, is at the surface a very unsuspicious-looking, rather coarse, variegated white and red sandstone; sometimes weathering into a hard rock of millstone-grit type, and sometimes crumbling into a loose sand or sand-rock mixed with clay in patches. It is usually about 6 feet thick. In some places specks, blotches and patches of coal or carbonaceous clay can be seen in the river cuttings, but not often; whilst on the higher hill-sides the sandstone rings under the hammer and gives no token of mineral wealth below.

In the vertical section (Pl. 1), I have expressed the lithological features and the chronological sequence of the rock formations above and below the coal as they would appear in a perfectly undisturbed normal section. This is the order in which they are seen some little distance above Hewson's mine, constituting the high mural scarps on the right bank of the Dore ravine, with the exception that they are tilted up sharply with a dip of about 40° north-north-west at the surface of the ground.

In such guise they are drawn on the right-hand side of the horizontal sketch section (Pl. 2). On the left-hand side of that section, which coincides with the south bank of the Dore ravine, the same rocks are observable; and from their dipping in the opposite direction at the surface arose the misconception that an anticlinal fold was therein implied. It will be seen, however, that the *order* of the strata on the left side of the section is not the same as on the right side. In fact, it will be seen that the order is inverted. This is the whole secret of the matter.

The difficulties implied by such a structure are fatal to the development here of a large and important coal-field; for such a structure tells a tale of so intense a crushing of the mountain region that all the rocks have come within 10° or 20° of the vertical when traced to the deep. Had the crushing of the region been less severe, we should have had the strata thrown into gentle folds of anticlinal and synclinal, and a coal basin might have been possible. As it is, the strata have been bent back upon themselves and have split along fold-faults marked F on the horizontal section (Pl. 2).

It is owing to the tendency of the free edges of rock beds to subside slightly down hill that we have the comparatively gentle dip of about 40° at the surface both in Hewson's and the Public Works Department mines. Whereas gorge-like sections, such as that in the Hertoh (Harno) R., show that when the heart of the mountain is reached the dip is very nearly vertical.

The question has been mooted whether these coal exposures are mere discontinuous "pockets," or whether they belong to a true seam which may be trusted to continue for some distance. I have no hesitation in saying that the latter is the truth with regard to them. They are not of the nature of the coal that many years ago was reported in the Upper Tertiary Sandstones in the vicinity of Murree, but which was proved by Mr. Medlicott to be of the "pocket" nature, due to the entombing of a stray tree-trunk or two. On the other hand, they are undoubtedly portions of a continuous band or seam of coal of lower nummulitic age, well known in the Salt-Range and the Jamu area. Possibly this seam may here and there locally prove to have been nipped out to nothing and to have swelled in the neighbourhood beyond its proper thickness.

From the structural considerations given above, it follows that in working the coal on the north side of the river the engineer must be prepared for the dip of the bed becoming continuously steeper, until within about 200 or 300 feet from the surface it assumes an angle of 70° or 80°; whilst on the south side it will reach the vertical about the level of the Dore ravine (in the neighbourhood of the Public Works Department shaft), then pass the vertical, until it rests at 70° or 80°, dipping in the same direction as the coal on the north side. After this it will become cut off by the fold-fault along the river.

These circumstances will, of course, necessitate deep and expensive working, bu I have a sanguine belief that a large supply of serviceable fuel may be extracted from these outcrops.

The locality of the Public Works Department mine should be first tested by an adit driven in at the river level.

On the north side of the river the outcrop from Hewson's runs away north-west up the hill slope, by what will probably be found to be a set of broken lengths. East of Hewson's there is a cross-fault running up the stream towards the north-west with an upthrow to the north-east of about 300 feet. Hence the coal-bearing bed has to be sought at a considerable height above Hewson's in that direction. In my full report these details will be illustrated by a map. At present I may say that the bed follows the base of the first inaccessible scarp found up the stream north of Hewson's. It gradually descends towards the stream-bed west of Mohar village.

Should the exploitation of the coal be undertaken soon, I can give particular directions on the spot as regards further operations.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

5. ENDING 31ST OCTOBER 1890.

Director's Office, Calcutta, 31st October 1890

The staff of the Survey is at present disposed in the following parties :—

Madras Party.—R. B. FOOTE, F.G.S., Senior Superintendent, Bellary District.

Burma Party.—THEO. W. HUGHES HUGHES, A.R.S M., Superintendent.
FRITZ NOETLING, PH.D., Palæontologist.

Baluchistan Party.—R D. OLDHAM, A.R.S.M., 1st Grade Deputy Superintendent.
Sub-Assistant Kishen Singh.
Sub-Assistant Hira Lal.

Hazara Party.—C. S. MIDDLEMISS, B.A., 2nd Grade Deputy Superintendent.

Darjiling and Sikkim.—P. N. BOSE, B.Sc., 2nd Grade Deputy Superintendent.

Head Quarters, Calcutta.—The Director.
C. L. GRIESBACH, C.I.E., Superintendent.
T. D. LATOUCHE, B.A., 2nd Grade Deputy Superintendent.
P. N. DATTA, B.Sc., Assistant Superintendent.
T. H. HOLLAND, Assistant Superintendent.

The Director was on tour in the Madras Presidency in August and September, a good part of the time being spent at Hyderabad in connection with the question of demarcating the limits of the Singareni Coal-field and the auriferous tract of Dhárwár rocks in the Raichur Doab. The settlement of the leasing of this coal-field and the gold area, following on the completion of the prospecting lease granted by His Highness the Nizam's Government to the Hyderabad (Deccan) Company, had come before the Resident, Sir Dennis Fitz-Patrick; and it was contended by the Hyderabad (Deccan) Company that no definite limitation of these areas could be made by a geologist or indeed anybody else, for which rather novel opinion they relied on their mining expert, who had paid a short visit to the country. The Singareni Coal-field being, however, an isolated tract of the lower Gondwana series entirely surrounded by crystalline and metamorphic rocks on which also the coal-rocks lie, there is really no difficulty in determining an encircling rim of these latter rocks, within which the coal-field lies and outside of which there are no branches or outliers.

Similar objections, which are however somewhat more reasonable, were raised with regard to the auriferous tracts of Dhárwárs in the Raichur Doab; it being of course impossible to say definitely that there could be no gold in the quartz-reefs and other fissure infiltrations among the rocks outside of the known area of Dhárwárs. The prevalence and restriction of auriferous reefs within certain tracts of the Dhárwár series is, however, so well established now, that the selection of sites for gold development must, for all practical purposes, lie within the Dhárwár belts; while the area of these has been determined with sufficient accuracy in the Raichur Doab, for all purposes of mineral concession or leasing. In other words, there is really no use in looking for auriferous reefs outside this tract in the Doab.

The reported occurrence of coal in the Coimbatore District was found to be attributable to the long-known exhibition of poor seams of lignite in the patches of later tertiary strata occasionally found in the adjacent Malabar District; at least, the locality mentioned appears to be really in the Malabar District; and until more definite information regarding it is available, further examination is unnecessary.

Arrangements were made for an immediate visit to the reported gold tract in Kolegal where, as it turns out, the old mine workings are in reefs which do not traverse the Dhárwár series. Mr. Foote will carry on his survey of the continuation of the Mysore gold tract into British territory in the Cuddapah District.

The boring for an artesian well at Lucknow was visited in October, with a view to advising the Government of North-Western Provinces and Oudh regarding the sinking of another well. The first boring, on reaching a depth of 1,189 feet, struck a porous stratum from which good water rose to a height of 29 feet above the hot-weather level of the Gumti river, which, however, only flowed out at the rate of 10 gallons a minute. This supply being far below the quantity required, the bore hole was run down to 1,336 feet, in the hope of reaching a better and freer discharge, but without success, when it was found impracticable to drive the tubing deeper. The proposal has now been put forward, that a fresh attempt should be made with tubing of a larger diameter, which it is assumed may, under the experience gained, be run down to about 2,000 feet.

This will, of course, entail a larger outlay: but, seeing that the fact of the existence of a sheet of water, with a head, has been now proved to exist under the Gangetic alluvium, the legitimate inference is that others will be met with at a somewhat greater depth likely to yield the larger and freer discharge desiderated. The settlement of this question of underground water-supply is of such vital importance to the province itself and to the next lower tracts of the Gangetic plain, that a stoppage of the exploration on its present stage would only leave room for renewed—and then inexperienced—attempts in the future.

Mr. Theo. W. H. Hughes is expected back from leave about the middle of November. He will proceed direct to Mergui *viâ* Penang to resume his exploration for tin.

Mr. C. L. Griesbach will shortly leave to take up work on the N.-W. Frontier; stopping on the way to examine the reported find of coal in Pinjaur.

Mr. R. D. Oldham has been deputed to accompany the Zhob Expedition, with a view to examining the reported occurrence of oil in that country.

Mr. T. D. LaTouche proceeds to Ranchi in order to take up the thorough exploration by borings and small pits of the Daltonganj Coal-field. It has been arranged that an officer of the Public Works Department should accompany Mr. LaTouche in order to superintend the putting down of borings at the places indicated by that officer. For this purpose, one of the new sets of boring plant recently received from the Secretary of State for India will be used.

Mr. P. Lake, on return from privilege leave early in January, will probably be deputed to Burma in place of Mr. LaTouche.

Mr. P. N. Datta will also be leaving about the middle of November for Assam, where he has been deputed to examine certain coal outcrops in the Garo Hills.

Mr. T. H. Holland, who was recently appointed to this Department by the Secretary of State for India, joined his appointment in October. He has, for the present, been placed in charge of the Museum and Laboratory.

List of Reports and Papers sent in to office for publication or record during August, September, and October 1890.

Author.	Subject.	Disposal.
R. B. FOOTE	Translation, from the German, of Note by Dr. Johannes Walther "On veins of graphite in decomposed gneiss (Laterite) in Ceylon."	Will be published in the "Records of the Geological Survey of India," Vol. XXIV., part 1.
R. D. OLDHAM	Note on the Deep Boring at Lucknow.	Published in the "Records of the Geological Survey of India," Vol. XXIII., part 4.
P. N. BOSE	Report on the Darjiling Coal between the Lisu and the Ramthi rivers.	Ditto ditto.
"	Extracts from Journal of a trip to the glaciers of Pandim, Kabru, &c.	Will be published in the "Records of the Geological Survey of India," Vol. XXIV., part 1.
C. S. MIDDLEMISS	Note on the coal seam of the Dore River, Hazara.	Published in the "Records of the Geological Survey of India," Vol. XXIII., part 4.
P. LAKE	Note on the basic eruptive rocks of the Kaddapah area.	Ditto ditto.
"	Report on the Geology of South Malabar.	Will be published as "Memoirs of the Geological Survey of India," Vol. XXIV., part 3.
P. N. DATTA	Compilation of Index to the first twenty volumes of the "Records of the Geological Survey of India."	Published as a Supplement with the "Records of the Geological Survey of India," Vol. XXIII., part 4.
R. LYDEKKER	Note on some fossil Indian Bird Bones.	Published in the "Records of the Geological Survey of India," Vol. XXIII., part 4.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1890.

Substance.	For whom.	Result.
Alluvial soil, for gold	MACKILLICAN & Co., Calcutta.	
Quartzose schist, for gold.	F. C. LETHORN, Calcutta.	
Coal, from a mine about 3 miles due east from Kalka, on the right bank of Kassolia river in Kawli Forest.	Commissioner and Superintendent, Delhi Division.	Moisture 2·34 Volatile matter 17·68 Fixed carbon 39·92 Ash 40·06 TOTAL 100·00 Ash—dark red. Does not cake, but sinters slightly.
Coal, found between the Singanama and Betul Roads near Burkoe, Chindwara District.	Secretary to Chief Commissioner, P. W. D., Central Provinces.	Moisture 5·62 Volatile matter 26·92 Fixed carbon 48·74 Ash 18·72 TOTAL 100·00 Ash—light red. Does not cake, but sinters slightly.
Quartz, for gold	MACKILLICAN & Co., Calcutta.	
Galena, in quartz	R. W. BACHRACH, Calcutta.	
11 specimens of minerals for determination.	C. T. AMBLER, Monghyr.	
Quartz, for gold	J. M. STONEY, Calcutta.	
Pegmatite, for gold	P. RICHARDS, 4, Clive Row, Calcutta.	
2 specimens of minerals for determination.	Ditto ditto.	
Specimen of mineral sent for determination.	W. M. SMITH, Sub-Divisional Officer, Deogarh.	=Garnets.
Copper, from mines near Kashgar.	LIEUTENANT BOWER, through DR. G. WATT.	Insoluble matter ·25 Cu (Copper) 98·17 Pb. (Lead) ·35 Undetermined 1·23 TOTAL 100·00
Quartz, for gold	J. B. CASS, 1a, Lall Bazar, Calcutta.	
Quartz, for gold	KILBURN & Co., 4, Fairlie Place, Calcutta.	
Pegmatite, for gold	MACKILLICAN & Co., Calcutta.	
Quartz, for gold	A. SIMSON, 4, Fairlie Place, Calcutta.	
Copper pyrites	E. C. GREVE, 44, Wellesley Street, Calcutta.	
Coal, from the Hertoh River, Hazara.	C. S. MIDDLEMISS, Geological Survey of India.	*N. Exposure.* / *S. Exposure.* Moisture 3·04 / 2·94 Volatile matter 9·80 / 5·08 Fixed carbon 80·86 / 11·86 Ash 6·30 / 80·12 TOTAL 100·00 / 100·00 Does not cake. Ash—brick red / Does not cake. Ash—pale buff.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1890—continued.

Substance.	For whom.	Result.
Quartz, for gold .	A. SIMSON, 4, Fairlie Place, Calcutta.	
Quartz, for gold .	A. PEPPÉ, Ranchi.	
Gneiss, with copper pyrites, for gold and copper.	DR. LAMB, 5, Old Court House Street, Calcutta.	
3 specimens of minerals for determination.	T. B. CASS, 1a, Lall Bazar, Calcutta.	
Carbonate of lead .	E. REUBEN & Co., 6, Pollock Street.	

Notifications by the Government of India during the months of August, September, and October 1890, published in the "Gazette of India," Part I.—Appointment, Confirmation, Promotion, and Retirement.

Department.	No. of order and date.	Name of Officer.	From	To	Nature of Appointment, &c.	With effect from	Remarks.

Notifications by the Government of India during the months of August, September, and October 1890, published in the "Gazette of India," Part I.—Leave.

Department.	No. of order and date.	Name of Officer.	Nature of Leave.	With effect from	Date of Return.	Remarks.
Revenue and Agricultural Department.	$\frac{470}{93\text{-}12}$S., dated 20th June 1890.	T. H. D. LaTouche .	Privilege leave.	2nd July 1890.		
Ditto .	$\frac{1176}{93\text{-}22}$S., dated 29th October 1890.	Ditto . .	Extension on duty for two weeks.	2nd October 1890.	9th October 1890.	
Ditto .	$\frac{930}{93\text{-}21}$S., dated 8th September 1890.	P. Lake . .	Privilege leave.	8th October 1890.		

Annual Increments to Graded Officers, sanctioned by the Government of India during August, September, and October 1890.

Name of Officer.	From	To	With effect from	No. and date of sanction.	Remarks.
	R	R			
C. L. Griesbach	800	850	1st Aug. 1890	R. and A. Dept., No. $\frac{770}{109\text{-}9}$S. dated 12th Aug. 1890.	
Hira Lal	200	220	5th Sep. 1890	R. and A. Dept., No. $\frac{906}{126\text{-}2}$S., dated 5th Sep. 1890.	
Kishen Sing	200	220	5th Sep. 1890	R. and A. Dept., No. $\frac{906}{126\text{-}2}$S., dated 5th Sep. 1890.	

Postal and Telegraphic Addresses of Officers.

Name of Officer.	Postal Address.	Nearest Telegraph Office.
R. BRUCE FOOTE	Madras	Madras.
T. W. H. HUGHES	On leave.	
C. L. GRIESBACH	Umballa	Umballa.
R. D. OLDHAM	Quetta (Baluchistan)	Quetta.
P. N. BOSE	Pankhabari	Pankhabari.
T. H. D. LATOUCHE	Ranchi	Ranchi.
C. S. MIDDLEMISS	Abbottabad	Abbottabad.
P. LAKE	On leave.	
P. N. DATTA	Calcutta	Park Street, Calcutta.
F. NOETLING	Yenangyoung	Yenangyoung.
KISHEN SINGH	Quetta	Quetta.
HIRA LALL	Do.	Do.

ADDITIONS TO THE LIBRARY.

FROM 1ST JULY TO 30TH SEPTEMBER 1890.

Titles of Books. *Donors.*

BEYRICH, *E.*—Ueber Geognostische Beobachtungen G. Schweinfürth's in der Wüste zwischen Cairo und Sues. 8° Pam. Berlin, 1882.

BRONN's Klassen und Ordnungen des Thier-Reichs. Band II, Abth. 3, lief. 7-9. Band IV, lief. 12-14. 8° Leipzig, 1890.

CAMERON, *Peter.*—A monograph of the British Phytophagous Hymenoptera. Vol. III. (Ray Soc. Vol. for 1889). 8° London, 1890.

GIRARD, *Jules.*—Recherches sur les Tremblements de Terre. 8° Paris, 1890.

GREEN, *William Spotswood.*—Among the Selkirk Glaciers, being the account of a rough survey in the Rocky Mountain Regions of British Columbia. 8° London, 1890.

GROTH, *Paul.*—Ueber die Molekularbeschaffenheit der Krystalle. 4° Pam. München, 1888. ROYAL BAVARIAN ACADEMY.

HOERNES, *R.* and AUINGER, *M.*—Die Gasteropoden der Meeres-Ablagerungen der ersten und zweiten Miocänen Mediterran-Stufe in der Österreichisch-Ungarischen Monarchie. Lief. VI. 4° Wien, 1890.

HYATT, *Alpheus.*—Genesis of the Arietidae. 4° Washington, 1889. THE AUTHOR.

KLOOS, *J. H.*—Entstehung und Bau der Gebirge erläutert am Geologischen Bau des Harzes. 8° Braunschweig, 1889.

KLOOS, *J. H.* and MÜLLER, *Max.*—Die Hermannshöhle bei Rübeland. 4° Weimar, 1889.

LINDSAY, *Lord.*—Screw-cutting Tables, for engineers and machinists: giving the values of the different trains of wheels required to produce screws of any pitch. 8° London, 1878.

LOMMEL, *Eugen.*—Georg Simon Ohm's wissenschaftliche Leistungen. 4° Pam. München, 1889. ROYAL BAVARIAN ACADEMY.

Palæontologie Française. 1re série, Animaux Invertébrés, Éocène Échinides, livr, 20. 8° Paris, 1890.

SAISE, *Walter.*—Exploration of Palamow Coal-field (Daltongunj). Flsc. Calcutta, 1890. E. I. RAILWAY.

SCHUYLER, *Eugene.*—Turkistan: notes of a journey in Russian Turkistan, Khokand, Bukhara, and Kuldja. 3rd edition, Vols. I-II. 8° London, 1876.

SCHWEINFURTH, *G.*—Ueber die Geologische Schichtengliederung des Mokattam bei Cairo. 8° Pam. Berlin, 1883.

SCHWEINFURTH, *G.*—Sur une récente exploration géologique de l' Ouadi Arabah. 8° Pam. Le Caire, 1888.

SHALER, *N. S.*—Aspects of the Earth: a popular account of some familiar geological phenomena. 8° London, 1890.

SHELLEY, *C. P. B.*—Workshop appliances including descriptions of some of the gauging and measuring instruments, hand-cutting tools, lathes, drilling, planing, and other machine-tools used by Engineers. 8th edition. 8° London, 1888.

Titles of Books. *Donors.*

SPON'S Mechanics' Own Book: a manual for handicraftsmen and amateurs. 3rd edition. 8° London, 1889.

STANLEY, *Henry M.*—In Darkest Africa, or the quest, rescue, and retreat of Emin, Governor of Equatoria. Vols. I-II. 8° London, 1890.

TRYON, *George W.*—Manual of Conchology, structural and systematic. Continued by H. A. Pilsbry. Vol. XII, pt. 45; and 2nd series, Vol. VI, part 21. 8° Philadelphia, 1890.

WATERHOUSE, *J.*—Practical notes on the preparation of drawings for photographic reproduction. With a sketch of the principal photo-mechanical printing processes. 8° London, 1890.

PERIODICALS, SERIALS, &c.

American Journal of Science. 3rd series, Vol. XXXIX, No. 234 to Vol. XL, No. 236. 8° New Haven, 1890. THE EDITORS.

American Naturalist. Vol. XXIII, No. 276, and Vol. XXIV, Nos. 281 and 283. 8° Philadelphia, 1889-90.

Annalen der Physik und Chemie. Neue Folge, Band XL, heft 2-4, and Band XLI, heft 1. 8° Leipzig, 1890.

Annales de Géologie et de Paléontologie. Livr. 7—8. 4° Palerme, 1890.

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Annales des Sciences Naturelles. 7me série, Botanique, Tome XI, Nos. 2-3. 8° Paris, 1890.

Annals and Magazine of Natural History. 6th series, Vol. VI, Nos. 31-33. 8° London, 1890.

Annuaire Géologique Universel Revue de Géologie et Paléontologie. Tome V (1888). 8° Paris, 1889. THE EDITORS.

Athenæum. Nos. 3267-3279. 4° London, 1890.

Beiblätter zu den Annalen der Physik und Chemie. Band XIV, Nos. 5-7. 8° Leipzig, 1890.

Chemical News. Vol. LXI, No. 1593 to LXII, No. 1605. 4° London, 1890.

Colliery Guardian. Vol. LIX, No. 1536, to LX, No. 1548. Fol. London, 1890.

Geological Magazine. New series, Decade III, Vol. VII, Nos. 7-9. 8° London, 1890.

Indian Engineering. Vol. VII, No. 26, and VIII, Nos. 1-13. Flsc. Calcutta, 1890. P. DOYLE.

Iron. Vol. XXXV, No. 908 to XXXVI, No. 920. Fol. London, 1890.

London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science. 5th series, Vol. XXX, Nos. 182-184. 8° London, 1890.

Mining Journal. Vol. LX, Nos. 2858-2870. Fol. London, 1890.

Nature. Vol. XLII, Nos. 1075-1087. 4° London, 1890.

Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie. Jahrg. 1890. Band I, heft 3, and Band II, heft 1. 8° Stuttgart, 1890.

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Palaeontographica. Band XXXVII, lief. 1. 4° Stuttgart, 1890.

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Petermann's Geographische Mittheilungen. Band XXXVI, Nos. 7-8. 4° Gotha, 1890.
THE EDITOR.

The Indian Engineer. Vol. IX, Nos. 168-181. 4° Calcutta, 1890. J. MC INTYRE.

GOVERNMENT SELECTIONS, REPORTS, &c.

BURMA.—Annual report on the Light-houses and Light-vessels off the coast of Burma for 1889-90. Flsc. Rangoon, 1890.
CHIEF COMMISSIONER, BURMA.

„ Tables for the transliteration of Burmese into English, with lists showing the names in English and Burmese, of the divisions, districts, sub-divisions, townships, and circles of Burma, also of the post offices, railway stations, police offices, and other places of interest. 8° Rangoon, 1890.
REVENUE AND AGRICULTURAL DEPARTMENT.

INDIA.—Administration report on the Railways of India for 1889-90. Part I. Flsc. Simla, 1890. GOVERNMENT OF INDIA.

„ Government of India. Civil Budget Estimate for 1890-91. Flsc. Calcutta, 1890. GOVERNMENT OF INDIA.

„ List of Officers in the Survey Departments, and in the offices of the Meteorological Reporter to the Government of India; Trustees, Indian Museum; Reporter on Economic Products; Director, Botanical Department. Northern India; and General Superintendent, Horse-Breeding Department; corrected to 1st July 1890. 8° Calcutta, 1890.
GOVERNMENT OF INDIA.

„ Quarterly Indian Army List for July 1st, 1890. New series, No. 4. 8° Calcutta, 1890. GOVERNMENT OF INDIA.

„ Selections from the Records of the Government of India, Foreign Department. Nos. 270-271, Flsc. Calcutta, 1890. FOREIGN DEPARTMENT.

MADRAS.—A manual of the Kurnool district in the Presidency of Madras. By Narahari Gopalakristnamah Chetty. 8° Madras, 1886.
MADRAS GOVERNMENT.

„ A manual of the Nilagiri district in the Madras Presidency. By H. B. Grigg. 8° Madras, 1880. GOVERNMENT OF MADRAS.

„ A manual of the North Arcot district in the Presidency of Madras. By Arthur F. Cox. 8° Madras, 1881. GOVERNMENT OF MADRAS.

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„ A manual of the Tinnevelly district in the Presidency of Madras. By A. J. Stuart. 8° Madras, 1879. GOVERNMENT OF MADRAS.

„ Malabar. By William Logan. Vols. I—II. 8° Madras, 1887.
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„ Manual of the Coimbatore district in the Presidency of Madras. By F. A. Nicholson. 8° Madras, 1887. GOVERNMENT OF MADRAS.

„ The Ganjam District Manual. By T. J. Maltby. 8° Madras, 1882.
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MADRAS.—Report on the Medical Topography and Statistics of the Provinces of Malabar and Canara. Compiled from the records of the Medical Board Office. 8° Madras, 1844. DR. WILL. KING.

TRANSACTIONS, PROCEEDINGS, &c. OF SOCIETIES, SURVEYS, &c.

ADELAIDE.—Transactions and Proceedings and Report of the Royal Society of South Australia. Vol. XII. 8° Adelaide, 1889. THE SOCIETY.

BALTIMORE.—American Chemical Journal. Vol. XII, No. 7. 8° Baltimore, 1890. JOHNS HOPKINS UNIVERSITY.

„ Johns Hopkins University Circulars. Vol. VII, Nos. 66-67, VIII, No. 68, and Vol. IX, Nos. 81-82. 4° Baltimore, 1888 and 1890. THE UNIVERSITY.

BATAVIA.—Nederlandsch-Indisch Plakaatboek, 1602-1811. Door J. A. Van der Chijs. Deel VII, 1755-1764. 8° Batavia, 1890. BATAVIAN SOCIETY.

„ Notulen van het Bataviaasch Genootschap van kunsten en Wetenschappen. Deel XXVIII, Afl. 1. 8° Batavia, 1890. BATAVIAN SOCIETY.

„ Tijdschrift voor indische Taal-Land-en Volkenkunde. Deel XXXIV, Afl. 1. 8° Batavia, 1890. BATAVIAN SOCIETY.

BERLIN.—Abhandlungen der Königlich Preussischen geologischen Landesanstalt. Neue Folge, heft 1. 8° Berlin, 1889. THE INSTITUTE.

„ Abhandlungen zur Geologischen Specialkarte von Preussen und den Thüringischen Staaten. Band X, heft 2. 8° Berlin, 1890. THE INSTITUTE.

„ Zeitschrift der Deutschen geologischen Gesellschaft. Band XLI, heft 4. 8° Berlin, 1890. GERMAN GEOLOGICAL SOCIETY.

BOMBAY.—Journal of the Bombay Natural History Society. Vol. V, Nos. 1-2. 8° Bombay, 1890. THE SOCIETY.

BRESLAU.—Jahres-Bericht der Schlesischen Gesellschaft für vaterländische Cultur. No. LXVII. 8° Breslau, 1890. BRESLAU SOCIETY.

BRUSSELS.—Bulletin de la Société Royale Belge de Géographie. Année XIV, No. 2. 8° Bruxelles, 1890. THE SOCIETY.

BUDAPEST.—Termeszetrajzi Füzetek. Vol. XIII, No. 1. 8° Budapest, 1890. HUNGARIAN NATIONAL MUSEUM.

CALCUTTA.—Archæological Survey of India. South-Indian Inscriptions, Tamil and Sanskrit. Edited and translated by E. Hultzsch. Vol. I. 4° Madras, 1890. THE SURVEY.

„ Epigraphia Indica and Record of the Archæological Survey of India. Part V. 4° Calcutta, 1889. THE SURVEY.

„ Indian Museum Notes. Vol. I, No. 4. 8° Calcutta, 1890. INDIAN MUSEUM.

„ Journal of the Agricultural and Horticultural Society of India. New series, Vol. VIII, pt. 4. 8° Calcutta, 1890. THE SOCIETY.

„ Journal of the Asiatic Society of Bengal. New series, Vol. LVIII, pt. I, Supplement; pt. II, No. 5; and Vol. LIX, pt. II, No. 2. 8° Calcutta, 1890. THE SOCIETY.

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CALCUTTA.—Proceedings of the Asiatic Society of Bengal. Nos. III—V. 8° Calcutta, 1890. THE SOCIETY.

„ Records of the Geological Survey of India. Vol. XXIII, pt. 3. 8° Calcutta, 1890. GEOLOGICAL SURVEY OF INDIA.

„ Survey of India Department. Notes for June to August 1890. Flsc. Calcutta, 1890. SURVEY OF INDIA.

CAMBRIDGE, MASS.—Bulletin of the Museum of Comparative Zoology. Vol. XVI, No. 9, Vol. XIX, No. 4, and Vol. XX, No. 1. 8° Cambridge, Mass., 1890. THE MUSEUM.

„ Memoirs of the Museum of Comparative Zoology. Vol. XVI, No. 3. 4° Cambridge, Mass., 1889. THE MUSEUM.

CHRISTIANIA.—Geodätische Arbeiten. Heft 6-7. 4° Christiania, 1888 and 1890. NORWEGIAN COMMISSION.

CINCINNATI.—Journal of the Cincinnati Society of Natural History. Vol. XII, No. 4. 8° Cincinnati, 1890. THE SOCIETY.

DEHRA DUN.—Account of the operations of the Great Trigonometrical Survey of India. Vol. XI. 4° Dehra Dun, 1890. SURVEY OF INDIA.

EDINBURGH.—Scottish Geographical Magazine. Vol. VI, Nos. 6-9. 8° Edinburgh, 1890. THE SOCIETY.

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GLASGOW.—Glasgow University Calendar for 1890-91. 8° Glasgow, 1890. GLASGOW UNIVERSITY.

GÖTTINGEN.—Nachrichten von der Königl. Gesellschaft der Wissenschaften. 1889. 8° Göttingen, 1889. GÖTTINGEN SOCIETY.

HARRISBURG.—Geological Survey of Pennsylvania. Atlas, Southern Anthracite Field, part II, A. A.; Atlas, Northern Anthracite Field, part V, A. A.; Atlas, Eastern Middle Anthracite Field, part III, A. A. 8° Harrisburg, 1889. GEOL. SURVEY, PENNSYLVANIA.

KÖNIGSBERG.—Schriften der Physikalisch Ökonomischen Gesellschaft. Jahrg. XXX (1889). 4° Königsberg, 1890. KÖNIGSBERG SOCIETY.

LEIDE.—Annales de l'École Polytechnique de Delft. Tome V, livr. 3-4. 4° Leide, 1890. ÉCOLE POLYTECHNIQUE.

LISBON.—Commission des Travaux Géologiques du Portugal. Description de la Faune Jurassique du Portugal. Embranchement des Échinodermes par P. de Loriol. Fasc. I. 4° Lisbonne, 1890. GEOL. SURVEY, PORTUGAL.

LONDON.—Journal of the Society of Arts. Vol. XXXVIII, Nos. 1958-1971. 8° London, 1890. THE SOCIETY.

„ Proceedings of the Royal Geographical Society. New series, Vol. XII, Nos. 6-7. 8° London, 1890. THE SOCIETY.

„ Proceedings of the Royal Society. Vol. XLVII, Nos. 289-291. 8° London, 1890. THE SOCIETY.

„ Proceedings of the Zoological Society of London. Part IV (1889) and part I (1890). 8° London, 1890. THE SOCIETY.

„ Transactions of the Zoological Society of London. Vol. XII, pt. 10. 4° London, 1890. THE SOCIETY.

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LONDON.—Quarterly Journal of the Geological Society. Vol. XLVI, No. 182. 8° London, 1890. THE SOCIETY.

„ *Ray Society.* Cameron, Peter.—A monograph of the British Phytophagous Hymenoptera. Vol. III. 8° London, 1890.

MADRAS.—Government Central Museum, Madras. Catalogue of Minerals, Ores, and Rocks; with a note on meteorites, of which the fall in Southern India has been recorded. 8° Madras, 1890. MADRAS MUSEUM.

MADRID.—Boletin de la Sociedad Geografica de Madrid. Tomo XXVIII, Nos. 4-6. 8° Madrid, 1890. THE SOCIETY.

MANCHESTER.—Transactions of the Manchester Geological Society. Vol. XX, Nos. 18-19. 8° Manchester, 1890. THE SOCIETY.

MELBOURNE.—Annual report of the Secretary for Mines during 1889. Flsc. Melbourne, 1890. MINING DEPARTMENT, VICTORIA.

„ Reports and Statistics of the Mining Department for the quarter ending 31st March 1890. Flsc. Melbourne, 1890. MINING DEPARTMENT, VICTORIA.

„ Prodromus of the Zoology of Victoria. By F. McCoy. Decade XX. 8° Melbourne, 1890. THE VICTORIAN GOVERNMENT.

„ Transactions of the Royal Society of Victoria. Vol. I, pt. 2. 4° Melbourne, 1889. THE SOCIETY.

MOSCOW.—Bulletin de la Société Impériale des Naturalistes. Nouvelle série, Tome III, No. 4; and IV, No. 1. 8° Moscou, 1890. THE SOCIETY.

MUNICH.—Abhandhungen der Mathematisch-physikalischen classe der k. b. Akademie der Wissenschaften. Band XVII, Abth. 1. 4° München, 1889. ROYAL BAVARIAN ACADEMY.

„ Sitzungsberichte der Mathematisch-physikalischen classe der k. b. Akademie der Wissenschaften. 1888, heft III; 1889, heft I-II. 8° München, 1889. ROYAL BAVARIAN ACADEMY.

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„ Bulletin de la Société Géologique de France. 3me série, Tome XVIII, Nos. 2-3. 8° Paris, 1890. THE SOCIETY.

„ Mémoires de la Société Géologique de France. 3me série, Tome XV, No. 2. 4° Paris, 1890. THE SOCIETY.

„ Mémoires de la Société Géologique de France. Paléontologie. Tome I, fasc. 1. 4° Paris, 1890. THE SOCIETY.

„ Compte Rendu des Séances de la Société de Géographie. Nos. 11-13. 8° Paris, 1890. THE SOCIETY.

PHILADELPHIA.—Journal of the Franklin Institute. 3rd series, Vol. XCIX, No. 6, and Vol. C, Nos. 1-2. 8° Philadelphia, 1890. THE INSTITUTE.

„ Proceedings of the Academy of Natural Sciences. Part I. 8° Philadelphia, 1890. THE ACADEMY.

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PHILADELPHIA.—Transactions of the American Philosophical Society. New series, Vol. XVI, pt. 3. 4° Philadelphia, 1890. THE SOCIETY.

PISA.—Atti della Societa Toscana di Scienze Naturali. Processi Verbali, Vol. VI, pp. 85-104. 8° Pisa, 1888. THE SOCIETY.

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SALEM.—Bulletin of the Essex Institute. Vol. XXI, Nos. 10-12. 8° Salem, 1889. THE INSTITUTE.

SAN FRANCISCO.—Proceedings of the California Academy of Sciences. 2nd series, Vol. II. 8° San Francisco, 1890. THE ACADEMY.

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STOCKHOLM.—Liste Systématique des publications de l' Institut Royal Géologique de Suède: 1862-1890. 8° Pam. Stockholm, 1890. GEOLOGICAL SURVEY, SWEDEN.

„ Sveriges Geologiska Undersökning. Ser. A. a. Nos. 84, 100, 103-107; Ser. B. b. No. 6; Ser. C. Nos. 93-98, 100, 101, 103-111, 113-115. With maps. 8° Stockholm, 1888-1890. GEOLOGICAL SURVEY, SWEDEN.

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ST. PETERSBURG.—Bulletins du Comité Géologique. Vol. VIII, Nos. 6-10. 8° St. Pétersbourg, 1889-1890. GEOLOGICAL COMMISSION, ST. PETERSBURG.

„ Mémoires du Comité Géologique. Vol. IX, No. 1, and XI, No. 1. 4° St. Pétersbourg, 1889. GEOLOGICAL COMMISSION, ST. PETERSBURG.

STUTTGART.—Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg. Jahrg. XLVI. 8° Stuttgart, 1890.

SYDNEY.—Annual report of the Department of Mines, New South Wales, for 1889. Flsc. Sydney, 1890. DEPARTMENT OF MINES, N. S. WALES.

„ Catalogue of the Australian Birds in the Australian Museum at Sydney, New South Wales. Part II, Striges. 8° Sydney, 1890. AUSTRALIAN MUSEUM.

„ Guide to the contents of the Australian Museum. 8° Sydney, 1890. AUSTRALIAN MUSEUM.

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„ Supplement to the catalogue of the Australian Accipitres or Diurnal Birds of Prey in the collection of the Australian Museum at Sydney, New South Wales. By E. P. Ramsay. 8° Sydney, 1890. AUSTRALIAN MUSEUM.

„ Journal and Proceedings of the Royal Society of New South Wales. Vol. XXIII, pt. 2. 8° Sydney, 1889. THE SOCIETY.

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