

probable; and in nearly every case where gravel deposits are seen, some side ravine below, having its sources high up, can be pointed out, whose glacier has formed a temporary stoppage to the main river into which it ran: and such effects are still in progress in the highest ranges of the mighty Himalayas. When glaciers extended down to 5,000 feet, what must have been the appearance of the upper Shayok, Indus and Chang Chüngmo, where 12 to 13,000 is the lowest level of the country; contemplation of such a scene in the mind's eye renders the formation of lakes and the accumulations of detrital matter a natural sequence very easy to imagine. Further, when such powerful forces of ice and water were in action, their results would have extended far down the main drainage lines, and are to be sought for at the débouchements of such rivers as the Indus, the Sutlej, Ganges, &c.; and I believe that the more recent accumulations of immense boulder beds composed of rocks from the inner ranges, such as may be seen in the Noon Nuddee, Deyrah Dhoon, and other places along the base of the Himalayas, may owe their existence to a glacial period in those mountains.

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*Notes on Geological features of the country near foot of hills in the Western Bhootan Doours.—By Captain H. H. GODWIN-AUSTEN, F. R. G. S., Topographical Survey.*

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In the report 'On the coal of Assam, with Geological notes on the adjoining districts to the south,' &c. by H. B. Medlicott, Esq., Deputy Superintendent of the Geological Survey, published in the Memoirs of that Survey,\* allusion has been made to certain geological features of the hills bounding the Western Bhootan Doours.†

A few more explanatory notes on the formations to be seen there may prove of interest in connection with the above paper, and lead others who may have the opportunity to observe them more closely. The base of the Himalayas is there so densely wooded that much

\* Mem. Geol. Survey of India, Vol. IV. p. 387. See pages 392 and 435, 436.

† See the map of "Bhootan and country adjacent" on the scale of 4 miles to the inch for all places mentioned in this paper.



is necessarily often hidden, and interesting and important beds are easily overlooked on a hurried scramble through the country. The point where I first noticed the absence of the usual sandstone formation, corresponding to the lowest Siwalik formations, so similar in every way to that in a like position in the Deyrah Dhoon, was near Dalingkote, where the Tsel river leaves the hills; here I only observed a low terrace of clay and boulders, quite a fluviatile deposit on the river bank, the bounding spurs from the main hills being of stratified gneiss. A short distance towards the Teesta on the west, these sandstones make their appearance and continue up to that river rising to a considerable height and thickness. The remains of a much larger accumulation of clays and conglomerates is seen some three miles up the Tsel towards the fort of Dalingkote forming a narrow flat terrace overhanging the river. The lowest terrace of clays and gravels extends away towards the plains, covered with a dense forest for eight miles, blending gradually with them into a clay country clothed with high grass. Proceeding from the Tsel river to the Tsakamchu, and thence towards Sipchu, the beds of two large streams are crossed, *viz.* the Nurchu and Mochu. Between these drainage lines, the road passes over a sub-angular debris from the adjacent hills of the gneiss rocks and clays, the terminal cliff being of considerable height and becoming much higher as one proceeds east. The lowest levels of the courses of streams which are below those south of Dalingkote, gradually increase as the longitudinal depression of the Jholdaka is approached, so that on and about the Mochu, the conglomerate cliffs rise in fine proportions, the upper level surface of the terraces being constant. But I must remark here that this is far below the highest level of like beds on the west of the Jholdaka or Dèchu, showing that these last have suffered the effects of denudation to a less extent, unless, in the instance of conglomerates on the Nurchu and Mochu, we are to suppose them to be later fluviatile deposits of those rivers. A very characteristic feature of the country in this part of the Dooars is the very sudden termination of these gravels and clays at about six miles from the base of the hills in a more or less abrupt scarp running east and west; this outer boundary rises higher than most of the intervening ground between it and the hills (which is deeply cut into by ravines and covered with dense jungle and forest)

forming at Tsulcha Pahar and Rungamutti isolated high points of ground. The watershed between the Dholla and Jholdaka is thrown off from Tsulcha and running due south towards Ramsahai Hath, terminates there in a marked low scarp of sand and gravel about 20 feet high, beyond this a more clayey level begins and blends into the dead level of the plains. Looking due east from Tsulcha over the Jholdaka, the conglomerate deposits are seen abutting on the river, and terminate at Tondoo in a high cliff about 120 feet high irregularly but horizontally stratified, some of the boulders being of large dimensions, one remarkably large, about 10 feet high, lay at the foot of the cliff. About half a mile below this in the bed of the Jholdaka the masses of gneissose rock were of very large dimensions, their size and position so far from the hills requiring the existence of more than the ordinary transporting power of moving water. This cliff follows the left bank of the Jholdaka and the road to Sipchu runs at the base of it as far as the trijunction of the Jiti and Sipchu with the Jholdaka. Looking up the first named river, the masses of conglomerate beds with clays, are seen to rise into very considerable proportions, and towards the east form low hills running up to the main mass of the mountains. I was unable to proceed far up the Jiti nulla, but it is far from unlikely that the sandstone formation may be found there, the look of the gorge gave somewhat the appearance of being cut through these rocks. The greater elevation of the newer deposits on this side of the Jholdaka also favours this idea, as they may have been raised by the upthrow of the sandstone on which they are seen to rest when both are present, and I may say generally unconformably. At the Jiti nuddee the road to Sipchu rises to the top of the high terrace that overlooks the left bank of the Jholdaka for the rest of the distance. No one, as they proceed, can fail to remark the succeeding sudden rises on to higher levels sharply and straightly defined. This with a slight slope to the main surface causes the mass of this formation at Sipchu to be of very great thickness; it is there seen abutting against the gneiss rocks quite 500 feet above the bed of the Dechu, and no trace of the tertiary sandstones are here to be seen. Close beyond this the conglomerates have been removed, and the gneiss extends low down to the bed of the river Déchu, but between

Sipchu and Jangtsa a remnant comes in as a valley deposit in a narrow high ledge overhanging the Déchu, and at Jangtsa the highest level must be quite 800 to 1,000 feet above it. This level ledge can be traced in a greater or less degree up the valley, being most conspicuously marked at the junctions of the main lateral valleys. Looking over the face of the country just described, at the abrupt termination of the conglomerate and clay beds at Tsulcha, &c. and the successive and regular high cut terraces on the east of the Jholdaka, no part of the outer hills that I have seen, gave more the appearance of denudation due to the action of the sea than this: all seemed in accordance with a slow but intermittent last elevation of the land.

The large mass of conglomerates, north of Tondoo, disappear before reaching Chamoorchi: there in the gorge of the Pyim Chu, only a low terrace of transported water-worn materials brought down evidently by that river is seen sloping gradually out into the plain towards Ambari. The hill on which the fort of Chamoorchi stands is of the metamorphic rocks, some of the beds being of a more shaly nature, but all micaceous. Neither here, nor on the right bank of the Pyim Chu was any trace of the tertiary sandstone formation, nor did I see it any where the whole distance to Buxa, not even in the re-entering angle of the large river, the Boro Torsa. In the Chamoorchi Doar, between the rivers Dahina and Raiti, is a dry flat plain, more or less stony on the surface, open and only covered with grass. It extends as far south as Garkunta and Huldabari Hath: the termination of higher level is very regularly marked also by the sudden rise of numerous small streams that flow due south, through a country where the surface beds are clay and free of pebbles. The distance that the gravel beds extend from the base of the hills, and these streams take their rise, is very regular, and conforms very closely with their contour at 8 to 10 miles. I also noticed that the bouldery character of the beds of the larger streams ceased at the same distance, the Jholdaka, the largest of them becoming at once sluggish, broad, and with a sandy bed at Ramsahai Hath, and the stony bed of the Raiti and Demdema are dry for a long distance; these outer gravels are evidently the most superficial recent deposits that have spread away from the several hill streams. East of the Raiti a long slope of gravel and boulders extends from the foot of the hills some 8 to 10

miles, these end at Rangali Bujna in abrupt but low scarps much intersected with ravines. This scarp is seen on the left hand on the road following the right bank of the Boro Torsa that leads to Balla ; its materials appear to have been carried out this distance by the above river, and are of very recent origin. About four miles from Tazigong, the site of the Bhutea stockade, the spurs from the mountains abut on the river, and a new and isolated feature in the geology of this part occurs. The rock is a hard compact limestone very similar to beds in the limestone of Masuri. The mass is of no great extent and dips at a very high angle to N. W ; the lower beds being shaly and thin bedded. I found no fossils, so that its age can only be conjectured ; certainly older than the middle tertiary, it may be nummulitic. The Balla hill in the immediate continuation of this limestone on the opposite side of the Torsa is a micaceous schistose rock, and in the bed of a small ravine near the foot of the ascent to Tazigong, I found several pieces of very pure soft steatite, which I was told the Bhuteas cut into small cups. I was unable to examine the foot of the hills to the east of Balla, having much ground to survey to the south, but looking in that direction the termination of the mountain spurs appeared somewhat detached from the mass, as if due to newer beds lying at the base of them ; they may either be a continuation of the sandstone at Buxa, or the higher conglomerate beds.

To the east of the Boro Torsa, no marked feature denotes where the gravels end, the level of the country is very equable, the beds of the streams being very sandy, bouldery and dry for a distance of 10 miles. The Basera river, one of the largest, is dry nearly as far down as Nathabari in the month of February ; but, although no scarp marks the commencement of a lower level in the country, this line coincides with what I have before said respecting the Balla and Chamoorchi Dooars. The larger streams have generally a narrow strip of kader land bounded with a low scarp marking their former, higher and lateral extension.

At Buxa the sandstones suddenly come in with the accompanying higher and unconformable conglomerate beds, the former with the prevailing high dip towards the main hills. I have already noticed the occurrence of this formation in a short paper in this Journal

(1865), I have now an addition of some interest, *viz.* that in the bed of Deemah nuddee a short distance west of Buxa, which flows through the sandstones and conglomerates, Assistant Surgeon J. Richardson has since informed me he found the fossil molar of an elephant, probably washed out of the upper beds.

The absence of the tertiary sandstones at the base of the Himalayas for a distance of over 50 miles is, as remarked by Mr. Medlicott, an anomalous case, and if any remnant be found hereafter, it must be small. In the deeper gorges of the main rivers such as the Jholdaka, Dahina, and Boro Torsa, they would be the more likely to shew, as they do on the Teesta, if nowhere else, but we only find stratified rocks of the most recent formations with the single exception of a small mass of limestone thrust up at a high angle at Balla. The question arises where are these usual formations, they suddenly disappear east of the Teesta, and as suddenly reappear east of the Torsa in equal force. Are they still below the surface over this area, or have they never existed, one of the suppositions brought forward by Mr. Medlicott. If they have ever found a place here, to what forces are we to attribute this single instance of total widespread denudation in so long a line of formations. Taking great physical features into consideration, it may be worthy of remark that the country and its rocks under consideration is to the south and east on the edge of a great natural basin of depression that must have been receiving for ages the drainage of the whole of the Eastern Himalayas, and considering its distance from the sea, the neighbourhood of Kooch Behar is yet one of the lowest in Bengal on the north and east. From Balla there runs in a north-westerly direction a high ridge, 8 to 10,000 feet, given off from the great Himalayan mass of Gyepmochi, and this narrow but high feature runs parallel to the deep transverse valley of the Am Mochu, following in all probability a great fault, and the existence of which is, in a measure, proved by the sudden termination of the limestone in the direction of its strike at Balla, for in the Dootia nulla on the left bank of the Torsa, I was unable to find any, but metamorphic rocks in its bed; and if the limestone be continuous, this ravine would cut through the whole of it. I am, therefore, more of opinion that the elevatory force that has raised the tertiary sandstones into the position they are found along

the whole base of the Himalayas, often to a height of nearly 3,000 feet above the sea, has here been exerted in a less degree, and that they are to be sought for yet below the upper conglomerates more or less deeply seated at a short distance from the base of the hills, as I have shewn by the dotted line in map (Plate V). Should further exploration shew more clearly how these sandstones near the Teesta disappear eastwards, how they commence again near and to the west of Buxa, and that they lie deeply seated in the intervening space, it will not a little form a connecting link geologically, though not orographically, with the hill mass south of the Brahmaputra; it is curious to find the last low eminences of gneiss in the Assam valley, *viz.* at Dhoobrie and Mateabug as noticed by Mr. Medlicott, to be upon a line in the direction of this great gneiss mass of the Himalayahs at Gyepmochi, the area so devoid of the tertiary deposits lying between them.

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