MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

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On 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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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.*

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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 Lépchas 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.

* 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 *primâ 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 Himalayas 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 Ráuiganj.

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 Ràniganj 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.
Ràniganj 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 Ránigan j 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 Ránigan j 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.

Chírangkhola naddi.

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.

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 Maliánaddi 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 Ránigunj :—

	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 Ránigauj 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 Rániganj field, and the question arises whether it is feasible to correlate our rocks with the Rániganj 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 Rániganj. 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 Rániganj 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 Rániganj 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

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* 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 Ráuiganj up the valley of the Damúda, and into Ríwa, that the ironstone shales and Ráuiganj groups gradually change in lithological characters. The ironstone shales, as such lithologically, become extinct, and the supposed equivalents of the Ránigauj 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 Ráuiganj 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 Títi 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 Títí 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 Tísta 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 Tísta, 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.

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.

Lithology of gneiss.

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.

Absence of granite.

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

Dáling and Dárjíling series post-Damúda.

* 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 Assám gneiss has been observed at the foot of the hills between Nepál and the Goalpára district.

Chapter V.—Tertiaries.

Lithology.

The Tertiaries fringe the older rocks continuously from close to the Mechi eastward nearly as far as Dálingkot. 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 Laugti 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.

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

ECONOMIC GEOLOGY.

Chapter VI.—*Coal—Graphite.*

Coal.

Principal known out-crops.

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—

		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 kodálís, 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

* 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 Ráníganj 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 Ránígánj, 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 Ránígauj 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 Ránígauj 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 kodális and picks, as was done in the Tíndharia 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 Dárjίling 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 Tίndharia 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.

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* 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 25lbs. 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 15lbs.

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 Ráníganj, 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 Ráníganj, 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 Ránígaj 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 Ráníganj 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 Ráníganj 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 Ráníganj coal delivered at Sukna *viá* the East Indian and Eastern Bengal Railways:—

	Rs.	A.
Cost per ton of Ráníganj 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 Ráníganj 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—1*st*, from Ránígaṇj to Rájmahál by rail (173 miles), and thence down the Ganges for about 130 miles; and, 2*nd*, 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 Ránígaṇj per ton	3	8
Loading at Ránígaṇj	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 Ránígaṇj or Karharbári coal cannot be delivered at Sukna under about Rs. 15 a ton. The actual cost of raising the coal at Ránígaṇj 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 Ráníganj 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 Ráníganj 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 Ráníganj 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 Ránígan 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 of ore, which seems to be about 20 feet thick, but it is obscured a good deal by surface soil. Above it, is more actinolite rock with crystals of magnetite, and then fine-grained gneiss dipping north-east at 30°. The magnetite of the main band occurs as an aggregation of irregular crystals about the size of peas. These cohere but slightly to each other, so that the rock is easily crumbled. In places the ore is pure magnetite, but more usually it includes a varying proportion of actinolite. At the other spot where the ore has been worked, it 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 by Mr. Tween with the following results:—

	Percentage of iron.
Magnetite	71·50
Micaceous hematite	69·89

Neither contain any phosphorus or sulphur.

The ore has been smelted at Síkbhar, but to a very trifling extent.* At the time of my visit there were only two furnaces, one of which was new. Neither was in blast at the time, but the method of smelting seems to be quite similar to that usually practised in Bengal. The micaceous hematite is not used, as it is said to yield a soft iron, unsuited to the manufacture of knives, &c., and it occurs besides in comparatively small quantity. The magnetite is well suited, in its texture, to native furnaces, from the ease with which it is crumbled down into convenient sized grains. It is more difficultly smelted than the micaceous hematite, but the 'kámís' (as the Nepáli workers in iron are called) assert that it yields a steely iron peculiarly well suited for making kúkrís and báns, from its combination of hardness and toughness. The raw spongy iron is sold at Síkbhar at six sírs per rupí. By the kámís it is re-heated and hammered out into small bars, which are

* The outturn, according to Jítman, a kind of munshí at the mines, has been only 80 máns of iron since the mine was opened.

doubled up and hammered out again. This operation is repeated two or three times before the iron is finally worked up into kúkrís, &c., which are tempered by heating and plunging into water.

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. The outturn might be largely increased, and a dozen or more native furnaces easily kept in blast. There is abundance of wood for such in the Rer valley, the upper part of which is entirely covered by virgin forest. At some future time the locality may attract notice for the production of a high-class iron on a larger scale. The workability of the coal will greatly affect this question, but the want of flux within a moderate distance must always be a drawback to iron-smelting in the Dárjíling hills. The conditions are not such as would induce one to look to them during the infancy of iron-smelting on European principles in this country.

Rangu naddi.

The actinolite rock, which accompanies the magnetite, is a peculiar variety of rock which I have not seen elsewhere *in situ*. Pieces of a similar stone are, however, brought down by the Rangu, a stream which joins the Tísta south-west of Kálingpung. The bed it comes from may be the same as that at Síkbhar, and a close search towards the head of the Rangu might be rewarded by the discovery of accompanying magnetite.

Sakkam-Chu.

Blocks of magnetic iron schist are washed down by the Sakkam river south of Dálingkot. The rock is composed of magnetite and quartz, the grains of each being sometimes distinct, but more usually intimately blended, so that the rock becomes almost compact.

Ma-Chu.

The Ma-Chu brings down large lumps of micaceous hematite. The hills through which these streams flow are uninhabited, and covered by dense forest.

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 Nepálís: 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 1¾ sírs of copper, or about 3¾ to 4½ 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 sírs 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 3¾ to 4½ 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 a 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.

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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 Nepál, 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

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

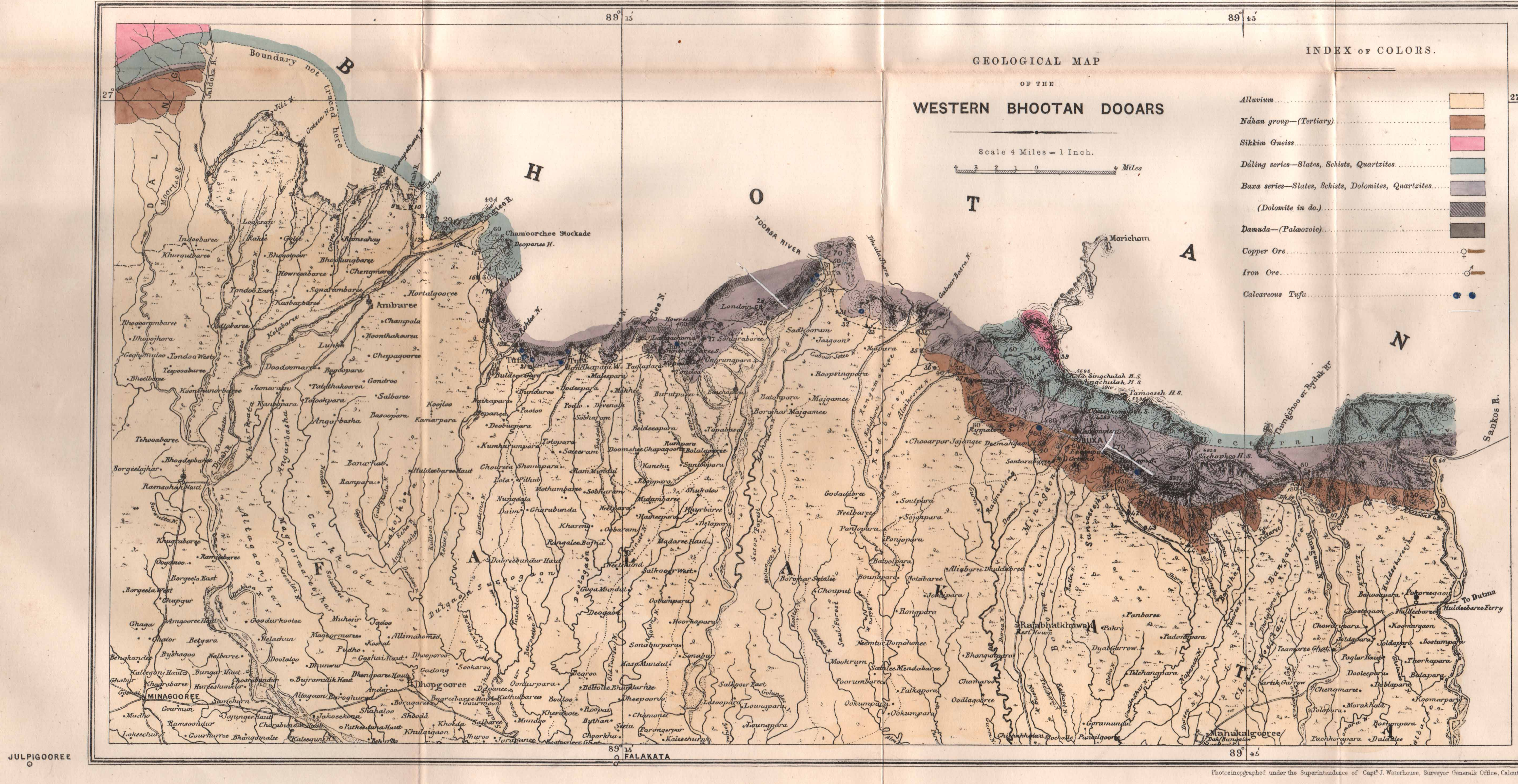
† No trustworthy comparison can be drawn between metalliferous *beds* of rock and true lodes like those in Cornwall.—F. R. M.

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 1½ 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.

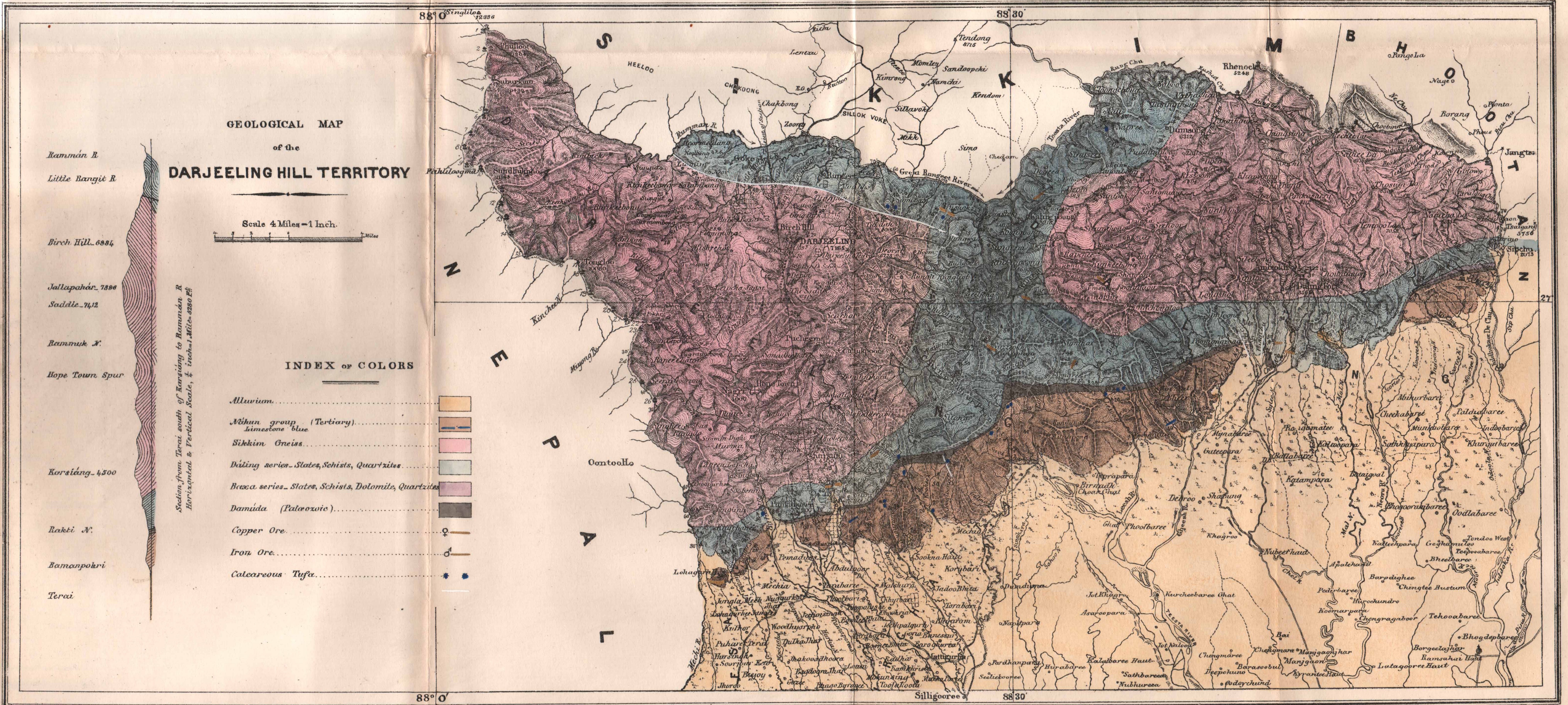
2ndly.—They bruise down the lump and mix it with cow-dung, then put it in a slow fire for two days; and for refining they again put it in the furnace with more cow-dung and charcoal, and give it a strong heat until the whole is smelted or converted to a fluid, the copper, being the heaviest, settles 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.



Photozincographed under the Superintendence of Captn. J. Waterhouse, Surveyor General's Office, Calcutta.


GEOLOGICAL MAP
of the
DARJEELING HILL TERRITORY
Scale 4 Miles = 1 Inch.
INDEX of COLORS
Alluvium
Nahun group (Tertiary)
limestone blue
Sikkim Gneiss
Daling series_ Slates, Schists, Quartzites
Baxa series_ Slates, Schists, Dolomite, Quartzites
Damuda (Palæozoic)
Copper Ore
Iron Ore
Calcareous Tufa
Section from Terai south of Karsiang to Rammán R.
Horizontal & Vertical Scale, ¼ inch = 1 Mile = 5280 Ft.
Rammán R.
Little Rangit R.
Birch Hill_6884
Jallapahár_7886
Saddle_7412
Rammuk N.
Hope Town Spur
Korsiang_4500
Rakti N.
Bamanpokri
Terai
SIKKIM
BHOTAN
NEPAL
DARJEELING
Great Rungeet River
Teesta River
Rhenock
Silligooree
88° 0'
88° 30'
27°