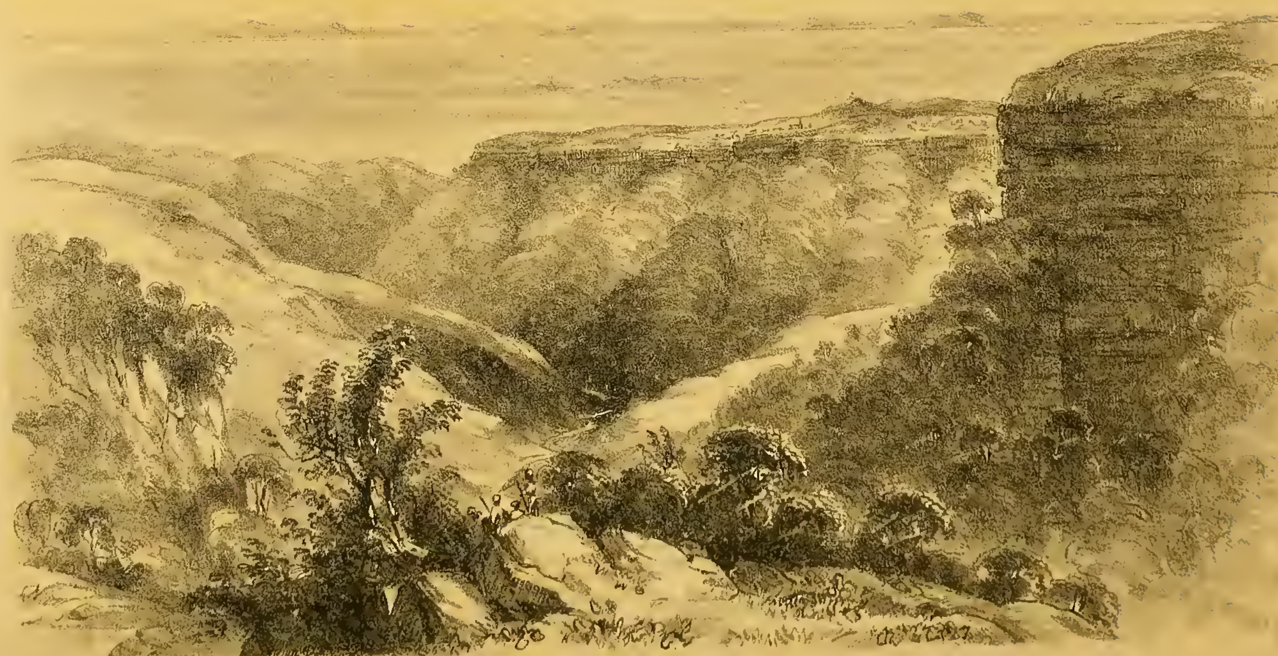
GEOLOGICAL SURVEY OF INDIA

Prof. F. B. Meek
with T. Oldham's compl.

# MEMOIRS

OF THE

# GEOLOGICAL SURVEY OF INDIA.



H.L. Frazer Lith

CHERRA & THE PLAINS OF SILHET.

Calcutta 1857.

# MEMOIRS

OF THE

# GEOLOGICAL SURVEY

OF

# INDIA.

VOL. I.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA IN COUNCIL.

UNDER THE DIRECTION OF

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# PREFACE.

When the Staff of the Geological Survey of India was increased in 1856, and its labours systematized, and extended to the Presidency of Madras, under the sanction of the Right Hon'ble the Governor General of India in Council, it was also ordered that the reports on different districts, examined geologically by its officers, should be published in one continuous and uniform series, not as previously in various journals, and in different forms. The present volume constitutes the first of the series.

As will be seen by a reference to its pages, it contains reports on various districts, for the most part descriptive of the local geology of the portions of the country examined, and illustrated by maps and sections. The maps given in this volume (as will also be the case in succeeding parts) are, in the majority of instances, on the same scale as has been adopted for the Indian Atlas, namely, four British miles to one inch. In cases where a very large area is covered uninterruptedly by the same rocks, and no details of interest occur, (as in the case of the extensive alluvial, and laterite plains of Orissa and Midnapore in the present volume,) a smaller scale is necessarily adopted. Such sections as are required to shew the structural relations of the various groups of rocks are also given. Figures and descriptions of important fossils will be given from time to time. And, when sufficient data have been accumulated, general abstracts of the results, embracing large areas, will be compiled.

The "Memoirs of the Geological Survey of India" will not, however, be confined to purely descriptive papers. From time to time such general speculations, and theoretical enquiries as may be suggested by the examination of the districts visited, will be published, (as in the present volume, Mr. Blanford's note on Laterite,) and also such researches on the practical application of the geological results, and such statistical information as to quantity and character of the economical products, as may be desirable.

In a new country, the mineral wealth of which is only now becoming known, the natural and inevitable tendency of such geological enquiries is more practical and economical than they would be, where civilization had longer held her sway, and where the energies and skill of many, interested in such pursuits, had been for generations brought to bear upon them. And yet this very condition, which renders such practical enquiries more important and needful, renders them at the same time more difficult, and in some cases even impracticable. Where no mines have been opened, from the character of which we might reason with some safety as regards others in the same country, it is difficult to form any sound opinion as to the abundance or nature of the mineral wealth of which surface indications may be found in a new country; where no quarries are worked, the nature and the contents of the rocks are not easily ascertained; where no roads exist, it is not an easy task even to gain access to many points of interest. In all such cases our reasoning must be on the broad scale; niceties of distinction, either in structure or position, or in contents, cannot be looked for. But when, in addition to these drawbacks, there are dangers of climate and season to contend with; when, for a very large portion of the country no maps whatever exist, and for other parts, such as are available, are but rude approximations even in the position of important points, and are altogether wanting in detail, the task of a geologist becomes one of no small labour, of no little risk. In former years moreover the want of any efficient libraries of reference, or collections for comparison, entirely impeded any sound progress. Happily, under the liberal support of the Governor General in Council, this difficulty is now being rapidly removed.

In the present volume will be found descriptive accounts of that portion of Bengal lying along the shore of the Bay, from the Chilka Lake to the north of Calcutta, and in succeeding volumes, Maps and description of the countries adjoining those now published will be issued, so as finally to combine into one general Geological Map of Bengal. A similar plan will be adopted with reference to Madras, and Central India, and whenever practicable, these maps will be all on the same scale, so as to combine into one.

In a country, however, of such immense area, and regarding the structure of which so little is known as India, it will occasionally be necessary to visit, and examine, and therefore to publish description of, districts not immediately connected with such systematic progress, as we have just alluded to. Of this class, is the report given in the present volume, on the Khasi Hills. Such reports would much more properly have been delayed until the adjoining districts could have been visited, but containing important information in itself, while many years would, in all probability elapse, before the neighbourhood could be revisited, it seemed desirable to publish it at once.

So far as possible, my anxious desire is that all such reports or memoirs as are published, should be drawn up by those gentlemen attached to the survey, who have had the fullest opportunity of becoming acquainted with each district.

A word on the orthography of Indian names. I have avoided any discussion of the question, I have preferred adopting the spelling in ordinary use, to any partial or imperfect rectification of it. And to a great extent for the following reasons. On the Maps issued under the authority of the great Trigonometrical Survey of India, the Jonesian system of orthography for Indian names is adopted; on the maps, prepared by the Revenue Survey of India, *issued from the same Office,* Gilchrist's system is used. It constantly, therefore occurs, and indeed unavoidably occurs, that where maps of the same district, or of adjoining districts, have been published, the names of the same places are given on these maps, both issued with the authority of Government, with totally different spelling. (Katak, and Cuttack, Radakol, and Rehrakol, represent the same places, and the instances are countless.)

Undoubtedly, it would be possible to correct all this, and reduce all to one uniform system, and undoubtedly, to a great extent this might be done by the Geological Surveyors, passing through the country. But I am satisfied that such an attempt would lead to even greater confusion than exists at present. No two persons have exactly the same appreciation of sound; words, which, as heard by one, would be to that person's ears correctly represented by a certain combination of letters having each an acknowledged and definite sound, would not appear correct to another. Nor is it possible to find any half dozen people in a district who would pronounce the same names in exactly the same way. In attempting therefore to rectify the orthography of such names without any fixed standard, we should only have introduced additional sources of error and confusion.

I confess, I cannot see any difficulty in adopting systematically one uniform orthography. The names of all these places exist in numerous native records; the derivation, and therefore the correct spelling, of most of them would be very easily ascertained, and the transferring or translating of these native names into roman letters which should, according to any uniform system that might be adopted, express the same sounds, would be a task easily accomplished by any ordinary clerk, instructed for the purpose. But until this be done, (and the question is one of great importance) I cannot see any prospect of improvement in the general orthography of Indian names, but rather a certainty of greater confusion.

In the accompanying reports no attempt, therefore, has been made to introduce any uniform system. Names of places have been given as they were spelled on the ordinary maps of the country.

It could scarcely be anticipated that in the few years we have been working in this country much could have been ascertained regarding the detail of its Geological Structure. Several results of great importance have, however, been arrived at. Among those now published, I may mention the separation into several distinct groups, of the rocks associated with coal in India, hitherto considered to belong to one series. Of these, the "Talcheer" group (the lowest) was first established by the brothers Blanford, from enquiries in the district herein described, and subsequent researches in other parts of the country have fully confirmed the justness of this separation, and established the constancy and importance of the subdivisions. The true value of the group, and its relations to the overlying rocks, as regards its fossil contents are not yet fully made out.

The "Damuda" series containing almost all the coal beds of Bengal Proper, Orissa, and Central India, was first separated from the rocks which overlie it, by myself, from investigations in Bengal, and in the Nerbudda district. At the same time I established the existence of a totally distinct series (? formation) of rocks above these coal-bearing beds, which had been previously classed with them. To these I gave the name of the Mahadeva, from the hills, so called, in the valley of the Nerbudda, where these rocks are well seen. Other series or formations also connected with these Damuda rocks, have been established; as the "Vindhyan" formation, first separated by the Brothers Medlicott, and so called by me. The Rajmahal group, &c., &c., all which will receive detailed illustration in future reports. Our data as yet, being only remains of plants, although numerous and well preserved, are, I regret to say insufficient to establish *with certainty* the parallelism of these groups with acknowledged European classifications. In addition to the above, the coal of the Khasi hills, which had been authoritatively referred to the age of the European "coal measures," has been shewn to be tertiary, the same fact has been established for the similar coal of the Tenasserim Provinces.

The second volume of these Memoirs will be devoted almost exclusively to Central India, (the Nerbudda, Bundelcund, &c.) and will carry still further, the description of the relative position and relation of the several series and groups of Indian rocks.

The difficulty of procuring good illustrations for such Memoirs in this country, is only known to those who have had actual experience of it. I only refer to it here, to express a hope that I shall be able, for future volumes, to secure something more satisfactory than are several of the bald outlines which appear in the present.

# CONTENTS.

## ERRATA.

Page, 153, line 4, for (*Fig.* 9) *read* (Fig. 8).
" 170, " 25, " that " those.
" 224, line 16, *for* alterations *read* alternations.
" 225, " 3, " shall " shale.

# LIST OF ILLUSTRATIONS.

## TALCHEER COAL FIELD.



## KHASI HILLS.

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## REPORT ON NILGHIRIS.



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## MIDNAPORE, ORISSA, &c.

*Pl. I. Fig.* 2. Section of the same slab, showing the outline of the rippling and the cross section of the double depression of the Annelide tracks—full size.

3 *and* 4. Sketches of Annelide markings on the surface of fine earthy sandstone from Korhadi near Nagpur, of full size, given for comparison.

*Pl. II.* Map of the Talcheer Coal Field—Scale, four miles equal one inch. The Topographical portion of the Map has been copied, with very slight alteration, from the Maps prepared under the superintendence of Captain Saxton, Deputy Surveyor General, for the use of which the Geological Survey is indebted to the kindness of Major Thuillier, Surveyor General's Office, Calcutta.

*Pl. III.* Sections of the Talcheer Coal Field.

Section 1 extends from Sarasua Hill, in the North-West of the field, in a right line to Gopalprasad, and thence Southward and Eastward to Karakprasad. This section shows the relations of the several groups of rocks occurring in the district, and the mode in which they have been faulted.

Section 2 extends from the Tikiria Nullah, on the Northern boundary of the field, to Gopalprasad, where it shows the relations of the carbonaceous shales to the accompanying rocks; and thence the section extends to the Southern boundary of the field at Jorasinga.

These sections are laid down to the same scale for heights and distances, namely, two miles to the inch, or double the linear scale of the accompanying Map. The outline of the surface is only approximately correct: the dense jungle and inaccessible nature of portions of the district, and the want of any accurate levels, preventing greater accuracy.

## KHASI HILLS.

*Pl. IV.* View of Cherra Poonjee, and the plains of Silhet,—looking down the gorge of the Temshung.

*Pl. V.* View of the Mawsmai falls, near Cherra Poonjee.

NILGHIRI HILLS.



MIDNAPORE, ORISSA, &c.

# MEMOIRS

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*Preliminary Notice on the Coal and Iron of Talcheer in the Tributary Mehals of Cuttack. By* THOMAS OLDHAM, *A. M., F. R. S., G. S., &c., Superintendent of Geological Survey of India, &c.*

A brief notice of previously existing knowledge regarding the reported Coal Field of the Tributary Mehals will prove interesting, before entering on the detailed report of the geological structure of the district.

Stirling's account of Orissa.

The earliest notice of the Cuttack district with which I have met is in a valuable paper by A. Stirling, Esq., entitled "An Account, Geographical, Statistical and Historical, of Orissa Proper, or Cuttack:" published in the *Asiatic Researches of Bengal*, Vol. XV., p. 163, 1825.

Although chiefly devoted to the description of the antiquities and political condition of the district, some few geological facts are also given.

Physical features.

The general physical aspect of the country is thus described:—"An "extensive little explored region on the West, "consisting chiefly of hills and forests, intersected "by many fertile plains and valleys, and a plain level country extending "from the foot of that barrier to the sea, evidently of alluvial formation, "the uniform surface of which is not disturbed by a single rocky elevation throughout its whole extent, nor does a single stone occur between "the beds of iron-clay lying on the Western frontier and the ocean, "if we except the curious spheroidal concretions of calcareous matter, or

" limestone nodules, which are found very generally dispersed" (p. 167.) Again, speaking of this flat tract, the author states that it is, in general, highly cultivated :—" South of the Mahanuddi, it may be generally " characterised as light and sandy; beyond that river, and especially in " the neighbourhood of the hills, it acquires a clayey consistency and " appearance, and is often remarkably white, and often too, for miles " together, it has the surface strewed with a thin sprinkling of gravel or " limestone concretions, called by the natives Gengti. This description " of soil extends nearly to Midnapore" (p. 171.)

Character of hills.

The hilly tract next comes under review. The distance between its boundary and the sea is stated to be nowhere more than 60 to 70 miles. " At Balasore a group " of fine rocky hills project boldly forth to within 16 to 18 miles of " the shores of the bay, which were known to old navigators as the " Nelligreen (Nilgiri) Mountains, and between Ganjam and the Lake, " a low ridge appears actually to run out into the sea, though in " reality separated from the water by a wide sandy beach" (p. 176.) Again :—" The hills visible from the low country, between the Brahmini

Rocks.

" and Ganjam, are chiefly a granitic formation, " remarkable for its resemblance to sandstone and " for its containing vast quantities of imperfectly formed garnets " disseminated throughout with veins of steatite considerably indurated. " They occur generally in irregularly scattered groups, having peaked " and waving summits, which seem to cross each other at all angles, " or in isolated conical and wedge-shaped hills, wholly disconnected " at their bases, and are all covered with vegetation to the very top. " The greatest height of those seen from the Mogulbundi may be about " 2,000 feet. Their ordinary elevation varies from 300 feet to 1,200 " feet. Ridges occur further in the interior of greater loftiness and " regularity, but I believe that an extended continuous chain of moun- " tains is nowhere to be met with in the Rajwara of Orissa. The pre-

" vailing color of the principal rock is red. As far as my observation " goes, it never occurs stratified. Its texture often approaches to slate, " and from its general decomposing and decomposed aspect, the quantity " of red spots which it contains being the ill-formed garnets above " noticed, and the frequent veins of red and white steatite which " intersect it, it presents altogether a most remarkable appearance."

The true gneissose nature of this rock will appear from the detailed account given below.

Mr. Stirling proceeds to say :—" The rock most abounding in this " division of the district next to the granite" (gneiss) " is that singular " substance called iron-clay by Jameson and laterite by Dr. Buchanan. " It lies in beds of considerable depth at the foot of the granite hills, " often advancing out for a distance of 10 or 15 miles into the plains, " where it forms gently swelling rocky elevations, but never rises into " hills : sometimes it is disposed in the manner of flat terraces of con- " siderable dimensions, which look as if they had been constructed with " much labor and skill. The composition and aspect of the Cuttack " iron-clay are very remarkable, from the innumerable pores and amyg- " daloidal cavities which it contains, filled with white and yellow litho- " marge, and from the quantities of iron ore pebbles and fragments " of quartz imbedded in it. By far the most interesting circumstance, " however, connected with it is its complete and intimate mixture with " the granite, which has been traced in several instances, and speci- " mens of which are in my possession, exhibiting the one rock entirely " invested by the other, though it is not easy to pronounce which " is the enclosing substance. The granite, at the places where the " specimens were principally collected, appears to burst through an " immense bed of the laterite, rising abruptly at a considerable angle. " Numerous broken fragments are strewed all around the line of " junction, and in some specimens the two rocks are so mixed together " as to form a sort of coarse breccia or conglomerate."

The true bearing of this important and interesting observation, as showing the origin of this "laterite," will also be found referred to below.

" South of the Mahanuddi," Mr. Stirling continues, " in the country " of Khoorda, a few isolated hills of white and variegated sandstone " occur, curiously interspersed among the granitic ones. An indurated " white lithomarge is found in company with them, from which the " natives prepare a white-wash to ornament their houses."

These are portions of the Atgurh sandstone district, referred to more particularly in the following Report.

He proceeds to give a description of the rocks in the most Northerly portion of the Cuttack Province, where gneiss, micaceous and hornblendic rocks occur; " talc " slate, mica slate, and chlorite schist, passing into serpentine and " pot-stone, being in great abundance;" and then notices the occurrence of iron in abundance throughout the whole of the Cuttack Hills, " in " the state chiefly of pisiform iron ore, earthy red ore, and ochrey red " ironstone. It is smelted principally in the States of Dhenkanāl " (Denkenal), Angol (Ungool), and Moherbenj." He also refers to the reported existence of gold in some of the rivers of Dhenkanāl and Keonjher.

Northern portion of Province.

The only limestone in the district is said to be the calcareous nodules referred to previously.

Several interesting notices of the extent to which the ancient temples and other buildings of the district have been invaded by the sands of the shores of the Bengal Bay will be found in this valuable paper; and the curious legend, by which the occurrence of the sandstone hills of Khandgiri, said by Mr. Stirling to be the only real sandstone hills in the country, is accounted for, as being " a part of the Himalayas, " which were taken up bodily, with their caves, ascetics, and all, by " Mahabìr Hanumàn, to build the bridge of Rama, but, by some "accident, were allowed to drop on their passage through the air, "when they alighted in their present position," is quoted (p. 312.)

Subsequently to the publication of Mr. Stirling's paper, I do not find any notice of the district, until, in the year 1837, Lieutenant Kittoe announced the discovery of extensive beds of coal in Ungool and Hindooe (Hindole), near the Kursooa and Byturnee streams. He states, that the coal and iron mines occur together.* In the following year (February 1838), he gave a section of a hill called Newraj to the West of the Station of Cuttack, where he expected that coal would be found.

Lieutenant Kittoe announces discovery of coal.

He makes the hill to be traversed by a large dyke of "dark-green trachyte, of a somewhat coarse glassy character, with minute vesicles,"† but on referring to the specimens which accompanied his paper, in the collection of the Asiatic Society, I can find nothing to countenance this view. On the other hand, the very marked and total absence of trap dykes traversing the coal-bearing rocks of this district, to which reference will be found below, makes the occurrence of such volcanic rocks more than doubtful.

Lieutenant Kittoe was subsequently deputed by the then existing Coal Committee to search for coal in these districts, and seems to have been quite unsuccessful. Indeed, from the account of his trip, the examination and description of the many and highly interesting antiquities of the District, for the description of which he possessed very admirable qualifications, would appear to have engaged his chief attention. He found no coal, but stated his opinion that coal could be found at some depth below the surface.‡ On what grounds this opinion was founded, he does not state.

In January 1842, Lieutenant Rigby, then Executive Engineer, forwarded to the Asiatic Society specimens of the building stones and other useful materials of the district, and in February 1843, the same Society

* Journal Asiatic Society, Bengal, Vol. VII. p. 320.

† Ibid, p. 152.

‡ Ibid, p. 679.

received, from Mr. Babington, specimens of iron and iron ores from Kutterbagga, 20 miles N. E. of Sumbulpore.

The total out-turn from these mines annually was stated to be 1,000 maunds.*

To this information, the Report of the Coal Committee, published in 1846, added, with regard to this district, as with regard to every other to which this Report refers, nothing but exaggeration and confusion of statements.

Coal Committee's Report.

Coal, the very existence of which was barely known, was magnified into "extensive beds of good quality and glistening lustre," and again the Gopalprasad Nullah coal was said to be exposed extensively on both banks, projecting to an average height of 15 feet above the sand of the river, for a distance of a mile. What was intended to be conveyed by this statement, I am not aware; but, with all the uncertainty attaching to it, in the abstract of coal which is given, these beds are stated to be "15 feet, probably several beds of this size."†

In 1847, Mr. A. J. M. Mills, then Superintendent, stated in his Minute,‡ "that the Killahs of Keonjhur, Nilghur, and Mohurbunje produce a "variety of minerals and are said to be worthy of geological investigation" (p. 90.) Of Talcheer, he writes—"Coal beds have been discovered in this "Killah. Captain Kittoe and Mr. Beatson have examined and reported on "them. The latter gentleman describes the field as above 30 miles in ex-"tent, covered with stunted jungle and composed of various kinds of sand-

* Journal Asiatic Society, Bengal, Vol. XI. p. 836 and Vol. XII. p. 164.

† Report, folio, 1846, p. 146. This is only one of many instances in which the strange exaggerations of this Report have created immense difficulties for future inquirers to surmount. Statements thus made, haphazard, are not got rid of by any amount of disproof, subsequently brought to bear upon them. The contradiction never can have exactly the same dissemination as the original statement, and, after years have elapsed, the latter is frequently re-produced, and doubts are again excited, more especially when, as in the present instance, such statements are published with a certain degree of authority attached to them.

‡ Selections from Records of Government of Bengal, No. III.

"stone and slate. The coal may be transmitted down the Brahmini River "to Hunsooa, the Export Salt Depôt, and from thence can be easily shipped "to Calcutta. The expense of carriage is against the opening of these "beds" (p. 89.) He mentions the abundance of Sàl timber in many places. "Iron is said to be abundant in Angool, and to be smelted there as well "as in Keonjhur and Mohurbunje" (p. 87,) "and to be also procurable in "the hills of Dhenkanāl" (p. 84.)

Mr. Superintendent Gouldsbury reports coal,

Such was the published information regarding this district up to the date of this Coal Committee Report (1846.) Mr. Gouldsbury, while Commissioner of the district in 1850, reported to the Government of Bengal the occurrence of coal in one of the localities previously mentioned by Lieutenant Kittoe, and forwarded specimens for examination, stating that the beds from which these specimens were procured were supposed by Mr. Overseer Harton (who had seen them while employed in cutting timber in the forests) to extend from 8 to 10 koss. The coal was supposed to be of good quality and the cost of its delivery in Calcutta was estimated.

which proves useless.

On being subjected to examination, however, by Dr. O'Shaughnessy, at that time Chemical Examiner to Goverument, this so-called coal proved to be nothing but a bituminous shale, "leaving 45·5 per cent. of incombustible ashes," and "totally valueless as a fuel." Not satisfied with this trial on the small scale, Mr. Gouldsbury forwarded 100 maunds for experiment in July 1851. This second specimen was collected with greater care than the first, but yielded 34·80 per cent. of ash, and, on trial on board the *Indus* Steamer, was reported to be "50 per cent. inferior to Raneegunge coal and quite unfit for steam purposes."

Further trials.

In November 1852, Mr. Gouldsbury again forwarded specimens of Talcheer coal, with a zealous determination to test, in the fullest manner, the value of the mineral produce of the district under his charge. These specimens were said to be taken from a depth of some feet below the surface, and to be of very much superior quality to those previously furnished. On examination, however, they proved to be little, if at all, superior. They yielded from 47 to 57 per cent. of ash and were in reality scarcely worthy of the name of coal at all.

Mr. Samuells forwards coal.

In September 1854, again, Mr. Samuells,* who succeeded Mr. Gouldsbury as Superintendent of the Tributary Mehals, urgently remonstrated against the neglect of these "extensive beds of coal, iron, &c." in a district combining so many promising features; and subsequently, communicating with the Curator of the Museum of Economic Geology in Calcutta, described his visit to the locality near Talcheer, from which Lieutenant Kittoe had previously obtained his specimens, and which will be found referred to below. It is about 2 miles above the Rajah's residence, near the village of Moolpal.

Mr. Samuells states† that he there made a cut down the bank of the stream (12 or 14 feet high) upon the bed of coal, finding first "a peaty "substance like coal, but so soft, that you could thrust a stick through "it; then coal shale, below which was indifferent coal, much mixed up "with shale; about 8 or 10 inches below which was a hard slaty rock: "the whole bed 5 or 6 feet in thickness." He proceeds to describe the Gopalprasad coal, when he states "that for several miles above Gopal-"prasad, and about a mile below it, the stream bank presents a succes-"sion of stratified coal cliffs, which have an exceedingly curious appear-"ance." The whole ground in the jungle to the rear of these cliffs is stated to be "covered for considerable distance with coal shale and dust. "The appearance of the coal about 6 feet back from the river and 2 "or 3 feet below its bed was excellent, hard, sparkling, and much less "laminated than the more exposed coal on the cliffs."

* MS. Correspondence with Government of Bengal, under dates cited.

† Journal Asiatic Society, Bengal, No. III., 1855, April, p. 249.

Upon examination* however, this coal proved to be, according to Mr. Piddington, wholly shale and what is called "Top Coal, that is, coal from the upper and generally inferior beds of a mine." Of the coal itself much was composed of layers, in which there were "about equal layers "of shale of a dull black, and of good bright bituminous coal." Even this coal, separated from its accompanying shale, yielded no less than 32·25 per cent. of ash!

A picked specimen of the bituminous coal gave 8 per cent. of ash. Mr. Piddington justly stated that such "coal" would not be worth sending to Calcutta for trial on a large scale, and advised a "shaft to be sunk for a good vein."

It did not, however, appear from Mr. Samuells' account, or from any previous observations, that there was the least ground for estimating, in any way, either the extent or the thickness of the coal-bearing rocks. A haphazard attempt at a shaft would have been wild in the extreme.†

State of information in 1855.

Such was the full amount of available knowledge (up to the year 1855) regarding the coal of the district of Talcheer, in the Tributary Mehals. It will be obvious, that no attempt whatever had been made to trace out the extent of area occupied by the field, to ascertain the thickness, general character, and relations of the rocks there occurring, or to investigate their connexion with, or their distinctness from, those occurring in other Coal Fields in India.

The results arrived at, as regarding the quality of the coal, were not very promising, but, at the same time, it was highly desirable to ascer-

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* Journal Asiatic Society, Bengal, No. III, 1855, April, p. 240.

† In 1855 (Journal Asiatic Society, No. II, 1855) Captain Saxton announced the discovery of beds of coal in the Gangpur Rajah's territories, some 50 or 60 miles N. W. of the town of Sumbulpore, or about 80 miles N. W. of the N. W. extremity of the field now under description.

Time did not permit of any of the gentlemen of the Geological Survey visiting this district during last season; but I may add, that Captain Saxton, having had the advantage of going over some of the Talcheer country with the Officers of the Survey, stated that this Gangpur coal was not in the least more promising than that of Talcheer.

tain the real state of the case, to see what prospects the district really offered, and what steps it would be proper to take for opening out its hitherto almost inaccessible jungles to the steady march of industry. Whatever the results should be, whether favorable or otherwise, it was to be hoped that the question, which for nearly fifteen years had been constantly recurring, might at last receive some definite reply, and that thus the energy annually devoted to re-opening matters previously decided might be more profitably applied to other and more valuable pursuits. With this view, and at the earnest request of the Honorable the Lieutenant-Governor of Bengal, Messrs. Blanford and Theobald were despatched to the district of Cuttack during last cold season, and the result of their labors is given in the accompanying Report; and having thus briefly recounted the knowledge previously accessible, I would now as briefly state the principal results of their detailed examination.

Geological Survey parties despatched.

And, first, with regard to *coal*. It is to be regretted that no beds of workable coal have been found in this District.

Results of their enquiry. COAL.

The extent of area, over which they could be looked for with any prospect of success, has been defined, and the general character of the rocks which occur within that area ascertained. These carbonaceous beds moreover, wherever they are seen, present a character so constant, that it appears highly improbable that any workable coal may be hereafter discovered.

Connected with this subject, a very mistaken idea appears to be prevalent in this country—an idea which is not altogether unnatural, and for which some confirmation may apparently be derived from the unguarded statements of some writers. It is constantly observed, and by many firmly believed, that, although coal beds may appear useless and inferior at or near the surface, they may confidently be expected to increase in

Erroneous notions about surface appearances of coal.

thickness and to improve in value or quality at a greater depth. "Top" and "inferior" coal are terms often used as synonymous, and when any coal exists at all, it is boldly recommended that, perhaps a shaft should be sunk, perhaps workings on the bed should be commenced, with the full expectation that other beds *must* be found, or that what is seen *must* improve at a greater depth. Nothing could be more mistaken.

It is indeed perfectly true, that exposure to ordinary atmospheric action tends to decompose coal as well as every other rock. This decomposition is rapidly expedited, if the coal should contain, as is frequently the case, iron pyrites or iron; and when such decomposition has taken place in coal, nothing but a soft black earthy-looking substance will remain. But in no case does this decomposition extend for more than a few feet from the exposed surface; and in every case when this occurs all accompanying rocks (shales, sandstones, &c.) will invariably be found to have suffered from the same destroying influences, and the whole group will present such appearances of being decomposed and changed, that no eye, which has had the slightest practice in such observations, can easily be misled. This weathering seldom extends to any distance, more especially when the coal or other beds are seen exposed in the face of cliffs, or in sections of river banks or ravines, and not on flat surfaces.

But no amount of change whatever can possibly convert a shale into a coal, nor is there the slightest ground for supposing, that beds which at the surface are beds of shale will, "in depth," as miners term it, become beds of coal.

IRON.

The *iron* produced in the Talcheer District has long been known as of excellent quality and highly prized for its tenacity.

Quality of iron.

It is, in fact, like most of the iron produced by the native furnaces in India (when cleaned), "charcoal iron" of the best quality. The greater portion of the produce is sent to the Cuttack market. The manufacture is however, from beginning to end, carried on in the rudest way, and is, here as elsewhere, pursued only by a particular caste of the people, who always appear to be among the poorest and most wretched of the inhabitants. Not that the profits of the manufacture are, in reality, so small as to be insufficient to yield them a better livelihood, but that their poverty and improvident habits, coupled with a certain degree of uncertainty in the returns for their labor, drive them into the hands of *mahajuns* (chiefly Bengalis), who, by a system of advances, and by payments in kind, become proprietors of the furnaces and also proprietors of the fuel.

Poverty of workmen.

Although not nominally, in reality this " truck system," which is of the most iniquitous kind, reduces the poor workman to perfect slavery, until at last he finds it impossible to obtain even a starvation allowance of food of the coarsest kind without the aid of these mahajuns. From these causes it is, that wherever seen, these iron-working villages are the most wretched looking in the whole country. They are in all cases distinct from the other villages, and at once bespeak the poverty of the inhabitants by the squalor and filth of their abodes. Seldom do they attain any size; in some cases, a single house marks the site of these " iron-works" ; in others some half-dozen are grouped together.

Constant changes of residence.

The wasteful consumption of fuel often compels them to remove to spots where it is more abundant, and nothing remains to mark the former site of their workings, excepting the huge heaps of slag so frequently met with in the jungles.

Description applicable to most iron-yielding districts in India.

This description is applicable to all the jungle districts which I have seen, where the manufacture of iron is carried on in this rude way. In reality, the processes adopted vary in very trifling respects, whether on the banks of the Nerbudda, near the Western bounds of the Peninsula; in the wild jungles of Central India; in the districts of the South-West Frontier; in Birbhoom; or in Cuttack. The form of the furnaces is slightly altered in each district, the proportions of ore and fuel used may be slightly different, but the general process is identical throughout.

Kind of ores used.

The ores used by the workmen in all these cases are without exception the oxide ores, whether in the state of magnetic iron, of red hœmatite (earthy, micaceous, or ochrey), or brown hœmatite. But in the vast majority of cases only the red hœmatite in its different varieties is used. I have never seen a native work in which any of the carbonated ores of iron were used. For the most part, to avoid the trouble of digging, the loose lumps found among the decomposed rocks of the surface, which become highly impregnated with iron by infiltration, are selected. Portions of these rocks found in beds of streams, and occasionally pebbles of laterite, are used. "In one instance," Mr. Blanford says, "at a small village in " Banda, an ore was found to be in use, which had much the appearance " of what is, in Cornwall and some other mining districts, termed a " *Gossan*, that is, the decomposed and highly ferruginous rock formed " generally at the outcrop of lodes.* The numerous deposits of arena" ceous iron ore found in the Damoodah beds of the Talcheer Coal " Field are comparatively little worked, although they are rich and " apparently well adapted for melting. There seems to be a preference " for ores obtained in small quantities with but little labor in digging, to " those which would require comparatively less labor for an equal pro" duce, although digging operations on a larger scale would be necessary. " Iron ores however, of one form or another, and of good quality, abound " throughout the district, and close to the surface."

Charcoal only fuel used.

The fuel used is in all cases charcoal. In the preparation of this charcoal where sàl is abundant, nothing else is used all over the country. In many districts, however, this timber has been nearly exhausted and other trees are used.

* This ore was said to be brought from the hills to the N. W., a distance of two days' journey.

In Cuttack this is not the case, and the natives employ nothing but *sàl (Shorea robusta)* for their charcoal.

Made of sàl timber.

Rude and wasteful as are the processes adopted in other parts of the country, the wild inhabitants of the Tributary Mehals appear to excel all others that I have heard of, in the ingenuity with which they seem to have adopted a process for obtaining the very smallest possible amount of useful fuel from the greatest amount of timber.

Mode of preparation.

" Only logs of one size are employed, namely, " about 12 to 18 inches in diameter.

" Trees of large dimensions cannot be broken up by the tools the na- " tives possess, and the trunks are left to rot in the forest. The smaller " branches are perhaps used for fire-wood; they are never, so far as I am " aware, used for making charcoal. The logs used are cut into pieces " about 5 or 6 feet long, which are piled on each other in layers crosswise, " and then the small stack of logs, without any other preparation, " is set fire to. When well lighted, water is thrown on, and the crusts " of charcoal formed are knocked off each log." *(Mr. Blanford's MS.)*

Smelting process similar to that in use elsewhere.

The smelting process so closely resembles that prevailing in other parts of India, that no great space need be devoted to a detailed description of it here. Mr. Samuells, then Commissioner of Cuttack, gave a brief account of this process, as practised in Cuttack, in the *Journal of the Asiatic Society of Bengal*, No. VII., 1855, pp. 249-250.

No flux used.

Charcoal and ore only are used; the former in large quantities. No flux whatever is employed. The iron is seldom even thoroughly fused, and the mass of crude metal, as taken from the small furnaces, is mixed up with fragments of unburnt charcoal, pieces of slag and semi-fused metal.

Size, &c. of furnaces.

The furnaces are, generally speaking, about 3 feet 6 inches high, of circular form, and about 1 foot inside diameter. In some places it is customary to increase the diameter towards the base; in others it is the same throughout.

The very impure metal resulting from this first operation is afterwards purified or refined,* by being subjected to a series of alternate heatings and hammerings, carried on, in an open hearth, much like the work of an ordinary blacksmith. These are repeated according to the purity required in the metal. By these heatings, the previously unburnt charcoal is consumed and the slag is fused and carried off, or driven out by the hammer.

Refining or cleaning of this impure metal.

In Orissa the blast for both of these processes is produced by bellows of the same form as that which is in use over a large portion of India for such works. It consists of two cross sections of the stem of a tree (mango is preferred), about 6 inches in thickness, and from 12 inches, the smaller and more commonly used size, to 2 feet in diameter. The upper portions of these are rudely hollowed out, and across the top of each is firmly attached a covering of leather, in the centre of which a small hole is cut. Into this hole is inserted a small piece of wood attached to a string, which is connected with a bamboo, one end of which is inserted in the ground at some distance, the other being brought immediately over the centre of the hollowed stem. Two of these are placed side by side.

Bellows, &c.

Mode of construction.

The string from the bamboo being attached to the leather top, the latter is pulled up as far as it can be extended, the cavity between the leather and the wood being of course filled with air. To produce the blast, a man stands upon this extended leather, placing his heel on the hole in the centre and thus closing the orifice. The air, being thus confined, is forced by the weight of the man upon the collapsing leather, to pass out through a hole cut

Method of working.

* This "refining" or cleaning of the metal, as it might perhaps, with greater propriety, be termed, must not be confounded with the process termed "refining" in Europe. The latter is effected on a totally different material, *viz.*, cast iron, and this refining does not produce wrought iron, but is only a preliminary process. The iron produced in the small native furnaces during the first melting must differ materially from cast iron, in its great impurity especially, and also in the much smaller amount of combined carbon.

iu the side of the hollowed stem, which is connected with a bamboo as a pipe to conduct this air to the furnace.

This action is continued alternately with the left foot and the right foot on the bellows, the weight of the man being thrown from one to the other, as each foot is alternately lifted.

The return movement of the bellows is effected by the bamboo or stick acting as a spring upon the leather.

The air thus forced through the blowing pipes made of bamboo passes into the furnace through tuyeres of clay. These are, in some places, very carefully made and carefully baked before use; in others they are composed simply of a lump of moist and well-tempered clay attached round the end of the bamboo, at the moment of commencing the operation of smelting.*

Tuyeres.

In Cuttack, this form of bellows is used, both for the first reduction of the ore and for the subsequent cleaning processes. In Birbhoom, and other parts of the country, a totally different form, more like an English blacksmith's bellows, is used for the second process, and the size of the bellows employed in the reduction of the ore is very much greater also; the weight of three men being employed to give force to the blast, instead of only one.

In all cases, this contrivance, rude as it is, seems to give a sufficient and tolerably equable blast, not ill adapted to the small furnaces employed, which are composed solely of clay.

The blast thus obtained sufficient and tolerably equable.

* As showing how very similar these Indian processes are to those formerly in use in some of the richest iron districts of England, the words of Dr. Plot, in his Natural History of Staffordshire, published in 1686, are interesting. He was writing not long after the first successful attempts to make iron with pit-coal and the introduction of machinery for "slitting" and rolling. But speaking of the general improvements in smelting, he says—"We shall find it very great, if we look back upon the *methods* of our *ancestors*, who made iron in *foot-blasts* or *bloomeries*, by men treading the bellows, by which way they could make but one little lump or *bloom* of *iron* in a day, uot 100 weight, leaving as much *iron* in the slag as they got out."

I have said that no flux is added to the mixture of ore and charcoal used in these operations. Of course there must be a certain amount of ash in the charcoal, which in all probability consists principally of carbonate of potash and soda and a little lime; and this will doubtless act, and act most effectively, as an admirable flux, taking up a part of the silica; but the quantity combined with charcoal is too small to have any very appreciable effect on the result in diminishing the loss of iron.

The ash of the charcoal must act as a flux.

The chemical reactions in the furnaces are simply these. Supposing, as is now generally believed by those who are the best authorities on these matters, that carbonic oxide is the principal agent in reducing the ore, the first result of the application of the heat is to promote the union of the oxygen of the air with the carbon of the charcoal, forming carbonic oxide (Co or $\dot{C}$.) The ores used being, as we have already explained, almost exclusively composed of the peroxide of iron and silica, the ash of the charcoal, left free by the separation of the carbon, takes up a proper proportion of the silica of the ore, leaving still the larger portion. At the same time the peroxide of iron is resolved into oxygen and the protoxide of iron, the whole of the oxygen thus set free uniting with the carbonic oxide and forming carbonic acid which is driven off.

Chief reducing agent carbonic oxide.

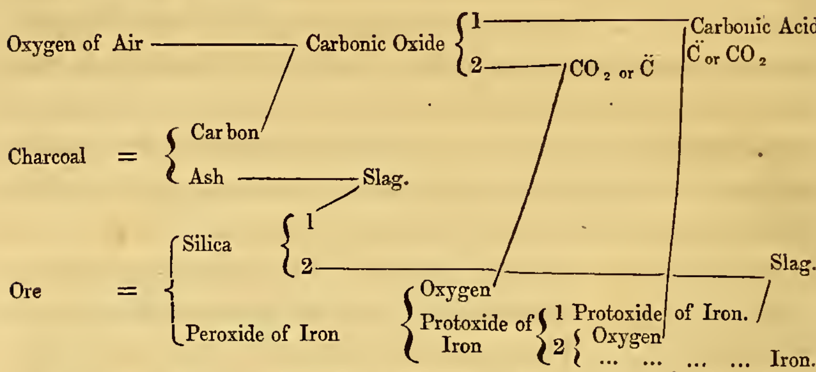
Chemical action in the furnace.

A portion of the remaining protoxide of iron is again further resolved into oxygen and iron, the oxygen, as before, uniting with a further proportion of carbonic oxide, and passing off in the state of carbonic acid, and the iron remaining; while the other portion of the protoxide unites with the unreduced silica and forms the silicate of the protoxide of iron. This is the ordinary slag of such furnaces, the silicate of the protoxide of iron, probably in the form of the tribasic silicate $Fe^3 \dddot{Si}$. *

* This is the same as the "tap cinder" of puddling furnaces, which contains no les than 55 per cent. of iron.

D

The accompanying diagram, prepared by Mr. W. F. Blanford, will exhibit these reactions :—




Character of iron from first melting.

The iron thus produced by this first process has never been thoroughly fused. It is brittle, owing chiefly to the impurities mixed with it; but these, by the continued exposure to the direct action of the blast in the open furnace in which it is cleaned, are either melted or burnt out, and the repeated hammerings remove the impurities.

No detailed analyses.

Unfortunately, there have been no analyses of such products in this country sufficiently detailed, to enable a sound opinion to be formed of the real composition of such slags, or impure metal, as I have spoken of. A rude analysis of slags resulting from similar processes, operating on very similar, though not quite so siliceous, ores in Birbhoom, gave to Dr. Macnamara* 55 per cent. of iron in the slag, with nearly 38 per cent. of siliceous matter, together with a proportion of lime.

* Two specimens of slag were tested, and the results were :—

| | Iron. | Lime. | Residue, chiefly siliceous matter. |
|---|---|---|---|
| No. 1, From Sandstone Ore, .. .. .. .. | 55·45 | 6·18 | 38·37 |
| No. 2, „ Hæmatite, .. .. .. .. .... | 54·00 | 8·43 | 37·57 |

*MS. Reports.*

This sufficiently shows the main constituents and proves the general composition to be as I have stated.

Some of the slags resulting from the rude operations of the native workmen are not however so heavily charged with iron as this; but few of them contain less than 40 per cent. of iron.

Assuming this, then, as the lowest or minimum percentage, and seeing that the iron in the ores reduced exists in the state of peroxide, it is obvious that, unless the ore used contain more than 36 per cent. of iron, no iron whatever can be obtained by the process adopted, *the whole of the iron going into the slag.* *

Improvements necessary.

The important question then arises, how are these processes to be improved? I have mentioned that the furnaces now in use are all made of clay, and I have described the rude system of blast which is employed. It is, I think, certain that neither could such means produce, nor such materials resist the effects of, a greatly increased temperature; and yet, if ordinary fluxes be used, to increase the per-centage of produce, such increased temperature is absolutely necessary.

Higher temperature necessary.

The tribasic silicate which now forms the slag is one of the most easily fusible of the silicates (excepting those of the alkalies), while the silicate of lime and alumina, the slag resulting from the English and European smeltings, requires a very high temperature to render it fluid, and the pure silicate of lime still higher (of course alumina could readily be added if needful.)

Change of furnaces, &c. therefore required.

A total change, therefore, of the system adopted must be introduced before any great improvement in this direction can result.

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* Remembering that the *average* of the clay iron-stones, from which nearly all the iron is produced in England, is not higher than 33 to 34 per cent., some idea may be formed of the imperfection and extravagance of the native process.

I have shown above, that the ash of the charcoal, which consists mainly of carbonate of potash, acts as an admirable flux so far as it goes, and I believe that much benefit would result from the large use of wood-ashes in the native furnaces. Wood-ashes could in all these jungles be readily and very economically procured, and I feel little doubt that the free use of these as a flux would largely increase the return of iron.

Wood-ash might be used largely with advantage.

When lime or rather limestone is used, as I have stated, the temperature necessary for the reduction of the resulting silicate is very high, and at this temperature a certain proportion of the carbon unites with the iron itself, the result being "cast iron," while at the lower temperature now employed, although at the cost of so large a per-centage of the iron itself, imperfect malleable iron is produced by the first process.

Cast iron.

Malleable iron.

As regards Cuttack, there is no lime-stone known to occur in the immediate neighbourhood of these rich iron ores, excepting the kunkur.

In Cuttack there is at present no flux known to exist, except kunkur.

It is not improbable, from some statements of Dr. Voysey, who found limestone between this and Nagpur, in some of his latest trips, that this rock may be found at no very great distance. If required at present, much of the kunkur will doubtless answer as a flux; but independently of the small quantities in which it is found, and the large areas over which even these small quantities are distributed, there is another even more serious objection to its use, from its extremely variable composition. This would render its employment very ineffectual, unless means were constantly adopted to ascertain this composition and in consequence to vary the proportions of it and of the ore when charging the furnaces.

Probably limestone may be found.

Difficulties in the use of the kunkur.

But may not other and simpler means be adopted for obtaining a better result from these rich ores? We think there may, and, with the experience of other countries to guide in such trials, believe that much might be done to develope the industry of this district.

Other means may be adopted.

The introduction of skilled labor and practical experience from Europe or elsewhere is common to all projects which might be started, and may therefore be assumed. But it is desirable to render this necessity as slight as possible. At the same time, although there appears from the statements of all observers to be little doubt of the abundance of fuel, this valuable material must be economised as far as may be possible.

Skilled labor to be introduced.

I think some form of reverberatory furnace will best meet these conditions, by which, with the least number of skilled hands, and with a small expenditure of fuel, a considerable yield of good malleable iron may be produced by the direct process.

Reverberatory furnace most desirable.

There are two modifications of reverberatory furnaces now in use which recommend themselves.

Two kinds of furnaces.

The first is one originally patented (in America) by Renton in 1851, for making wrought irou direct from the ore. This process is now being carried out upon a commercial scale at Cincinnati in Ohio and at Newark in New Jersey.

Professor John Wilson described the practical application of this patent in some detail in his account of the several branches of the iron trade of America, as represented in the Great Exhibition at New York, and his words may be quoted with advantage. He says:—" In shape " the furnace is like the ordinary puddling furnace, at the extremity of " which a chamber of the following dimensions, 10 feet high by 6 feet

Renton's furnace as described by Professor J. Wilson.

" broad and 7 inches in depth, is built up in fire-brick, forming in fact a " kind of large vertical muffle or retort.

" This is entirely surrounded on all sides by the flues or chimney of the " furnace. When in operation, this muffle or retort is filled with a charge " of ore and coal both finely broken, and carefully mixed up together, in " the proportion of 20 to 25 per cent. of coal to 75 to 80 per cent. of ore.*

Mode of working.

" The heated gases from the furnace playing round it raise the temper- " ature of its contents sufficiently to induce com- " bustion of the carbonaceous matter, which com- " bustion is carried on slowly at the expense of the oxygen of the ore. " When the ore is sufficiently deoxidised, it is discharged from the bottom " of the muffle as required into the welding furnace, where the heat is " considerably increased, and the iron is readily worked into balls, and " thence taken to the hammer in the ordinary way.

" The iron by this process cannot be said to be *puddled,* as the ore " never really melts, but having first been deoxidised in a close chamber, " is simply welded together in what the patentee of the process calls his "ore-welding" furnace. He appears to think that the great merit of " the process lies in the use of the closed chamber, in which the iron is " perfectly protected from the wasting effect of the flames and gases of " the furnace during the process of deoxidation, which would otherwise, " as they always do, oxidise and slag the ore : the probable reason why all " attempts to work the ore in open chambers have failed.

Deoxidation at lower temperature ensuring greater purity.

" The temperature at which the deoxidising action is carried on is not " sufficiently high to cause the iron to combine " either with the carbon of the fuel or with any of " the impurities, as silica, phosphorus, &c., which " are always found in common cast iron.

"The balls were drawn from the furnace for "tilting" every half hour, " their size depending on the quality and yield of the ores used."

* The muffle referred to by Professor Wilson held a charge of 12 cwt.

A moderately rich hœmatite, yielding about 35 per cent. of metal, was being used when Professor Wilson saw the furnaces in operation, and the balls weighed about 80 ℔s. each. The average yield obtained in the furnaces was stated to be about 45 per cent., and the average weight of the balls to be about 100 ℔s.*

Professor Wilson states that the action of this furnace was excellent and the production rapid.

In America coal is the fuel used, but we might substitute charcoal.

The fuel used in America was coal, but there seems no reason whatever why charcoal should be less effective if used in proper proportions.

Ekman's furnace.

The second form of furnace to which I referred above, and for re-calling my attention to which I am indebted to my colleague, Mr. H. F. Blanford, is that known as Ekman's, which is used in Sweden for the manufacture of charcoal iron.

Construction, &c.

The principle is simple. The body of the furnace is of the construction of an ordinary reverberatory furnace, the bed of which is shorter than usual. Upon this bed the ore, mixed with charcoal and a small proportion of flux, is laid and is here occasionally rubbled. The blast enters at the crown of the furnace, but is previously passed through about 6 feet of ignited charcoal or coke. By this means a large quantity of carbonic oxide (CO.) is formed, and raised to a high temperature. This powerful reducing gas then passes through the tuyere, and, together with the gases from the furnace, is blown directly upon the ore, the flame of the furnace being kept highly reducing by regulating, in the ordinary way, the supply of air below the bars. By this means a spongy mass of metal containing, mixed with it, a considerable quantity of slag, is formed upon the hearth. This is balled and shingled in the ordinary way.

Mode of working.

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* *Vide Journal of Society of Arts*, London, 1853-54—J. Wilson's Lecture on Iron Manufactures of America, as exemplified in the Exhibition at New York.

This very simple plan of furnace is extremely effective, its yield is large, and its production rapid and equable.

I feel satisfied that the introduction of either of these plans, or some slight modifications of them, would prove of much greater advantage than any attempt to establish iron works on the system adopted in England for the treatment of the ores of that country, which are essentially of a different character from those now referred to.

Fuel.

The question of the amount of fuel is an all-important one and worthy of more serious consideration than it has hitherto received.

Great want of accurate and recorded observations.

Here, as in almost every direction, in questions bearing upon metallurgical processes in this country, we are met by the serious difficulties arising from the want of accurate investigations.

In Europe the average yield in charcoal of all the ordinary varieties of wood, when charred, is well established. In India I am not aware of a single trustworthy experiment on such subjects.

Charcoal of the sàl used in ordinary by the natives.

Experience has proved to the native workmen, that for their ordinary processes, the charcoal made from the sàl *(Shorea robusta)* is best adapted. For some special processes other charcoal is preferred, that of bamboos for instance, of the bhyr, &c., but I am unable to state what the real or even relative calorific values of such charcoals are.

But for a rude calculation, we may, I presume, estimate that if made on any thing approaching to sound principles, the charcoal derived from the harder timbers of this country will be equal to the average quality of charcoal prepared in Europe from the hard timbers of that country.

Again, we cannot say what proportion the charcoal obtained bears to the wood employed. Doubtless, on the system of rapid burning now in use among the natives, the yield is very small; but this would of course be remedied at once, and a few trials carefully and accurately conducted would soon show the proper rate of combustion to attain the maximum useful effect.

The relative per-centage of charcoal obtained by quick methods, and by slow methods of charring, varies with the same timber not less than from 9 to 12 per cent.*

Amount of moisture absorbed unknown.

Another question regarding which we really know nothing bearing on this country is the amount of moisture, which the charcoal produced from the woods of India will absorb after manufacture within a given time; and yet this, considering the very great moisture of the atmosphere in these countries, is an important consideration.

This, in Europe, has been found to vary, in the same time, from 0·80 per cent. (beech charcoal) to nearly 9 per cent. (fir) and even to 16·30 per cent. (black poplar.) The total quantity taken up in nearly three months varied from 10 to 12 per cent., and there can be little doubt that either this quantity would be materially increased, or the time required for its absorption would be considerably shortened in moist climates.

Amount, composition, &c. of ash of charcoal, not known.

The amount of ash also, and the composition of that ash in the several varieties of charcoal, which could be procured in any quantity in this country, is unknown. The amount of such ash, where it has been ascertained, is found to vary from much less than 1 per cent. to about 3·50; in some case even reaching as high as 6 and 8 per cent., but yielding a general average, on a large number of experiments, of 1·65. As I have above shown, the composition of the ash, no less than its amount, will exercise

| | | | | |
|---|---|---|---|---|
| * Oak, quickly charred, gave | 15·91, | slowly charred | 25·71 | per cent. |
| Beech, „ „ „ | 14·15 | „ „ | 26·15 | „ |
| Birch, „ „ „ | 12·20 | „ „ | 24·70 | „ |
| Pine, „ „ „ | 13·75 | „ „ | 25·95 | „ |

And the list might be greatly enlarged. *See* Karsten and Winkler's Experiments quoted in Ronald's and Richardson's Technology, Vol. I., p. 60.

an important influence on the results of any smelting processes undertaken.

These are only a few of the questions which bear very materially on the full and accurate investigation of such subjects, and for the solution of which we have as yet no data in this country.*

Only an approximative estimate is possible.

Any estimate therefore that can be now made, as to the amount of charcoal required for such manufactures as we have contemplated, can only be considered approximative.

Heating power of charcoal.

We may assume, I think, that the heating power or calorific value of charcoal, is slightly superior to that of the best quality of coke, and from 3 to 5 per cent. superior to that of good coal.†

We shall be scarcely safe therefore in estimating for a smaller quantity of charcoal per ton of ore used than would be required of coal.

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* I confidently hope that as soon as the establishment of the Museum of Practical Geology, recently sanctioned by the Supreme Government of this country, shall be fairly organised, we shall be able to remove the doubt which hangs over this and other similar subjects.

† The following are the results (in brief) of experiments :—

| | lbs. |
|---|---|
| 1 lb. of Charcoal (average of birch, fir, alder and oak) gave as a mean result in lbs. of water raised from 0 to 100 centigrade, ...... ... | 72·00 |
| 1 lb. of Charcoal (average of 11 varieties,) ........ ...... .... | 71·90 |
| 1 lb. of French Coal ( „ „ 3 „ ) ........ ...... .. | 62·80 |
| 1 lb. of Lancashire Coal „ 4 „ ........ ...... .... | 64·47 |
| 1 lb. of Newcastle „ „ 4 „ ........ ...... .. | 68·88 |
| 1 lb. of Welsh „ „ 6 „ ........ ...... ...... | 73.34 |
| 1 lb. of Coke from Durham Coal ........ ...... ... | 71.59 |
| Pure carbon yielding .................. ........ ...... ..... | 78·15 |

The relative pyrometrical heating effects of the different fuels burnt in contact with air may be thus given in degrees centigrade :—

| | | |
|---|---|---|
| Wood ........ | 1575 to | 1750 |
| Wood Charcoal ........ | 2100 | 2450 |
| Coal (5 per cent. ash) ........ | 2200 | 2350 |
| Coke (5 per cent. ash) ........ | 2350 | 2450 |
| Pure Carbon ........ | 2458 | |

[*Scheerer's Metallurgie.*

Amount of timber per acre, &c. as yet unascertained.

Further, the amount of timber which may fairly be looked for as the annual supply from a given area is as yet in this country unknown.

Probable average.

Supposing it to be equal to that of well cared-for forests in Europe the out-turn per acre may be calculated at about 8 tons of kiln-dried wood* (from 6½ to 12 tons.) If intended to yield a continuous annual supply, about one-eighth of this amount may be obtained, or about 1 ton of dry wood per annum.

Yield of charcoal from wood.

The yield of charcoal which might be obtained from thoroughly dried wood, as determined by Mushet, varied from 26·0 per cent. from lignum vitæ to only 16·4 per cent. from Scottish pine; the average of his experiments giving (from 15 varieties of wood) 22·4 per cent. We may take I think safely the average of the harder varieties and say that the yield would be nearly 25 per cent., that is, that one acre of land would yield an annual supply of 0·25 of a ton of charcoal. One square mile therefore, supposing it to be equally covered with forest, would yield (640 acres) 160 tons of charcoal.

As I have said, this estimate can only be taken as rudely approximate. I believe it to be under the truth; and that, under any fair system of conservancy and of charcoal-burning, the out-turn would be greater.

Probable yield of charcoal per square mile.

We may therefore, I think, say 200 tons per square mile. For the production of one ton of wrought iron, on the English system, three tons of charcoal will, on the average, be required. I mean, of course, to reduce it and convert it into malleable and marketable iron. If the systems I have alluded to be adopted, less than 2·5 tons will be amply sufficient. In other words, one square mile of forest will yield an annual supply of charcoal

* The moisture in wood was fouud by Hartig to vary from 18·6 per cent. in hornbeam up to 51·8 per cent. in black poplar. (The average of 22 varieties giving 38·7 per cent.) The produce of an acre therefore is now generally calculated in kiln-dried wood, to avoid the uncertainty arising from this great variation in the amount of water in the timber.

sufficient for the production of 67·7 to 80· tons of wrought iron per annum; or on the more economical system for the out-turn annually of say 1,000 tons of bar iron, about 12·5 square miles of forest would be required, that is to say, an area included in a square of 3·6 miles on each side. In other words, for the annual supply of charcoal for 1,000 tons of wrought iron, a circle of 4 miles diameter would suffice.

To increase this produce of course the area of supply should be proportionally increased. Thus, for the annual production of 10,000 tons of iron, an area of 125 square miles would be necessary, an area comprised within a circle of about 12·5 miles in diameter. In this case, supposing the site of the manufacture to be placed near the centre of the supplying area, the distance from which the fuel would have to be brought would be not more than 7 miles. Again, if we take the extreme limit from which fuel might be carried with profit, as about 10 miles on all sides of the furnace, we shall have a circle of 20 miles in diameter, which, allowing something for the clearances which must exist, will give us about 300 square miles, affording charcoal sufficient for the manufacture of 24,000 tons of iron annually.

These calculations are necessarily based on the supposition, that the produce of each acre or square mile of the area will be nearly alike, and also, that the whole of the estimated area is under forest. There are few, *if any*, places in the country, where such conditions will be found to exist; and bearing in mind the necessity for open spaces for the works themselves, the amount of ground which must inevitably be given up to sites for houses and to ordinary cultivation in the vicinity of such large works, I think it would be very unsafe to anticipate that, within a circle of any given radius, in any desirable locality for such undertakings, there would be found more than one-half of the entire included area yielding good forest return: that is, on the same data as are taken above, a circle of 10 miles radius would yield a supply of fuel annually sufficient for the production of 12,000 tons of wrought iron; but even this would represent about 250 tons per week; and is, in any case, a larger amount than can fairly be looked for from any one establishment for many years to come.

It is, of course, presumed that strict care will be taken to cut the forest systematically, and to renew its growth steadily and constantly, and it is here, as before, estimated that with ordinary care sàl timber will within eight years have reached a sufficient size to be fit for cutting. I am disposed to think this time will be sufficient, but if ten years be requisite, a proportionate amount must be deducted from the estimated out-turn of charcoal given above.

There would unavoidably be a considerable waste in all this charcoal, both from the crushing of the masses in stowage and from their breaking up during carriage. This could not be taken as less than 10 to 15 per cent. of the whole. In parts of this country where pine trees could be readily procured, this dust might perhaps be profitably economised by adopting some one of the many methods by which the tarry products of such resinous woods could be saved, and by then mixing the dust of the charcoal with a certain proportion of this tar, thus forming an artificial fuel. This is no new process, but is frequently done, and might, I think, in the event of the establishment of such works as we have been referring to along the foot of the Himalaya Range, be successfully introduced.

It is unnecessary to give here any detailed estimates of the cost of such works. Their cost will necessarily depend on so many circumstances, and will vary so materially with the amount of out-turn estimated for, that any detailed estimates are only likely to mislead. If one-half of the highest amount calculated for above be taken as the basis of the estimate, for the out-turn of 6,000 tons of wrought iron annually (on the English system of high blast furnaces for production of cast iron, its subsequent refining, puddling, rolling, &c.), a complete establishment could not be erected for less than £60,000 to £70,000 spread over three years. At least one-sixth of this would be in the first instance saved by the adoption of other systems, and there would be a further saving annually in the cost of labor. For other portions of the process, I think the cost of working may be not unfairly considered as nearly the same as it would be in England, the greatly enhanced value of skilled hands in this country being counterbalanced by the lesser cost of ordinary labor.

Nor would I undertake to give any safe idea of the profit which would be derived from such a manufacture. This depends on too many varying facts, ever to be fairly estimated until the exact site of such works be fixed on, the extent to which they are to be carried, the distance of the markets, the cost and *kind* (a most important element) of carriage, &c. &c. But it may, I think, be safely stated, that there is no sound reason why iron should not, under proper management and in a well-selected locality in this district, be manufactured at a cost equal to, if not less than, that at which it is produced in England. Putting aside all other considerations, therefore, the cost of freight of English iron, which may be taken to average about £1 per ton to Calcutta, will be saved, or will be, in fact, so much additional profit on the manufactured product, supposing it to command the same price in the market.

Other advantages.

In other respects (*e. g.* the presence of ample and continuous water power, the comparative proximity to the sea-coast, and to water-carriage and other advantages which are noticed hereafter) this district seems marked out as one likely to yield a profitable return for such undertakings.

Labor.

There are, at the same time, difficulties to be overcome in the want of labor and in other ways; but these would all yield to a little energetic determination, and the climate in many parts is not more unhealthy than in other portions of Bengal.

Gold.

The occurrence of *gold*, and the localities where it is sought for, will be found noticed below.

## Additional Note.

*Pages* 17-18. The only published analyses of the iron ores of Cuttack are those given by Mr. Piddington in the *Journal of the Asiatic Society of Bengal*, 1855, p. 708. Two varieties, forwarded by Mr. Samuells, were experimented on. One, from Kunkerie, of "ochrey red iron ore," yielded a per-centage of peroxide of iron equivalent to 46·8 per cent. of metallic iron; the other, from Paleyra, is stated to be a "mixture of the hydrated carbonate of the protoxide of iron, with a large proportion of earthy matter," although, by some typographical error I presume, the details of the analysis do not show any carbonic acid whatever. It yielded, according to Mr. Piddington, 60·60 per cent. of protoxide of iron, equivalent to 47· per cent. of metallic iron, with some manganese.

*On the Geological Structure and Relations of the Talcheer Coal Field, in the District of Cuttack. By* MESSRS. W. T. *and* H. F. BLANFORD *and* WM. THEOBALD, JUN., *Geological Survey of India.*

THE portion of country examined during the cold season of 1855-56, in the district of Cuttack, lies between the Rivers Brahmini and Mahanuddi, extending from the Western boundary of the reported Talcheer Coal Field in East Longitude 84° 20′ to a few miles East of Cuttack. It will also be necessary to make a few remarks on the hills of the Nilgherry Range to the South-West of Balasore, and on a small tract of sandstone South of Cuttack and of the Mahanuddi, as being geologically, as well as physically, closely connected with the district which forms the main subject of this Report.

Physical features of the district.

The chief physical features of this district may be simply and briefly described. From the coast a cultivated alluvial plain, varying from 15 to 45 miles in breadth, extends to the base of the hills forming the district of Cuttack.

From this plain small isolated and steep hills rise in a few places to the North of Cuttack and, taken in connection with the bosses and whale-back ridges which stud the surrounding country, present all the features of an up-raised archipelago, and lead to the belief that, at no very remote geological period, the sea of the Western portion of the Bay of Bengal dashed against many a rugged cliff and rolled around clusters of islands which studded over what is now the Province of Cuttack: indeed, a comparatively trifling depression of the country might re-produce the same phenomena. Upon entering the hills, they are seen to consist not of long continuous ranges, but generally of insulated and rugged ridges, seldom more than 10 to 15 miles in length, and having one uniform direction, nearly due East and West, parallel with the lamination of the gneiss and with the main faults of the district. This is better seen near the Coast than inland; as to the West of Ungool, the hill-ridges, though preserving the same general direction, are longer than near Cuttack.

The hills, as well as the low country, are for the most part well wooded and present few naked bluffs (even among the almost precipitous sand-stone escapments of the Talcheer field). Their outline, however abrupt, is always more or less rounded, and it is evident that they owe their present form principally to marine action. The accompanying Sketch *(Fig. 1)* of some small hills North of Cuttack shows their general character.

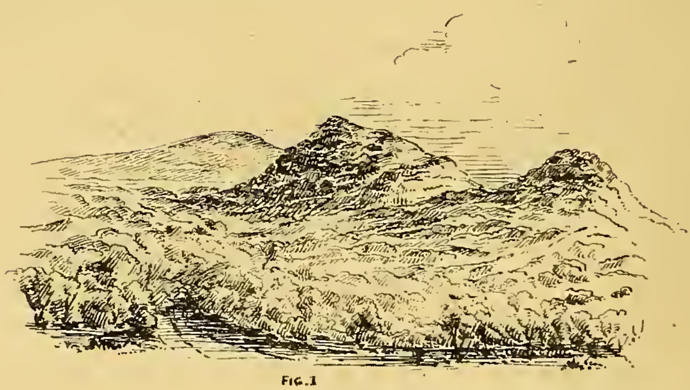

FIG. 1

Wherever the sandstone of the sedimentary deposits rises into hills, it presents a totally different aspect: these hills, though generally appearing flat-topped, being found on ascending them to consist of a series of sharp steep ridges separated by deep and precipitous valleys, evidently due to the denuding action of fresh water, of the effects of which, upon a considerable scale, they afford a fine example.

Rivers.

The only large rivers of this district are the Brahmini and the Mahanuddi, both navigable during the rains for boats of large size and for canoes at most times. None of the tributaries draining the narrow country between them attain to very considerable size. One of the largest is the Tikiria, which drains the Northern part of the Talcheer basin, and always contains a considerable quantity of water. In the hills of Rehrakōl, where the forests are thick, all the streams flow permanently; while the sandy nullahs of the more level country are dry, excepting after heavy rains. One of these, the Tengria, having a bed in some places of 150 feet wide, is interesting, as being the stream on whose banks (near the village of Gopalprasad) coal was said to exist in very large quantities. Passing Westward the hills preserve a very similar character, but increase in number and height, until (in Raun-Hill in the Raj of Rampur) they attain an elevation of 2,200 feet.

The district is but thinly inhabited, and the greater portion of the more level, and all the rising ground is thickly wooded and covered with dense jungle. The wooded valleys and water-courses are the favorite haunts of many wild animals, where even the bright rays of the mid-day sun can scarcely penetrate the thick shade of their cool retreats. Here are to be found the bison *(Bibos Cavifrons)*, the hog, bear, tiger, leopard, hyæna, wild dog, &c., the sambur, nylghai, with spotted and other deer.

The character of the country of necessity materially increases the difficulties of accurate examination. While the dense wooding and thick luxuriant jungle render it impossible to obtain continuous or satisfactory sections, the deadly exhalations rising from the deep unventilated valleys and ravines, which offer a most tempting shade, render the climate during eight months of the year, most unhealthy and dangerous.

Geological structure, &c.

The country generally may be described as a district of metamorphic rocks, with occasional dykes and veins of igneous origin, and containing basins of sedimentary deposits. The whole tract of ground around and between the (so-called) Coal Fields, and also the hills of the district, consist essentially of different varieties of gneiss, covered in the low coast country, and in the river deltas, by alluvial deposits.

In proceeding to a more detailed description of the rocks of the district, the following order will be adopted :—

Order of description of the rocks of the district.

1*st.* Igneous rocks.
2*nd.* Metamorphic ditto.
3*rd.* Sedimentary deposits.
4*th.* Rocks of chemico-aqueous origin.

IGNEOUS ROCKS.

The igneous rocks of the district are limited in extent and importance, occurring only as small dykes and veins traversing the gneiss. These are principally composed of granite, but occasionally of a rock of dioritic character. The granite veins vary much in composition, some being nearly pure quartz and felspar, others again containing felspar of two different kinds (one being orthoclase felspar of the adularia variety, the other perhaps albite), also large crystals of mica and quartz. The dykes are very narrow none exceeding 2 feet in breadth, and the majority being probably under 4 inches; those of smaller size are very numerous. It appears strange, considering the general distribution of these granite veins, and their great number in some localities, that no nucleus, however small, of igneous rock has been discovered in the district, although doubtless, judging from the highly granitoid condition of the metamorphic rocks in many places, some such nucleus does exist at no very great depth.

Minerals in the granite, &c.

The minerals of the granite within the area described are not numerous. The intruded rock of most frequent occurrence is a highly felspathic, largely crystallized variety of granite, sometimes containing crystals of black tourmaline of large size. This occurs in veins from 1 to 2 feet in thickness; it is seen in the bed of the River Brahmini, near Kamlong, in a nullah near the village of Gutiapal and near the village of Ramidi. Near the last-mentioned place a dyke-formed vein of about 18 inches in breadth, which can be traced for some distance rising above the general surface of the ground, contains, in addition to the schorl crystals,* (sometimes $1\frac{1}{2}$ inches in diameter), crystals of apatite, beryl or a pseudomorph of that mineral, and a transparent yellow mineral, probably chrysoberyl. The essential minerals of the rock are adularia felspar, some crystals of which are 6 to 8 inches in length; quartz; and well-crystallized and honey-colored mica. In the bed of a nullah, which crosses the Ungool and Cuttack road near Rasul, a granite vein occurs, containing good crystals of zircon much resembling the Arendal variety; also a black mineral, probably titaniferous iron. Pegmatite (probably of recent origin) occurs in the gneiss to the West of the Coal Field near Ampul, rather in irregular strings than in well-marked dykes; but it does not appear in contact with the sedimentary rocks.

No dykes, &c. in the sedimentary deposits.

No basaltic or other dykes of any kind are found traversing the sedimentary rocks in this district, and the fact of their total absence is very interesting when considered in comparison with their abundance in the Coal Fields of the Ganges basin and the West of India, and the immense prevalence of trap in Nagpur and further to the West. Apparently the district of Cuttack lay beyond the area of tertiary volcanic action.

Age of the granite, &c.

The granite (the pegmatitic variety perhaps excepted) is unquestionably of prior date to the sedimentary rocks of the district, although no pebbles of the largely crystallized varieties have been observed in the coal measures. They however are of so decomposable a character, and the masses of individual minerals composing them so large, that, if subjected to denudation and subsequent attrition, they would probably yield little else than quartz pebbles, such as do frequently occur in the conglomerates in question. The granite, of which pebbles are so numerous in the lower beds of the coal measures, is *not the granite of this district*, but much more finely crystallized than any

* These crystals of schorl, however, appear to be in this district only exceptional, and none were found approaching in size those said to occur in the country to the North.

which here appears *in situ*, though possibly only a variety of the largely crystallized schorl granite. Its source is at present undetermined, but may probably be looked for to the West, in the granitic hills described by Messrs. Hislop and Hunter as extending over the country East of Nagpur.

The granite veins, &c. probably cotemporaneous with the metamorphism of the gneiss.

It appears probable that the granitic veins above described are cotemporaneous with the metamorphism of the gneiss, for the following reasons :—

*First*,—From their character and composition.

*First*,—Their very largely crystallized character, and the almost complete separation of the minerals composing them, would show that their rate of cooling must have been very slow, which, considering their small size, rarely, if ever exceeding 2 feet, can only be accounted for by supposing that the surrounding mass was in an intensely heated state at the period of their intrusion; and *Second*,—The change which has taken place in the structure of the gneiss, as well as in its mineral composition, frequently to the distance of some feet from the walls of the veins, exhibits an amount of what may be called secondary metamorphism, which a granite vein of 2 or even 3 feet in thickness could scarcely be expected to produce in a perfectly or even nearly cooled rock.

*Second*,—From the change produced in the gneiss.

Dykes of a hard green rock, apparently consisting principally of quartz and hornblende, (amphibolite ?) are seen passing through the gneiss in a N. E. and S. W. direction at various points near the S. E. boundary of the Talcheer field, especially at Sakuasinga and near the small village of Ramidi. The N. E. Fault, between Benagaria and Jorasinga, which for a distance of 4 miles forms the boundary of the coal measures, runs during part of its course along the line of one of these dykes, as do also the N. E. Faults between Kaliakota and Ramidi.

The rock itself is of greater age than the coal measures, since, although it can frequently be traced through the gneiss up to the boundary, it never penetrates into the sedimentary deposits. It seems, however, to have afforded lines of weakness through the gneiss, along which faults have taken place subsequently to the deposition of the coal measure beds.*

METAMORPHIC ROCKS.

The metamorphic rocks of this district may be defined as consisting of different forms of gneiss, micaceous, quartzose, and hornblendic,† all the forms passing into each other and each exhibiting many varieties. The most marked of these, and one which prevails over a very large area, is an almost pure quartz rock, in which the felspar usually present in gneiss has entirely disappeared and mica only remains in very small quantity; and this is frequently replaced by a talcose mineral. We very rarely find the mica entirely wanting, and even in that case the rock is always distinctly cleavable, by which it is readily distinguished from ordinary quartz rock. Another peculiar form is the hornblendic gneiss, which generally consists essentially of hornblende and quartz, the former being frequently a highly crystalline variety, approaching in character to actinolite, and predominating to so great an extent, that the rock is almost entirely composed of it.

The micaceous gneiss presents every modification, being fine-grained, coarse-grained, quartzose, &c. &c. Perhaps some such division as follows might be made of the metamorphic rocks :—

| | | |
|---|---|---|
| *Gneiss.* | (Var. *a.*) | Hard, coarse, compact, and felspathic, becoming sometimes lithologically a perfect granite. |
| | (Var. *b.*) | Soft, laminated, quartzose or micaceous. |
| | (Var. *c.*) | Compact, but sometimes soft, containing garnets frequently decomposed. |

* This rock also forms a small hill near Deinchi in Rehrakōl, being there garnetiferous. (A similar rock occurs at Parisnath.)

† Hornblendic gneiss, meaning gneiss in which the mica is replaced by hornblende, may perhaps not be considered as a correct term ; but the ordinary one, hornblende-slate, would, in the present case, be certainly improper, as the rock is not a slate at all, but a highly crystalline rock, not even cleavable.

| | |
|---|---|
| *Hornblendic Gneiss,* or *Hornblendic Schist.* | Soft and laminated. |
| *Quartz Schist,* or *Schistose Quartz.* | Occurs frequently in bands, separated by softer micaceous layers. |

One variety prevailing in the Eastern part of the district, and constituting the hills North and North-west of Cuttack, is granular and quartzose, showing little indication of foliation, except when seen in the mass, and containing abundantly red spots of peroxide of iron which replace decomposed garnets.

In the immediate vicinity of granite veins the gneiss is often extremely micaceous, consisting indeed of little else than black mica, the laminæ of which are invariably parallel to the walls of the vein. This character never extends for more than a few feet from the cheeks of the granite vein, and must be regarded as an alteration of the gneiss produced by the intrusion of the granite.

To the North of the Talcheer Coal Field a highly quartzose gneiss, with little or no felspar, and but a very small proportion of a pale silvery mica, occurs. The mica, although so trifling in amount, is nevertheless disposed in well-marked planes of foliation. The pebbles in the alluvial conglomerate aud gravel which cover the Coal Field chiefly consist of this rock.

Hornblende Schist occurs in bands generally of no great thickness at various points to the North of the Talcheer Coal Field, but has been nowhere observed on the Southern boundary. At the junction of the Tengria Nullah with the Brahmini, half a mile South of Bijgol in Talcheer, this rock is seen, being there composed of well-defined crystals of actinolite. More compact varieties, with a well-marked foliated structure, also occur.

A more typical variety of gneiss occurs over a large area to the South of the Coal Field, and probably is of considerable extent in that direction.

The gneiss occasionally assumes so closely the appearance of granite, that were it not for the evident identity in origin of these portions with that of the more typical gneiss surrounding them, they might almost be mistaken for a true granite. This is well seen, among other places, near the village of Kokodong, on the borders of the Talcheer field, where large bosses of apparently highly porphyritic gneiss, containing disseminated garnets and imperfect crystals of adularia felspar, rise above the general surface of the ground, and distinctly show the effects of exfoliation. Also, in the bed of the Brahmini below Santapara, the same gneiss appears, weathering into the form of rounded bosses, which scale off at the surface in the same manner as many granites. Occasionally, the whole weathers into rounded masses imbedded in soft decomposed gneiss, presenting much the appearance of a sedimentary boulder bed, for which indeed it might readily be mistaken, when occurring, as it frequently does, just at the junction of the gneiss with the coal measures.

The accompanying Sketches will give some idea of the appearances presented.

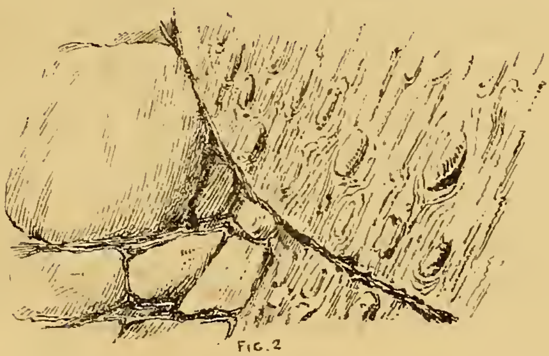

FIG. 2

Fig. 2 shows a mass of this rock traversed by a small fault near Karakprasad, and illustrates the mode of its origin and the different stages of decomposition. Another good instance of the same action is seen in the bank of the Brahmini opposite the village of Santapara. *(Fig. 3.)*

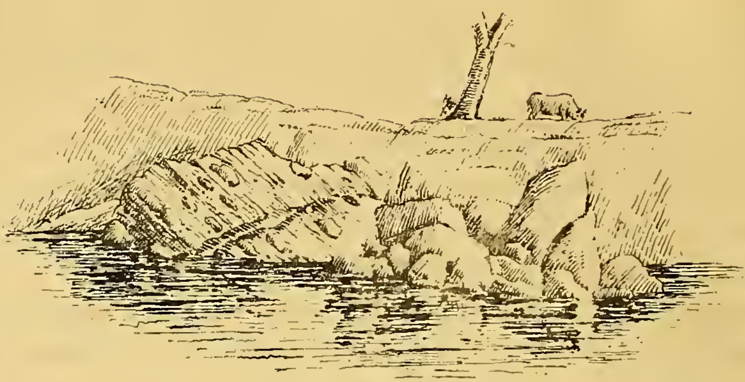

FIG: 3

It is only in the more felspathic varieties of the gneiss that this decomposition has been observed to any extent, and principally in the neighbourhood of faults, or on the borders of the coal measures, where the broken and porous nature of the adjoining rock would allow the free access of water. The rounded hummocks produced by the weathering and exfoliation vividly recal the *Roches Moutonnees* of the glaciers. Indeed, these rocks occur under circumstances in which we might expect to see all the results of glacial action simulated, if any other cause than ice were capable of producing them. A rapid river, carrying down pebbles of considerable size, its rapidity augmented here and there by the very bands of rocks over which it sweeps, must surely exercise most of the powers of those famous debacles to which glacial appearances have been referred.*

And if, as has been lately asserted,† many of the *Roches Moutonnees* have been produced by exfoliation, we have here a case in which

* *Russia and the Ural Mountains*, by Sir R. Murchison.

† A. Schlagintweit on Bavarian Alps, Quar. Jour. Geol. Soc. 1854, p. 346.

additional simulation of glacial action might be expected; but nothing of the kind here occurs, there is no *scratching* whatever apparent, and the causes of the smooth rounded surfaces appear too evident to be mistaken.

The great variations in the mineral composition of the metamorphic rocks appear nearly, if not exactly, to follow or to run parallel with their planes of foliation, which throughout the district have a general direction about W. N. W. to E. S. E., dipping at a very high angle, generally almost vertical. Thus we have the hornblendic gneiss, stretching along the Northern boundary of the Talcheer field in this direction; and although not continuous, it has been traced for 25 miles and again re-appears; while the highly granitoid gneiss of Santapara extends similarly along the Southern boundary. The same cause would appear also to have given a direction to the great faults of the district, and doubtless affected the general lie of the short hill-ridges throughout. It is not improbable, that many of these hills were produced by large faults, since most of those on the immediate borders of the coal measure beds can be traced to this cause, and the abrupt character of the hills would seem to point to the same conclusion. It will be very interesting to follow up similar observations along the great lines of metamorphic rocks in Bengal.

SEDIMENTARY ROCKS.

The only sedimentary rocks occurring in this District, (with the exception of "laterite" and some other superficial deposits), are sandstones, conglomerates, and shales in part carbonaceous. These occur, as before mentioned, in two basins,* which may be called the Talcheer and the Atgurh basins, of which the former is the larger, and forms more particularly the subject of the present Report.

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* Doubtless, when the country shall be more fully examined, many more will be discovered; a large one, as announced by Captain Saxton, certainly exists North-west of Sumbulpur, and others in Nagpur.

The Atgurh basin.

The smaller or Atgurh basin is in the immediate neighbourhood of Cuttack and extends for about 20 miles up the Mahanuddi to the West of the Station.

Talcheer basin.

The larger or *Talcheer basin*, which has been more specially examined, is about 50 miles North-west of Cuttack, and of considerable size, extending nearly 70 miles from East to West, or rather, more nearly South-east to North-west, from the East of Karakprasad on the Brahmini to beyond Rampur in Rehrakōl, with an average breadth of 15 to 20 miles, or between the parallels 85° 28′ and 84° 20′ East Longitude and 20° 50′ to 21° 15′ North Latitude. It occupies almost the whole of the tributary Raj of Talcheer with portions of those of Denkenāl, Bāmrah, Rampur, Rehrakōl, and the forfeited state of Ungool. Almost the whole of the Northern boundary, and a large part of the Southern, are formed by great parallel faults, having in the former case an aggregate down-throw of upwards of 2,000 feet.

Age of these sedimentary rocks.

The supposed equivalents of these rocks in other parts of India have been referred by various observers to different geological epochs, and most recently by Dr. Carter and by Messrs. Hislop and Hunter, have been classed together as one great group, referred to the oolitic age. Some of them are without doubt contemporaneous with the coal-bearing rocks of the Damoodah Valley, of Nagpur, &c., the fossils (all of them plants) being identical. Before enumerating or describing the proposed divisions of these beds, it should be premised that the sections exposed are by no means good enough to give satisfactory measurements. The general flatness of ground over much of the country, the consequent shallowness of the nullahs, and the great thickness of the alluvial deposits in many of the valleys, prevent the rocks from being visible, except at intervals, in the water-courses, which in a country of this character, so thickly wooded and almost destitute of natural or artificial sections of any other kind, afford the only opportunities of examining and judging of the nature and succession of the rocks.

The banks of the Brahmini, the only large stream passing through these beds, seldom expose anything but alluvium, especially to the North of Talcheer. But at the extremities of the field, and particularly towards the Southern boundary, the lower beds are seen well exposed, resting undisturbed upon the gneiss.

It is from this part of the field principally that the succession of the beds has been made out and the following division of them established.

Division of the sedimentary rocks threefold.

There appear to be three main divisions of the sedimentary rocks, each resting unconformably on the denuded surface of the one beneath. They may be classed, as in the section below, with the names respectively attached.

The thickness of the beds, as given in this section, must be considered as merely approximative, most of the beds differing much in various parts of the field owing to denudation as well as to original differences in deposition, and moreover exact measurements being in most cases impossible from the nature of the sections.

*Section in descending order.*

| Proposed Names. | Characters of beds, subdivisions, &c. | Estimated thickness in feet. |
|---|---|---|
| 1. Mahadewa Group or Upper Grit Series. | 1. Unfossiliferous, quartzose grits, conglomerates, and coarse sandstones, the conglomerates predominating towards the base of the series. | 1500 to 2000 |

*Section in descending order.—(Continued.)*

| Proposed Names. | Characters of beds, sub-divisions, &c. | Estimated thickness in feet. | |
|---|---|---|---|
| 2. Damoodah Group or Carboniferous Shale Series. | Fossiliferous. | | |
| | *a.* Interstratifications of blue and black shale, often very micaceous, iron-stone, and coarse fel-spathic sandstone. | 1500 or more | Total nearly 1800. |
| | *b.* Carbonaceous shales of Gopalprasad and Talcheer, &c. | More than 150 | |
| | *c.* Shales and coarse sand-stones interstratified, the latter predominating chiefly at the base. | Not less than 100 | |
| 3. Talcheer Group or Lower Sandstone Series. | But slightly fossiliferous. | 500 to 600 | |
| | *a.* Blue nodular shale. | | |
| | *b.* Fine sandstone. (" *Tesselated Sandstone.*") | | |
| | *c.* Boulder Bed. | | |

Probable thickness of the beds much greater.

According to the estimate here given, the total thickness of all the beds might somewhat exceed 4,000 feet, which is probably much under the truth.

From the unconformity between each series, it is very uncertain, whether the upper beds of each epoch are in any case seen, or whether they have not been in all cases removed by denudation previously to the deposition of the overlying strata. Thus each member of the series may have been, and probably was, originally much thicker than it now appears.

Order of description: ascending.

In describing these beds more minutely, it will be found most convenient to proceed in order of ascent and to commence therefore with what have been called the *Talcheer Group*. These beds are seen in the South-east portion of the field, where they occupy a tract of variable width, extending Westward about 20 miles from the Brahmini River, and being terminated on the West, by a fault, which brings the middle or Damoodah Group in contact with the gneiss. The boundary of these lower beds and the gneiss is, as may be seen by a reference to the map, very much complicated by a number of small faults,* which render it very difficult to obtain good sections or continuous measurements. The lowest bed, which we find resting on the gneiss, is most generally the "boulder bed," which occasionally assumes the local form of a coarse conglomerate. But at times this bed is entirely wanting, and the tesselated sandstone rests immediately on the gneiss. This "boulder bed" is a peculiar one. It consists essentially of boulders of granite and gneiss, those of the former comparatively small and the latter of much larger size, frequently from 4 to 5 feet in diameter, imbedded in a matrix, which varies from a coarse sandstone to the very finest shale. In some places (as *e. g.* near Purongo) the matrix is a dark-green silt, without any admixture of sand, but full of boulders of all sizes. Occasionally it is very fine in grain and sometimes assumes a shaley structure. A good instance of this, and one in which the boulder bed is seen resting on the gneiss, is shown in the accompanying

The boulder bed (3 *c* of section.)

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* These may often be fallacious, and the gneiss seen abutting against the beds above the "boulder bed" may be merely the top of hard knolls in situ, rising through the boulder bed, which has spread over an irregular and knolly bottom. (*W. T. Jun.*)

Sketch *(Fig. 4)* of a nullah section near the village of Kandusa on the Northern boundary of the field.

Fig. 4

The boulder bed is occasionally replaced by a very coarse sandstone, which is seen resting on the gneiss in some places, as to the South-west of Takua on the Tikiria Nullah and to the East of Laija in Rehrakōl. In the latter case, the sandstone bed is probably 20 to 30 feet in thickness, (the section in the bed of a small water-course being very imperfect), and above the sandstone the usual boulder bed occurs of considerable thickness, probably not less than 100 feet and exhibiting all its typical peculiarities. In the former case (near Takua) the true boulder bed is absent, but an ordinary conglomerate of quartz or gneiss pebbles appears to replace it, pebbles being rare in the next beds as usually seen.

The most usual matrix of this boulder bed is a fine bluish sandy and rippled shale.

The question naturally, indeed inevitably, suggests itself—How these enormous blocks of stone, manifestly requiring a great force to abrade and transport them, are found mixed with a sediment so fine, that in any, except a very sluggish current, it must have been swept away, and could not have been deposited? It seems difficult, in so hot a country, to conceive what yet appears to be the only probable explanation of this phenomenon, which indicates that the boulders must have been conveyed hither by *some* floating substance and deposited among a very fine sediment which was at the time in course of deposition by a very sluggish current. It is true indeed that, in some Mountain Lakes (*e. g.* that of Geneva), a fine sediment may be brought in and deposited by one tributary stream, while boulders of considerable size are being swept down by another; but besides the extremely local nature of all such deposits, the very conditions of their deposition would seem to prevent their forming any one bed like that which we are considering.

The "boulder bed" how produced.

Should any evidence hereafter accrue, allowing the inference that these beds may have been formed in a lake, on a high table land, where the winter temperature was sufficiently low to admit of ice reaching the waters of the lake without melting, then an adequate explanation of the phenomenon may be given, as it resembles exactly the effects of the action of ground-ice, which, enabling boulders to be carried down by a sluggish current, would undoubtedly produce such an intermixture of large rounded masses of rock and of fine silt, as is seen in the present case.*

Perhaps ground-ice.

Possibly a more minute examination of the boulders may reveal groovings and scratchings on their surfaces. The presence of these, however, on the supposition of ground-ice having been the means of transport, should not by any means be looked for with certainty, and

* Lyell's Principles, 1853, p. 219, and De la Beche's Geological Observer, p. 242-3.

their much rounded condition seems quite opposed to the idea of transport by true glaciers.

No sign of action of glaciers.

Indeed we have here no evidence whatever of the action of glaciers, the deposit differing greatly from the glacial drift and Permian breccias of England.

It must also be borne in mind that the temperature necessary to allow of glaciers reaching the sea or a lake is very much lower than that at which ground ice might be formed and carried down by rivers. While the existence of the former is determined by the mean temperature of the whole year, the latter depends on the lowest temperature of the winter season, and therefore may readily, and does, occur in countries,* whose mean temperature is comparatively high. *(W. T. B.)*

Tesselated sandstone.

Immediately over the boulder bed is commonly found what we have named the "tesselated sandstone."

This is a fine-grained, compact, quartzose sandstone, of a pale yellow color, characteristic of this part of the series, having well-marked stratification, never ferruginous, and rarely, if ever, conglomeritic. The name given to it, "tesselated sandstone," is indicative of the tendency which it exhibits, especially when most finely-grained to weather in a very peculiar and characteristic manner, splitting up into polygonal fragments of from 2 to 3 inches in diameter, and presenting

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* Thus, in the Northern part of the Black Sea, at the present day, Coast Ice is always formed in winter, and this too in salt water; the winter temperature there being equivalent to that of Central Norway, which is only a degree or two South of countries in which glaciers come down to the sea level; while, on the other hand, the summer temperature is that of Spain. An example perhaps more to the purpose is found in Thibet, where all the conditions, under which such a deposit as that we are considering might be produced, exist. The winter temperature of Thibet is as low as that of the Black Sea, the country lying between the January Isothermals of 23° and 41° Fahrenheit, while in summer the temperature is equal to that of Sierra Leone, Ceylon and Southern India, the July Isothermals being between 77° and 81° Fahrenheit. This country lies only 10° to 15° North of Cuttack.

much the appearance of a tesselated pavement. *(Fig. 5).* Owing to its almost invariable appearance at the surface of the ground, its presence is always easily detected.

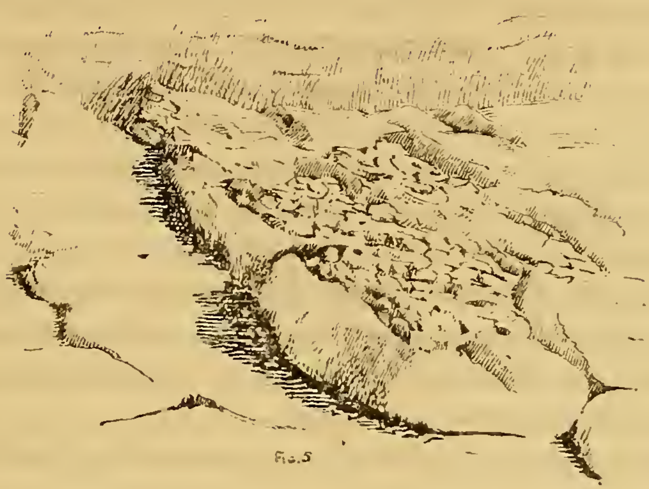


Fig. 5

Like many other beds of the Talcheer basin, from its nearly horizontal position, it frequently covers a considerable area, although its thickness never appears to exceed 200 feet. An obliquely measured section in a nullah near Purongo seems to show that in that place it is about 200 feet; here there are alternations of coarse and shaly sandstones, much rippled (the ripples indicating a current from the North) and having occasional thin beds of shale interstratified.

Perhaps the boulder bed (c of Section) might rather be considered as the lower portion of this sandstone than as a distinct bed, since, though its peculiarities entitle it to a separate description, it frequently passes into this tesselated sandstone. Indeed the same may be remarked of the whole lower series, which may most justly be viewed as one great bed, which, as a general rule, is shaly above and sandy beneath, although in the shaly portions interstratifications of sandstone are not infrequent, while in the sandstones beds are found so fine as to resemble tripoli. In

Traces of organic remains.

these occur the organic remains observed in this group, and they consist only of fragments of stems, too imperfect to allow their affinities to be determined. On the rippled surface of a thin bed of sandstone alternating with shale

Annelide tracks.

near the village of Purongo, annelide tracks have been discovered. *(Pl. 1. Fig. 1.)*

The coarser sandstones frequently contain, in considerable quantity, small irregular fragments of a blue shale precisely similar to that which is interbedded with them ; and as there are no indications of any older sedimentary rock in the district from which these fragments could have been derived, while their angularity precludes the idea of their having been derived from any distant source, there appears at first sight a difficulty in accounting for their appearance, which may perhaps be due to the following cause.

It may frequently be observed in the larger rivers of this country, as the Brahmini and Mahanuddi, (which during the rains bring down large quantities of water with considerable velocity, so that coarse sand is the only detrital matter deposited in their beds), that when during the dry season they retire into a much diminished channel, large pools of water charged with fine sediment are isolated in the depressions of the bed of the river. These being at rest, gradually deposit this fine sediment in the form of a superficial layer of mud, which, on the evaporation of the water, becomes hardened by the sun into a kind of shale, in many instances almost undistinguishable from that of the coal measures above described.

This, moreover, frequently cracks and breaks up into small irregular fragments, which, upon a sudden influx of water, (*e. g.* on the occurrence of a freshet), would become mixed up and imbedded in a new deposit of sand, and, when elevated, present exactly the appearance above described. Periodical alternations in the direction of a current might also produce similar results. If the deposit of shale were thick, it might resist disturbing action, and after a certain period, during a gradual depression, a regular alternation of bands of shale and sandstone might be produced, such as is frequently seen in the beds in question.

The area occupied by this rock in the North of the field is not considerable. It is found at the mouth of the Tikiria, and extends for about a mile along the small fault which constitutes the Northern boundary of that patch of the lower beds occurring North-west of Bijgole. It is covered by shales, which appear along the Southern boundary of the same patch. Around Konia, on the Tikiria, it is the lowest of the sedimentary beds which appears, and rests directly on the gneiss. Thence it continues to the Westward, till it is cut off by the junction of the small fault just mentioned, with the Konjiri and Bodaberna fault, near the village of Boinpur. It re-appears to the North of this, at Dourisai, East of Dereng, continuing to run between the Dereng and Kerjang faults, with a Westerly dip, till covered by the shales North-west of Dereng. A small patch resting on gneiss appears to the North of the Konjiri and Bodaberna fault just East of Dourisai, and again, somewhat to the West, a band of it covers the gneiss between the Konjiri and Dereng faults. From this place, although the gneiss re-appears at the surface, sandstones always cover a part of the area between these faults (a distance of about a mile), and the gneiss finally disappears beneath the sandstone near the village of Porah on the Tikiria. Thence the latter extends, with a continued Westerly dip, till covered by shales and upper beds West of Kerjang. The same bed apparently re-appears to the Westward in the Tikiria valley, near Balham, in Rehrakol, separated from the main body of the Talcheer field by a strip of gneiss. It forms a small band running up the valley, but the thickness of the alluvium and the denseness of the jungle rendered the sections few, and the beds could be only superficially examined. They were apparently cut off by a quartz vein, doubtless on a line of fault running East and West about two miles South-east of Konchonipur; but as no rock of any kind could be seen up the valley beyond the fault, owing to the depth of the alluvium, this is not quite certain. Near the fault shales were observed. Sandstones also appear near Laija, Gusirimal, &c., in Rampur, but they are only slightly developed and very shaly.

Blue nodular shales—3 a. of Section.

Still ascending in the series, these sandstones are succeeded by what have been called "blue nodular shales," consisting of a considerable thickness (probably nearly 400 feet) of bluish, dove-colored and greenish shales, very fine, with occasional sandy beds. These constitute the uppermost beds of the lower group of sedimentary deposits in the Talcheer field. Sometimes, as in the vicinity of the Brahmini, they pass almost into the sandstone below them, and their upper surface is much denuded, and a totally distinct series of beds deposited upon them. Their presence is almost always marked by large quantities of small angular fragments of them being found mixed with the soil; and the jungles growing upon them, as upon the lower sandstones, are thin and stunted, affording a means of discriminating between the areas occupied by them and by higher beds. These shales do not occupy any considerable area. They are found resting on the lower sandstone near Bijgole, and again West of Dereng between the Dereng and Kerjang faults, where they dip slightly to the West, till cut off by the junction of these faults near Porah. About 2 miles West of Kerjang Hill Station, they occur in the Tikiria Nullah, dipping at very high angles (about 60°) to the Westward, but beyond this they are covered up by higher beds. They re-appear, as already mentioned, in Rehrakol, near the villages of Sirdapur, Deinchi, &c., where they cover a considerable area. They continue thence along the boundary of the field, apparently brought against the gneiss by small faults, till they are cut off by a fault near Gusirimal, re-appearing again beyond, but apparently soon again cut off by other faults. The small dislocations of this part of the boundary are very difficult to understand, but affect its general course very little.

In a section of the blue shales in the River Brahmini, a short distance below the village of Serang, and also in the shales South of the fault between Kamlong and Ningrakota, rounded pebbles or small boulders of gneiss have been observed. *(Fig. 6.)*

Fig 6

Boulders or pebbles of gneiss in the shale.

At first sight, as the pebbles, as here seen, are but few in number, their occurrence might perhaps be referred to the same cause to which similar appearances of pebbles in the chalk formation in England have been attributed, *viz.*, the transporting power of tree-roots, &c.

Transporting agent ? not tree-roots, &c.

So exceptional a mode of transport does not seem to afford a satisfactory explanation of such phœnomena, and it would appear, in this case, to be entirely set aside by the total absence, as far as observation showed, of any traces of wood or carbonaceous matter, which must surely have appeared if pebbles, to any extent, had been drifted down by tree-roots, &c. Moreover, when the consideration of this fact (*viz.* pebbles occurring in these shales) is viewed in connection with the occurrence, previously remarked, of a thick boulder bed with a matrix of fine silt, there seems to arise a confirmation of the view there suggested, and stronger ground for assuming the existence, at that time, of the only other, and only adequate means of transport for pebbles and boulders, in such circumstances as here observed, *viz.*, the agency of ground ice. This appears the only theory which can satisfactorily explain all the observed phœnomena.

Action of floating or ground ice.

The absence of organic remains from the beds of this group, so far as examined, complete as regards animal, and partial as regards vegetable, remains, is difficult to comprehend, and seems clearly to indicate different climatal conditious from those now prevailing in a country where every pool teems with life, molluscous, articulate and vertebrate. That freshwater life was equally prolific in Mesozoic times in colder countries is proved by the Purbeck beds in England and the Staffan shales in Scotland.

Damoodah Group.

Lithological character.

The beds of the middle series, or the Damoodah group, of the sedimentary rocks of the Talcheer basin, are easily distinguished from the underlying beds of shale and sandstone, on which they rest unconformably. They consist of coarse grey and brown grits, frequently ferruginous, of carbonaceous shales with coal interstratified, and of red and blue shales and white clays and sandstones. Palæontologically, they are characterized by containing plant remains, chiefly of the genera vertebraria, pecopteris, glossopteris and trizygia.

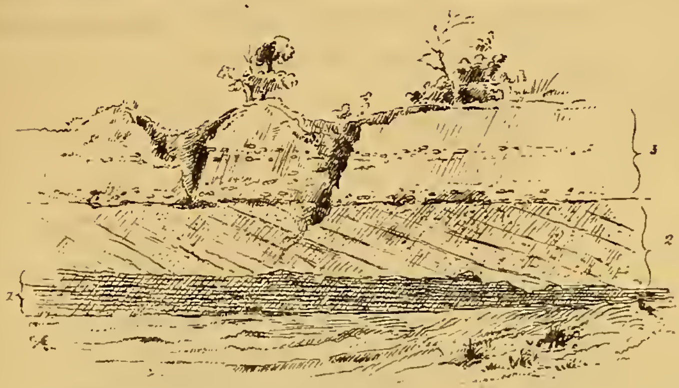
Palæontological character.

Extent.

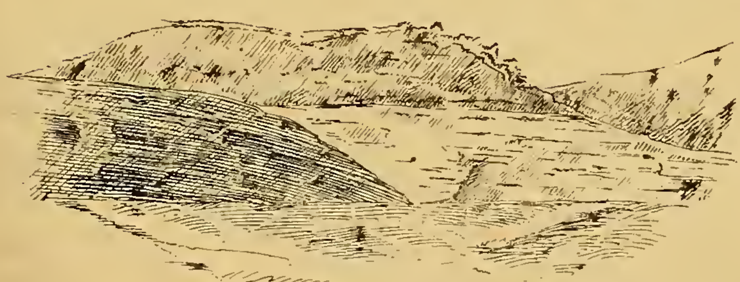
They extend over a large area in the Eastern portion of the field, where the uppermost or Mahadewa division, which in the West rises in the form of flat-topped hills, has been partially or wholly denuded, leaving a broad tract of gently undulating country, extending from the banks of the Brahmini to beyond the village of Antigura, a distance of nearly 30 miles.

They also appear near the village of Patrapara.

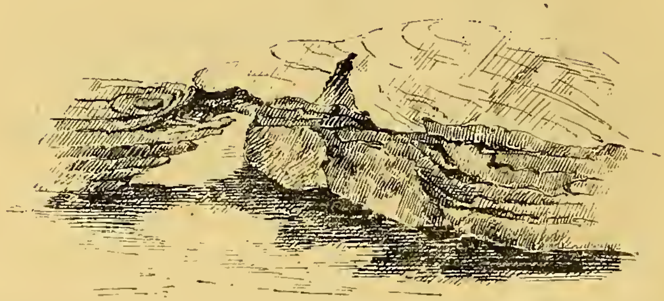
The sections which best exhibit the relation of these beds to the underlying shales of the lower group are seen in a nullah near the village of Kuyo, in Talcheer. *(Fig. 7.)*



Here a soft incoherent white sandstone, much false-bedded, and forming the lowest bed of the group, is seen resting on the eroded surface of the dove-colored shales of the lower group, with but slight unconformity. Another well shown section, in which the shale presents the appearance of having been a low bank, against which the white sandstones were deposited, is seen in a nullah about a mile East of the former. *(Fig. 8.)*



Here, as indeed along the whole of the Southern boundary, the unconformity is but slight, both series of beds having a gentle dip towards the North. Over these white sandstones are seen greyish or light brown felspathic grits, very false-bedded, not containing pebbles or boulders. They frequently contain large irregular ferruginous concretions, with a concentric structure, but no traces of fossil remains, either animal or vegetable. (*Fig.* 9.)



It is impossible to estimate, with even approximate accuracy, the thickness of these beds, as for the most part they do not exhibit any planes of bedding, and their mineral character varies but little throughout. There is a good section seen in the bank of the Brahmini, below the Rajah's residence at Talcheer, where they seem to be nearly horizontal; but as there is reason to suppose that they are here faulted against the lower beds, probably this section, from which there should be assigned to them a thickness of about 100 feet, exposes only a part of the series.

Towards the upper portion, these beds acquire a very shaly character, and closely resemble the highest beds of the group.

There is a well-marked distinction between them and the beds immediately overlying, which nevertheless rest apparently quite conformably upon them.

Carbonaceous shales of Gopalprasad, &c.—2 b. of Section.

This overlying bed (called in the Section the carbonaceous shale bed of Gopalprasad), although a bed of very small extent, is by far the most interesting in the field, both geologically and economically.

Importance.

In it have been collected, with trifling exceptions, all the fossils found in the Talcheer basin. It is also the only bed containing coal, though (even in it) not in sufficient quantity to allow of its being worked. The beds consist essentially

General character.

of a very carbonaceous shale, through which are irregularly interspersed small seams of coal, varying in thickness from 3 inches to the most attenuated layer; the shale, however, always predominating to a very great extent. The shale beds containing the coal (forming on an average one-fourth to one-third of the entire mass of the bed) are from 1 to 6 feet in thickness, the coal com-

Mode of occurrence of the coal.

monly occurring in lenticular patches running irregularly between the laminæ. They have been always observed as overlying a clay bed of greater or less thickness.

Ferruginous clay.

Beds of ferruginous clay, from 1 to 2 feet or more in thickness, occur at intervals in the carbonaceous shales, and one of these immediately overlying a shale bed in the large nullah West of Gopalprasad has with its associated beds yielded the

Fossil remains in these shales.

majority of the fossil stems, ferns, &c., as already noticed. At Talcheer, besides glossopteris and pecopteris (both common), some marks resembling seed vessels, and one possibly the spike of an equisetaceous plant, were found in a sandy shale overlying the carbonaceous beds. These remains have not yet been compared and defined, but doubtless many of them are identical with some of those previously found in the Damoodah and Nagpur Coal Fields. These carbonaceous shales occur only in three places, *viz.*, at Patrapara in Ungool on the banks of the Medulea Nullah, at

Localities of these carbonaceous shales.

Gopalprasad on Tengria Nullah, and on the banks of a small nullah about 1½ mile from the Rajah's residence on the Brahmini. In the first-mentioned place, near Patrapara, the section exposed was the following, in descending order :—

| | Thickness (q. p.) |
|---|---|
| Clay (containing Vertebraria,)... ... ... ... | 10 to 20 feet. |
| Carbonaceous Shale,... ... ... ... ... ... ...... | 6 „ |
| Blue Grey Nodular Shale (Underclay ?) ... ... | 4 „ |
| Carbonaceous Shale ? | |

This is all that is visible, the beds being nearly horizontal and covered by alluvium in the lower part of the valley, while, in its upper part, higher beds succeed. Probably the carbonaceous shales exist below this section, the blue nodular clay not appearing to belong to the lower beds and being probably an underclay.

In Talcheer the section is somewhat obscure, but appears to be essentially the following.

Coarse sandstones belonging to the lower bed (2 c. of Section) are seen in the Brahmini, beneath the Rajah's residence, dipping at very low angles to W. N. W., *i. e.*, towards the mouth of the nullah in which the coal shales are seen : for about 400 yards from the junction of this nullah with the Brahmini no section is exposed, and then carbonaceous shales of no great thickness appear in the banks, and these dip under sandy and shaly beds, somewhat micaceous and rich in vegetable impressions.

At Gopalprasad alone does a good section appear of this bed, affording clear evidence of its position in the series.

The bed there extends for 4 or 5 miles along the Tengria Nullah above Gopalprasad, and again re-appears for a short distance below, being probably brought up by a small fault. Along all the small nullahs to the West of Gopalprasad, between that village and Kunkerai, which runs from the South into the Tengria, these beds are seen dipping Northwards, and below them are found the shaly upper beds of the underlying grits. At Kunkerai the carbonaceous beds are suddenly cut off, whether by a ault or an overlap it is not very easy to decide from the want of sufficient sections; probably by the latter.

They do not re-appear to the West, as far as has been examined, anywhere except at Patrapara, as already mentioned, where they are seen only in the deep ravine of the Medulea Nullah, which alone penetrates to a sufficient depth to reach the strata concealed beneath the thick alluvial deposit of the Ouli valley.

These shales appear merely for the space of a few feet in the banks of a nullah at Konkurapal, near Ungool, where they form the summit of an anticlinal, and both to the North and South dip away beneath a series of shales and grits sometimes fossiliferous.

These shales highly carbonaceous.

There is in these shales abundant carbon to support combustion, as is manifested by the beds being found sometimes completely burned and cemented on the surface into a substance resembling furnace clinkers, as is well seen in the Tengria Nullah, about 400 yards below Gopalprasad. On the Medulea Nullah, opposite to Patrapara, the shales were seen burning: a large mass had fallen from the bank of the nullah, and this with the adjacent beds was on fire. This may have arisen from spontaneous combustion, the Patrapara coal shale containing large quantities of iron pyrites, aggregated in small balls about half a line in diameter, and generally much decomposed. At Gopalprasad and Talcheer this is not the case, but it is easy to conceive how conflagration may have been caused in various ways; among others by jungle fires, especially amongst loose masses, heaped up by the side of a dry nullah. Indeed, it is probable that in this way alone has combustion arisen. The greater part of the shales East of Gopalprasad appears to have undergone at some former period this process of combustion, so that all their carbon is removed, and the beds have assumed a white porcellanous appearance.

The natives attribute this combustion to the fact of a deity having taken up his abode in the beds, and accordingly expend large quantities of *ghi* upon them, in honor of the resident.

Near Patrapara, from the denudation of the whitish sandstones and a part of the coal, the beds of the upper grit are found resting on the denuded surface of the coal beds.

Bluish and lilac shales and sandstones, micaceous and felspathic (2 a of Section.)

Below Gopalprasad the Tengria Nullah runs nearly due North for some miles, and after leaving the carbonaceous shales, sandstones, sandy shales, and bluish and lilac micaceous beds are brought down by small faults, with downthrows to the North.

These beds, interspersed with beds of felspathic sandstone of greater or less thickness, continue to be seen, with a Northerly dip, until a synclinal axis with an East and West strike is reached near the village of Bodhpur. Here beds of the upper group (including a conglomerate of boulders of the tesselated sandstone to be mentioned hereafter) occur, resting on the shaly strata. The latter re-appear in the small nullah, near Horichandapur, with a reversed dip, *viz.*, to the South-west. An anticlinal occurs a mile or two South of Boinpur, the axis having apparently a nearly due East and West strike. Good, though not continuous, sections are seen in the nullahs passing near Boinpur and Konkurapal, (the latter called the Ulani Jore), and the lowest beds seen in the latter appear to be the uppermost of the black shales. Further North, the shaly beds, dipping at a considerable angle (20° to 25°), disappear under the upper grits of the field in some places, and in others are faulted against the lower beds, or the gneiss, by the Konjiri and Bodaberna fault. The latter case occurs in the Western part of the area covered by these rocks, near Kerjang, and is also seen West of Mosaniota.

The beds, as seen in the Ulani Jore and Boinpur Nullahs, consist of interstratifications of blue and lilac shales, frequently micaceous, and containing abundantly plant remains (fragmentary), with coarse white speckled sandstones and ferruginous sandstones which exhibit a concretionary structure. These contain glossopteris, the shales generally vertebraria.

In the Boinpur Nullah, the following series occurs, commencing from the South, consequently in ascending order :—

| *Rock.* | *Angle of Dip.* | *Direction of ditto.* |
|---|---|---|
| Gritty Sandstone, ... ... ... | 15° ... ... | N. N. E. |
| Shales and Ironstones, ... ... | 18° to 20° ... ... | N. 30° E. |
| Gritty Sandstone, ... ... ... | Do. ... ... | Do. |
| Shales, ... ... ... ... ... | Do. ... ... | Do. |
| Grits and Shales, ... ... ... | Do. ... ... | Do. |
| Coarse brown, grey and whitish Sandstones, with black specks, occasionally conglomeritic or ferruginous, ... ... ... ... | 15° to 30° ... ... | E. |
| Section wanting for about 1,200 feet along the nullah. | | |
| Shales containing boulders of Gneiss and bands of Ironstone, ... ... ... ... ... | 20° ... ... | N. 40° E. |
| Blue Shales, nodular and slightly micaceous, ... ... ... | 15° ... ... | Abt. N.E. |
| Ironstone and Shale, ... ... | Do. ... ... | Do. |
| No section seen for 700 feet along the nullah. | | |
| Thick { Blue Shale and Sandstone, ... ... ... | 17° to 20° ... ... | N. 30° E. |
| Thick { Nodular Shales and Ironstones, ... ... | about 20° ... ... | N.E. to N.N.E. |
| No section seen for about 300 feet. | | |
| Bluish Sandy Shales, ... ... | 20° ... ... | N. E. |
| Coarse Sandstone (6 feet thick), | Do. ... ... | Do. |
| Sandy Shales and Ironstone, ... | Do. ... ... | Do. |
| No section seen for 500 feet. | | |
| Sandy Shales, ... ... ... ... | 23° to 25° ... ... | N. 50° E. |
| Ditto ditto, ... ... ... ... | 18° ... ... | Do. |

| *Rock.* | *Angle of Dip.* | *Direction of ditto.* |
|---|---|---|
| Sandstone, shaly below, ... | 25° ... ... | N. E. |

No section for 250 feet; to these succeed rocks of the Upper Group

| | | |
|---|---|---|
| Sandstones, ... ... ... ... | ? ... ... | N. E. |
| Coarse Conglomerates, ... ... | ? ... ... | ? |

Then the gneiss is brought up by the Konjiri and Bodaberna fault.

The distances here mentioned, along which no section is seen, are measured horizontally along the nullah, of course not always coinciding with the direction of the dip. In one of these beds, there may perhaps be a repetition of the phœnomena of the boulder bed. The total thickness of the series of beds above the carbonaceous shales cannot fall short of 2,000 feet, for underlying the above section (itself above 1,500 feet) is a considerable thickness of beds not here mentioned, as they only crop out at intervals, generally in the form of coarse sandstones not readily distinguishable from those of the lower part of the series. If these all rest conformably upon each other, as there seems every reason to suppose they do, and are not repeated by faults, they must be from 400 to 500 feet in thickness. The rocks termed in the section ironstones are highly ferruginous sandstones with a concretionary structure.

These beds occupy a considerable area in the North-eastern portion of the field, which they cover entirely, with the exception of some patches of the upper grit, but it is impossible to determine the boundaries with accuracy, owing to the similarity of the sandstones of the two series.

Their Westerly limit is to the Northward the Ouli valley, while further South they are overlapped by the beds of the "upper group."

UPPER OR MAHADEWA GROUP.

The junction of the beds of this, the "upper" or Mahadewa group, with the underlying beds, is from the cause cited extremely obscure, except in a few places, where a difference of mineral character allows an accurate division to be made.

In almost all these cases, great unconformability exists, much more than marks the junction of the lower and middle groups.

If, instead of descending the Tengria Nullah from Gopalprasad, we ascend it, we find, resting on the carbonaceous shales, beds of a different series, which, though resembling some of those associated with the shales, yet differ from them in being much coarser, more conglomeritic, and more generally ferruginous ; in the absence of ironstone, and more especially in the want of any blue and lilac shales and of all organic remains (except possibly some very indistinct vegetable markings at the base of the series.)

These are the lower portion of the grits of the upper group of the field. They are evidently of much later date than any of those hitherto described, as all the lower beds had been enormously denuded previously to their deposition, and very unequally denuded. Thus, in the Tengria Nullah, just mentioned, there is observed, towards the West, a total absence of the great thickness of shales and sandstones, which only 4 miles further to the East rest on the carbonaceous shales. Still further West, near Kunkerai, greater denudation apparently existed, for near this village these upper grits appear entirely to overlap the carbonaceous shales and rest on the underlying beds.

Of *much later date* than the lower beds.

Great denudation of lower beds.

The sections hence to Patrapara are seldom good, and are valueless for the establishment of any point, as the great similarity between these beds, and those underlying them, renders it impossible to distinguish the two in the absence of clear and well-marked sections.

At Patrapara, however, the unconformability of these rocks with those underlying them is particularly well seen. One side of a nullah exhibits the carbonaceous shales, with some 10 to 20 feet of clays resting conformably on them ; while on the other side are seen the upper grits resting upon their denuded surface.

A clearer evidence could scarcely be desired of the great and very irregular denudation, which the beds of the lower and middle groups must have undergone previously to the deposition of the grits ; the distance between these sections being only the breadth of the nullah, or about 30 yards.

Greater denudation in the West of the field.

In the West of the field these upper grits invariably rest on the lower measures and generally on the blue shales, while to the East much less denudation seems to have taken place, and these beds are found resting *apparently* conformably on the upper sandstones and shales of the middle series. This conformability, however, is doubtless only apparent; and the dip of beds so coarse and universally false-bedded, as the upper grits, is of course almost impossible to ascertain with accuracy. Moreover, according to all appearances, it seems probable that the lower beds, both at the time of their denudation and of the subsequent deposition of the upper beds, retained in a great measure their original horizontality, and over a large portion of the field they still do so; so that a pseudo-conformability in dip exists between them and the upper beds.

Although there are no well-marked and constant divisions in the upper series, there appears to be a succession of beds, with slightly different mineral characters, which are more or less persistent. Thus in the lower portion, probably at about 200 to 300 feet from the bottom of the group, there is frequently found a bed of sandstone containing boulders evidently derived from the "tesselated sandstone" of the lower group.

This bed is frequently seen at considerable distances from any locality, where this tesselated sandstone reaches the surface; for instance, on the Tengria Nullah, both above and below* Gopalprasad; also in the Patrapara Nullah.

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* It is not quite clear from the section, whether these boulders of tesselated sandstone in the locality below Gopalprasad occur in the lower beds of the upper group, or in the uppermost beds of the middle group; the point where they occur being just on the East and West synclinal axis, which passes near the village of Bodhur (*see ante*). The probability is that the beds there belong to the middle series, and if so, this is an additional and interesting proof of unconformability between the middle and lower groups.

This bed does not seem to occur in the sections exposed in the Boinpur and other nullahs.

At a somewhat higher level, but still in the lower part of the group, a thick and very irregular conglomerate occurs, consisting chiefly of quartz and gneiss pebbles, the former predominating. These vary greatly in size, from very small pebbles up to those of a foot in diameter, and are firmly cemented together. In places there would seem to be two or more of these bands, as near Intosora in Rehrakol, while in other places the bed seems wanting altogether, as *(e. g.)* on the extreme West of the field, where it appears to be replaced by an ordinary pebbly sandstone. It is evidently a beach deposit, and this satisfactorily accounts for its partial occurrence. Another feature worthy of remark is the appearance of red mottled clays, which occur indifferently throughout the series, but are probably but very irregular in their continuance.

Throughout the Ghora Hills, which are entirely composed of these rocks of the upper group, many of the rocks have been much altered by the infiltration of iron, which has in all probability taken place subsequently to their upheaval. There is no certain evidence of this, but the infiltration is proved to have been at least subsequent to their deposition by its very partial occurrence and by the manner in which many of the boulders in the conglomerate have been colored only to a certain depth by the iron. These upper grits occupy only a very small area East of the Ouli valley and appear to have been mainly removed by denudation. East of the old Sumbulpur road they are sometimes let in by synclinals, and they occur along the Konjiri and Bodaberna Fault in patches, the largest of which forms Konjiri Hill, with an elevation of probably over 500 feet. The mass of this hill is composed of sandstone with conglomerate at the top, the pebbles from which conceal a large portion of the underlying sandstone.

Localities of the upper grits.

West of this another narrow patch appears South of Dereng village, and extends along the South side of the Konjiri Fault for 5 or 6 miles, its presence being marked by small hills in which the hard conglomerate appears, while all the surrounding strata have been denuded to a level surface. Then the middle group abuts against the fault till beyond Kerjang, when the conglomerate comes in, being perhaps brought down by a North and South fault, and thence to the Westward only grits and conglomerates appear. They cover the whole Western half of the (so-called) Coal Field, with the exception of a few patches, and rise into ridges of hills of considerable elevation, some perhaps as high as 1,500 feet.

Faults.

It may be useful here to mention some of the more important faults of the Northern part of the field, to which allusions have been made. The principal are :—

1*st.* The Kerjang Fault, which forms the boundary of the Talcheer field for about 35 miles, from Dolham in Rehrakol to Takua in Talcheer, and which passes through Kerjang Hill.

2*nd.* The Konjiri and Bodaberna Fault, branching from the above near Kondaigula, West of Kerjang, and running nearly parallel to it for many miles. This has been traced for nearly 28 miles, from Kondaigula to beyond the Brahmini. Both these faults have a downthrow to the South, together amounting to at least 2,000 feet, and probably to considerably more.

3*rd.* The Dereng Fault, having a downthrow to the North, running between the other two, and of much smaller size ; it appears to branch from the Kerjang Fault near Porah, and extends to beyond Dereng where it seems to die out. Its observed course is about 12 miles, the downthrow probably never more than 200 to 300 feet.

Atgurh basin.

The Atgurh basin near Cuttack appears to be entirely occupied by grits, but too little time has yet been bestowed upon it for the accurate appreciation of their relations, rendered difficult of comprehension as they are by dense impenetrable jungles and deep alluvium. Indeed, inasmuch as in the Talcheer field all the country occupied by the lower beds is level, while in the Atgurh basin all the level country is covered by alluvium, it is not at all impossible that in the latter field representatives of the Damoodah group, &c., may be concealed beneath the alluvial deposit. The hills of Atgurh, in truth, are like islands in a sea of alluvium, which on every side separates them from the gneiss and each other.

In some of these hills, beds have been observed resembling the clays at Patrapara, the resemblance being strengthened by the occurrence in them of imperfect vegetable remains.

Alluvium.

The alluvium has been frequently alluded to in the preceding pages, owing to its troublesome and inveterate tendency to conceal the beds and their boundaries. It consists of a mixture of sand and gravel, frequently ferruginous or kunkeriferous, sometimes both.

It is of considerable extent and depth. Its greatest observed thickness in the Ouli valley considerably exceeds 100 feet; and throughout the area of the upper grits, from the denudation of which it appears to have been derived, it abounds in all plains and valleys, excepting those evidently excavated by fresh water, from which it is generally absent, and in which it is never of any great depth. The lower portion of it seems sometimes to pass into laterite, as on the Brahmini.

Age as yet undetermined.

Since it contains, so far as observed, no fossils, and has been investigated over a comparatively small area, it is impossible to specify its age. The surface is probably a fresh-water accumulation, since, during the rains, the greater portion of it is subjected to inundations from the numerous rivers flowing through the district; but to what depth this character extends, and whether at greater depths any change takes place in its mineral character and composition, are points remaining for future investigation.

Rocks of chemico-aqueous origin. Laterite.

Laterite has but little extension in Orissa. It occurs to some extent round Cuttack, and frequently borders the hills between that station and Balasore, besides occurring in small patches upon the plains. On the Talcheer field it is very sparingly distributed, and never of great thickness, its principal development being on a slightly rising ground West of the town of Talcheer, where it overlies some sandstones of the middle group. Between Bapūr and Rasul, on the Cuttack and Ungool road, the laterite forms low hills, having an elevation of probably 150 to 200 feet above the sea level, indicating considerable elevation and depression since its deposition or formation.

Origin.

With regard to the origin of this laterite, the infiltration of iron from springs, &c. may serve to explain the greater part of its occurrence in the Cuttack district. In all cases it seems to be the result of alteration of the rock below, this alteration consisting essentially of an addition of iron (the peroxide.) It certainly has not arisen simply by the peroxidation of the iron contained, because many of the rocks which have been changed into laterite must have been almost entirely devoid of ferruginous matter. This is especially the case with the white clay converted into laterite at and near Midnapur (where the laterite is particularly well seen.)

A very interesting case is seen North of Cuttack. Around the gneiss hills which have been mentioned as rising suddenly from the alluvial plain, a quantity of water-worn pebbles are always found, evidently the remains of an old beach. Although, owing to weathering, these pebbles have somewhat lost their rounded form and smooth surface, yet their mode of occurrence and the absence of large angular blocks prove that they are of beach origin and not merely rolled from the hills. Around some of the hills, though not all, this pebble bed is cemented by laterite into a conglomerate. In its depressions, this is covered by a rather sandy alluvium, and appears to underlie all the paddy-fields. The gneiss, of which all the pebbles are composed, is slightly ferruginous, but not at all sufficiently so for these pebbles alone to have supplied the iron in the laterite. There has evidently been a supply of the metallic oxide from some extraneous source. Again, near Kunkerai, on the borders of Talcheer and Ungool, in a small nullah, a section of from 8 to 10 feet is exposed, the bottom of which is composed of the ordinary coarse sandstone of the upper grits, *in this case not all ferruginous:* this, towards the surface, becomes broken up into rhomboidal fragments, which towards the top decrease in size by sub-division, precisely as is so often seen in beds disintegrating near the surface. These sandstone fragments, in proportion to their decrease in size, become more and more impregnated with peroxide of iron, the surface being covered with a brown glaze of the hydrate, while at the same time they all distinctly exhibit a concretionary structure. These fragments form in fact the iron ore of this district, and according to an assay made by Mr. Piddington, contain 66.00 per cent of peroxide of iron. (*Cf. Journal of Asiatic Society Bengal,* 1855, *p.* 708.)

The apparent increase in the proportion of iron contained in the fragments nearer the surface may simply arise from the iron being segregated in the undecomposed pieces from the disintegrated mass, and there may be an equable distribution of iron from the surface to the point at which disintegration commences. Upon this point much light may be thrown by chemical analysis; this however can but little affect the main facts, which establish incontestably a deposition of iron peroxide in the sandstone from the surface to the depth at which the disintegrating action of surface water ceases. Towards the surface the appearance assumes a new phase, and true laterite is found in small quantities.

In the soil, where all traces of the original sandstone have disappeared, small nests of peroxide of iron, from $\frac{1}{3}$ to $\frac{1}{4}$ inch in diameter, abound, and a certain degree of consistence seems to be given by these to the otherwise friable sandy soil.

When exposed, this soil appears firmly bound together by the hydrate of the peroxide of iron. To the same source is due the brown glazed appearance of laterite generally, and probably its increase in hardness upon exposure to the action of the atmosphere.

Two points seem to be established by these sections—*first,* that laterite is due to the alteration of rocks by surface action; *second*, that the source of the iron is extraneous.* What that source is, and why the oxide is so partially distributed, it is impossible to say, with our present limited knowledge of the rock, as regards its composition and mode of occurrence.

Inferenees.

"Kunkur" abounds throughout the alluvium of the district, especially when that deposit is spread over undulating plains. It does not appear ever to rise to any considerable height on the hill sides, &c. It occasionally penetrates the porous beds of the grits, appearing however only to fill up cracks and interstices. In deep alluvium it does not seem to occur.

Kunkur.

Under all circumstances, its segregation or deposition from water containing carbonate of lime in solution is evident. The lime has been in the first instance probably derived from the hornblende and felspar of the metamorphic rocks.

Along the great faults forming the Northern boundary of the Talcheer basin, there occur at intervals hills formed of a peculiar and hard rock, at each side of which the sandstones appear altered. At first sight this has much the appearance of a trap dyke, but a little examination shows numerous small cavities filled with chalcedonic quartz, and pseudomorphs of some tabular mineral, possibly of gypsum or sulphate of barytes, abound, facts which clearly establish the aqueous origin of the rock.

On further examination it appears that the central mass is an enormous quartz vein, containing a breccia of the sandstone in which it occurs, and by the infiltration of silica into the porous sandstone on its sides a considerable band of

Quartz veins.

* That is to say, in the Orissa district, and also as far as has been seen near Raneegunge, in the Burdwan field, and at Midnapur. With regard to the basaltic laterite of Central and Western India, this does not appear so clear, as basalt, which occurs there, is a highly ferruginous rock, quite competent to supply iron for laterite by its decomposition.

hardened rock is produced. When it abuts against the gneiss, this also is somewhat hardened; but from its slight porosity, the effect does not extend so far from the vein, and is necessarily less apparent than in the softer sandstone. Some of the hills composed of this rock cannot have an elevation of less than 500 feet above the plain in which they stand, and although very steep, must be of considerable breadth at their base. Bodaberna hill, a trigonometrical station, is entirely composed of this vein and the hardened sandstone on its sides, and so, in great measure, is Kerjang hill.

This rock appears on the Bodaberna Fault from Dereng to beyond Kerjang, and on the Kerjang Fault from Takua to Kondaigula in Rehrakol.

It follows the fault bounding the field on the North-west from Dolham to Purtabahal, and perhaps further, and again occurs near Konchonipur, where its relations have not been thoroughly made out. The fault there is possibly the great Kerjang Fault, thrown back by the fault which bounds the field on the North-west.

This rock is probably identical with the so-called pseudomorphous quartz mentioned by Mr. Williams as occurring in the neighborhood of Hazareebagh.*

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General remarks on the field.

General dip of field South-east to North-west.

In taking a general view of the Talcheer field, we observe that it is divided, as it were, into two parts by the large valley of the Ouli; that to the East of this is the area of the lower divisions, while to the West there is an immense preponderance of the upper grits. Hence there is throughout the field in general a dip from East to West, or rather from South east to North-west, compensated by the great faults which form the North and North-west boundaries, and which intersect in the neighborhood of Dolham in Rehrakol.

* *Vide* Report on the Kymore Mountains, &c., p. 80. It should be remarked that the quartz veins, mentioned by Mr. Williams, occurred in metamorphic rocks.

There was also a much greater denudation of the lower beds towards the West before the deposition of the grits, as is evidenced by the lower beds being overlapped by the upper; but the amount of denudation in the district, since the deposition of these grits, has been probably greater than during any previous period.

Denudation unequal.

Scattered all over the Talcheer country, heaps of quartz pebbles from the grit conglomerates and of boulders of the grits themselves abound, while on some of the gneiss hills on the margin of the field similar evidence of the former spread of these rocks exists. It becomes therefore desirable to examine what evidence there is of the occurrence of similar beds in adjoining districts. In the first place we have on the East, in the vicinity of Cuttack, beds of a composition similar to that of the upper grits, and forming doubtless an outlier of this field.

Similar beds in other districts.

To the South nothing accurate is known of any rocks not metamorphic; but to the West a basin of sedimentary rocks occurs in the Gangpur Rajah's territory,* and far beyond are the Nagpur beds described by Messrs. Hislop and Hunter.†

To the North again, there is a long break, so far as any but the vaguest evidence is concerned, but basins of sedimentary strata are probably dotted over the country. No description however has been given of any nearer than the Rampur and Upper Damoodah Coal Fields, partially examined by Mr. Williams in 1848, and still further to the East the Burdwan or Damoodah field. To the North-west are the Coal Fields of Palamow, Sirgooja and others, and possibly a chain of small Coal Fields connecting these with the great field, which is stated to exist West and North-west of Sumbulpur. But of all these

* Captain Saxton. Journal Asiatic Society, Bengal, Vol. XXIV. p. 186, March 1855. Captain Haughton's Geology of the South-west Frontier, p. 3.

† Quarterly Journal Geological Society, Vol. XI. p. 345. Journal Asiatic Society, Bengal, Vol. XXVI. p. 157.

nothing is accurately known. For comparison we must therefore have recourse to the Nagpur and Damoodah fields, in both of which we shall find most interesting points of connexion with the Talcheer district.

Fields to be compared; Nagpur and Damoodah.

The Nagpur beds deserve the earlier notice at our hands, as they present the greater number of analogies with the strata of Orissa. The distance in a straight line from Nagpur to the westernmost edge of the Talcheer basin is about 330 miles; but according to Messrs. Hislop and Hunter's map, outliers extend for some distance to the East of their field, and these, doubtless, connect the Nagpur with the Gangpur field.

Nagpur beds.

The strata of Nagpur are divided by Mr. Hislop into four groups, which evidently from his description, though he does not assert the fact, rest unconformably on each other; the uppermost bed (especially), a thick ferruginous sandstone,* being stated to contain angular fragments and boulders of the lower beds. It will be useful, and probably sufficient, to present parallel sections, in order to exhibit the homologies of the Nagpur and Orissa strata. To this have been appended the apparent representatives of the beds of the Talcheer basin, which are found in the Damoodah field :—

*Characters, &c. of the beds of*

| Names proposed. | Orissa. | Nagpur *(Hislop.)* | Damoodah *(Williams.)* |
|---|---|---|---|
| 1. Mahadewa Group. | Thick, coarse and false-bedded sandstones and conglomerates frequently ferruginous.<br>——<br>Unfossiliferous.<br>——<br>Thickness at least 2,000 feet. | Thick ferruginous sandstone of Mahadewa Hills and Nagpur.<br>——<br>Unfossiliferous, except some tree stems.<br>——<br>Thickness about 2,500 feet. | Wanting. *(?)* |

* Mr. Hislop, in his description, does not appear to have sufficiently distinguished this upper sandstone (of the Mahadewa beds) from the kunkur-yielding alluvium, which seems to compose his upper series at Nagpur. (*Vide* Quarterly Journal Geological Society, Vol. II. p. 369.)

*Characters, &c. of the beds of*

| Names proposed. | Orissa. | Nagpur *(Hislop.)* | Damoodah *(Williams.)* |
|---|---|---|---|
| 2. Damoodah Group. | *a.* Coarse sandstones and micaceous shales.<br>*b.* Bituminous or carboniferous shales.<br>*c.* Coarse sandstones and micaceous shales.<br>——<br>All fossiliferous.<br>——<br>Thickness 2,000 to 2,500 feet. | Laminated sandstones, sometimes containing mica.<br>Blue and red and bituminous shales, abounding in vegetable impressions.<br>——<br>Thickness per estimate about 300 feet, 15 feet given of shales (argillaceous.) | Coal sandstones and shales of the Ramghur, Burdwan, &c. districts.<br>——<br>Fossiliferous.<br>——<br>Thickness about 2,600 feet. |
| 3. Talcheer Group. | *a.* Bluish and greenish shales.<br>*b.* Fine sandstone. ("Tesselated.")<br>*c.* Boulder bed.<br>——<br>Annelide tracks and obscure plant remains.<br>——<br>Thickness about 500 feet. | Clay shales of various colors, generally red and greenish.<br>——<br>Very slightly fossiliferous, contain annelide tracks.<br>——<br>Estimated thickness about 80 feet. | In the Burdwan field wanting. ?<br>In the Ramghur field shales of about 1,000 feet and a boulder bed.<br>——<br>Thickness in Ramghur 1,000 feet. |
| 4. ? | Wanting. | Crystalline dolomitic limestone. | Wanting. |

It is evident from this, that we have in every thing essential an exact parallelism between the Nagpur and Talcheer fields.

Parallelism evidently great.

The fossils of the Nagpur field are probably identical with those of the Talcheer strata. They contain certainly the same genera, *viz.*, glossopteris, pecopteris, vertebraria, &c.

Fossils.

The mineral character and the order of superposition in both series are precisely the same.

Mineral character and order of superposition.

Difference of thickness less important. Why?

And although there is much difference in the thickness of corresponding strata, this is a matter of comparatively trifling importance, in considering beds which have been so much denuded. It must, moreover, be borne in mind that the thicknesses given by Mr. Hislop are only those of the beds as seen in some particular places, while those here assigned to the Talcheer beds are the *estimated gross thickness of each series* in the area.

Of the thickness of his second group, Mr. Hislop professes his ignorance, mentioning 15 feet only as that of the argillaceous shale immediately underlying the upper sandstone.*

The limestone is indeed wanting in Orissa ; but it seems very doubtful, whether it is even approximately of the same age as the overlying beds, as it is clearly a metamorphosed formation, and, according to Mr. Hislop, altered by the granite of the plutonic formation on which it rests.† It is certain that the limestone is of a later date than the ordinary metamorphic rocks of the district, since it rests on their denuded surface, but it may well have become altered by some of the subsequent outbursts of greenstone, pegmatite, &c., and still be much older than the sandstones and shales which are unaltered. It is indeed stated by Mr. Hislop that the sandstone of Sitabaldi Hill, near Nagpur, is metamorphosed to a considerable extent, though he does not mention any cause, which in this case is probably the trap of the hill.‡

We thus appear to have strong reasons for believing that these same beds, described by Mr. Hislop, formerly extended with but slight alteration

* Mr. Hislop, in his later paper on the Umret coal, estimates the beds (of the middle and lower groups) at 300 feet and 80 feet respectively, and states that the latter are much sunken to the East. (*Quarterly Journal Geological Society*, Vol. XI. p. 560.)

† May this be a granitoid gneiss?

‡ If, as seems highly probable, the relations of the metamorphic rocks of Nagpur with the shales, sandstones, &c. of the district be the same as in Orissa, probably Mr. Hislop errs in attributing the disturbances observed to the plutonic intrusions in the district (excluding trap.) If, as in Orissa, all these intrusions of pegmatite and greenstone, &c. were prior to the deposition of the sandstones and shales, the disturbances must of course, as in Orissa, be due to subsequent upheaval, faulting and denudation.

in character for from 400 to 500 miles to the East of Nagpur; their extension to the West in the Nerbudda valley having been long known.

Further let us consider the relations of the Orissa strata with those of the Damoodah valley, as described by Mr. Williams.

And here, too, some most interesting connexions may be discovered, although it does not appear certain that any representatives of the upper grits are seen in the Damoodah Coal Fields. It is evident that the middle group is there far more developed than in Orissa, and there are unquestionable representatives of the lower beds of Talcheer.

Mr. Williams has arranged the strata of the Damoodah or Burdwan Coal Field in three divisions, without very clearly specifying on what grounds, but apparently from some supposed relations to the upper and lower measures, and the millstone grit of the South Wales field. At the bottom of his lowest division, he gives the following section *:—

| No. of Bed. | Mineral Character. | Thickness. | |
|---|---|---|---|
| | | Feet. | Inches. |
| 139 | A bed of inferior coal | 15 | 0 |
| 140 | A grey argillaceous shale | 26 | 0 |
| 141 | White and light grey sandstone *conglomerate, containing boulders of white quartz* of 12 inches in diameter | 325 | 0 |
| 142 | Greenish-grey argillaceous shale, alternating with thin beds of sandstone | 200 | 0 |
| 143 | Greenish-grey argillaceous shale, containing large concretions of limestone. | 153 | 0 |

From want of more exact knowledge of these two lowest beds, it is impossible to say whether they are the true representatives of the lower shales, sandstones, &c. of the Talcheer field; but as they agree with them in position and mineral character, it is at least highly probable that they are the same beds.

* *Vide* Geological Report on the Damoodah valley, by D. H. Williams, Esq., pp. 73 and 74.

But in the Ramghur Coal Field of the Upper Damoodah, the position of which is somewhat nearer to Orissa, we find much greater similarity of mineral character in the lower beds (all the strata being unfossiliferous no better ground of comparison can be expected), as Mr. Williams expressly mentions a boulder bed, the description and position of which are precisely similar to those of the corresponding bed in the Talcheer basin.*

Mr. Williams says :—" The lowest beds of this (Bohcaroh) field are to " be seen in the bed of the Boodu Nullah, on the South side of the village " of Jarbah; they are thick conglomeritic accumulations from the " crystalline rocks. These beds of conglomerate differ essentially from " anything before seen associated with the carboniferous rocks, being " *composed of enormous boulders of granite, some of which measure* " *from* 3 *to* 10 *feet in diameter:* these are also intermixed with large " boulders of white quartz, chlorite rock, hornblende, and mica schist. " * * * These conglomerates alternate with (? underlie) greenish- " grey beds of shales and thin beds of fine-grained sandstones, and have " a developed thickness of 900 to 1,000 feet under the lowest known " beds of coal."

Again, speaking of the Ramghur Coal Field, he says :—The lowest beds are well exposed " on the surface near the village of Poonoo, and are " principally constituted of rounded boulders of white quartz, gneiss, " and other members of the crystalline formation. This conglomerate " is, in fact, perfectly identical with that great boulder conglomerate " observed 20 miles to the Westward, near the village of Indrajarbah " (Jarbah of preceding extract.) The boulder conglomerate has been " observed to underlay the three Coal Fields posited in the zillah of " Ramghur, and evidently appears to be the lowest member of the coal " strata in India with which we are acquainted."

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* Geological Report on the Kymore Mountains and Ramghur Coal Field, by D. H. Williams, Esq., pp. 25, 26, 39 & 40.

These extracts seem to establish the existence of a boulder bed in Ramghur, about 200 miles due North from Talcheer, associated with strata exactly resembling those of the lower (" Talcheer") beds of the Orissa fields.

But the homologies of the beds do not end here. A few sentences after the above extract we read :—

" The conglomerate developed near the village of Poonoo is nearly " horizontal, but to the South of the village it dips to the E. of S. at angles " varying from 8° to 14°, and before reaching the banks of the Damoodah " River, the coal-bearing pudding-stones, sandstones and shales come " in and extend along both margins of the above-named stream."

Here it will be remarked that there is no mention of the " greenish-grey shales and thin beds of fine-grained sandstone," said, with the conglomerate, to attain a thickness of 900 to 1,000 feet in the Bohcahroh Coal Field, and the inference that must be drawn is that they are absent in the Ramghur field, as otherwise Mr. W. would in all probability have mentioned them as another proof of the same deposit underlying all the field. On the Upper Damoodah field therefore, as in Orissa, it is probable that there is *unconformability* between the representatives of the Damoodah and Talcheer groups.

From the evidence, then, which is thus presented, there can be little doubt of the parallelism of the lower beds of Damoodah and Talcheer.

When the organic remains of the middle group at Talcheer shall have been examined carefully, and compared with those of the Damoodah or Burdwan field, their identity will probably establish the relations of these beds. As regards mineral character, it seems not at all impossible that the bed marked 141 of Mr. Williams's Section (*v. ante*) of the lowermost coal measures of that field, described as " white and light " grey sandstone conglomerate, containing boulders of white quartz 12 " inches in diameter," with a thickness of 325 feet, may correspond to the bed marked (*c.*) of the middle group of the Talcheer field.

Age of the beds of the Middle or Damoodah. Group.

A few words as to the much questioned age of these coal-bearing strata (the middle, Damoodah, group of the Orissa district) may be useful. Their supposed equivalents have, by Dr. Carter and Messrs. Hunter and Hislop, been included in one great group, which they refer to the Oolitic period.

It will be remembered that the three groups established in the district under consideration (Talcheer) correspond in a remarkable degree to the groups at Nagpur, as described by Messrs. Hislop and Hunter (Nos. 1 and 2 of comparative table, p. 75.) But between these beds they find and describe others which they call the "*Mangali shales.*" These are fossiliferous, but "contain scarcely any organic remains common to the "inferior layers about Nagpur."

Now there is strong evidence, although not absolute certainty, that these Mangali shales are not older than the "argillaceous sandstone" which Mr. Hislop has shown to be the equivalent of the coal-bearing rocks (Damoodah group) of Bengal. They are found immediately underlying the upper beds, and in geographical position between points where these upper beds rest unconformably upon the "argillaceous sandstone."

The great unconformity between the middle and upper group (Damoodah and Mahadewa beds) indicates very clearly a considerable lapse of time, so far as the Talcheer district is concerned. During this time it is possible that the Mangali shales were deposited, either locally or perhaps more generally, in which latter case they may well have been removed by the extreme denudation which has evidently been in active operation in the district.

If then this speculation be admitted (nothing less than a detailed examination in the field can establish or disprove it), and the Mangali shales be supposed to afford the representative of the time indicated by the great break in the continuity of the series in Talcheer, the remarkable distinctness of the fossil contents of these shales becomes of most important significance. We have already quoted Mr. Hislop's statement, that in few respects do these organic remains agree with those from the "argillaceous sandstone" and other beds. But they differ further in this, that from these Mangali shales have been procured the only *animal* remains hitherto obtained in the district (with the exception of some minute *estheria* or *posidonomya ?)* And these organic remains have fortunately been in a sufficiently good state of preservation to admit of their careful examination and description. The most important of these was the cranium of a reptilian animal, which has been described and figured by Professor Owen,* and which he has referred to the remarkable labyrinthodontoid group of Batrachians.

This group was for a long time referred by geologists to the Triassic epoch, of which it was even considered characteristic. But more recent research, and the advance of more accurate classification,† has shown that the strata from which the labyrinthodont remains in England have been obtained are truly Permian and belong therefore to the great Palæozoic group of formations. If, therefore, the homologies of this higher group of animals are to carry their full weight of evidence, and to be admitted as against the more imperfect testimony of vegetable remains, the Mangali shales would appear to be referable rather to the Permian epoch than any other. And, *a fortiori*, the plant-bearing beds of Nagpur and their representatives in the Talcheer and the Damoodah and other Bengal fields must be considered as certainly not more recent than the same epoch (the Permian.)

The lower sandstones, shales and boulder bed (of the Talcheer group No. 3) must of course be of greater age; and, if the glacial hypothesis, before suggested, be adopted, must have been deposited under conditions widely differing from those existing at the time of formation of any of the overlying beds.

Again, the Mahadewa group, iron banded sandstones, &c., are, as evidently, much more recent; but the absence of fossils and of any

* Quarterly Journal Geological Society, London, Vol. 1854, p. 473; 1855, p. 37.

† Reports of British Association, 1849, p. 56. Ramsay on Permian Breccias, Quarterly Journal Geological Society, 1855, p. 198.

newer beds (excepting recent fresh-water deposits) overlying them renders their precise age indeterminate.

In concluding this Report, it will be well briefly to mention a few of the most important general facts regarding the district which have been arrived at:—

Resumè. General conclusions.

1st. The oldest rocks of the Cuttack district are gneiss and the accompanying largely crystalline granite; the metamorphism of the former being probably coeval with the intrusion of the latter.

Oldest rocks of district. Gneiss, &c.

2nd. The sedimentary rocks of the district are composed of three groups, each resting unconformably on that beneath it, and these are evidently parallel with groups observed elsewhere, *viz.*, in Nagpur and Damoodah.

Three groups of the sedimentary rocks.

3rd. The Talcheer basin, and most probably that of Atgurh also, are not original basins of deposition, but are the remnants of a large area of sedimentary deposits subsequently denuded, and leaving these isolated patches in some measure preserved by being let down by faults among the harder crystalline rocks. Most of the fields examined are found to be bounded by faults along a great portion of their peripheries.

Not original basins of deposition.

4th. The trap dykes, &c., so conspicuous a feature in the coal fields of the Rajmahal, Damoodah, and Nerbudda districts, and playing so important a part in the Geology of Central and Western India, are entirely absent in the Cuttack district; not even any trap pebbles or boulders having been found in the alluvial deposits. Hence it is inferred that the district was beyond the area of volcanic action at the time of these intrusions.

No trap dykes, &c.

5th. Considerable marine denudation, in recent as well as more ancient periods, is evidenced by the rounded form of the hills, while a recent very gradual elevation is indicated by the gradually decreasing height of the hills towards the Coast, and the broad plain stretching to the base of the hills.

Denudation.

A careful examination of this plain would doubtless be most interesting, and would well reward the attentive observer by the information which it must yield.

With regard to nomenclature, the names applied in this Report have been adopted on the principle so frequent in forming the Geological Vocabulary, *viz.*, that of naming beds after the localities where they have been first discovered and most accurately described, or where they are best developed.

Hence the names "Mahadewa," "Damoodah" and "Talcheer" groups. Mr. Carter, indeed, in an admirable paper on the Geology of India, some time since proposed the names Punna sandstone and Kuttra shales, for the supposed equivalents of these groups; but it is far from certain. that the Punna sandstone is the equivalent of the Mahadewa and Rehrakol beds. Indeed, recent researches tend to prove the contrary; and the Kuttra shales are not only of equally doubtful relations, but embrace an heterogeneous mixture of beds of different ages.

Perhaps the best known development of the upper beds is in the Mahadewa* hills, to the North-west of Nagpur, as described by Messrs. Hislop and Hunter, therefore that name has been adopted. The greatest development of coal-bearing strata of India yet examined is in the well-known Damoodah* field, and this, moreover, was the first described with any accuracy; while it seems that now, for the first time, has the lower group been clearly distinguished from the overlying strata. Hence, from the district, the name "Talcheer group" is given to it.

It should be remarked that, throughout this paper, the term "Laterite" is employed solely in a lithological sense, implying a peculiar porous ferruginous rock of apparently concretionary structure, and similar to that well known as occurring in the vicinity of Midnapur. It has no reference to geological position, inasmuch as it is

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* These names, Mahadewa and Damoodah, have been both already proposed by Mr. Oldham.

still undetermined whether the rock in question be not of various ages in different localities.

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In the foregoing remarks the occurrence of ores of iron in the district has been only incidentally noticed, but a few more detailed observations, may be useful on a matter of so much importance; the manufacture of iron being carried on to some extent in part of the area under consideration.

Sources of iron in the district.

The iron of the Talcheer field, though very similar throughout in its mineralogical character, occurs under different conditions, of which three may be particularized:—

1*st.* Red argillaceous peroxide, changing into the brown hydrated peroxide, and containing a variable amount of siliceous sand.

2*nd.* Fine sandstones and shales, much impregnated with iron, of variable quality.

3*rd.* The coarser sandstones of the upper group, in which (but more abundantly in the conglomeritic alluvium which contains fragments of them) the ore is plentifully distributed in the form of flattish irregular concretions, sometimes as large as a man's head.

This last, already alluded to, is the chief source of iron in the district. These concretions are generally tolerably free from siliceous admixture. They are formed of innumerable thin coatings of the argillaceous oxide, generally arranged round a central core of similar nature; but very fine and rich.

Whence the very large amount of iron was derived, it is very difficult to say.

The manner in which the ore is obtained is simple enough, but the labor expended is so very disproportionate to the amount produced, that it would be impossible, without having recourse to a more scientific and economical system, to meet any increased demand.

Mode of obtaining the ore.

At present the ore is procured by digging small pits and trenches in the surface gravel, and *picking* one by one from the pieces thrown out. Those judged sufficiently rich are transported in wicker carts to the village, often a distance of some miles; and even of these but a small portion comparatively passes into the furnace, as on breaking up the pieces a large amount is thrown away on account of its poorness.

Fuel.

The country, as noticed above, abounds in timber; but the present method of using it, for the preparation of charcoal, is absurd and ruinous in the extreme.

For this purpose, after cutting down their trees (generally selecting the sàl *(Shorea robusta)* probably as affording most conveniently logs of a suitable size), the natives loosely build up a large pile of logs of small size, to which, without any further precautions, they set fire, and allow it to burn freely, all the better pleased if a wind be blowing, as then the cremation proceeds more rapidly. When the pile is considerably diminished, water is thrown on it, and what remains as charcoal is collected for use. The trunk is allowed to take fire, or is set on fire where it fell, as the people are either too lazy or too ignorant to break it up; and indeed they have no axes fitted for such work; their ordinary axes being wretched tools, not three fingers broad, and sometimes not a pound in weight.

Furnaces, &c., now used.

The furnaces at present in use, and the processes of smelting, &c., offer no peculiar features, and present but little variation from those adopted in other parts of India, and therefore need not be dwelt upon. In a few places, it appears, the ore is roasted previously to smelting, the object probably being to render it more friable and perhaps facilitate the separation of the more siliceous particles.

Localities of the ore.

The most promising portion of the field, with regard to the supply of iron, &c., is along the North margin. The large villages of Hondapa and Rampur may be looked on as marking East and West limits, within which the ore is most abundant, although neither of them is situated on the iron-bearing sandstone.

The manufacture is carried on in the vicinity of the villages of Gurjing, Ampal, East Kotasingha, Datimal, Susab, Takaba, Ramgamat,

&c. &c. Of these the last mentioned is one of the most favorably situated, being built in a locality where an exhaustless supply of ore may be had within a few hundred yards; though, as has been already implied, it is not usual to quarry or work the rock *in situ.*

Scarcity of labor experienced.

As may be seen, by reference to the map, the villages are but sparsely scattered. They are also of small size, many not containing twenty houses and some not a dozen. Therefore, as will be supposed, there is some difficulty in procuring a *sufficient* supply of labor.

Such are the present circumstances of the iron manufacture as carried on in this district, and certainly, from the enormous waste of fuel, the wretchedly defective manipulation, the very inadequate furnaces employed, &c. &c., the results presented, are—in an ecomonic point of view—about as unsatisfactory as could well be imagined.

They are such as to preclude any sanguine expectation of self-improvement on the part of the natives, who, after long experience, still follow methods so pernicious, and to destroy all reasonable hope of any material increase in the return of metal, without a thorough reform of the present most wasteful and unproductive sytem of working.

Some of the means, whereby the processes of the manufacture might be improved, and the resulting produce increased and made available, have been already considered, and our researches on these points, with especial reference to this district, have been referred to in the previous notice of "The Coal and Iron of Cuttack" by Mr. Oldham. It is unnecessary, therefore, to discuss these questions here.

Labor.

There are great difficulties to be overcome, as before mentioned, from the scarcity of labor and the great deficiency of mechanical skill on the part of the natives of the country. But there are many counterbalancing advantages, which might stimulate to the endeavor; and among the principal are, the abundant, almost exhaustless, supply of fuel and water, the form of occurrence of a great

Encouraging considerations.

portion of the ore, *viz.*, as concretions readily separated by a blow of the hammer from the surrounding matrix, requiring, therefore, comparatively little expense to be incurred in picking the ore, and its mode of arrangement, spread over the country in nearly horizontal beds, intersected by streams.

From these advantageous circumstances, it seems clear, that the ore might be delivered at much less cost than the clay ironstone of the Damoodah valley. And we may indulge a hope, that at some not far distant period, we may, under an improved system, see the skilful and productive manufacture of iron (at once the means and the evidence of civilization) effectively carried on in this part of the Talcheer district.

Gold.

Gold is occasionally washed in the Tikiria River, and was also a few years since obtained from the sands of the Ouli. The latter case is rather interesting, since the localities are in a sandstone country, through which the Ouli mainly flows. It is said by the natives that the metal is only found after very heavy rains, and the quantity collected must be very small.

The method employed is to wash the sand of the river in an oblong wooden dish, about 27 inches long and 12 broad ($1\frac{1}{2} \times \frac{3}{4}$ cubit), or occasionally on the surface of a large stone hollowed to the same shape as the dish. In either case, a small depression is made about the centre, in which the gold is collected.

On the upper course of the Brahmini River, in the Pal Lahara especially, gold is said to be worked to a considerable extent, but time did not allow of these washings being visited.

Diamonds.

Diamonds are procured from the sands of the Mahanuddi River, which adjoins the district described on the South, but we believe only rarely, and in no quantity.

## NOTE.

*Page* 83. The evidence in favor of a (geologically) recent very gradual elevation of the Coast, in the District of Cuttack, has been alluded to above. But this evidence is by no means limited to this district, and the same reasoning is confirmed by more extended researches along the entire shore of the Peninsula. In many places, the occurrence of marine shells, of existing species, in great plenty, at considerable distances from the present sea shore, renders this evidence more obvious and more conclusive. During a recent visit to Madras, I had an opportunity of seeing some of these and, by the kindness of Dr. Balfour and of Dr. Hunter, of procuring a tolerable series of such shells which are of great interest. All of those which occur in the surface deposits, although at some distance from the shore and quite beyond the reach of the sea at present, appear to be of species now existing, and known to occur in the living state in the vicinity. But under the surface sands and clays, at irregular depths according to locality, there occurs a bed of dark-blueish clay or silt, which contains numerous shells, often partially decomposed, and among these there are more than one species not now known to occur on the Madras Coast, although still existing in the present seas. The most remarkable of these is the *Placuna placenta,* of which specimens are abundant, but which is not now found on that part of the shore of the Bay of Bengal.

Detailed examination of these deposits, and of the remarkable shelly sandstones, extending for many miles along the Coast near the Southern extremity of the Peninsula, will doubtless add much to our present knowledge on these points, and will, in all probability, enable us to decide, not only the fact of the elevation of these shores in modern times, but also the character of that elevation, its relative amount in various localities, and the extent of area over which it has occurred.

T. O.

## *Note on recent investigations regarding the extent and value of the auriferous deposits of Assam, being abstracts of Reports by* Captain E. T. Dalton *and* Lieut.-Colonel S. F. Hannay, *dated October* 1855.

The results of previous researches by Captain Dalton and Colonel Hannay have been already made public (*Journal of Asiatic Society of Bengal*, Vol. VII. page 625 and Vol. XXII. page 511.) The same gentlemen were therefore requested by Government, during 1855, to undertake a further examination of the auriferous deposits of Upper Assam, and were supplied with ample funds for carrying out their investigations. They submitted, through Colonel Jenkins, Commissioner for Assam, the report of their proceedings, in October 1855, a brief summary of which is here given.

They proceeded from Suddya, up the Brahmapootra, to the bend of the river, a few miles above the gorge of Brahmakoond ; but finding that the deposits became less and less rich as they penetrated farther into the hills, they returned to Parghat, 8 miles below the Brahmakooud. Here the river debouches from the mountains, after cutting through an enormous deposit of earth and boulders, to the depth of 150 feet.

This is, in all probability, an ancient deposit of the river itself. It appears to extend some distance into the hills ; and to the South of the Brahmakoond forms a series of terraces, indicating the various levels at which the river has successively flowed in past times.

It was remarked, that the gold which was obtained above Parghat contained a certain proportion of small dendritic fragments and cubical crystals, whereas below that point the whole of the metal was found in the form of flattened spangles (" pepites"), a circumstance evidently due to the attrition it had uudergone in its downward course.

The authors were unable to trace the original rock containing the gold *in situ.* Various kinds of granite, in the form of boulders, accompanied by gneiss and greenstone, occurred at the Brahmakoond. Felspathic rocks and slates are *in situ.* The granite and gneiss boulders frequently contain pyrites, and are accompanied by magnetic iron sand in large quantity. Much quartz, consisting of pure white quartz, (vein-quartz?) ferruginous quartz, and cellular quartz was also found.

The spots selected by the native gold-washers are those salient angles or reaches of the river, where the alluvial deposits, cut away by the stream from the opposite bank, are partially re-deposited, after having undergone the sifting action of the current. The highest point in the river, at which the natives work, is Dora-Mookh, a few miles below Parghat.

At a point 4 miles up the Dora stream, where it issues from the hills, a thick deposit of pure *Kaolin* was found resting on white quartz, and probably brought down and deposited by the river. It is termed by the natives *rookmani-pitha.*

At Gooroo Mora, 18 miles below the Brahmakoond, the yield of gold, from 70 maunds (2½ tons) of gravel, washed in a Californian cradle, worked by four men, was 30 grains, valued at 2 Rupees 8 annas. In the native trough (or Dooruni), worked by three men, the yield from 25 maunds (18 cwt.) of gravel, washed in one day, was about 12 grains, worth one Rupee. This was not considered by the natives as a good yield, and they stated that, after a heavy flood, they can sometimes obtain about double that amount from the same quantity of gravel.

The Digaroo Tributary, which comes from the hills to the Northward, and brings down large boulders of crystalline limestone, granite, gneiss, serpentine, and quartz, was also searched for gold, but unsuccessfully, except within about 5 miles of its junction with the Brahmapootra, or about 7 miles from the hills; and here gold only occurred in small quantities.

The Noa-Dehing, a large tributary from the South, was also examined with similar results. The gold was accompanied by platina and magnetic oxide of iron, and occurred in larger average proportion than in the Brahmapootra, but only in the form of minute spangles, very liable to be carried away during the washing. The gold was found to diminish in quantity, as the localities were nearer to the hills.

The great Dihong River, flowing from the hills to the Northward yielded gold in considerable quantity, from its junction with the Brahmapootra to about half way between that stream and the hills. One hundred and fifty maunds (or $5\frac{5}{7}$ tons) of gravel yielded 90 grains of gold, equal to $16\frac{1}{5}$ grains per ton; and if the large fragments of rock, &c., which are removed by hand, be excluded, the yield may be estimated at 22 grains to the ton. This stream is considered by the natives to be the richest in Assam.*

The apparatus employed in these investigations were a Californian cradle ("long tom") worked by four men, and which was found to give the largest daily yield per man; three native troughs, or *Doorunis*, each worked by three men; and a Singpho washing dish, worked by one washer and one assistant.

From these Reports, it will be evident, that the mode of occurrence of gold in Upper Assam is similar to that in California, in the Ural, and in Australia, *viz.*, that it is derived from the crystalline rocks in the first instance, but only becomes sufficiently concentrated to render it worth working in the alluvium, after this alluvium has undergone repeated washings in the river current, by being successively cut away, washed, and re-deposited, as the river changes its course. There, as elsewhere, it will be found a fruitless task to attempt and trace the gold to its source, under the impression that the original rock *in situ* would afford a richer yield than the same rock pulverized and sifted by the action of the river. Even were an auriferous quartz vein discovered, it is more than doubtful (judging from the experience of gold miners every where else), whether

* This is the great feeder of the Brahmapootra, and supposed to be the continuation of the Tsampoo of Thibet, which drains the Northern slope of the Eastern Himalaya.

such a vein could be worked profitably. In the river, there exists a natural agent performing on a large scale all the operations of mining and of pulverizing the material, and of concentrating the gold in the comminuted matrix. Thus the operations remaining to be performed by the gold-washer are only the final portions of the entire process.

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The authors of these Reports forwarded four specimens of gold. These have been subjected to careful examination by Dr. T. Boycott, Assay Master at the Calcutta Mint, who kindly undertook the assay. The results were as follow:—

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|---|---|---|---|---|---|
| No. 1 | Gold, from the | Brahmapootra, | yielded | 88·281 | per cent. of pure gold. |
| No. 2 | „ „ „ | Noa-Dehing | „ | 93·880 | „ „ |
| No. 3 | „ „ „ | Dihong | „ | 90·234 | „ „ |
| No. 4 | „ „ „ | Hookong | „ | 86·588 | „ „ |

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*Note on Specimens of Gold and Gold Dust procured near Shuè-gween, in the Province of Martaban, Burmah, by* Thomas Oldham, *Superintendant of the Geological Survey of India.*

During the early part of the year 1853, Captain Wyndham, 5th Regiment Madras Native Infantry, made an excursion from Shuè-gween to the gold-washings in that neighborhood. They are situated about 10 miles from Shuè-gween in a South-westerly direction, near the junction of the Meaytan Creek with the Shuè-gween Creek. Captain Wyndham procured a small quantity of the gold, and subsequently Captain Berdmore, Deputy Commissioner for Martaban Province, obtained some better specimens, and also specimens of the soil or sand, from which the gold is washed. These were submitted to me for examination, and the results are given below.

Of these specimens, that numbered 1, and said to be the surface-soil, is a *gravelly sand,* consisting principally of small grains of quartz, minute flakes of bright-colored mica, generally of a rich golden tint, and of pebbles of various kinds of matamorphic and crystalline rocks, (as gneiss, micaceous quartz rock, green-stone, hornblende slate, &c.) A few small crystalline pieces of topaz occurred in the sand, and one or two minute red garnets were also found. Mixed with this sand, in small quantities and in minute grains, is some magnetic iron sand, and a few acicular crystals of schorl (which may also be seen imbedded in one or two of the pebbles of quartz.)

Of this sand the specimen forwarded did not altogether amount to the fifth part of a cubic foot. The whole of this was carefully washed and examined. By simple washing, there was obtained from this sand 0·75 of a grain of gold in minute flakes. The residue, after washing, was then carefully agitated with mercury, in order to obtain by amalgamation any portions of gold which might be too minute for mechanical separation. From the amalgam thus obtained, the mercury was then volatilized, and the gold carefully separated. Its weight was 0·20 of a grain.

From the specimen of the soil forwarded to me, there was therefore extracted in all 0·95 of a grain of gold.

The specimen labelled No. 2 was a yellowish ferruginous sandy clay, having much the appearance of being the result of the decomposition of the upper portion of the rock *in situ.* This was reduced to a fine state of division, carefully washed, and the sandy portion, consisting chiefly of ferruginous quartz grains, separated. The rest was carefully examined, but no traces of gold were discovered.

The fine, slightly sandy clay, which remained after washing, would answer well for the coarser kinds of pottery; it stands the fire well, and is sufficiently tenacious to admit of being readily moulded.

The specimens of gold forwarded consist of varieties ranging from dust of the finest kind that could be mechanically separated to small nuggets. Of the latter kind were two specimens "purchased at Shuè-gween." These very well illustrate the mode of occurrence of the gold in its native state, imbedded in quartz, while the other specimens show that the general form in which it is found in these washings is in small rounded flakes, or flattened plates of various sizes.

This gold is of considerable purity. One specimen was examined with some care, and yielded, in 100 parts, 92·00 of gold, and 8·00 of silver. This result however, although tolerably accurate, must only be taken as approximative, as I had not apparatus of sufficient delicacy to admit of an accurate analysis or assay being made. It is, however, sufficient to show that the Shuè-gween gold is fully equal in value to the average quality of Australian gold.

The occurrence of gold of fair purity being undoubted, the question remains as to the amount in which it may occur, and the probability of its yielding a profitable return.

If the specimen of the auriferous sand forwarded by Captain Berdmore be taken as a fair average sample of the kind of soil, and of the amount of gold contained in it, it would follow from our examination, (by which means nearly a grain of gold was procured from about the fifth part of a cubic foot of the soil,) that a cubic yard of the same sand should afford about 135 grains of gold. Or, if we reject from the calculation the portion obtained by amalgamation, *viz.*, 0·20 of a grain, we should have as the yield by washing alone, 101·25, or say on an average 100 grains of gold for each cubic yard of the sand washed.

This sand is stated to be the surface soil, and being therefore readily accessible, without the labor of sinking deep pits, or the cost of keeping such pits open, two men could with great ease raise and wash a cubic yard of such sandy soil in a day. There would, therefore, be 100 grains of gold as the remuneration for one day's work for two men, or 50 grains per man per day. This gold would be worth about (£3) three pounds (British) per ounce, that is, the produce per man per day would be equivalent in value to $\frac{50}{480}$ of £3, or to six shillings and three-pence per day: an ample remuneration, no doubt, for ordinary workmen; but scarcely sufficient to tempt many adventurers to visit the locality.

I would not be understood to state that such *would* be the average yield of the auriferous soil of the districts referred to. Such deposits, from the very conditions under which they have been formed, are necessarily very variable in character and in richness; and experience alone could furnish a fair estimate. But judging from the only data to which I have access, such would be the amount obtainable from this sand.

I would further state that the geological structure of the greater portion of the Malay Peninsula, extending to Arracan Northwards, so far as it is at present known, indicates the probability of auriferous deposits being found throughout the whole extent, on the flanks of the central ranges of high ground. The ascertained existence of gold in more localities than one in the Tenasserim Provinces, at Shuè-gween in Pegu; and the association, in all these localities, of magnetic iron sand with the gold, (a mineral which is so constant an accompaniment of gold, as to have been frequently called by miners "the mother of gold,") confirm this reasoning from analogy. And I have little hesitation in stating my conviction, that such auriferous deposits will be found to occur at intervals throughout the whole range, and that *locally*, they will prove to be very rich.

With reference to the deposits at Shuè-gween, the mode of occurrence of the gold in minute particles and flakes at once shows, that in order to obtain even an approximation to the full yield of gold, some means must be adopted more efficient than the rude processes now in use among the natives.

When forwarding the specimens referred to above, Colonel Bogle, Commissioner of the Tenasserim and Martaban Provinces, stated "that there was not the least doubt that the natives have always been in the habit of washing for gold dust in the Shuè-gween River, and that under the Burmese Government, there was a Farmer General of this branch of revenue, who used to pay a certain sum into the Royal Treasury (the exact amount unknown), and let out the privilege of washing to numbers of persons."

How far it might be desirable, or even practicable, to establish a system of control over the persons employed in gold-washing, or to render it necessary for each person, or each party, to obtain a license for digging within certain limits, paying a small tribute for the privilege of digging for the gold, but irrespective of the quantity procured, it is scarcely within my province to say. But, in whatever way this may be arranged, or whether the gold-seekers pay any tribute or not, inasmuch as every increase to the amount which the district can produce, must inevitably promote its welfare, and add to the general wealth and comfort of its inhabitants. I think it extremely desirable that some more efficient, but at the same time simple, apparatus for separating the gold by washing, and also for amalgamating it with mercury, should be furnished to some intelligent person in the district, as patterns. I would venture to say, that the greatly increased amount of gold, which would be obtained by the use of such improved appliances, would quickly lead to their general adoption within the district. If my examination of the specimens forwarded to me can be taken as yielding anything like an average result, it would appear that nearly one-fourth of the entire amount of gold occurs in such minute particles, that it cannot be separated by washing; and I have very little doubt, that a very considerable portion, even of the larger and heavier flakes, are also lost. Indeed, I should think, that the total loss might fairly be estimated as one-half of the entire amount of gold contained in the sand; and all this is, in all probability, irretrievably lost.*

* The substance of this note was originally published in No. XIII. of Selections from the Records of the Bengal Government, in 1853.

*On the Geological Structure of a portion of the Khasi Hills, Bengal.*
*By* Thomas Oldham, *A. M., F. R. S., G. S., M. R. I. A., &c., &c.*

## PRELIMINARY REMARKS.

The following brief sketch of the geological structure of a portion of the Khasi Hills, on the North-Eastern frontier of Bengal, is the result of observations made during two short visits to those hills, in the wet seasons of 1851 and of 1852.

Shortly after my arrival in India in the commencement of the year 1851, finding that it would be impossible at that season of the year to commence field operations in the plains of Bengal, I proceeded to the station of Cherra Poonjee, intending to examine the mode of occurrence, extent, and character of the iron ores, which had for many years been known to have been worked in these hills. I arrived at Cherra Poonjee in the middle of the month of June, and left again in the beginning of November. During that season, I visited some of the principal washings for the iron ore, traced out some of the coal beds, and examined and reported on the coal pits at Lakadong in the Jynteah hills. Advantage was also taken of the few fine days which occurred to make a careful survey of a part of these hills, extending Northwards from the station nearly to the Kalapani; and also of the station itself.

During the five months' duration of my visit in that year, 1851, there fell at Cherra Poonjee nearly 400 inches of rain, and there were only sixty-three days on which the amount was less than one inch: during this small number of working days, and having no assistants, I was unable to accomplish very much.

Returning to the same hills during the rainy season of 1852, I was enabled, by the zealou said of my Assistants, Mr. Medlicott and Mr. St. George, to complete the survey of the hills, commenced by myself during the preceding season, from the station across to Nungklow. A Map, on a scale of one mile to the inch, was the result of these combined labors, and was published in 1854 to accompany the first issue of this Report. The small outline Map of a larger area, given herewith, is the result of flying sketch surveys made by myself during trips across the hills to Lakadong, Nonkradem, &c. (*a*)

During this second visit, I crossed the hills to Nonkradem, and examined the rocks in that vicinity, and from thence to the plains at Lacat. The season of 1852 was much drier and finer than that of 1851, and we were thus enabled to continue actively engaged in the field until the very day before leaving the hills. On reaching the plains, we immediately proceeded to the field again, so that the results of our labours were unavoidably put aside, until the return of the monsoon of the succeeding year, 1853, enabled me to devote some time to their collation. The survey of the Khasi hills was then plotted, and the Maps completed, together with a plan on a larger scale of the station of Cherra Poonjee itself.

The want in this country of books of reference, or collections for comparison, compelled me, after a preliminary examination, to submit a selection of the fossils collected, for careful examination and description in England. These were unfortunately lost at sea, and, until the data for such comparison can be again procured, any report on the district must unavoidably be very incomplete. It will, nevertheless, be in all probability sufficient to make known the principal facts in the physical structure of these hills, and to indicate some of the more important economical considerations springing from this structure.

It was a source of great regret, that, owing to the season of the year during which I visited these hills, I was unable to examine the lower parts of the ridge, where many points of great geological interest

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(*a*) It includes a large portion of the country, of which a similar sketch Map was constructed by Dr. J. D. Hooker during his visit to these hills, but is entirely based on independent data. The Southern portions, including Sylhet, Jynteah, &c., are taken from the Revenue Survey Maps by Capt. Thuillier, and from the sheets of the Indian Atlas. The small plan of Lakadong is from original survey, and was originally published in No. XIII. of the Selections from the Records of the Bengal Government.

still await solution. Densely covered as these portions are with close jungle, abounding in swamps, a sojourn there during the wet and hot months of summer would be almost certain death to an European: and I was therefore obliged to forego my desire of visiting these districts. It will be seen that in consequence several questions of importance have been left still unsolved.

The extent of our labours was seriously affected, not only by such circumstance of locality, but also, by the peculiarity of the climate. During such wet seasons not much out-of-door work could be accomplished, especially when the country had to be surveyed and mapped topographically, as well as examined geologically. And even during the season of 1852, which, as I have mentioned, was drier and finer than that of 1851, much interruption to such pursuits was unavoidable, where the fall of rain during the *three* months of our visit was not less than 276 inches! *(a)*

A brief sketch of the economical applications of some of the mineral products of these hills is added to the outline of their Geology.

I have to express the great obligations I was under to Colonel Lister, Political Agent for the Khasi hills, and to his Assistant, Lieutenant Cave, for their valuable and ready co-operation in every way to facilitate my enquiries. To Mr. Cave also and to Mr. Raban, Adjutant of the Sylhet Light Infantry, I was indebted for their instructive company during several trips among the hills, which enhanced my enjoyment most materially; and, which, from my almost total want of acquaintance with the language of the country (at least during my first visit) proved essentially valuable. Indeed, without the benefit of their local knowledge, my success would have been much more limited than it was.

*(a)* During these three months, the actual number of days during which no rain fell at Cherra Poonjee, was 21, *viz*: in July 3; in August 6; in September 12; while of days on which the fall was trifling or less than one inch of rain there were 25, *viz*: in July 3; in August 12; in September 10; giving a total number of fair working days, inclusive of Sundays, of 46.

ON THE

# GENERAL FEATURES OF THE HILLS.

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THE station of Cherra Poonjee *(a)* is situated near the Southern crest of the extensive plateau of tolerably flat-topped hills, which rise suddenly from the plains of Sylhet, and stretch in a direction nearly due East and West, almost continuously from the valley of the Brahmaputra on the West, to Munnipoor and into the Burman empire on the East. On three sides this range is surrounded by a great extent of flat country, the elevation of which above the sea is but trifling. On the North, it is separated from the Bhotan Mountains by the great valley of the river Brahmaputra, and the territories of Assam. On the South, the extensive plains of Sylhet intervene between it and the Tipperah hills; while on the West, the valley of the Ganges and the level districts of Mymensing, Rajshaie and Moorshedabad, separate it from the Rajmahal hills.

Outline of range.

Seen from the plains to the South, this range of hills presents rather a tameness of feature. It has a remarkably regular and flat outline, few points overtopping the general ridge, and few deep glens or valleys breaking the crest.

Garo hills.

The Western extremity of this ridge is known by the general name of the Garrow or Garo hills, being inhabited by the half-civilized tribe of that name. A large

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(a) Cherra Poonjee is approximately in latitude 25° 16′ 35″ North; and longitude 91° 43′ 55″ East.—*(Thuillier and Smyth's Manual of Surveying for India, 1852.)*

portion of their territory is said to be overrun by dense and almost impenetrable jungle. They hold little intercourse with adjoining tribes, are reported to be very treacherous, and, excepting along the outskirts of the ridge, are but little known *(a)*. The Eastern boundary of the Garo territory is but ill defined, but may rudely be said to correspond to the 91st degree of Eastern longitude.

Khasi hills.

Adjoining the Garos, on the East, is the territory of the *Khasis* (Kasiyas, Khasias, or Cossias). It stretches East and West for about one degree of longitude, and, in the North and South direction, from the plains of Sylhet to those of Assam.

Jynteah hills.

Still further East, and joining the Khasi territory, are the Jynteah hills, which have passed into the hands of the British Government in India, having been forfeited by the Jynteah Rajah in 1835.

Cachar, &c.

To the East of the Jynteah hills, are the tribes of Cachar, the Nagas, &c., which inhabit the country from the Jynteah boundary Eastwards to Munnipoor. Their geographical limits are very little known.

My own observations were confined to the Khasi territory, and indeed only to a portion of it, with a rapid examination of parts of the Jynteah hills.

Character of escarpment on South.

In this portion of the range, the hills rise very suddenly and abruptly from the plains. At a short distance from their base, and stretching along nearly parallel to the great range, though with interruptions, is a broken series of small rounded hillocks, often beautifully wooded. These rise from 1 to 200 feet above the general level of the plains, and are composed of layers of sand,

*(a)* Captain C. S. Reynolds, in an interesting account of a visit to the Garo hills in 1848, mentions nothing but granite, and says he was unsuccessful in finding coal, limestone, or iron. He had, however, no opportunity of making an extensive examination.—*(Journal of the Asiatic Society of Bengal, Vol. XVIII. page 45.)*

clay and gravel, very irregularly disposed, and often highly indurated by a ferruginous cement *(a)*. They occur at various distances from the base of the hills, between which and these small knolls there is generally a flat space, densely covered with jungle, and abounding in swamps, thickly clothed with tall reeds and grasses. Behind this swampy tract rises the great range of the hills, by a rapidly inclined slope, closely wooded and surmounted by a deep precipitous face, which forms a marked feature in the landscape. The crest of this precipice attains an elevation of about 3,500 feet, and, above this long and nearly horizontal line, the hills rise gradually with undulating and irregular slopes to the average height of 5,000 to 5,400 feet, with a few summits of still greater elevation, but none much exceeding 6,000 feet. The entire slope of the hills up to the base of the precipitous portion is thickly clothed with wood, among which a few patches here and there have been cleared for cultivation.

On North.

Again, on the Northern side of this range, the country suddenly drops at Nungklow to the level of the Boripani river, or more than 2,000 feet, and then gradually dies away into the valley of the Brahmaputra, by a succession of sharply undulating hills and ridges, which stretch from this Boripani river, immediately under Nungklow, to near Gowhatty, in Assam. The whole of these districts, forming the descent from the comparatively flat table-land of the top of the ridge (and which, on the South, extend for about six miles, and on the North for about twenty), is densely wooded, while the upper and more level parts of the hills are clear, free from jungle, and, where the surface is not actual rock, thickly carpeted with grass. The same fact is observable in the many deep glens and

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*(a)* The pretty station of Sylhet is built among these hillocks ; and they are also well seen at and near Chattuc. On the summit of one of these knolls is placed Mr. Inglis's bungalow, and on an adjoining one the monument to the memory of the late George Inglis, Esq., "for many years Judge of Sylhet," which forms a conspicuous landmark for a great distance around.

water-courses, which penetrate the hills on either flank; the sides of these glens being almost invariably thickly and beautifully clothed with wood, which ceases abruptly at the top as if cut off with the axe along the crest of the glen; the want of protection from the prevailing winds, as well as the character of the soil, entirely preventing the growth of any timber.

River gorges deep and numerous.

On the Southern flank of the range, within the Khasi territory, the many streams which drain the ridge, and carry off the enormous fall of rain that annually takes place here, flow in deep though not wide glens, which stretch into the hills for

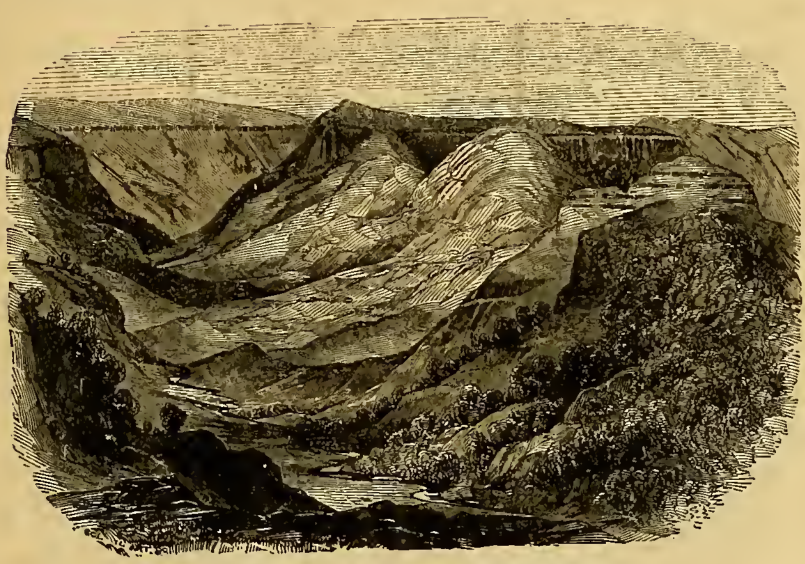

*Fig. I.*

many miles, and add greatly to the variety and beauty of the scenery. Most of these glens are very deeply excavated, the bottoms, or river beds, even at the distance of several miles from the outskirts of the hills, being some thousand feet below the general level of the top of the plateau. In outline, all these river gorges or glens are remarkably alike; the upper portion of their sides being nearly perpendicular and precipitous faces of rock, which rest upon a rapidly inclined talus, sloping down to the level of the water beneath. Of this general character, depending, as I shall have to remark, on the geological structure of the district, a good instance may be seen in the accompanying view of the glen to the North and East of Surareem, as seen from the South. (Fig. 1.)

Station of Cherra Poonjee.

Situated immediately to the West of one of these great glens, and almost overhanging its precipitous sides, is the station of Cherra Poonjee, at an elevation above the sea of 4,120 feet, while the bottom of the glen adjoining is nearly 3,000 feet below. The sanitarium occupies a small level plateau, of a rudely triangular shape, bounded on the East and North-East by this deep glen; on the South by the equally grand glen of Mawsmai; while on the West, the small ridge in which the coal mines are situated rises with a sharp bluff some 300 feet above the level of the plateau, and is continued on the North-West by the rounded sandstone hills, on the tops and slopes of which the native village of Cherra Poonjee is placed. To the North, the hills rise gradually until the average level of the central portion of the range is attained; from which the view *(a)* looking South ranges over the flat of Cherra, to the immense expanse of the plains of Sylhet, and to the distant Tipperah hills, the irregular outline of which bounds the horizon. (Plate IV.)

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*(a)* For the originals of this sketch, and of Fig. 2, I am indebted to Lieutenant Cave, Assistant Political Agent.

General features of plateau towards the South.

The same general physical features are continued Northwards from Cherra Poonjee to Mow-phlang (Moflong), 18 miles distant; the hills presenting an almost uninterrupted, and nearly level top, broken only by the deep and narrow river gorges, which intersect it, and which form the most striking feature of the scenery.

Further to the East, and extending into the Jynteah hills, the same general character continues along the Southern flank of the range; the deep valleys East of the flat-topped ridge on which Nonkradem is placed, being exactly similar in outline, and general feature, to those around Cherra Poonjee.

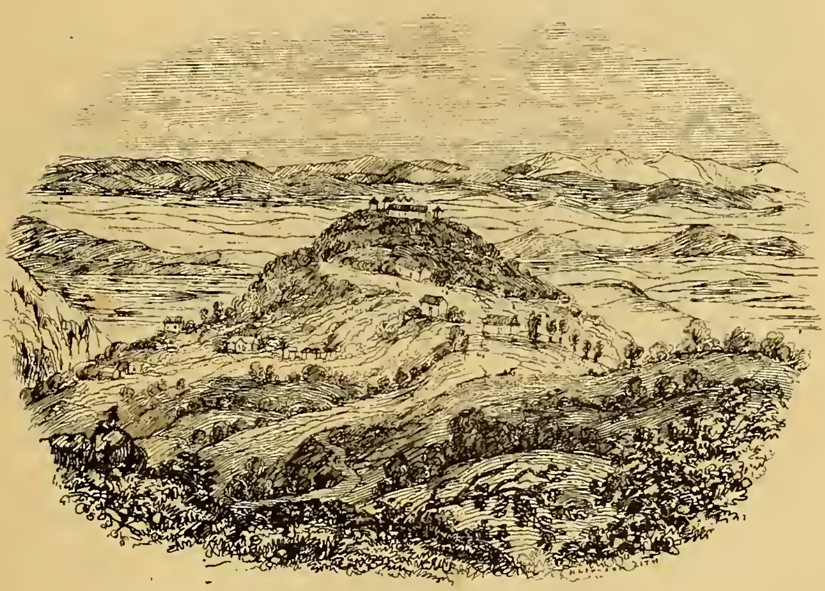

Fig. 2.

Contrasting very strongly with this general character of the Southern portion of the range of hills, the surface of the Northern portion presents a remarkably wavy and undulating outline. This character extends from the neighbourhood of Mow-phlang to Nungklow, and may be well seen near to, and North of the village of Myrung (*a*) (Fig. 2), or, looking Southwards from Nungklow (Fig. 3), towards the Kullong rock. River

General features of plateau towards the North.

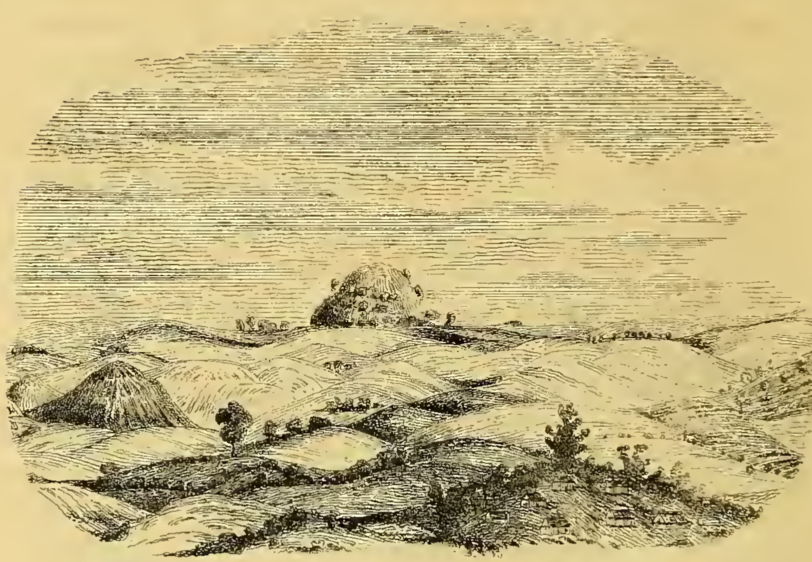

Fig. 3

valleys diversify the surface of this wavy plain, but these are of very different character from those to the South. More open and spreading, they offer none of those precipitous cliffs so common around Cherra

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(*a*) The buildings on the rising ground in the centre of the view are the guard-house and outpost of the Sylhet Light Infantry at Myrung: while the larger house, a little below, is one of the staging bungalows on the road to Assam, a part of which road is seen in the foreground. The houses of the small Native village of Myrung are on the slope of the hill. The indistinct outline of the snowy peaks of the Himalaya may be traced to the left of the sketch.

Poonjee, and are by no means so deeply excavated. Waterfalls also are numerous; but they partake more of the character of "forces" and rapids, than the remarkable falls which rush over the precipitous cliffs to the South, and which are so well seen in the valleys of Mawsmai, and Mawm'luh, near to Cherra, and some of which, in the height and unbroken character of the fall, are perhaps unsurpassed in the world (Plate V.).

This general character of the surface continues to the Northern edge of the plateau, where, at Nungklow, the hills drop suddenly, and almost precipitously to the level of the Boripani river. *(a)*

Table land.

There is a tolerably continuous and level table land, stretching East and West, nearly in the parallel of Mow-phlang, and extending towards Nurtiung. Through this ridge pass the deep gorges of the river Oomgot and its feeders. Still further to the East and South, the glen of the Mentedoo is bounded by the comparatively level country extending Southwards towards Lakadong, where we again meet a precipitous flank of the hills, dropping down to Burghat, and thence continued by outlying minor ridges of sandstone and limestone into the flat country of Jynteahpoor.

Geological Structure corresponds to physical features.

Coincidently with this remarkable alteration in the general features of the hills is an equally remarkable change in their geological structure; the whole of the Northern portion of the hills from the parallel of Mow-phlang (with the exception of a few isolated patches to which we

*(a)* Close to the Suspension Bridge, across which the road to Assam is carried over this river, there is a beautiful waterfall. It cannot be compared as to height of fall with those near to Cherra, the whole fall, which is broken into two leaps, not being more than 150 feet. But in the force and massiveness of the stream, the bold dashing of the waters, the richly wooded and varied outline of the hills around, and the absence of any of that feeling of tameness, which always impresses the spectator in the horizontal and repeated lines of beds in those around Cherra Poonjee, this fall is, I think superior to any other I have seen in the Khasi Hills. It is wilder, freer and nobler.

shall hereafter refer) being composed of granites and of metamorphic rocks, presenting on the whole a gneissose character, with a few intercalated beds of slates and quartz rock, and dykes of greenstone ; the bedded rocks occurring at every angle of inclination and being much disturbed : the Southern portion, on the other hand, is composed of sandstones and limestones with associated beds of coal and shale, which, as a whole, rest horizontally on the older rocks.

In addition to these, basaltic and greenstone-like volcanic rocks are well exposed in some places. These are of still more recent age than the sandstones with which they occur.

After this very brief sketch of the general aspect and structure of the hills, it remains to describe a little more in detail the various rocks which occur in the district examined, and their mutual relations. Taking these in the order of their relative epochs, the metamorphic rocks demand the first place. Of the igneous rocks, which have so materially modified the aspect, position and structure of these mechanical deposits, we shall speak afterwards.

Rocks, &c.

METAMORPHIC ROCKS. (Gneiss, micaceous slates, clay slates, hornblendic slates, quartz rocks, &c.)—A very large area in the Khasi hills is composed of slaty and gneissose rocks, presenting for the most part a highly crystalline character, and traversed throughout their entire extent by numerous veins of granite, and here and there by dykes and bursts of greenstone. With slight interruption, these rocks stretch from the most Westerly portion of the hills, which I have examined, to the most Easterly. They occur at Nungklow, on the Northern verge of the hills immediately over the valley of Assam, and here form the entire escarpment of the hills down to the Boripani river ; from Nungklow, they extend South to the Kullong rock (where a great mass of granite protrudes through them), and from thence to near Mow-phlang, where they become covered up by the sandstones. They seem to wind round the Northern flanks of Shillong hill and stretch thence by Pomrong to Coote, Mooshai and Suneassa ; and into the Jynteah hills.

Throughout this area, they maintain, on the whole, a tolerably constant character ; they are greatly contorted in every direction, these contortions affecting every variety of rock. In the midst of so much disturbance it is difficult to say that the rocks have any prevailing direction or dip, although they appear to have a tendency to great rolls ; the inclination of the sides of these curves trending to the North and South, or to a little West of North and East of South.

Gneiss, &c., near station of Cherra.

In the immediate vicinity of Cherra Poonjee, these rocks are well seen in the deep glens which surround the station, and from the lower parts of which the thick covering of the more recent sandstones has been denuded. In Cherra valley, we find in the bed of the Temshung river alternating beds of quartzose slates, quartz-rock, and gneiss, dipping at very high angles, and much disturbed. They form in many places bold cliffs along the banks of the stream. Associated with these and traversing them in veins is a fine-grained granite of nearly homogeneous texture, itself cut up by numerous veins of a coarsely crystalline and highly felspathic porphyritic granite. These veins are of all sizes, and some of them are in too great mass to be looked upon as mere cotemporaneous veins, or segregated masses, but look like the results of a second intrusion of molten rock into the fissures of the previously indurated mass. Others are small and ramifying, and consist chiefly of largely crystalline felspar of a deep and beautiful flesh-red colour, and of black mica ; the latter occasionally in crystals measuring an inch across. Zircon occurs in these veins.

Hornblendic rocks.

With the gneissose and slaty beds we find occasional layers of hornblendic rocks associated. The same series continues without intermission up to the base of the conglomerates, which, on the flanks of the glen, rest nearly horizontally on these rocks.

Blue and Grey Schists, &c.

Passing Northwards from Cherra Poonjee, the metamorphic rocks are concealed by the tertiary sandstone, until they are again exposed on the Northern side of the deep glen close to and North of Mow-phlang, across which the road to Assam passes. Here the general character of the rocks is very different. They are blue and grey flaky schists associated with quartzose, and micaceous layers, dipping at high angles, and with tolerable continuity to the North and West. Some of the beds near to this are smooth-grained gritty clay slates, of a greenish-blue colour, and flaky. In one or two places attempts have been made to extract slates for roofing purposes from these beds. In these rocks, however, there has been but little "cleavage" structure superinduced, and the surfaces of the original lamination of the rock, which are the only surfaces along which it can be separated, are too uneven and at too irregular intervals to admit of slates suitable for ordinary purposes being obtained from them. Heavy coarse flags might be raised here, and these would answer well for the covering of out-offices, sheds, &c.

Greenstone intrusion.

In this glen, the slate rocks rest immediately upon or against a great mass of greenstone (to which I shall refer again), and at the junction are considerably indurated, and at the same time split up by numerous divisional planes which pass across the laminæ, and break up the mass into small angular pieces. Similar greenstone is seen cutting through the rocks in several places to the North of this, and on the surface is decomposed into a coarse ferruginous, or ochrey mass. The slates continue of the same general character, as far as the remarkable flat called Lung-king-ting-now. Descending into this flat from the higher ground to the South, there is a considerable thickness of black earthy slates, with hard gritty quartzose layers, also black in colour. These slates are markedly different from any of the rocks in the vicinity, and are not met with again in the section. They are probably the uppermost beds of the entire slaty series met with in this district.

This flat space, nearly half a mile in width, is a remarkable feature in the hills. It has all the character of a dried-up bed of a former lake, and is one of the very few instances in which such appearances are seen in these hills. Greenstone occurs at both sides of the flat space, and appears to form the surface below, but a thick covering of clay and sands conceals all the rocks; and on rising up the steep slope on the North towards Sohiong, the same gneissose and highly micaceous rocks, as have been described in the Cherra valley, again appear. These are well seen in the village of Sohiong; they consist of thin bedded gneiss and micaceous slates, with hard gritty quartzose layers, dipping at high angles, or nearly vertical. They are much twisted both in plan and section, but have on the whole a dip to the S. E. at angles varying from 60° to 85°. The old road, which passes close under the rude entrenchments of the village, exposes them well, and they are also seen on the side of the beautifully wooded glen to the East, on the verge of which the village is built.

Former lake bed.

Northwards from Sohiong, the same rocks continue, but on the whole they gradually become more crystalline and solid, and the frequent recurrence of large blocks of granite points to the existence of many veins, or intruded masses of that rock, the boundary and extent of which cannot, however, be easily traced. Such is the case in the neighbourhood of Nung-bree, again near Myrung, and still further to the North, at Nung-rumai (commonly called Normai); but the general surface of the country is composed of these gneissose and slaty rocks.

Veins of granite, &c.

The constant occurrence of these masses of granite, and also of minute veins ramifying among the layers of the slates and gneiss, gives convincing proof, that the thickness of these rocks is here very slight, and that the great mass of the granite, which is well seen at a short distance to the East and West, continues at no great depth below the surface, under the gneissose beds

Crystalline texture of rocks.

(see Section), while at the same time the highly and largely crystalline texture of the small and minute veins shews that the whole mass must have been in a highly heated condition when they were formed.

Gneiss, &c., in East of hills.

In the Eastern portion of the hills, similar rocks are met with in the valley of the Mentedoo. They occur in thin layers of gneiss and mica slates dipping at high angles (60°—70°) towards the N. and N. E., abounding in small quartz veins. They are much less contorted than in the Western portion of the hills, and are here capped by horizontal beds of sandstone. The gneissose rocks continue all up the valley of the river, forming the talus or slope of the high ground on either side. At Joowai village, and stretching along the top of the ridge on which it is placed, for some little distance towards the East, a thin capping of horizontal beds of sandstones and conglomerate, forming an outlier of the more extensive beds to the South-East, conceals these rocks, and affords an excellent instance of the total unconformability of the two series. (Fig. 4.)

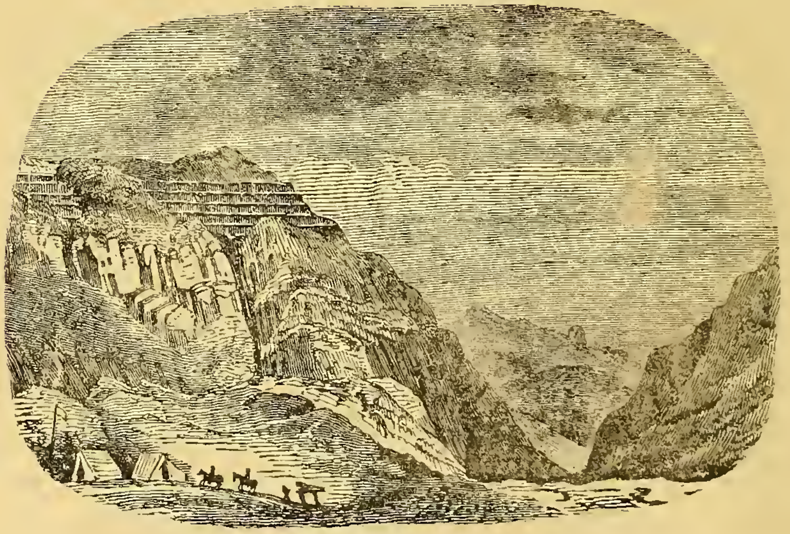

Fig. 4.

Under the sandstones are highly micaceous and shining slates, with thick beds of hard gritty micaceous gneiss: numerous veins of quartz occur traversing the rocks, and large veins of granite also pierce them in many places. At Joowai village (a) these slaty beds dip as a mass to the S. and S. by E., at angles varying from 45° to 70°.

At Joowai.

Similar rocks are seen wrapping round the edges of the granite about four miles East from Coote village; while between this and Pooring, largely crystalline greenstone crosses the valley. At this village itself (Pooring) the rocks are gritty gneiss in thick strong beds.

Coote, Pooring.

Descending from this into the Oomgot valley, we find hard close-grained siliceous slates, and thence towards Pomrong we have gneiss and micaceous slates in thick beds. These alternate continually, and are well seen in some of the river gorges, through which the feeders of the Oomgot pass: veins of quartz abound, and the rocks, although much contorted, have a general inclination to the North-West. Granite veins also occur.

Oomgot, &c.

Throughout the series of rocks, which I have just described, few mineral products of any value are found. I have above alluded to the attempts made to obtain good roofing-slates from some of the beds. In a few places, as under Nungklaw, &c., small crystalline grains of magnetic iron abound in some of the beds, precisely of the same character as that obtained from the granite,

Minerals, few.

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(a) Joowai is one of the largest villages in these hills. It is beautifully situated on a ridge, overhanging the rich and well-cultivated glen of the Mentedoo River. The hill slopes on either side covered with scattered pines and other trees, and the flat holms at the bottom cultivated like a garden, give the place quite an English aspect. In the village itself magnificent groups of bamboos throw a grateful shade over the houses, and large tanks and ponds are formed among the undulations of the ground The houses are of a better class, and in many respects assimilate more to those of the Bengalees than among the Khasis proper, while the physiognomy of the people themselves, and their superior stature, seem to confirm the idea of an intermixture of race.

and occasionally in greater abundance; but in most of these cases, the additional hardness of the rock would prevent this ore from being extracted with as much economy from the slates, as from the granite.

Metamorphic rocks azoic.

I have not been able to trace the existence of any organic remains whatever in these rocks. They are, as far as I know, throughout the entire group, truly azoic.

Two groups.

There would, however, appear to be two very distinct groups of these metamorphic rocks, differing materially in the amount of alteration to which they have been subjected, and also in the variety in composition and character which the beds exhibit. The older and more altered group of these is represented by the highly crystalline gneiss, quartzite, &c., of the valley of Cherra and other places. These, as I have already described, consist of alternating beds of gneiss, quartzose schists, and quartz, greatly contorted, and traversed in every direction by veins of finely crystalline granite. With these are also associated occasionally beds of hornblendic rocks.

On the other hand, the upper group, which is quite unconformable, is essentially slaty, consisting of blue and grey flaky schists, with some micaceous and quartzose layers. These are also disturbed, but not to the same extent as the gneissose beds below, and, although occasionally granite veins are found piercing them, these veins are by no means numerous or large. Unfortunately nothing organic has as yet been discovered in these rocks to give evidence of their age. In *lithological* aspect they have many resemblances to the Lower Silurian slates of Europe, but this resemblance is of no value whatever in fixing their date. To an Indian Geologist, the two groups may be more readily described as representing, the lower or gneissose group, that of Bengal Proper, and the upper or slaty group, that of the Sikkim Himalaya (Darjiling). The latter is in all probability the representative of, or on the same geological horizon as, the metamorphic rocks of the Nerbudda and of the Curruckpore hills. My stay in the Khasi Hills did not afford me sufficient time to trace out accurately the boundaries of these two groups.

SEDIMENTARY DEPOSITS.—In ascending the Khasi Hills from Teriaghat, the rocks met with throughout the greater portion of the rise are sandstones of varied mineral character. In the lower part, the prevailing colour is a greenish brown; passing on the one hand into a grey, and on the other into a red tint. Occasionally we find beds of a light grey or whitish colour, variegated with red and ferruginous spots or patches; but these are more frequent in the upper portion of the series. Beds of shale and shaly sandstone, and clays of yellowish and blackish grey colours, are associated with the sandstones. Several of the beds of sandstone are highly calcareous, and sometimes pass into calcareous grits.

Tertiary Sandstones.

On the upper beds of this series the station of Cherra Poonjee is placed, and here we find, resting conformably upon the sandstone, a series of beds of limestone, coal, and shales, to which we shall refer again.

Limestone, Coal, &c.

The sandstone beds are well exposed in the perpendicular cliffs of the valleys adjoining the station. It is not, however, always easy to obtain means of examining the series satisfactorily. The only paths, which pass down the sides of the glens, have naturally been selected where some fallen mass has produced a spur or slope along which the path can wind, but where the rocks are concealed; while the greater portion of the vertical cliff is inaccessible. Most of the slopes also are clothed with dense forest. It is therefore with some difficulty that the actual succession of the beds is traced out, and I can therefore merely state the general divisions of the group.

At the base, whenever it is clearly seen, and resting quite unconformably upon the up-turned edges of the older rocks, there is a thick mass of coarse conglo-

Succession of beds.

merates. The pebbles are chiefly of quartz, both crystalline and granular, all considerably rounded, and of all sizes, from six inches diameter to one inch. Masses double this size are found, but are not common. These are imbedded in a felspathic gritty cement. This conglomerate is well seen in the Cherra valley ; and in places it is fully seventy feet thick, forming a very well marked line of cliff along the sides of the glen. On this coarse conglomerate rests a sharp semi-angular grit of a dark brownish colour varied by numerous light specks. These are scarcely-rounded fragments of felspar crystals, of a light flesh-red colour, which give the rock a very peculiar aspect. Locally, these beds become coarser and pass into a pebbly grit, and in this case, it can occasionally be seen that these imbedded pebbles are partly of granite, and not altogether of felspar *(a)*. With local variation in texture and coarseness, these beds are at least 150 to 200 feet thick.

Fossiliferous beds.

Over these come sharp grits of reddish-brown and greyish-brown colours, in which are many casts of shells, generally imperfect and fragmentary *(cardium, &c.)* Higher up, the sandstones have a greenish-brown tint, and contain numerous remains of echinodermata. These beds become calcareous, and then decompose into a brownish-red sandy rock, which on the fresh fracture is a very hard mass of a bluish tint. Where the fossils occur in the grits, they are only casts, or the place of the original shell is filled with a soft yellow impalpable clay ; where the rock is calcareous, the shells of the echini are replaced by carbonate of lime. It is almost impossible, owing to the nature of the matrix, and to the highly crystalline condition of the carbonate of lime, to obtain good specimens of these. At the base of the fossiliferous beds there are locally developed some beds of a nodular dark grey shaly sandstone (Mahadeo).

(*a*) These beds are well seen at the zig-zags, on the road to Teria-ghat from Cherra Poonjee, of which they form a considerable portion.

These beds containing the echini (*Cyrtoma* of McClelland) form a well-marked line along the face of the Cherra valley, where the beds are calcareous, and are again well seen under Mawm'luh, where they were first noticed by Dr. McClelland (*a*). Associated with these echinoderm remains, and occurring also a little below them, are large plicated oysters, generally in fragments.

Plant remains.

Over this group are numerous beds of soft earthy sandstones, of brownish and red tints, with intercalated beds of clay and thin shales. These continue with little intermission until the flat of Cherra Poonjee is reached, where thick-bedded strong sandstones occur, not very hard, and of a reddish colour. In these beds I have not observed any remains of shells, but impressions of stems of large plants, very rudely preserved and in most cases much too indistinct for identification, are not uncommon.

Limestone.

Over these sandstones, and separated apparently by a thin bed of stiff blue clayey shale, comes the limestone which forms the bluffs of the small detached ridge in which the coal has been worked to the West of the station of Cherra Poonjee. This limestone is here about 80 feet thick, separated above by eight to ten feet of sandstone and shale from the coal, which again is covered by alternating beds of soft grits and clays to the top of the Hill *(see below)*.

Thickness of tertiary group.

The thickness of the entire group, which I have just described, is, near to Cherra Poonjee, not less than 2,000 feet. Throughout the whole of this great thickness the beds are entirely conformable, and are very nearly horizontal in position. They are irregularly developed, beds of sandstone and clays often

(*a*) These beds of sandstone, which, being soft and loosely coherent, are readily acted upon, and decompose into a friable sand in which the harder portions of the organic remains continue imbedded, gave rise to the idea, which Dr. McClelland has published, of their forming a sea-beach. The true relations of the beds, or so-called "beach," can be well seen in the adjoining cliffs, where the conformable association of these beds with the other sandstones may be traced.

thinning out, within the space of a few hundred yards, from some feet to some inches in thickness. Throughout the entire series also, but more especially in the upper portion, there is a frequent repetition of the most remarkable cases of false bedding and oblique lamination, evidencing a constantly repeated change in the force and direction of the currents, and in the other conditions under which these beds have been deposited. The accompanying sketch shows one, and by no means an extreme instance of this kind. (Fig. 5.)

False bedding.

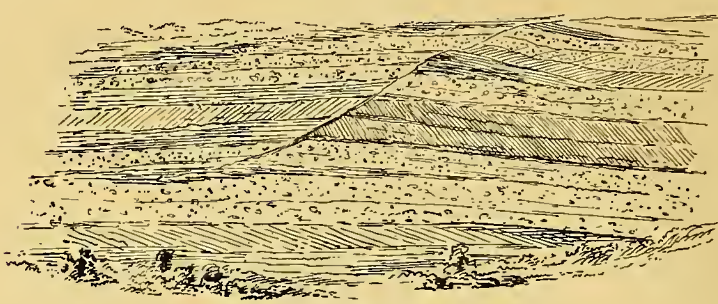

*Fig. 5.*

The beds are, I have already mentioned, nearly horizontal throughout, but dip slightly and continuously as a whole, towards the South and South by West. This dip is very slight, but is easily traceable when observed over a considerable area. And the same fact is even more markedly seen when the range of the hills is observed from the plains to the South at sufficient distance to enable the eye to take in a considerable sweep. In the following sketch of these hills (Fig. 6.), as seen from the River Soorma, near Sonamgunj, the sandstones and associated beds, so well marked all along the range by the steep precipitous cliffs they form, as in the vicinity of Cherra Poonjee, are seen gradually to drop down to the level of the plains, as they pass to the West (*a*). The occurrence of beds of coal, which at Cherra Poonjee are

Beds nearly horizontal.

(*a*) The station of Cherra Poonjee is placed on the hills to the extreme right of Fig 6. on the next page.

at the top of the hills, nearly at the level of the plains close to Laour, and towards the West (as noticed by several observers), is in some degree a confirmation of this statement. The same fact appears to hold with reference to the sandstone group towards the East also, for we find beds of the same nummulitic limestone, coal, and sandstone, with the same group of beds below them, forming the hills near Lakadong; but there attaining only an elevation of not more than 2,500 feet, while at Cherra they reach 4,500 feet(*a*).

Apparently a general anticlinal near Cherra.

(*a*) The thin outlying caps of sandstone at Joowai are, in this part of the hills, analogous to the outliers of Nungbri and Laidom, North of Cherra Poonjee.

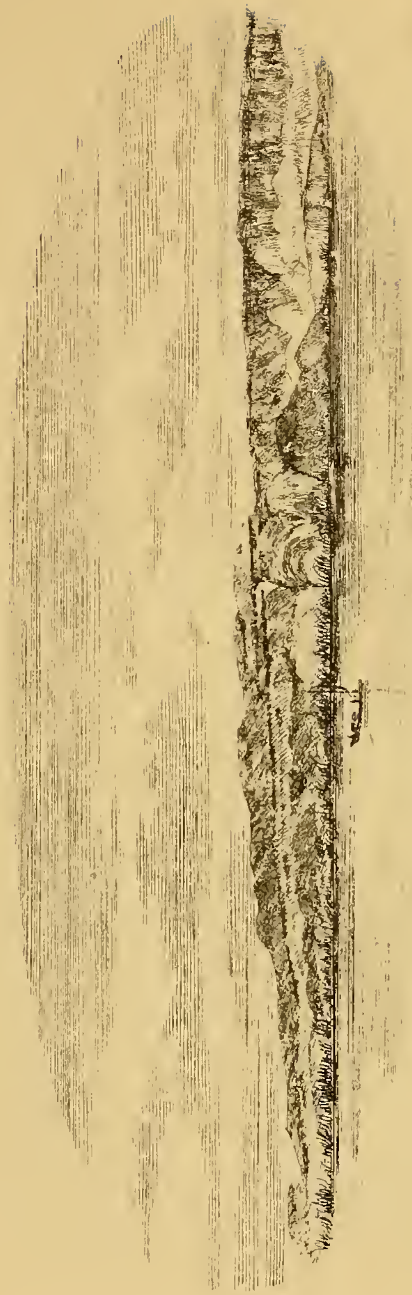

Fig. 6.

These sandstones stretch inland from Cherra Poonjee to near Mowphlang *(see Map)*, retaining on the whole their nearly horizontal arrangement, and presenting throughout the same general lithological character. This horizontality of the beds, and alternating disposition of the shales, grits and coarser sandstones, is well seen in the splendid cliff which bounds the great valley of Cherra to the North. Here also dark earthy grits, with iron pyrites, are seen to alternate with the sandstones. The same series again occurs in the cliffs bounding the valley North of Lairungoo (*see Fig.* 1). The total thickness of the group has, however, considerably diminished here, and the metamorphic rocks come much nearer to the surface. But little change in the mineral structure of the series is traceable. At one or two places along the route, patches of coal (of very poor quality however) occur associated with the sandstones (as at the Northern end of the Native village of Cherra Poonjee ; about half a mile further on ; and near Surareem), and occasionally blackish-grey shales, with numerous small fragmentary impressions of carbonized vegetables. At the roadside near the Kala-pani, beds of dark earthy and pyritous sandstones and shales, similar to those near to Cherra Poonjee, occur.

Sandstones extend into hills.

Near to this, the sandstones begin to show the effects of the intrusion of volcanic rocks (to which we shall refer again), both in their position, and in their texture. Dropping into the valley of the Kala-pani, about half way down the South-Eastern side of the glen, we meet with highly crystalline greenstone underlying the coarse sandstones. The beds in junction with the greenstone have been greatly altered ; their colour has become a deep purple ; they are intensely indurated, and are in fact quartz rock. Further, instead of breaking into the laminar and irregular pieces, which these sandstones ordinarily yield, a blow of a hammer fractures the mass into small prismatic blocks, having a semi-columnar structure. The original lines of deposition have, in fact, been obliterated, and a new series of divisional planes

Greenstone near Kala-pani.

produced. These planes are perpendicular to the deposition planes of the rock, and have a prevailing direction North-East and South-West, and nearly at right angles to this. The dip is about 25° to the South-West.

On the Northern side of this valley, the sandstones again appear, here again nearly horizontal, and forming the steep cliffs along the top of the glen. *(Plate VI).* The road winds up the steep slope of the valley side, and passes through a cleft in these sandstone beds. The greenstone forms the whole of the river bed, and extends up the side of the valley for more than one-half the distance. The lowest beds on the Northern side are coarse pebbly conglomerates, greatly indurated. Passing over the ridge into the adjoining and parallel little valley (between the Kala-pani and the Boga-pani), we lose the sandstones again, and find a continuous sheet of the greenstone forming the whole of the bottom of the glen. Upon it rest on both sides the coarse conglomerates and sandstones much indurated and disturbed. Thus under the village of Maw-be-lurkar, conglomerate is seen very highly inclined, and greatly indurated. Huge masses of this rock have in other places fallen from their natural position and threaten to block up the glen *(a)*. Toward the Northern end of this glen, the originally continuous covering of the sandstone has been denuded, so as to leave only a few small outliers resting upon the greenstone, and forming the highest tops about here. Some of these outliers are very small, not more than a few hundred feet square.

Local denudation of sandstones.

Along the line of road, the greenstone continues to show until the valley of the Boga-pani is reached. In the bed, and on the banks of the Wattam, the stream which here joins the Boga-pani (*b*), the greenstone is

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(*a*) This little valley, although in the magnitude and grandeur of its features greatly inferior to the larger glens close by, is yet one of the most beautiful in the hills, and owes not a little of this beauty to the contrast between the steep cliffs of the sandstone above with their dark and richly-coloured surfaces, and the steep grassy slopes of the greenstone below. In this valley the edges of the beds of sandstones are remarkably rounded and smoothed, as from the long continued action of water.

(*b*) Boga-pani.—Ka-um-yam, " stream of tears," because it often prevents men from crossing, or separates friends, or because it frequently carries off men in its torrent.

Kala-pani.—Ka-um-iong or black water.

well seen, but close adjoining in the glen of the larger river, there is a magnificent exhibition of the disturbances to which the mechanical rocks have been subjected.

Secondary sandstones, &c.

In the valley of the Boga-pani, and covering a considerable area adjoining, a series of very highly contorted and much altered beds of sandstones occur, which, both in their prevailing mineral composition, their colour and arrangement, appear to be totally distinct from, and also of much older date than, the sandstones near to Cherra Poonjee. The beds are at all angles, vertical and nearly flat, rolled over and bent in the most fantastic forms; several complete arches or folds are seen cut through by the river, forming a series of parallel curvings, which are even more beautifully seen owing to the different tints of the different beds (*Fig.* 7). These contortions

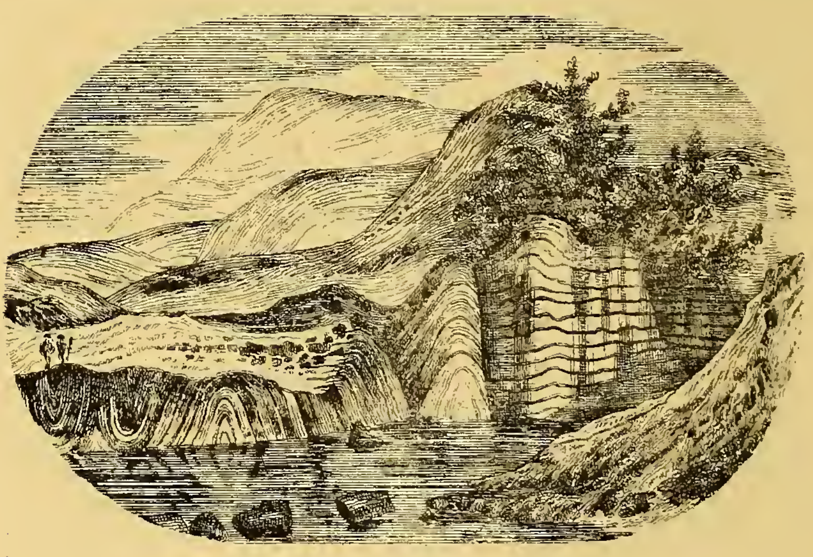

Fig. 7.

continue, though less markedly, all along the river valley. The beds of clean grits have been so indurated, as to appear quite glassy and like quartz rock; the grains still appearing distinct. The conglomerate beds also are hard, have a talcose and soapy character, and the shaly beds are more slaty. False bedding, of the same character as that seen so commonly round Cherra Poonjee, is here observable; and current-marking (*a*) is well shown on many of the beds. In mineral texture they would appear much more nearly allied to the old slates and quartz rocks before described.

Passing up to Mow-phlang, these sandstone beds continue to exhibit gradually a less amount of change as they rise upon the hill. These rocks here exhibit also a tendency to a cleavage, or divi-

Incipient cleavage.

(*a*) I have in several places in this report used the term "current marking," which I have been for many years in the habit of employing to express that peculiar structure ordinarily called "ripple-marking." This latter term is decidedly erroneous, the structure, as has been often remarked, not being the mark of a ripple, but rather a ripple itself. Current-marking is less objectionable, although the marks left by currents are so numerous, and of such various kinds, that it is scarcely definite enough. "Rippling" would probably be the simplest and best term, although even this will to many convey the idea of water being the only agent to produce such appearances. That this is not the case, the most cursory examination of a sandy beach, or of the dry sands of a river-bed, will convince any one. In fact, this peculiar structure is as frequently produced by the action of wind, as by that of water; and may often be seen as perfectly marked in the dappled clouds of the sky, as on the sea-shore. It is simply the result of the continuous passage of a fluid over materials, whose physical texture admits of free motion among their particles; this passage or current of the fluid being only of such strength or rapidity as to drive, shove, or impel these particles forward without maintaining them in suspension. Rippling ceases to occur when either the size of the particles moved or the force of the current is so altered as to alter the mode of progression of these particles. Any one, who will attentively examine the motion of the dry sand of the sea-shore, or of a river-bed, will see, that in all cases when this wavy surface is developed, the particles of the sand are regularly forced up the long and wind-ward or current-ward slope of the ripple, and reaching the top, fall by their own gravity down the steep or leeward side; the same process being again repeated with succeeding particles, so that the entire upper surface of the sand is in slow and continuous motion. A sudden increase of the force of the wind or current, such as a sudden blast, will obliterate all this wavy appearance, precisely as it would obliterate the regular and continuous waving or rippling of the surface of water; and on the wind re-assuming its normal force, this waving will be again re-produced.

sion in planes, different from the planes of bedding; along these cleavage lines many discolorations have taken place, which give the rocks a much more variegated aspect and parti-coloured look, than they would otherwise have had.

Close to the staging Bungalow at Mow-phlang, the same rocks are seen cropping out on the hill-side and dipping here at an angle of 75° to the South-East; cleavage planes show here also, and give the rocks a peculiar aspect. The prevailing direction of these planes is East and West, and they are nearly vertical.

General dip to S. E.

The same general dip of the mass of these rocks (to the South-East), with many contortions and twistings, continues all across the country East of the Boga-pani, and between Laikro and Uswirr Hill *(see Map)*, forming on the surface an undulating but tolerably level outline, but showing in bold escarpments in some of the river gorges. This is well seen in the upper portion of the valley of the Wattam stream. A few dykes of the greenstone, which is so largely developed in the lower part of this valley, cut through the sandstones and appear on the surface.

Stretching Northwards from Mow-phlang hill, the sandstones and associated beds form the level ridge along which the path to Shillong hill passes. For some distance from Mow-phlang the same intensely altered character continues in these rocks, but more Northerly the beds seem less changed (as about Sadow village), and, forming the top and some distance down the flanks of Shillong hill, we find sandstones scarcely indurated or altered at all. They are fully as soft as, and in other respects very similar to, the tertiary sandstones at Cherra.

I had no opportunity of tracing out the boundary of these sandstones here, or of examining their connection with the granite to the South of the hill.

But one of the most interesting facts in the history of these rocks is well seen in several places nearer to Mow-phlang, and between that village and Mawreng. I allude to the occurrence of veins of granite piercing them. These veins are in places one to two feet thick, but generally smaller; they bifurcate and pass across the bedding of the rocks, or along the planes of deposition; these planes being much contorted. The veinstone is a highly felspathic, but smally crystalline granite; mica black and brilliant; the quartz greyish-white, and the felspar with a slight pinkish tint. This is the only place where I have seen this fact exhibited.

Veins of granite in these sandstones.

Unfortunately no organic remains whatever have been observed in this group of highly altered sandstones; and I had no opportunity of examining more than a limited area, within which the actual connection of these sandstones with the decidedly tertiary beds of the vicinity of Cherra Poonjee could not be traced. But, taking into consideration the horizontal and undisturbed position of the tertiary group, as contrasted with the strangely contorted and upturned arrangement of the other, the loosely coherent and soft nature of the one as compared with the intensely hardened and metamorphic character of the other; and the fact just mentioned that these altered sandstones are penetrated by granite veins, while the tertiary sandstones rest undisturbed upon the unequally denuded surface of granite, I have little hesitation in thinking that there may be here remaining portions of a much older group of rocks: possibly, the representatives of some of the rocks which occur in Central India and elsewhere.

Probable age.

This important question can only be solved by a careful survey of the country to the West and South from Mow-phlang, which I was unable to visit.

Separated by some miles distance from the sandstones near to Mow-phlang, and forming an isolated cap of very limited area, on the hill close to the village of Nungbri are some beds of coarse soft grits, of a yellowish-red tint, with finer sandstones and thin earthy layers. The total thickness of these

Outliers of tertiary sandstones.

beds is not more than 50 feet. A similar cap of very similar sandstones forms a long, narrow, flat-topped ridge, on which the villages of Maw-sutai and Laidom are placed, about three miles North of Myrung. This ridge stretches nearly East and West for about two miles, but with a very irregular outline, and contrasts well with the wavy surface of the adjoining country by its flat top and scarped sides, seen best from the North. The extreme thickness of the beds of sandstone here does not exceed 100 feet. No fossils were found in these sandstones, with the exception of a few very imperfect impressions in one of the beds near Nungbri, much too indistinct for identification, but which appeared to be similar to those found in the Cherra Poonjee beds. They were all vegetable remains. In the absence, therefore, of any fossil evidence, and arguing only from the mineralogical character of these beds, without the occurrence of any well-marked layer admitting of identification at distant points, it is impossible to assert, positively, that these sandstones at Nungbri and at Laidom belong unquestionably to the same series as the Cherra rocks; although I believe such to be the case, and that these caps of sandstone are only the now detached and outlying remnants of a once extensive series of beds which stretched continuously over these hills, and which have been subsequently denuded. These patches remain as a measure by which we can estimate the amount of matter which has been removed.

Extent toward the East of hills.

Sandstones similar to those occurring near Cherra Poonjee are seen along the Southern flank of the hill range, as far Eastwards as Burr-ghat, and from this they continue still further in the same direction. I have only had an opportunity of visiting these districts to the East during two trips, in one of which I passed up from the plains to Joowai, and in the other went down from the hills by the ridge of Molih, Nonkradem, and Kung-diah, to Lacat. I can therefore only speak of the rocks exhibited in these two sections, although there is no question that the same group of rocks continues all along.

To the North of Nonkradem, the ridge on which that village is situated is separated from the similar level ground further to the North by a deep transverse glen (seen in foreground of Fig. 8) in which gneissose and schistose rocks are well

Outliers near Nonkradem.

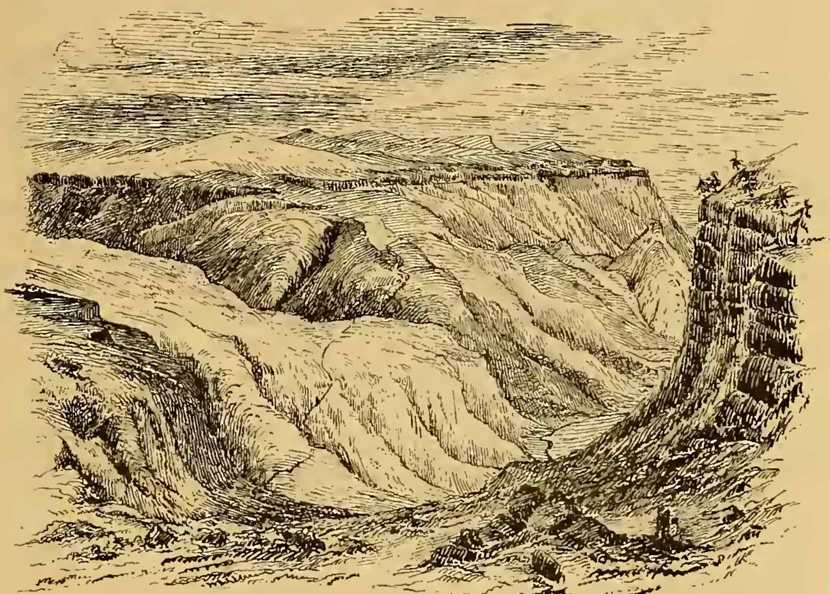

Fig. 8.

exposed. Resting nearly horizontally upon these and forming a cap on their up-turned edges, the sandstones stretch almost continuously from this to Lacat. At the northern extremity of this broad flat ridge, where the ground narrows by the approach of the deep valleys on either side, this sheet of sandstone is divided into several small outliers separated by slight depressions in the ridge: some of these are not more than 100 yards square. But, proceeding to the South, the sandstones gradually become much thicker and form the entire surface. About Molih they form thick beds of red ferruginous grits alternating with shaly beds and clays. Close to the village to the North, some traces of coaly layers are seen.

The same ferruginous sandstones, associated with black pyritous shale, continue to show along the ridge towards the South. In the sandstone beds there are frequent nodular concretions, highly ferruginous. The beds continue nearly horizontal, but are occasionally inclined from 15° to 20°. Passing Southward to a small village called Tung-ji-nath, we find these dark red ferruginous sandstones resting upon other beds of a much lighter tint. Associated with the latter there is a bed of good *coal* about three feet six inches thick on an average *(a)*. It is seen in a deep croom or ravine close to the village of Tung-ji-nath. The section of the rocks immediately with the coal is as follows, in descending order :—

Ferruginous beds with coal.

| | | ft. | in. |
|---|---|---|---|
| Hard ferruginous grits, ... ... ... ... ... | | | |
| Light reddish sandstone, ... ... ... ... | | 35 | 0 |
| Dark-coloured shaly sandstone in thin laminæ, | | 2 | 6 |
| Sandstone of darkish colour, ... ... ... ... | | 1 | 0 |
| Dark-coloured shale, thinly laminated, | 2 0 to | 1 | 6 |
| Coal, ... ... ... ... ... ... | 4 0 to | 3 | 6 |
| Black shale in thin layers, ... ... ... ... | | 0 | 6 |
| Soft dark sandstone, micaceous and carbonaceous (thickness not seen). | | | |

Quality, &c., of Coal

This coal seems very similar in quality and character to the Cherra coal. The bed is partially exposed for about forty feet on the face, and in this short space it varies in thickness from four feet to three feet and a half: and within a few yards of this to the West it has thinned out to one foot and a half. Towards the East, as far as it is seen, it continues of tolerably even thickness. It dips very slightly to the East by North ; dense close jungle prevented me from tracing it much further (*b*).

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*(a)* From this bed subsequently to the date of my report, a considerable quantity of coal was extracted and despatched to Calcutta.

*(b)* From large slabs of the thin-bedded sandstones of the neighbourhood, the defences of Molih are built. These slabs are placed on edge and side by side, and form a wall about six feet high. Through this the entrance to the village is by a well-constructed and covered gateway. The whole forms a rude defence, of little value certainly in the modern system of attack, but which would have afforded a great protection against the arrows of any hostile clan.

The hill drops suddenly for about 400 feet close to this village on the South, and below this there is a slightly undulating plateau very similar to that of the Mahadeo, South of Cherra Poonjee. This continues to the River Kowa-i-assa, a short distance North of the village of Kungdiah *(a)*. Sandstones of varied coarseness, with softer and shaly beds between, continue all along, until, about a mile North of Kungdiah, beds of soft fossiliferous sandstone, slightly calcareous, appear. The shells are preserved in carbonate of lime, and are well seen from the contrast of their white colour with the dark greenish-brown tint of the rock. Traces of coal occur close to Kungdiah.

Near Lacat.

From this to the plains at Lacat, nothing but sandstones are visible, for the most part ferruginous and gritty; some pebbly conglomerate beds are also seen. In the upper portion of this section, no limestone is seen corresponding to that at the station of Cherra, nor does it show immediately at Lacat, although abundantly worked at a short distance to the West of that place.

Near Lakadong.

Further to the East below Lakadong the same series of rocks is seen: passing from Burr-ghat, where a thick coarse conglomerate occurs (similar to that at the base of the sandstone group near Cherra) through a series of sandstones of varying mineral character, but markedly similar to the succession at Cherra. The same varieties of organic remains are here found also: and the same beds marked by the presence of plicated oysters and of echini. These beds occur at about the same distance below the nummulitic limestone, over which the coal of Lakadong is found. In other respects also, the parallelism of this lower bed of limestone at Lakadong, and of the series of sandstone beds beneath it, with the limestones and underlying sandstone of the Cherra series, appears to be completely established.

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(*a*) Singh Manick, the Kyrim Rajah, generally resided here, in preference to Nonkradem, the principal town of his territories.

I have before alluded to the extension of these sandstone beds towards the North from Lakadong. About three miles North from Rombai, slaty sandstone and dark carbonaceous shales occur nearly horizontal. They are well seen in the small rivers or streams. The slaty beds are shining and micaceous. The country about here and towards Rombai *(a)* is chiefly grassy table land, a large proportion of which is under cultivation. The same character, with the interruption of a few rounded dells or glens, continues to near the village of Bappung. These glens have a remarkably regular and constant direction, all bearing nearly due North-East and South-West, the steep scarp of the rocks in all cases facing the North, while the Southern ridge slopes gradually away. North of the village of Bappung, and a very short distance from it, there is a well-marked ridge formed of horizontal beds of sandstone, with a few shaly partings, sometimes dark-coloured, nearly black and carbonaceous, with glistening specks of mica. This ridge has a curiously-rounded outline, and is eaten into regular re-entering angles and bays, like a shore long exposed to the wash of the ocean waves. Not far from Bappung, in a low flat depression to the West and North-West, granite is seen. It is largely crystalline, and somewhat porphyritic, and in general aspect very similar (though not quite so large in grain) to that near Lailangkot, North of Cherra. Its connexion with the sandstones is not very clearly seen. North of this, the rounded hills are again composed of horizontal sandstones occasionally conglomeratic, and frequently presenting fine instances of false-bedding. This latter is common also in the beds to the South.

And to the North.

Similar sandstones and conglomerates are seen stretching along the top of the hills, bounding the valley of the Mentedoo River, in horizontal beds, resting unconformably on the up-turned and degraded edges of

Along valley of the Mentedoo.

*(a)* About four miles North from Rombai, pines *(Pinus chinensis)* first appear; they become plentiful, large and healthy, a little North of Bappung.

the beds of gneissose slate. (Fig. 9.) The lower beds here are con-

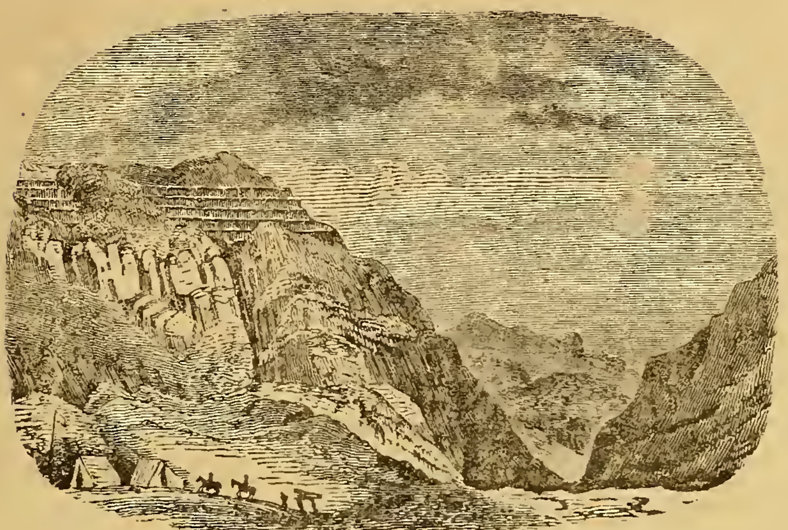


Fig. 9

glomeratic, occasionally coarse; large rounded pebbles of quartz, and *also of the hard gritty gneissose beds below*, being imbedded in a fine sandstone. This character changes to a fine gritty sandstone, formed of sharply angular pebbles of quartz in regular layers. Intercalated with these, are some slaty beds very irregularly developed, occasionally carbonaceous, dark-coloured, and micaceous; occasionally light-coloured, compact and earthy. Deep ferruginous stains are frequent, and the rocks have often, in consequence, a very variegated tint. The beds here are perfectly horizontal.

The country between Nonkradem and Joowai, I had no opportunity of visiting. The same sandstones, which I have been describing, evidently continue across; cut into, and denuded by the deep river gorges, in which the other and older rocks are exposed. And the same rocks appear also to continue further to the East from Lakadong.

Tertiary Limestone.

I have already alluded incidentally to the occurrence of limestone near to the station of Cherra Poonjee and elsewhere in the Khasi hills, and, the relations of the limestone to the coal at Lakadong in the Jynteah hills, will be pointed out. But the importance of these limestones, both in a geological and in a practical point of view, calls for a more detailed description.

Near Cherra Poonjee.

The limestone is well seen in the small isolated ridge bounding the station of Cherra Poonjee to the South-West. This little ridge rises with a steep and perpendicular escarpment from the level ground of the station. Along its base an irregular talus of fallen masses of limestone, coal, and sandstone conceals the actual junction of its lower beds with the sandstone beneath. In one or two points this is indistinctly seen, and a bed of hard blue stiff clay, only a few inches thick, separates the mass of the limestone from the sandstone, on which it rests perfectly conformably; and is like it, therefore, nearly horizontal. The thickness of the limestone beds here is at least 75 feet. In the texture and character of the beds slight differences are traceable, but these are not remarkable. As a whole, it is similar throughout, compact, of a grey-blue colour, hard and splintery, with an irregular conchoidal fracture. It is generally thin-bedded, but some of the beds attain a thickness of two and three feet: these thicker masses are, however, frequently divisible into others, the partings being well seen when the rock has been weathered. The uppermost beds are a little more earthy in composition, and between these beds and the mass of thin bedded limestone below, there is locally a thin (from half an inch to one and half inch) layer of calcareous sandstone interposed. This is not, however, constant. Throughout the whole of these beds fossils are found. In the compact layers, these do not show on the fresh fracture of the stone, the shells or other remains being entirely replaced by the limestone; while

Fossils.

in the more earthy beds they become distinct, and easily recognizable. In the lower beds small, nearly globular, echini *(Echinolampas)* are abundant, associated with turrited gasteropoda *(Cerithium, Turritella, &c.)* occasionally of good size. Above this, small corals with nummulites, principally *N. spira,* are more prevalent, while in the upper layers there is a greater variety of shells. Pectens of small size and invariably in single valves occur; also Turritella, Naticæ, Patella (?) associated with Nummulites. The latter go through the entire series of beds.

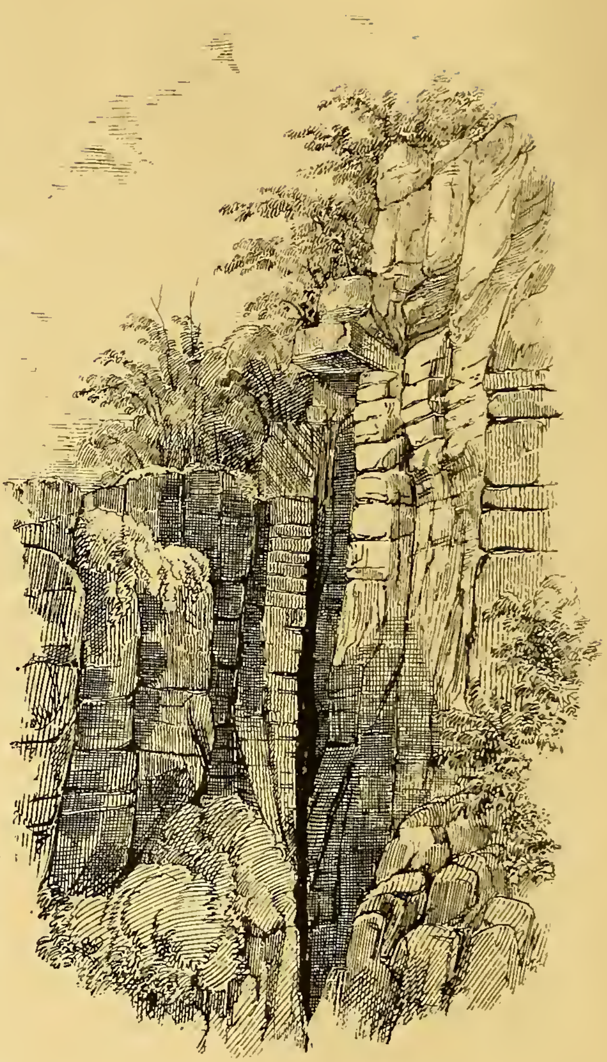
Extent of limestone.

The limestone beds stretch with an irregular outline, but with a similar bluff escarpment throughout, Westwards to near the village of Mawm'luh. From this the outcrop turns again Eastwards, and passes to near Mawsmai. Along this face, and more especially towards Mawsmai, the limestone cliffs are much less regular, being broken up by numerous fallen masses, which stretch out from the main mass of the rock, and are thrown into the most irregular and fantastic outlines; the beauty of which is greatly increased by the curious shapes into which the masses decompose, and by the richly-varied tints, which the moss-clothed rocks present. The whole is thickly covered with wood. Again, turning Northwards towards Cherra, the mass of the limestone has been denuded along the depression through which the road passes, and is found in a small detached outlier to the East of it.

Direction of escarpment.

We shall notice again the direction of some of these cliffs of limestone, and the probable cause of this direction. Parallel to the principal faces of these escarpments we find a series of jointing planes or fissures, accompanied by slight disturbances in the position of the beds. Some of these are well seen along the face of the cliffs West of the station, and produce very beautiful pictorial effects, the fern-clad sides of the deep clefts being brought strongly into contrast with the sunless depths of the chink beneath. (Fig. 10.)

Fig. 10.



Independently of the clear evidence which these steep escarpments of the limestone afford of the long continued denuding action along the base of these cliffs totally different from the ordinary causes now in operation to degrade and remove these rocks, there is further proof of their having been subjected to much local excavation by running water in the several large caves which penetrate these rocks; and whose smooth and polished marble-like sides, at once indicate the force which has excavated them. Of these the most remarkable are those near Mawm'luh and near Mawsmai at opposite sides of the ridge. That these caves or excavations in the

Denudation, great caves, &c.

limestone were formerly much more numerous, may also be inferred from the many sudden and sometimes nearly circular depressions which occur on this ridge, and which have obviously been caused by the falling of the rocks above into a hollow or excavation below, from which they have subsequently been gradually removed. The same process is still in operation to produce similar effects, though on a minor scale. The

Subterranean streams.

waters of the many streams which disappear underground in the adjoining district, are undoubtedly gradually excavating the rocks beneath, and the support being removed from the upper beds these must inevitably fall in, and be themselves gradually removed.*(a)*

Limestone at base of hills.

Limestone, very similar to that which occurs at Cherra Poonjee, is found in large quantity at a much lower elevation on the hill side. At the village of Tungwai (Tingye) there is a great extent of this rock exposed, and here there are large quarries from which many thousands of maunds of this stone are annually removed. The limestone stretches from this up the hill side for some distance. In general aspect and character it is very similar to the limestone at Cherra, but presents in its lower beds some marked differences. The occurrence of much larger nummulites, and of a large Ovula (*O. depressa*) are among these. These differences are very much less marked at Tungwai than to the East of the Walingtia River, where there are immense quarries of limestone. Here the larger nummulites (*N. spira*) become much more abundant, and are almost the only fossil found in these beds. In other beds above these, the smaller foraminifera abound, and also fossils very similar to those found at Cherra Poonjee. The abundance of some of these small foraminifera, which form nearly the entire mass of some of the beds, give the layers at first sight an oolitic

*(a)* In several places in this neighbourhood considerable streams go underground for some distance. The stream seen in *Fig.* 13 passes in this way under the cliff of limestone and coal.

character, although, where the surface is a little weathered, the cause of this structure becomes evident.

Limestone at Lakadong.

*Near Lakadong.*—I have already mentioned the mode of occurrence of the limestone at Lakadong; it is in every respect similar to that at Cherra Poonjee. At Lakadong, however, there are two distinct deposits: one occurring under the coal of that place, and being, I believe, the parallel of the limestone at Cherra: and the other, above the coal and overlying sandstones. Of the latter deposit, which at Lakadong attains a thickness of at least 50 feet, there appears to be no representative at Cherra Poonjee.

Again, precisely as at Cherra Poonjee great deposits of a nummulitic limestone are found at the base of the hills, so below Lakadong there is a great extent of similar limestone. This is seen on the banks of the Harry River, North of the village of Pichadar Poonjee. The beds here dip at a high angle (55° to 65°) to the South, and support a great thickness of sandstones and shaly beds, which are all conformable to the limestone below.(a) To these deposits of limestone and their mode of occurrence, I shall again refer.

Ancient denudation of the limestones.

Reverting to the nummulitic limestones of Cherra, there are some very interesting appearances presented by the upper portion of the deposit. In the mass of the upper beds (which, as I have mentioned, are more earthy than the lower), there are imbedded several small patches of coal and coaly mud. The upper surface of the limestone is also very irregular; and here and there filling up the hollows in this wavy surface, and covered by the sandstone, are thin pieces of coal and coaly shale. In one place the upper beds of the limestone have been removed to the depth of some feet, in the form of a channel or gully, as if by the action of a stream: and this gully has subsequently been filled in

(a) Having merely seen these beds in passing up the stream, I cannot enter into any details regarding them.

with the sand now forming the beds of sandstone overlying the limestone. These deposits of sand have naturally conformed to the surfaces of the hollow into which they have been carried, but the upper surface of each successive layer has gradually become more and more level, the saud necessarily accumulating in greater mass in the hollows, until, at a distance of about four feet from the general surface of the limestone below, the beds have again become regular and horizontal. This remarkable depression in the limestone, coincides with a crack or joint which passes nearly vertically through all the beds below, but along which there is no dislocation or faulting (Fig. 11). That the

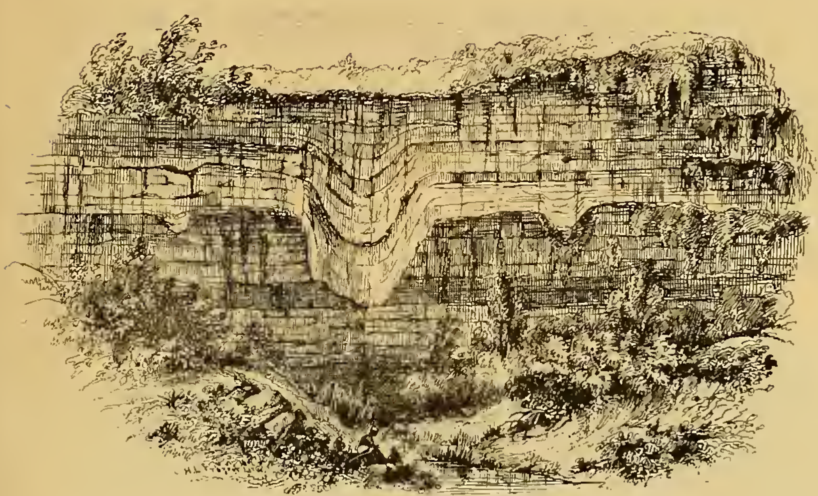


Fig. 11.

limestone beds must have been considerably indurated or at least desiccated, previously to this excavation taking place, is evident from the sharp and unbroken edges with which the horizontal layers of the limestone come against the sides of the sandstone filling the hollow. No soft mud, such as these limestone beds originally consisted of, could have remained at the steep angle of the sides of this gully. And I think it also evident, from similar reasoning, that the same forces which produced the excavation in the limestone must have continued in operation during a portion at least of the time occupied in the deposition of the sandstones above. The surface of the limestone has been subjected to a wearing action of a similar kind, but in a slighter degree, in several other places closely adjoining *(see Fig.)* It is therefore clear that while all the organic remains contained in the limestone point to its marine origin, although under no great depth of water, the occurrence of the imbedded patches of coal in its upper beds, and of the small and isolated pieces of coaly matter filling up the hollows on its surface, and the peculiar way in which it has been excavated as by a running stream, combine to show that it must have been brought to the surface and subjected to sub-aerial forces prior to the deposition of the overlying sandstones.

Coal, &c.

Resting immediately on the limestone which we have just described, there is a group of alternating beds of sandstones, shales and coal, which form the uppermost beds of the small ridge in which they occur. The section is as follows, under the surface :—

| | ft. | in. |
|---|---|---|
| Earthy sandstone beds, covered with jungle ... | | |
| Sandstone slightly tinted red ... ... ... ... ... | 6 | 0 |
| Shaly sandstone whitish and grey ... ... ... ... | 1 | 0 |
| Sandstone, earthy and ferruginous, with concretions of ironstone ... ... ... ... ... ... ... | 2 | 0 |
| Grit, free and open grained, softer towards top ... | 2 | 6 |
| Sandy shales, thin-bedded ... ... ... ... ...... | 1 | 0 |
| White grit, sharp and angular, no cement ... ... | 7 | 0 |
| Coal ... ... ... ... ... ... ... ... ... ... | 3 | 0 |
| Shale greyish-black with fragmentary impressions of vegetable remains ... ... ... ... ... ... ... | 1 | 6 |
| Sandstone, hard, ferruginous and nodular... ... ... | 2 | 0 |

| | ft. in. |
|---|---|
| Sandstone, thin shaly beds with carbonaceous particles, giving a blackish-grey colour to the rock; beds very irregularly developed ... ... | 1 0 to 2 0 |
| Ferruginous sandstone ... ... ... ... ... ...... | 3 0 |
| Thin-bedded earthy sandstones ... ... ... | 1 0 to 2 0 |
| Sandstone, hard, ferruginous, and earthy, very irregular and varying from ... ... ... ... | 3 0 to 6 0 |
| Limestone (as described above.) | |

Character of coal beds.

The coal seen in the foregoing section becomes in the lower part of the bed very shaly, and passes into the grey shale on which it rests. A little to the South of this section (which is taken just above the cliff of limestone facing the station of Cherra), this thick bed of coal, which is here of uniform quality throughout, becomes split up by several small intercalated layers and wedge-shaped masses of sandstone. These gradually increase to the detriment of the coal, and shortly after the coal has died out altogether. In the coal itself iron pyrites occurs, disseminated and in

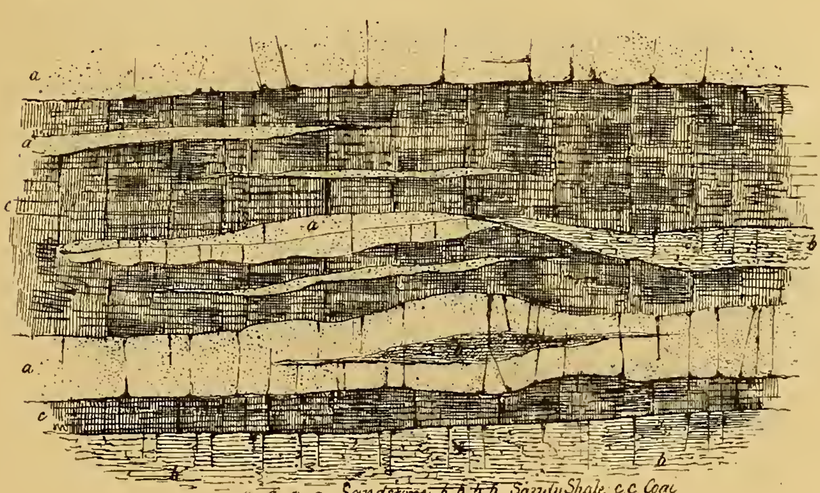



Fig.12.

crystalline lumps: it is found in all parts of the bed, both near the top and bottom, but chiefly the latter. It is not however very abundant. The accompanying sketch of a part of the coal-bed will show its appearance where the intercalated sandstone is partially seen (Fig. 12). The roof of the coal is a thick bed of whitish clean grit, composed of sharp angular quartz grains, entirely without any perceptible cement. It is occasionally coloured with deep ferruginous stains.

Horizontal; worked by adits.

The whole series of beds is very nearly horizontal, and is sharply scarped on its outcropping edges. The coal has been extracted by means of adits driven in horizontally on the bed, and the position of the seam has enabled the required drainage of the mines to be effected with very little trouble or expense. The entrances to some of these adits are seen in the accompanying sketch of a portion of the ridge seen from the North, and which also shows the general position of the mines (Fig. 13).

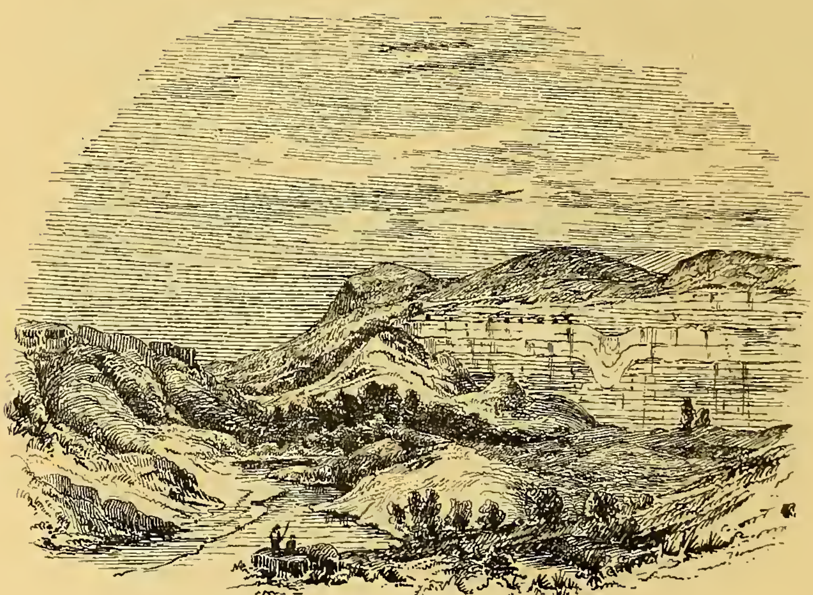


*Fig. 13.*

Coal is also seen near to Cherra Poonjee exposed on the road-side at the Northern extremity of the native village; again about half a mile further on traces of coal are seen, but in both these places it seems too much disturbed and too irregular to be of any value.

Coal near Cherra Poonjee village.

Coal again occurs further to the North near the little village of Surareem on the road-side, but in very small quantity. This out-crop would seem to be connected with the thick bed which shows under the village of Lairungoo, in the face of the steep glen, towards the East *(see Fig. 1)*. Close under the Southern end of the village, this bed of coal is six feet thick, dipping about four degrees towards the North-West. The seat of the coal here is dark carbonaceous shale, with fragmentary vegetable remains highly carbonized, about one foot thick: under this is a reddish-grey sandstone. Passing Northward along the face of the cliff, the coal thins out to one foot, and again increases to five feet. Owing to the thick covering of forest and of fallen debris, the section is not very easily made out. Limestone of precisely the same character as that at Cherra Poonjee, and containing nummulites and other similar fossils, occurs under the coal; separated as at Cherra Poonjee by thin-bedded and strong sandstones. The much greater distance of this bed of coal from the plains, and the greater elevation at which it occurs, will prevent its being economically used, excepting for local supply.

Near Surareem.

Coal is also found at, or near to, the village of Bairung, South of Cherra Poonjee; and at a much less elevation (1,250 feet above the sea level). It is seen in a deep dell, or kind of amphitheatre, in the rocks. Imbedded in sandstone there are some few irregular appearances of the coal. It has been slightly opened out, and worked. The dip is from 3° to 5° to the South. The *coal* occurs in irregular beds of carbonaceous mud, mixed with sand and clay, with occasional patches of tolerably good coal imbedded. It

Near Bairung.

is in three distinct layers, and the section in descending order, is as follows:—

| | ft. | in. |
|---|---|---|
| Thick-bedded sandstone ... ... ... ... .. | | |
| Sandstone, hard and fine-grained ... ... ... ... | 1 | 4 |
| Coal, tolerably good, from 8 in. to ... .. ... | 1 | 6 |
| Coal, or a carbonaceous mud, with many carbonaceous particles imbedded, so as to be slightly inflammable ... ... ... ... ... 3 0 to | 6 | 0 |
| Sandstone, (clean sharp freestone) ... ... ... ... | 11 | 0 |
| Coal irregularly bedded, soft and earthy ... ... | 1 | 6 |

From this section it will at once be evident, that no good coal can be looked for from this deposit.

I had no opportunity of visiting the coal said to occur near to Cheyla, and further to the Westward near Laour. I have already referred to the coal found close to the village of Tung-ji-nath, South of Nonkradem, and still further to the East.

Near Cheyla and Laour.

As regards the extent of the Cherra Poonjee bed, which is the most important, it follows the ridge of the limestone (see Map), and crops out at intervals round its bluff escarpment. Thus the coal is seen at the most Northerly point of this ridge, and again near to the road from Cherra Poonjee to Maw'smai. But independently of the very irregular development of the coal itself, and the want of continuity in the bed originally, a large portion of the surface included within the outline of the limestone, as shown on the Map, has been susbequently denuded of the upper beds of sandstone, coal, &c., while, as I have already noticed, other portions have been removed by falling into, and filling, large cave-like excavations in the underlying limestone. I shall have occasion to refer again to this question of the amount of coal to be found here.

Extent of Coal at Cherra.

A fault, or rather a group of two or three small faults, cuts this ridge and has upthrown the coal, limestone, &c., on the West about forty feet. This fault heads North 35° East or nearly North-East. It is rudely parallel with the face of the ridge on the West, which has itself in all probability been the result of the degrading forces having acted upon or against a line of division in the mass of the rocks. The main joints in the limestone have also the same direction.

Fault.

Near Lakadong.

Coal occurs at Lakadong in the Jynteah hills, and has been worked to some extent.

The village (Lakadong) is situated on a small elevated plateau or level space, surrounded on all sides by crooms or valleys, some of which are deep. In the centre of this level space rises an irregular wooded hillock, chiefly composed of thick-bedded limestone, which crops out boldly on its sides. (Plate IX.)

Position of Lakadong.

By the road or path, Lakadong is distant from Burr-ghat on the Hurry river about 7 to 7½ miles, and is at an elevation of about 2,350 feet above the level of the sea, or about 1,800 feet lower than Cherra. At Burr-ghat the road meets the river, and here the coal can be transferred to boats.

Mode of occurrence.

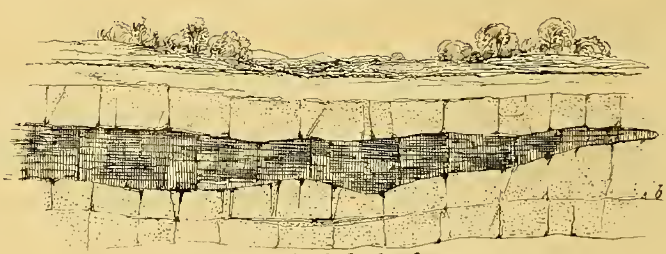
Round the small plateau of Lakadong, the coal is seen in several places, appearing in the face of the crooms, as well as in a few small pit-like hollows in the middle of the level ground. The whole area included in this plateau does not amount to one square mile. Under the greater portion of this space a bed of coal appears to spread, though very irregularly developed, and of this only a very small portion has hitherto been extracted.

Close to the village itself (at *a* on plan) the coal is exposed in a small water-course. It is here about five feet thick, dipping at a small angle (4° to 6°) towards North by East with a sandstone roof and floor. The roof is of sharp gritty texture, ferruginous, quartzose, and hard ;

white and reddish in colour; irregularly bedded ,but firm, and would form an excellent mining roof; under this from twelve to fifteen inches of good coal; then about twelve inches of hard black micaceous shale, difficult to work; then about three feet of good coal, mixed here and there with sandy masses, similar to those which occur in the lower portion of the Cherra coal and at Bairung.

West of this (at *b* on plan) there is a deep pit-like hollow, overgrown with jungle, whence some coal has been extracted. The bed where thickest (to the North) is about three feet, not bad coal, though fragmentary, but it rapidly and within fifteen to twenty feet thins out to one foot, and then dies away altogether. There is no appearance of any fault or break, a very slight "trouble" which heads East and West being all that is visible. A deep hole here pierces to the beds below, and appears to me to have principally resulted from the falling-in of the rock in all probability into a large cavity or open space in the limestone beneath.

The roof of the coal is here, as before, sandstone, but it appears somewhat softer and less coherent. The accompanying sketch (Fig. 14) will give an idea of the irregular manner in which the coal is developed.




*a a Coal. b b Sandstone.*

Fig. 14.

The dip here is N. 10° E. at about 5°.

To the North of this (at *c*) another working has been opened in the face of a deep glen or croom, where the coal is of considerable thickness and in great mass, but as in the other localities, very irregular. There appear at first to be two beds here; but I am disposed to consider it all the same bed. This appearance arises from the same parting of hard black shale, which when first seen was not more than a foot in thickness, having here assumed a thickness of not less than two feet six inches to three feet, and being used as a division between the series of workings. The coal has been wrought in open adits. The upper portion or bed is about four feet ten inches to five feet thick; it is fragile soft, and easily broken, and produces in working a very large amount of small coal, I should say very nearly one-half, certainly one-third. Under this is the parting of hard shale varying from two feet three inches to three feet in thickness, below which there are again other adits driven into the coal below. This lower bed is in one place at least eight feet thick, but within a short space it dwindles to four feet. The roof of the coal here is sandstone, of the same lithological character as in the other localities. It is from seven to eight feet thick. The floor is composed of sandstone, in irregular beds, less gritty than that above the coal. About eighteen feet below the coal and these irregular beds of sandstone, we find thick limestone full of nummulites, and in every other respect similar to the limestone under the coal at Cherra. We are enabled to see this by the falling-in of an old cave in the limestone, by which a deep hole has been formed towards the northern end of the croom. The coal in this locality dips slightly to the North-East, but, from the irregular development of the beds, it is difficult to say that it has any definite dip at all.

Precisely the same beds have again been worked a little to the North of this (about 50 yards), dipping here 30° South of East at an angle of 8°. They have scarcely been cut into, the excavation not having extended more than four feet from the face of the rock. There is here a similar parting of hard shale, of about the same thickness, and of the same lithological character as in the other localities.

A short distance to the North-East of this, another nearly circular pit or croom exposes the same coal again (at *d* on plan). In one place the bed is from eight to ten feet thick, while within less than twenty feet it dwindles down to one foot. At the Southern end of the croom a fault or slip, the walls of which are very irregular, cuts it off altogether. This break crosses the rocks from North-East by East to South-West by West. The same nummulitic limestone as before is here seen at about the same distance below the coal, eighteen to twenty feet. The accompanying sketch (Fig. 15) represents the mode of occurrence of the coal.

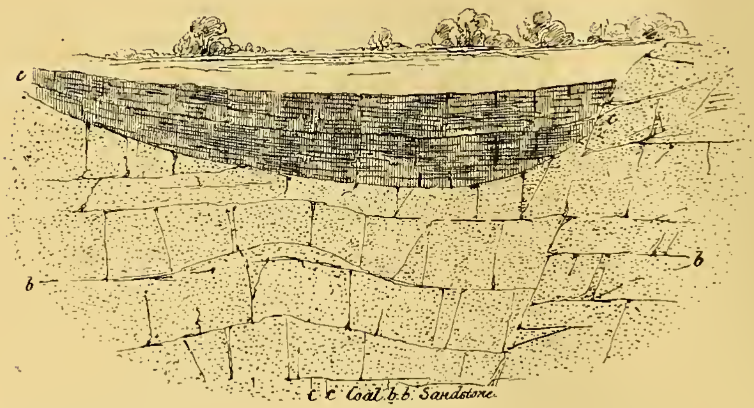



Fig. 15.

The most extensive workings as yet opened are situated Eastward of this, on the side of a deep croom facing to the East (at *e* on plan). Here the coal has been excavated in five headings, which have been carried in some distance (about 9 fathoms). The coal is about seven feet thick and of good quality: but it varies, and in one of the headings sandstone appears, cutting off the coal for half its thickness, and having much the appearance of being the result of a slip-fault. It has not been opened sufficiently to make this clear. The beds dip slightly 1° or 2° to the N. N. E. The workings have been carried up towards the out-crop, or on the rise of the coal, and a considerable portion of the coal immediately accessible here has been, I should think, worked out.

There are also a few small breaks in the coal, up-throws chiefly, shifting it a foot or so. These head with the dip, or direction of inclination of the coal.

Detached from all these localities, and South and West of the rising ground in the centre of the table-land, are two open crooms or hollows. The one (at *f* on plan) most Northerly is very small, and at about thirty feet below the surface is a very irregular mass of coal imbedded in sandstone; a fault here passes across the rocks from North-East to South-West, and cuts all off. In the other (at *g* on plan), still to the South of this, a bed of coal is seen continuing for about one hundred feet, not more than three feet thick, in places not more than one. It is poor coal; the roof is of sandstone, yellowish, red in colour and ferruginous. The floor of dark slaty shale, slightly micaceous, dipping slightly into the hill. The edge of the croom runs North 30° West, and, judging from the smoothed and scratched surface of the rocks, it appears to be formed by a break running in that direction.

In addition to all these there are two other crooms to the East of the village, and close to it, where a thick bed of coal is seen, but has been scarcely worked at all. (These are marked *g* on plan.)

Different beds.

North-East of the village, and distant about 2¼ miles, another thick bed of coal is visible. I was informed by the Khasis who showed me this coal that no other European had previously seen it. The coal is in parts even twelve feet thick, but it thins out again within a short space to three feet, and even less. The roof and floor are here, as in the other localities, of sandstone, dipping very slightly to the North or West. This coal is at least two miles further from Burr-ghat than the coal at the village of Lakadong; but the Khasis asserted that it could be conveyed to the river at the same rate as from the village.

Such is the mode of occurrence of this coal and of its associated rocks. As regards the quality of the Lakadong coal, it is very similar to that from Cherra. It burns briskly, blazes freely, leaves very little ash, and possesses considerable heating and illuminating power. But for domestic purposes, it is a remarkably good, lively, and cleanly coal, like that from Cherra; however, it is open to the serious objection of being very brittle and disintegrating readily. The whole mass of the coal is traversed by very numerous little cracks or fissures, which tend to split it up into smaller portions, and these fissures not preserving that parallelism and regularity which render the "backs" in most English coal such an advantage in the working of them, but traversing the mass in every direction, it results that not only is there a considerable waste in the amount of small coal produced by the excavation, but also that the large coal is itself procured in blocks of irregular form, and consequently ill-adapted for convenient stowage.

This, with the fragile nature of the coal, will, I am convinced, so far as *sea-going* steamers are concerned, fully counterbalance the advantages which this coal has over some other Indian coals as regards heating power; but this objection is much less forcible as regards river steamers, or for stationary engines.

As regards the *quantity* of coal existing in the field, it is difficult to form anything like a very accurate estimate, owing to the great irregularity of its development; but we may, I think, fairly calculate the quantity of coal easily accessible as being equal to one-half a square mile with an average thickness of three feet, which would give about 1,500,000 cubic yards of coal, or about 40,500,000 cubic feet or maunds. But, even granting that this estimate is beyond the actual fact, there can be no doubt that there is a sufficient quantity to meet the demands of many years to come.

Igneous Rocks.—Granite.—In describing the sedimentary rocks

Extent of area.

in the preceding pages, I have in several places incidentally referred to the occurrence of granite, both in veins and in mass. The largest area of this rock which occurs in that portion of these hills we have visited, is near to the large iron-washing villages of Molīm and Nonkrīm. Its boundary stretches with an irregular outline from the Southern flanks of Shillong hill, passing the villages of Lungqueer and Mawreng, and crossing the Boga-pani a little North of Laikro. From this the boundary turns Eastwards, and skirts the river on the Southern bank towards the village of Lailangkot. Another large granitic area occurs to the West of this, stretching from the village of Lybersai, South of the ridge on which are placed the villages of Cockleederah and Cudderah, towards Lunkoi.

General composition.

Throughout this area, the lithological character of this rock is tolerably persistent. It is a highly felspathic and largely crystalline rock: the felspar being of two kinds, one whitish-pink, which together with the other ingredients forms the general mass of the rock, the other of a deep flesh-red colour in large crystals, which, imbedded in the general mass of rock, give it a porphyritic character. The quartz is generally of a greyish-white tint, but not abundant, the mica blackish and greenish-black. Hornblende does occur, but is rare. The granite frequently presents also another character, often seen in such rocks, namely, the occurrence of large masses of a harder texture, and slighlty different proportional composition, imbedded in the general mass. These masses are never so largely crystalline as the ordinary granite adjoining. Owing to the large amount of felspar which enters into the composition of the granite, it decomposes readily, and for a depth of many feet from the surface is quite soft and incoherent.

Iron occurs imbedded.

Imbedded in the mass, and almost as constant an ingredient in the composition of the rock as any of the other minerals, occur small crystalline grains of titaniferous iron, which, from their abundance locally, give the rock a very spotted aspect. They are not equally distributed, being absent or comparatively absent in the harder concretionary masses, and abundant in the adjoining softer portions of the rock. There is no vein of this ore, but it occurs freely disseminated, and associated with the other minerals. It appears, on the whole, to be more abundant near to the junction of the granite with the overlying rocks than elsewhere. As yet no excavations have been made to any depth sufficient to enable an opinion to be formed, as to whether the presence of this ore continues in depth or not.

Mode of extraction.

The simple mode of extracting this ore from the granite, adopted by the Khasis, is to loosen the soft and partially decomposed granite, with a long iron rake, and suffer the loosened masses and sand to fall into a running stream below, by which the disintegrated particles are still further separated, and the lighter minerals being carried away, the heavier portions including all the iron ore remain, to be again more carefully separated by repeated washings. In this process, the softer portions only of the rock being removed, the huge lumps and masses of harder consistency, being deprived of their support, fall and remain heaped around in the greatest confusion, gigantic monuments of former workings. In many places through the hills, huge piles of these great blocks, now perfectly overgrown with moss, bear testimony to the industry of the natives in former times. Some are of immense size, and the accumulation of these masses, occasionally grouped in the most fantastic forms, gives a strikingly characteristic feature to the scenery of the granite country. The accompanying sketch of the valley of Nonkrīm, will give some idea of the great size and confused heaping of these blocks. (Fig. 16.)

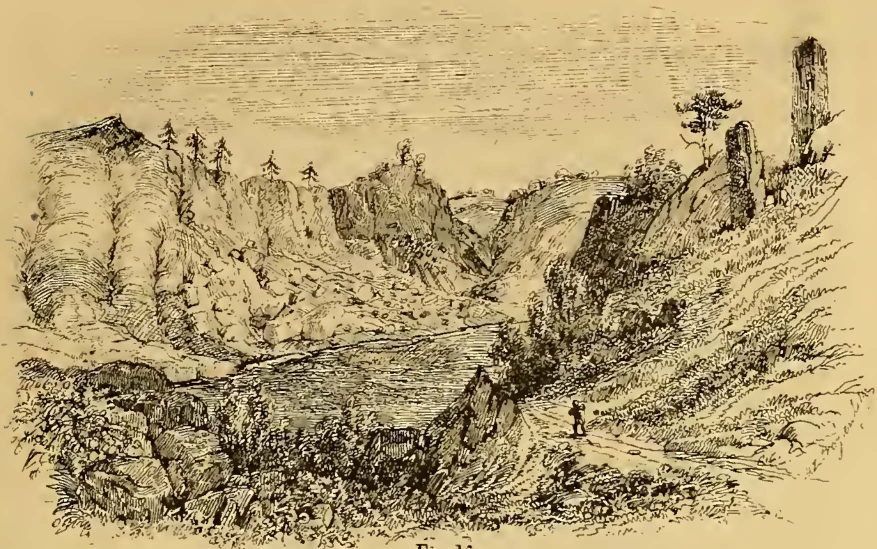


Fig. 16.

This blocky character exists in all the glens within the granite district, even where no iron workings have existed and where there has been no excavation, artificially, of the rocks. Contrasting the view already given (*Fig.* 9.) of the ridge on which Nonkradem is built, its remarkably flat top, and precipitous sides, with the glen to the North in the granite (Fig. 17) seen from the same point, the difference is at once evident.

Immense blocks left.

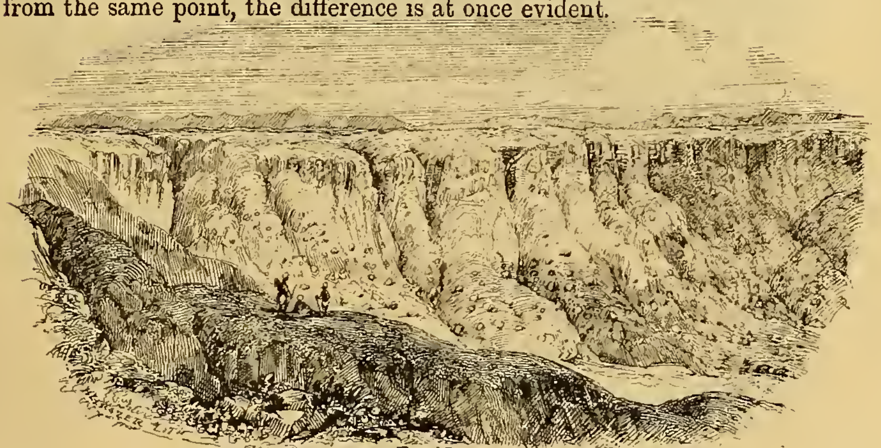


Fig. 17.

Granite near Joowai.

Granite of similar lithological character is seen again several miles to the Eastward of the districts to which I have just referred. It shews on the surface four or five miles North of Joowai, and again near to the village of Pooring, and between that and Nurtiung. It is essentially the same in composition as that near Molīm, though not quite so largely crystalline. The boundary of this granite I had no opportunity of tracing out.

Kullong hill.

Independently of these more extended areas in which granite occurs, it is seen in a few more limited and isolated positions. Of these the most remarkable is the curious and very prominent rock, called the Kullong *(a)* (Fig. 18). This huge mass

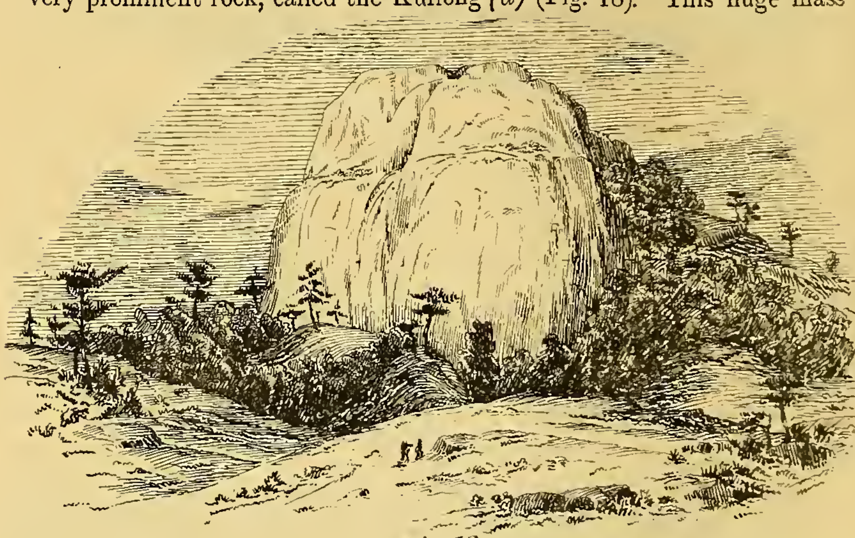


*Fig. 18.*

of granite stands up boldly from the undulating surface of the country around, looking like a great dome of about 500 feet high. To the East and North-East it slopes a little more gradually, and is thickly clothed with timber. On the Western and South-Western sides it presents a naked mass of rock rising nearly perpendicularly upwards of 700

*(a)* See also *Fig.* 3.

feet from the bottom of the undulations in the ground below. Round its base some large and fine pine and other trees cluster, the dark foliage of which contrasts beautifully with the naked and weather-beaten face of the rock itself. This very remarkable rock is one mass of highly crystalline granite, rising from the rounded knolls of the gneissose country around. To the West, judging from the immense blocks which are strewed over the surface, the granite would seem to extend ; but on the South, the East, and the Northern sides, the bedded gneiss and slates encompass it. It appears to be in fact an exhibition by nature on a gigantic scale of a phenomenon similar to that which may be seen throughout the entire of the granitic area, and to which we referred above, namely, the occurrence of those huge blocks of rock imbedded in, and of a similar character to, the mass, though much more highly indurated. The Kullong rock would seem to be a monster exhibition of the same fact, which no human hands have exposed, but which the action of natural causes, continued for ages, has laid bare. *(a)*

Structure, &c.

In the same parallel with the Kullong, and to the East, granite occurs cutting through, disturbing, and altering the slates in junction with it, near the village of Laidom. This exhibition of it is interesting from the fact of the outlier of tertiary sandstones which occurs here, resting quite undisturbed and horizontally upon the granite, as well as on the adjoining slates, the surface of both having been planed down to the same general level prior to the deposition of the sandstone upon them. The granite is seen at both sides of the isolated cap of sandstone.

Granite near Laidom.

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*(a)* As might be expected with a tribe whose prayers are chiefly, if not solely, offered up to avert the wrath of spirits, whom they imagine to dwell in woods and rocks, this Kullong is asserted to be the abode of a powerful demon, whose enmity a Khasi dreads much to evoke.

The occurrence of huge blocks of granite in several other places throughout the hills, indicating the former existence of washings for iron ore, points also to the existence of this rock in these places. Time, however, did not admit of a detailed examination of these localities. I have therefore preferred, on the map, to include these within the general area occupied by the metamorphic rocks, which are pierced by innumerable granite veins, rather than to attempt an amount of detail for which I had not sufficient data. Thus, at Nung-rumai, (Normai) and at Nungklow, and in some other localities, there is no doubt of the existence of granite, but it is probably very limited in area.

Evidence of occurrence elsewhere.

I have already described the occurrence of granite in considerable mass and also in veins of varying size and composition, in connection with the metamorphic rocks of the Temshung valley to the East of Cherra Poonjee.

Veins of granite.

A reference to the map will show that the points at which granite shows through the hills have a somewhat definite arrangement, and occur on lines having an Easterly and Westerly direction. Thus the granite of Lunkoi on the West is continued by the granite of Molīm and Nonkrīm, and still further East by that which shows near Pooring and North of Joowai; while the line of the Kullong is shown further to the East in the exhibition of this rock near to Laidom.

Line of direction of granitic intrusions.

Greenstone.—This is another interesting form under which igneous rocks are exhibited in the Khasi Hills.

The most important locality where these rocks occur has been already alluded to in describing the sandstones of Cherra, and the alterations which have resulted from the contact of these volcanic rocks in a molten state. A few words of additional detail will therefore suffice here. The rocks which form the greater portion of the valleys of the Kala-pani and of the Boga-pani, with

Locality, &c.

the small intermediate glen, are throughout of a very constant lithological character. They are all a basaltiform greenstone, dense and close-grained, with very few and small vesicles, or air bubbles. The rock divides into prismatic masses, assuming in places a semi-columnar aspect; but this structure is not well developed. Where long exposed it decomposes on the surface into a ferruginous ochrey sand. Near the junction with the overlying sandstones this greenstone is traversed by numerous small veins of quartz which fill all the cracks and fissures in the mass. These do not occur at any distance from the sandstone, and appear to be the result of the subsequent filling in of small cracks by silica derived from the overlying siliceous rocks. This is the general character of the rock throughout the large area over which it is exposed.

General character.

North-East of Mow-phlang greenstone occurs, not in the form of a great underlying sheet of rock supporting the sandstones, but as a dyke or wall of this igneous rock, cutting through the beds of the mechanical series. Here the character of the rock is somewhat different; instead of the basaltiform structure and composition, which prevail in the mass, it is diallagic more largely crystalline, and is a true diallagic greenstone. I am disposed to view it, however, notwithstanding this difference in aspect, as connected with, and probably an off-shoot of, the great mass of greenstone to the South.

Dykes.

Other dykes occur in the district South of the village of Laikro, which have, though in a much smaller degree, the same mineral aspect.

All these dykes have a common direction, namely, they all head or strike nearly due North-East, coinciding with the main or general direction of the great river valleys in which the greenstone is so well exposed. *(a)*

Direction of dykes.

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*(a)* The road from Cherra Poonjee to Gowahatty in Assam passes for several miles over this greenstone between the valley of the Kala-pani and that of the Boga-pani. This

Trappean rocks are also seen South of Cherra Poonjee. Below the great ridge, or to the West of the hill under Maw-m'luh village, at an elevation of about 2,400 feet above the sea, or about 1,700 feet below the level of Cherra, and, forming the top of the small ridge which here unites Maw-m'luh with the partially detached hill on which Laikenso is placed, there occurs an earthy greenstone or claystone, in places very ferruginous; its fissures being coated with peroxide of iron. It is highly vesicular, the cavities being filled with agates, and agaty flints, of various colours. The rock itself is of a blueish tint. The high-coloured flints, in which a deep earthy red is the prevailing tint, have been described as jasper (Gleanings in Science, vol. i. p. 374). The colour in some pieces is good, but I did not see any lumps of good size; and most of the pieces are greatly shattered.

Jasper, &c.

An earthy greenstone similar to this is also met with in passing down from the Mahadeo to Bairung village, and at about the same elevation. The ground between these two localities is too densely covered with jungle to permit its examination sufficiently for tracing the continuity of this trap.

A thick vein, or dyke of highly crystalline greenstone, passes in a North-East and South-West direction across the

Dyke near Mooshye.

excellent road reflects the highest credit on the skill of Col. Lister, who planned and executed it throughout. It is, with scarcely an exception, admirably laid out, and constructed; while the remarkably well-turned bridges of cut stone, by which the larger streams are crossed, show what can be done by the well directed intelligence of the natives of these hills. The communication across the Boga-pani, one of the largest and most dangerous streams on this line of road, was interrupted early in 1851 by the carrying away of the Suspension Bridge in a great flood, which flood also swept away several other bridges on the road. These latter have all been repaired, or renewed, but I am not aware that any thing has been done to re-open the communication across this torrent. The mail bags are still, I suppose, passed across during the rains suspended to a rattan stretched between the banks, and the only means of crossing for some months in the year is by a temporary bridge of the rudest construction put up by the natives.

rocks, a little West of Mooshye ; and a similar mass is seen to the East of the villages of Rasheer and Pooring, holding precisely the same general direction, and probably connected with that near Mooshye. It is of the same basaltiform aspect as the greenstone seen near the Boga-pani and Kala-pani rivers.

Direction of dykes, and of faults in tertiary beds, coincides.

Looking at this well-marked direction of the various dykes or masses of greenstone seen within the area examined, and its constancy, and taking it in connection with the direction of the faults observed in the coal at Cherra Poonjee ; with the direction of the principal joints or planes of division existing in the limestones there; with the direction also of the great lines of the river-valleys, which a reference to the map will show to be remarkably parallel within the sandstone area, and which undoubtedly have been formed along great lines of disturbance ; we are, I think, justified in concluding that the maximum force of these intruding igneous rocks has been exerted in a direction nearly North-East, and that consequent on this force there has been a series of divisional planes produced in the Sedimentary rocks, which have a nearly parallel direction ; and that these divisional planes, associated in some cases with actual dislocations or faults, have influenced very largely the operation of the ordinary degrading forces in producing the present features of the district.

Geological age, &c., of the rocks.—In the preceding description of the lithological aspect and mode of occurrence of the various rocks in the Khasi hills, I have not entered at all into the question of their geological epoch, except in the most incidental manner. The full discussion of this interesting question can only be undertaken after a careful examination of the fossils occurring in these rocks, and I shall therefore reserve all details of this kind for a future occasion, at present simply stating in the broadest way the general relations of the rocks.

Metamorphic rocks: two groups of.

With reference to the mechanical rocks described above under the general head of "metamorphic," I have already stated that, so far as they have been examined, they are entirely and completely *azoic;* no trace of either animal or vegetable remains having been found in them. The distinct age of the two groups to which I have above referred is shewn by their unconformability as well as by their different lithological character; but I have not attempted on the accompanying map to separate them, my examination of the hills having been too brief and too limited to enable me to trace their boundaries exactly. Of the still more recent sandstones, I have already briefly spoken above. There is a well-marked group of sandstone and shaly beds greatly altered, very much disturbed, and pierced by veins of granite, totally distinct from any of the more recent beds, but the age of which cannot be determined in consequence of the absence of organic remains. In lithological aspect, they greatly resemble many of the highly altered beds of Central India and the Nerbudda; but this resemblance may be very deceptive. Possibly in the absence of any evidence of their age, it may be the most convenient way to consider them simply as secondary, without attempting any distinctive classification, thus indicating their intermediate position between the metamorphic rocks below and the tertiary sandstones, &c., above. I was at first disposed to view them as an upper group of the metamorphic rocks themselves—a classification justified by their very highly altered condition. But this would to a great extent mask the real circumstances of the case, and they have therefore been set down as secondary. Their age is to a certain extent very well marked by the intrusion of the granite veins in them, while these are totally absent in the tertiary beds above; and also by their highly inclined and greatly disturbed positions.

Nummulites.

The group of sandstones, limestone, coal, &c., occurring along the Southern escarpment of the hills, is of much greater interest. In these, many organic remains occur, some of which have been incidentally alluded to. Of these certainly the most characteristic are the fossils of the limestone beds, and among these the nummulites are most important. The existence of these fossils in the so-called " Sylhet limestone" had been long known. It was pointed out by Mr. Colebrooke in his valuable paper on the geology of the North-Eastern frontier of Bengal *(a)*, and has subsequently been alluded to by several other writers. The *tertiary* age of this rock, inferred from the occurrence of these fossils, had also been more than once referred to, and generally acknowledged. In the most recent account of the geological structure of these hills, Dr. McClelland speaks of this rock, but refers it to the parallel of the upper portion of the cretaceous group of Europe. The state of geological knowledge regarding the distribution of these remarkable foraminifera at that time, undoubtedly justified this author in making such reference, although from more recent researches geologists now agree in assigning the rocks containing these nummulites to the earlier *tertiary* era.

Dr. McClelland's views.

But this reference of Dr. McClelland's only relates to the limestones found near Teria-ghat at the base of the hills, as he distinctly draws a line of demarcation between these and the limestones found close to Cherra Poonjee station ; which latter, together with the associated coals, he refers to the lowest portion of the coal measure group *(b)*, and to the same age as the coal beds of the Hazareebaugh and Nerbudda districts. It would be quite out of place to discuss here the age of the latter deposits, or that of the great coal-fields of the Damoodah and Adji. It will suffice to state simply that there are no grounds whatever for referring the limestones, and other rocks which occur at or near to the village of Cherra Poonjee, to an older geological epoch than those found at the base of the same hills. They are both nummulitic ; they are both

*(a)* Geological Transactions, London, Vol. i. 2nd Series.

*(b)* Reports of Coal Committee, Calcutta, 1838, pp. 26, 33 ; and 1846, pp. 100, 103.

mineralogically alike, and both unquestionably belong to the same great division of geological time.

There is some little difficulty in ascertaining exactly what Dr. McClelland's views, regarding the arrangement of the rocks at Cherra Poonjee, were. In the earliest announcement of his discovery of fossil shells in these hills, made in September 1835 *(a)*, he merely states, "that he had discovered a large number of shells at various altitudes from 1,000 to 4,200 feet, and even in and around the station of Cherra Poonjee itself," among which he thought he recognized Pecten, Turritella, Melania, Serpula, Cirrus, Pleurotoma, &c., "and that these remains were in rocks hitherto considered as primitive." In the following year, he exhibited to the Asiatic Society, Calcutta, the collections made by him during his trip to Assam, and stated that fossil shells were found in such number and variety at Cherra Poonjee, as to afford most unquestionable evidence "of the tertiary nature" of the Khasi mountains: and further, that when the specimens had been compared with the fossils from the Paris and London basins, "it might be possible to find their place in the Eocene and Pleiocene groups of Lyell." While this would seem to indicate that he referred to the epoch of the formation of the rocks, and not to that of the formation of the mountains, the next sentence appears to shew that it was the *period of upheavement* to which he alluded, as he thinks this is the first instance of "any extensive deposit of fossil shells in the Sub-Himalayan rocks, calculated to throw sufficient light on the period of their "upheavement" *(b)*.

In the following year (1837), a short communication from the same author was read to the Geological Society of London, in which he refers to the nummulitic limestone at the base of the hills, and to the occur-

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(*a*) Journal Asiatic Society, Bengal, Vol. iv. p. 520.
(*b*) Journal Asiatic Society, Bengal, Vol. v. p. 519.

rence of fossil shells in a "well-defined marine beach" at about 1,500 feet above the sea, out of his collection from which he had identified about twenty species as identical with Paris-basin fossils. Next referring to the Cherra Poonjee limestone, he describes it as reposing on the sandstone of the hills, and as having afforded him twenty-seven species of shells, among which he identified *Pileolus plicatus* of Sowerby.(*a*) "On this limestone rest the coal, &c."(*b*) In the Report of the Coal and Mineral Committee greater details are given; and in discussing the question of the relative levels of the Indian coal-fields, and the causes to which these may be referred, the same author states that the coal of Cherra Poonjee is accompanied by rocks identical in nature with those found bearing a similar relative position to other beds of coal of the same (coal measure) formation; refers the great thickness of sandstone which occurs under the coal and limestone, to the old red sandstone of English Geologists; and alluding to the similarity between the limestone which occurs beneath the Cherra coal and the limestone of Central India, proceeds to state, with reference to the researches of Mr. Scott and Mr. Cracroft, that, "no chronological distinction had been previously established between the limestones in this quarter, although the Cherra rock is distinguished as a formation from the nummulite limestone, as well by means of its fossils, as by the beds with which it is associated."(*c*) The same author again described more particularly the occurrence of these fossil shells in the so-called beach, and states that in one place the echinida which occur with them (*Cyrtoma*, of McClelland), are found "in a greenish-grey friable sandstone, which will probably prove to be the equivalent of the green saliferous marls of the upper new red sandstone."(*d*) According-

(*a*) This, however, is an *oolitic* fossil.

(*b*) Proceedings Geological Society, London, June 12, 1837.

(*c*) Report Coal Committee, 1838, p. 33.

(*d*) Calcutta Journal of Natural History, Vol. i. p. 155.

ing to this determination, therefore, there would be in the Khasi hills representatives of the old red sandstone ; of the carboniferous ; of the new red sandstone ; of the cretaceous and of the tertiary groups.

Now whatever doubt there may be as to the relative position of the limestones which occur at the base of the hills in many places, and those found at the top, there can be no question whatever as to the relative position of the sandstone in which these echini occur, and of the limestone and coal of the Cherra Poonjee station, inasmuch as the succession of beds can be uninterruptedly traced upwards from the one to the other. If therefore these sandstones, occurring on the slope of the hill, belong, as Dr. McClelland thinks probable, to the new red sandstone group, it is difficult to see how he can refer the limestone and coal, which occur some 1,500 feet stratigraphically above them, to the carboniferous epoch.

Limestone and sandstone conformable.

There does not appear to be any ground for supposing that this limestone belongs to a different geological era from the sandstone below it. They are both perfectly conformable, and have formed a continuous and uninterrupted series of deposits, the calcareous nature of some of the sandstone beds proving that the sources of lime existed long prior to the formation of the purer calcareous muds, now constituting the limestones. It is possible that some of the sandstone beds may have been geologically coeval with the upper or latest portions of the cretaceous group of Europe (and this question can only be decided by a careful comparison of the organic remains): but there is little doubt that the Cherra limestone is of the older tertiary or *Eocene* epoch. (*a*)

(*a*) While thus differing altogether from the conclusions of Dr. McClelland, I am anxious to bear testimony to the general accuracy of his descriptions; and to state my conviction that the errors in his deductions arose as much from the state of geological knowledge at the time he wrote, as from any want of proper investigation ont he part of the author. The notion; by no means fully exploded in 1838, that good coal could only be found associated with rocks of a certain era in geological succession, would seem to have held

But although a question may exist regarding the geological date of the sandstones below, there can be none whatever that the sandstones, coal, &c., above this limestone, are either of the same epoch as the limestone itself, (and therefore Eocene,) or of a still later date. In either case this Cherra coal (which has hitherto been referred to as the lowest portion of the coal measures)(*a*) is undoubtedly *tertiary*.

Interval between the deposition of limestone and upper sandstones.

I have above described the appearance presented by the upper surface of the limestone, and the curious manner in which it has been scooped out, and the hollows filled either by sandstone or vegetable matter. For such degradation of the surface, I conceive that a considerable time must have elapsed, and a considerable change of condition have occurred. And it is, therefore, possible that this bed of coal, and its associated sands (for so slightly indurated are they that they scarcely deserve the name of sandstone), may belong to a still more recent sub-division of the tertiary group than the underlying limestone; and that this may be, at Cherra Poonjee, the last remaining relic of a series of beds corresponding, in time, with the largely-developed groups of the Siwalik hills and of the Salt range; beds analogous to which the researches of Mr. Scott have proved to exist along the Western flanks of the Garo hills, not far from the Khasi range.

No fossils have been as yet discovered in these overlying beds, which would throw any light upon this question, and the occurrence of beds of similar coal, much lower in the series, and associated with the sandstones (as at Tung-jinath), and of precisely similar nummulitic limestone

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such sway over his mind, that to meet this difficulty, the stronger evidence of organic remains (which Dr. McClelland to a great extent interpreted accurately) was rejected, or explained away on an untenable hypothesis. The extent of the author's researches during his very brief visit is the most convincing proof of the *zeal* which he brought to his investigations.

(*a*) Of course, all the reasoning founded on this assumption, and the comparisons thence drawn between the coals at Cherra and at Hazareebaugh, &c., as to quality, and the cause thereof, cease to be applicable. See Coal Committee's Reports.

repeated above the coal (as at Lakadong) tends rather to prove that they all belong to the same formation. In either case, this coal, which has here been so far mineralized as to produce a good blazing coal, of a fine jetty aspect and highly bituminous character, is the representative of the thin and small patches of lignite which occur abundantly in the tertiary strata of the North-West.

And this analogy strengthens the conclusions drawn from an examination of these deposits in the Khasi hills, as to the uncertainty of any continuance of these seams. Both with reference to the coal at Lakadong and at Cherra Poonjee, I have already pointed out the very irregular manner in which the beds have been developed, and I am inclined to think that this is only another instance in which the deposits of vegetable matter, belonging to this geological epoch, are of local and limited extent resulting from local and limited causes.

With a few brief remarks on the disturbances to which these rocks have been subjected, I shall conclude the foregoing outline.

Granitic intrusion.

The approximation to a linear direction (East and West) in the granitic areas has been noticed above. The only really marked instance, however, of granitic intrusion, as distinct from granitic disturbance and elevation, does not exhibit this direction (at Laidom); and from this and other circumstances, it would appear that the line or axis of the greatest exhibition of granite has been a line of elevation, and not of intrusion or fracture; in other words, that the disturbances or dislocations on this line have been long subsequent to the alteration of all the rocks affected. On the other hand, the disturbances resulting from the exhibition of the other class of igneous rocks (the trappean) have taken place along the lines, or line of intrusion and of fracture. The coincidence in direction between these intrusions and the principal river-valleys in the Southern part of the hills, and the dependence of the physical features of the district on this geological structure have been noticed above.

Along the base of the hills, from the parallel of Cherra Poonjee, to Burr-ghat, not continuously, but with few interruptions so far as I know, limestone is found extensively almost at the level of the plains. Now this limestone is of very similar character to that which is also found at the top of the ridge. It contains many of the same fossils, and altogether is very like the beds above. It is invariably at considerable angles of inclination, from 40° to 60° (instead of horizontal as in the hills), and for the most part this inclination dips away from the general range. This is well seen South of Burr-ghat, and may also be noticed near to Teria-ghat. Resting upon this low-lying limestone there occurs a great thickness of sandstones of varying character, with intercalated shales. These are well seen in the banks of the Harry river, leading up to Burr-ghat; and throughout, they appear conformable to the limestone. As I have already stated, that in consequence of the season of the year, it was unsafe to visit these localities, I can only mention the occurrence of these rocks, and regret that I could not more satisfactorily examine them. But, coupling the remarkable similarity of the limestones above and below, with the remarkable continuity of the beds at the base, I think there is evidence to show that the present steep face of the hills on the South is formed along a great line of disturbance and elevation, stretching nearly due East and West; and that from this the very remarkable rectilineity in the direction of this range has resulted. The direction of this line of steep escarpments coincides with the direction of the granitic elevations, and has possibly resulted from the same force.(a)

Probable instance of great faults.

Accompanying this great disturbance there is also some confusion along the face of the hills, arising from the necessary occurrence of many great slips and fallen masses; and, the whole surface subsequently becoming densely clothed with forest,

Landslips, &c.

(a) Dr. McClelland indicated the existence of a great fault along this line in his accounts of the structure of these hills. Reports, Coal Committee, 1838.

it is no easy task to unravel its complicated structure, or to obtain a clear insight into the causes which have produced it.

General conclusions.

I shall here briefly enunciate a few of the principal conclusions resulting from a general review of the previous descriptions of the geological structure of these hills. These are: that the general basis of the range is granite; resting upon it is a series of metamorphic rocks, gneiss, micaceous slates, quartz rocks, &c., which have been greatly altered, disturbed and contorted by the granite which now supports them; that in connection with these changes there appears to be evidence to show that the line of greatest elevation caused by this granite, or rather by the forces to which this granite is the index, had a direction East and West. Subsequently to these disturbances and alterations of the older slates, these rocks have been subjected to long-continued and great wear and denudation; and upon their degraded surface was deposited a series of beds of sandy and earthy character, of varying composition, but in the aggregate, of considerable thickness, which have subsequently been subjected to great alteration. Another interval of considerable duration must now have occurred, during which disturbing forces were again exerted; for, upon the upturned and degraded edges of these schistose and quartzose beds, others have been formed of very different character, the prevailing composition of which is sandy, and which, as a mass, give abundant evidence of being shallower water deposits than the lower beds.

Again disturbances have taken place, contortions of these beds have been forcibly produced by the exertion of great forces of intrusion and pressure; and these forces appear to have been accompanied, if not produced, by the exhibition, on a considerable scale, and over a considerable area, of volcanic-like masses, which have been emitted in a highly heated condition, and have consequently exerted those modifying effects which might be expected to result from such an exhibition of heated masses on the large scale.

Above and upon these again, another series of beds of varying character, sandstones, limestones and coal, of considerable aggregate thickness, was formed. Throughout the whole of this series, from top to bottom, in the conglomerates found at its base, in the clean sandstones higher in the series, in the fossils found in these beds, in the irregularity of their development, and the constantly repeated occurrence of current-marking and "false bedding," there is sufficient evidence to prove that the entire group, not less than two thousand feet in thickness, has been deposited and formed in water of no great depth. The same evidence is extended by the organic contents of the limestones. To admit of this occurring, there must have been a gradual and continuous depression of the surface within this area, maintained during the deposition of the whole of the series. These sandstones have subsequently been invaded by igneous rocks which have been forcibly intruded among them, and have produced considerable alteration in their texture and structure. There is no evidence to show the exact period at which such intrusion took place ; but it must have been subsequently to the formation of all the sandstones.

The whole succession of groups has been subsequently elevated until it attained its present position. There is no sufficient evidence to show whether this elevation, or rather, the commencement, of this elevation, was synchronous with or not, or was caused by or accompanied by, the intrusion of the trappean rocks.

The elevation of the rocks to their present position must, however, have been gradual and long-continued, to admit of the remarkable conditions under which we find them as shown by the many detached and small outlying portions at considerable distances from the main mass.

Coincidently with and subsequent to this elevation of the hills, *en masse*, the ordinary atmospheric causes of degradation, which, owing to the peculiar climatal conditions of the district, are here exerted with great force, have been in operation to produce and modify the present aspect of the surface. And, further, the action of these forces appears to have been determined, as to the *direction* of its maximum effect, by a series of lines of jointing and fracture, and occasionally of dislocation or faulting, resulting from the earlier intrusion of the volcanic rocks.

The very gradual and continuous slope of the plains at the foot of the hills, will show that long subsequently to the period of their elevation, a sea had washed their base, and formed the widely-extended flats, from which their steep escarpments rise.

Viewed in connexion with the geology of India, in a wider and more general way, one of the first points which arrests attention is the remarkable coincidence in the general direction of the main lines of disturbance in these hills (East and West), and of those which have affected the coal-fields, or " Damoodah" and " Mahadeva" groups of Bengal and of Central India. Whether there be any synchronism, as would appear probable, can only be determined by more widely extended examination. At the same time I would refer to the bearing on this question of the supposition I have already thrown out (*a*), that it may not be improbable that the great lines of disturbance traceable in the Nerbudda valley, may be continued up the Assam valley. But even if these disturbances be synchronous to a certain degree, it will not at all follow that the whole extent of the disturbance or fault was produced at the same time. Disturbances may have been frequently repeated along the same or parallel lines of weakness.

Again, the circumstances under which the nummulitic rocks occur in the Khasi hills are curiously similar to that under which they are found elsewhere in India. They are generally indicative of a moderate depth of water (see page 169), and they are here also only found in the proximity of the mountain range. It is remarkable that these facts should be so constant, and that these nummulitic rocks should not occur anywhere in the broad plains of the Indian peninsula. This

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(*a*) Journal of the Asiatic Society of Bengal, 1856. p. 250.

would seem to bear out Captain Strachey's views that the elevation of the Himalaya ranges, or at least of a great portion of those ranges, had taken place previously to the deposition of the nummulitic rocks, and that, in fact, these ranges formed the land from the shores of which the nummulitic sea extended Southwards with a very gradually inclined bottom. But what then are the representatives or parallel of these nummulitic beds in the more central part of India? Can the group to which I have already elsewhere *(a)* given the name Mahadeva be in this position? And may not the irregularly developed beds of limestone, which are found accompanying those sandstones, be the faint representatives of this widely extended and largely developed nummulitic limestone? The solution of this question must be left for further and more extended research.

Again, in connexion with the occurrence of an upper group resting upon the true nummulitic rocks, in all known localities, extending from Arabia and Persia on the West, to Burmah on the East, this upper group being characterized generally by the presence of gypsum and of petroleum (the "gypsiferous series" of Loftus *(b)*, I would allude to the occurrence of petroleum springs in the vicinity of Cherra, and also further to the East near Cachar as an additional proof of the remarkable constancy in general character and detail, which this important group of rocks presents over such a widely-extended area.

Physical Geography.—Some of the striking peculiarities in outline and general character of these hills have been already alluded to, and have been illustrated in the sketches which accompany this report.

The curiously flat-topped plateaux of the range forming long swelling grassy plains, marked here and there by small outstanding hillocks, which scarcely interfere with the general level, cannot fail to suggest the idea of long continued denuding forces acting at tolerably fixed levels. Of these plateaux or terraces, a remarkable one is that on which the station of

*(a)* Jour. Asiat. Soc. Bengal, Vol. XXV. p. 252. *(b)* Quar. Jour. Geol. Soc. London, Vol. XI. p. 254-270.

Cherra Poonjee is itself placed. This marks an elevation above the present sea level of about 4,200 feet—an elevation which includes a vast area in the Khasi Hills, and which is marked not only by this flat ground at Cherra Poonjee, but also by the flats around Nonkradem, at the top of the long spur on which that village stands; by the flats around the Kala Pani; by those forming the beautiful park-like and wooded downs around Joowye; and, again, more to the North, by the plains around Nungklow. In fact the great mass of these hills would be brought under the present sea level by a depression of 4,300 feet, only a few isolated points remaining as islands where this extensive range now stands.

A second apparently well marked level of terracing is passed over on the road from Cherra Poonjee to Teria Ghat at the Mahadeo, forming the level of the top of the precipitous scarp of these hills which faces the South. This marks a level of from 2,200 to 2,400, and similar plateaux at the same, or very nearly the same elevation may be traced in other places along the face of the hills. The flats under Tungjinath on the Nonkradem spur, and the plateau of Lakadong, and of a considerable area of country near it, are about the same elevation and of the same character.

A third, though less marked terracing, seems to be indicated at the level of 750 to 800 feet. Along the Southern face this is greatly concealed by the dense forest which covers the hill slopes, but may be traced in several places.

It is impossible to do more than simply indicate the occurrence of these terraces and their probable cause. To trace them out in detail would require a much more accurate map than was at our disposal, or than we could devote time to construct. And even with such an aid, the inaccessibility of many parts of the hill sides, so as to determine their relative levels with accuracy, would render such details only attainable after great labour, risk, and time. Those which I have mentioned are alluded to, not so much as specially connected with these hills, as in illustration of the general fact, which every season's further examination of India seems to confirm, that there have been in most parts of the country long continued intervals of time during which the denuding and degrading action of oceanic forces has continued to act; and has produced in places great table lands, or expanses of flat country, or, where these do not exist, a remarkable uniformity in the general elevation of the country, however broken up that general elevation may be by isolated peaks, or separate but minor ranges, or by river valleys and other depressions.

River valleys or gorges.

Another very peculiar feature in the Khasi Hills are the curiously deep and narrow gorges or valleys in which all the rivers, in the Southern portion of the hills, find their course to the plains. The level of the stream under Cherra Poonjee is some 3,000 feet below that of the station: into the Mawsmai valley the streams which drain the flat of Cherra are precipitated in one unbroken leap over the sandstone scarp for about 1,800 feet, and then fall rapidly over the steep talus for about a thousand feet more. The same facts may be seen in the Maw'mluh valley, and may be traced in all the valleys of drainage along the Southern face of the hills. Further inland also, for a certain distance, the same character of all the river valleys continues, and the streams of the Kala Pani and Boga Pani both flow in deep and narrow gorges with very steep sides. (See Plates IV., V., VI., and Fig. 1.)

Now, although believing that marine denudation has exerted its powerful influence in modifying the features of these hills in former times and at different levels, as I have just stated, it is not possible to see how any littoral action, or any such ordinary marine action, could have produced those long, deep, and sinuous gorges here seen. On the contrary, these river gorges appear to me to have been excavated almost entirely by the force of the streams which have flowed, and still continue to flow through them. And they appear to me to offer a magnificent instance of the almost incredible power of degradation and removal, which atmospheric forces may exert under peculiar and favorable circumstances. I have already noticed the causes which seem to have influenced the *direction* in which those forces have acted.

Enormous fall of rain.

It will not be easy for those who have been accustomed to investigate countries where the average annual fall of rain amounts to thirty or forty inches, distributed with tolerable equality over the whole twelve months, to form a fair estimate of the immense forces brought into play in these hills, where the fall of rain in 24 hours is not unfrequently two feet six inches, or equal to the whole year's fall in most places in Europe, and where the annual fall, not distributed over the twelve months but concentrated into four or five, amounts to some fifty feet, or six hundred inches!

I took an opportunity of visiting one of the streams in these hills after a heavy and sudden fall of rain. The water had then risen only about thirteen feet above the level at which it stood a few days previously; the rush was tremendous—huge blocks of rock, measuring some feet across, were rolled along with an awful crashing, almost as easily as pebbles in an ordinary stream. In one night a block of granite, which I calculated to weigh upwards of 350 tons, was moved for more than 100 yards; while the torrent was actually turbid with pebbles of some inches in size, suspended almost like mud in a rushing stream.

Removal of soil.

To the denuding force of these heavy and sudden falls of rain is also due the almost total absence of any soil in the flats of the hills near the Southern escarpment. All has, in fact, been washed away, and a thin crop of coarse grass alone finds sustenance on the rocky surface. The marked absence of trees, the growth of which is cut off as with the axe along the edges of every flat, is largely due to the same causes, but also largely to the blighting storms which sweep over these hills. On the sloping sides of the valleys trees grow abundantly, and at many places luxuriantly: there they are sheltered, and abundantly supplied with moisture.

But this water exerts its degrading forces not only on the surface of the flats, or where, in rushing over the precipitous scarps it excavates deep basins beneath, but it pours through the many fissures and clefts in the sandstone and limestone, and springs from the solid face of the rocks at different levels, tearing with it fragments of the hardest masses, and precipitating them into the gorges below.

Rapidity of degradation.

The rapid degradation which these hills must undergo is well shown by the vast amount of suspended matter, which is carried down by the streams issuing from them during the rains. I have more than once seen streams which, in the drier weather, were beautifully pellucid, so turbid and charged with suspended matter, that a white card was invisible at the depth of one inch and a half! that is, through a stratum of water of that thickness. I have also measured the bulk of such sediment allowed to subside in a carefully divided tube, and found it more than once to amount to one-fifth of the total bulk, and in one case to very nearly one-third. In all cases this sediment was a fine clayey sand. Taking these facts in connection with the enormous fall of rain, it will be readily seen how rapid must be the degradation and denudation of these hills.

Nor is this without other proof also. Mr. Griffith, in his journal, notices the fact of the steady retrogression of the Mawsmai falls, which he calculates to have been at the rate of five feet in the year, and he even proceeds to calculate on this supposition the lapse of time which must have passed since these falls were originally at the general face of the rocky scarp of the hills, estimating that it must have taken 5,700 years for the falls to have receded to their present position.*(a)* But without attempting any estimate of this kind, which must inevitably be erroneously based on such imperfect and unsatisfactory data, the testimony of all the natives supports the conclusion that these falls have continually receded, year after year.

*(a)* Griffith's Private Journals, &c.—Calcutta, 1847.

Excessive floods.

I will here quote the account I gave in connection with a continuous series of meteorological observations in these hills of a great flood which took place in the month of June 1851 in these hills. During that month a heavy flood occurred in the Boga Pani and other mountain streams, which caused much injury, carried away several bridges, among others the iron suspension bridge over the Boga Pani, and near the mouth of the same river flooded and swept away a considerable portion of the large village of Cheyla. It occurred on the 14th of the month, on which day there was by no means so heavy a fall of rain as on many other days in the same year, and a visit to the localities where the greatest damage was done, at once showed that the greater proportion of the mischief resulted not so much from the actual amount of rain that fell and the rise of the waters consequent thereon, as from the waters being impeded in their course and ponded back by numerous slips of earth and stones, carrying down with them trees and under-wood. The torrent meeting with such obstacles must have been restrained, until its accumulated force burst through every barrier and swept every thing before it. In parts of the Boga-pani valley, the rise was not less than 50 feet. Next morning the richly wooded slopes of that valley were scored with innumerable gullies and deep cuts, extending frequently from the level of the water up to the very summit of the lofty banks. From one of these deep cuts, in which a little trickling rill usually flowed, a mass of stones of various sizes had been carried down, which I found, on a rough calculation, to contain not less than five thousand tons of material. The stones varied in size from 20 cubic feet to one or something less; but all the smaller and finer material had been entirely swept away. Of the large suspension bridge which had spanned the river, not a vestige was left; a single screw bolt, which had formed one of the fastenings of the wall plates, alone indicated that such a structure had ever existed; and when the waters had subsided, one of the heavy cast-iron standards which had supported the chains, could be seen about 250 yards down the stream, jammed between huge blocks of stone in the river bed. In some of the little re-entering angles of the road, where a projecting rock had diverted the force of the stream and caused an eddy to form in which the water had been comparatively still, fine sand was heaped up to a thickness of from five to six feet. A thick range of trees which formed a shady covering to the road for nearly a mile, and between it and the river, was entirely and cleanly swept away, and with it the strongly built revetment wall which supported the road.

Mode of distribution.

The peculiar modes of distribution of such material, depending on the rapidity of the current, the inclination of its bed, and the fineness or coarseness of the material, can here be studied with great advantage. There is, however, one peculiarity. While the two extremes of such action are well seen, in which the rushing torrent drives before it on its rapidly inclined bed huge blocks and masses, or in which the more tranquil stream can only keep suspended the finest debris, there is a comparative absence of all intermediate stages. Within the hills, the river beds are strewed with rolled masses and boulders of great size; but when the streams emerge from these rocky gorges they pass almost immediately into a country of perfectly uniform level, and therefore become comparatively stagnant. At a very short distance from the foot of the hills not a single pebble even as big as a nut is to be seen. And from this to the shores of the Bay of Bengal one unbroken deposit of fine sandy mud and sand continues without interruption.

The curious way in which such turbid streams raise their banks above the ordinary level of the country round, may be well seen after rain at the base of these hills. Along the edges of the ordinary channels of many of these streams high and continuous banks have been formed, which are not uncommonly five and six feet above the general level of the land all around. On these banks, fed by the continuous moisture from the stream, thick coarse rushy grasses luxuriate. When the water rises it naturally forces its way through these when they act completely as a filter. I have many times seen water so turbid that it might almost have been called mud, in which great clouds of suspended matter were floated along, overflowing such banks, and rushing out at the other side into the general flat of the jheels, *perfectly clear*, though dark in colour: the breadth of the bank not being more than 3 feet! It is not surprising, therefore, that these banks should continue steadily to rise. In this way also, the striking contrast between the clear, dark coloured water of the jheels, and the muddy turbid streams is readily accounted for.

The great difference in the physical features of the Northern and Southern portion of these hills, has been described above; and the coincident change in the geological structure of these two portions. But, in addition to this change, it must be remembered as materially influencing the general result that the fall of rain within these hills, and even at no greater distance than twenty miles to the North of the Station, is little more than one-half of the amount which falls at Cherra Poonjee, and along the outer scarp of the hills, where the rain-charged-clouds which pass Northwards from the Bay of Bengal, and over the flat country intervening, first meet the hills, and are suddenly cooled down and deprived of their moisture. The different force also with which the sea would act along the Southern scarp of these hills exposed to the wide sweep of the Indian Ocean, and along the Northern, where its forces would be confined and limited by the long bay-like indentation of the valley of Assam, has been very justly insisted on by Dr. Hooker, *(a)* as, to a great extent, accounting for the difference in character of the two escarpments.

These instances will suffice to show the rapid degradation which is now progressing in these hills, and to prove that, however inadequate they might at first appear, the ordinary atmospheric forces under the

(*a*) Himalayan Journals, Vol. II., page 324.

peculiar climatal conditions which occur in the district under consideration, are amply sufficient to have produced, during the lapse of ages, those peculiar and striking gorges which we have described. And certainly few grander instances of the force and amount of fresh-water denudation could be quoted.

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## FOSSILS.

NOTE.—The unfortunate loss of the collection of fossils made by me during my visit to the Khasi Hills, when on its way to England for examination, has prevented my adding much to our palæontological knowledge concerning these rocks. In the valuable work of Messrs. D'Archiac and Haime, on the fossils of the Nummulitic group of India, sixteen species are given as occurring in Eastern Bengal. Of these, one rhizopode (*Alveolina ovoidea)* is identified; six species of Nummulites, *(N. Scabra; obtusa; Lucasana; Beaumonti; exponens; spira)*, and a single species in each of the following genera, but in all cases indeterminate:—Cardium, Modiola, Pecten, Ostrea, Terebratula, Melania, Pileolus, Trochus, Cerithium. To this limited number I can add, from a few poorly preserved duplicates which remained of my collection :

*Nummulites perforata ; N. lævigata ? ; N. Lyelli ? ; N.* 2 species undetermined ;—*Echinolampas* 1 species ;—*Pecten corneus ? ; P. Bouei* ?—*P.* species undet.; *Nerita Schmideliana ? Ovula depressa.*

Some future opportunity may occur of replacing the lost collection, and it will then be found that the fauna of the Nummulitic group in Eastern Bengal is nearly as rich in species as that of well known localities in Western India.

# ECONOMICAL GEOLOGY.

In the preceding pages, a brief outline of the Geological structure, and a few notices of the mineral products of the Khasi Hills have been given. Some of these products are important, both from the extent to which they are wrought, and from their being the great source of supply for the large demand of the Calcutta and other markets; and others from the possibility of their being applied to meet a demand at present unsatisfied. It will therefore be desirable to enter into somewhat greater detail respecting these.

The most important are lime, coal and iron; and in this order I shall give a few further particulars of the circumstances under which they occur, the conditions affecting their conversion, and the economical purposes to which they are applicable.

Lime.—The so-called "Sylhet limestone" has been long known. I cannot find any record of its first use in the production of lime. At least twenty years before the close of the last century, we find that the Hon'ble Robt. Lindsay had directed his attention to this trade, and, although known and carried on extensively before his day, he probably was the first European who had exerted himself in the matter *(a)*. In 1828, Mr. Inglis was well established at Chattuc as an extensive manufacturer of lime (*b*); and in the year 1830, the "manufacture of the Sylhet lime" is described as a generally known trade (*c*).

The neighbourhood of the Khasi Hills is still the great source of lime for the supply of the Calcutta and other markets.

The extent of this trade, and the importance of the product as an element of progress in civilization, demand a brief reference to the circumstances attending it.

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(*a*) Lives of the Lindsays, Vol. III. page 149.

(*b*) Asiatic Researches, Vol. XVII., page 499.

(*c*) Gleanings in Science, Vol. II, February 1830, pp. 61, 63, article signed T. R.

The principal localities of the manufacture are at Chattuc and at Sonamgunge, and along the banks of the river Soorma between these two villages (a). The rude kilns in which the stone is burnt stretch for miles along either bank of the river; and the many large and well-constructed buildings, in which the lime is stored until required for market, give an aspect of wealth, comfort, and prosperity to the district which contrasts forcibly with the almost unlimited extent of marsh and jheel that bounds the view on either side lower down the river.

Almost the entire range of the limestone quarries, along the base of the hills Eastward from Laour to Burrghat belong to the firm of Inglis and Co., whose principal Establishment is located at Chattuc. Westwards, some smaller quarries are in the hands of Mrs. Stark, Mr. Sarkies, and of some native merchants.

The extent and importance of the trade will be more evident from a consideration of the quantity of stone raised annually, and of the quantity of lime produced.

Quantity raised.

On an average of 10 years, ending in November 1851, the amount of limestone quarried on the borders of the Khasi Hills is stated to have been annually :—

| | | |
|---|---|---|
| By Messrs. Inglis and Co., ... ... ...... | Maunds | 14,48,550 |
| „ Mrs. Stark, Mr. Sarkies and native merchants,... ... .. ... ... ..... | „ | 2,31,500 |
| Total average amount quarried annually, ... | „ | 16,80,050 |

equal to 60,000 tons of limestone yearly (b).

(a) The name of the latter village, (Sonamgunge,) appears to be derived from this manufacture, and to be a corruption of *Chunamgunge* or *lime village*. It is a large and populous place, and the market-town for an extensive district. It is beautifully situated on the Soorma where this river makes a sudden bend to the South, and commands an extended view of the range of hills to the North.

(b) I am indebted to the kindness of Henry Inglis, Esq., Cherra Poonjee, for the above information, extracted from the books of the firm for me: Mr. Inglis states that, "the quantity given above, as burnt by natives, may have been a little less, certainly not more.

| | | |
|---|---|---|
| From this stone there have been burnt by natives, who have for the most part purchased the stone from Messrs. Inglis and Co. on the average of ten years, annually, ... ... ... | Maunds. | 12,34,000 |
| By Messrs. Inglis and Co.,... ... ... ... | „ | 1,57,000 |
| „ Messrs. Stark, Sarkies, &c., ... ...... | „ | 80,000 |
| Giving a total average amount of lime, ... | „ | 14,71,000 |

The whole of this very large amount is quarried from the several places along the foot of the hills, where the limestone occurs close to the level of the plains, and from whence it can be removed by water. The quarrying of the stone is carried on at all seasons, but chiefly during the spring and cold months; and the stone, broken into pieces of convenient size, is piled up in suitable localities until the rains in May, June and July fill the little streams from the hills sufficiently to float the small dinghies or canoes which are here used. As soon as this takes place, every available boat is at once employed for the removal of the stone into the larger streams. It is scarcely possible to conceive a busier scene than the neighbourhood of some of these large quarries presents after a good fall of rain. Hundreds of men and women are actively engaged loading their canoes, and then rapidly shooting down the narrow stream, while others are hastily poling the empty boats returning up the current again to load, and shoot down the rapids with their freight of stone. The whole place seems alive with eager workmen, who, from experience, know well the necessity of taking advantage of the rapid rise of the waters. So sudden is the fall of these little nullahs, that even the light canoes, which draw only a few inches of water, are frequently left stranded in the middle of their course.

In this way the greater portion of the stone is removed from the quarries, these small dinghies carrying the limestone only into the larger streams where all is quickly thrown on the bank, or into the water near the bank, to be again re-shipped into larger boats for conveyance to the place of manufacture.

Locality of quarries.

In that portion of the hills which lies more immediately to the South of Cherra Poonjee, the largest quarries are near the village of Tungwai or Tingye, from which the stone is brought to the neighbourhood of Pondua, to be again removed from thence to Chattuc. Other very large quarries are in the vicinity of the great orange groves between Teria-ghat and Lacat, from which also the stone is conveyed to Chattuc for burning.

The whole of this limestone belongs to the nummulitic group. It varies but slightly in mineral character, and produces a good, sound, but not very strong lime, of good colour, and which slacks readily. Some of the beds are magnesian, and more gritty in aspect, and the lime from these is somewhat darker in tint than that produced by the purer beds.

Fuel used; form of kilns.

At present, the only fuel employed in burning this limestone is wood or reeds (called nál), principally the latter, which are collected in immense quantities from the extensive jheels in the vicinity. The kilns are placed on the banks of the river, which are cut down perpendicularly for some feet to form the face, in which the opening into the lower part of the kiln is made. The excavation is circular in plan, and nearly semi-globular in shape; and generally of sufficient size to take, when piled up, from 500 to 700 maunds of stone. After ignition each kiln is, in ordinary weather, allowed to burn for about four days and nights, when the burnt lime is removed from the kiln, at the top. The kiln, if sound, is then again charged, again lighted, and, after a sufficient interval, again emptied.

Mode of burning.

The system, in ordinary use in Europe, of drawing the lime from the bottom of the kiln, and replacing it by fresh stone and fuel at the top, so as to keep up a continued combustion as long as required, is quite unknown in this district. Such a system, indeed, is quite incompatible with the rude and imperfect kilns here in use, and also with the kind of fuel now employed. There can be no question, however, that the cooling down of the kiln on the removal of each charge causes a very considerable waste of heat, while the impossibility of burning lime on the present plan, excepting during a few months of the year, entails a great additional loss. The burning, at present, does not properly commence until the end of January, or until February, and must be completed by April.

Twelve hundred maunds of stone yield, on the average, one thousand maunds of lime, and will require from 3500 to 4000 bundles of nál or reeds for their combustion. The stone delivered at the kilns, on the river bank, costs (1853) from 14 to 18 or sometimes 20 Rupees per 1000 maunds.

Possible improvements.

I have no doubt that the manufacture of this lime would be improved, and at the same time rendered more economical, by the adoption of the ordinary form of lime-kiln; from which the lime is drawn below, and the charge renewed from above, while the burning is a continuous process. Consequent on this would be the use of coal, as the sole, or, at least, as the greater portion of the fuel employed. For such purposes, the small coal (of which a large proportion is necessarily produced in hewing the coal of this district) would be most effective, and could thus be economized. At present while the cost of removing this small coal would be the same as for large coal (*viz.* 4 annas per maund to Pondua), I am disposed to think that no great saving would result from its use. But any improvement in the facility of conveyance for the coal from Cherra Poonjee would inevitably tend to a further economy in the manufacture of lime also. The highly blazing character of the coal, and the consequent difficulty of keeping it burning in close furnaces and in kilns, are, to a certain extent, objections to its employment for such purposes: but this applies with less force to the small coal; and a very few trials would soon point out the proper proportion of fuel to be used, and the proper mode of charging the kiln. On the other hand the very small amount of ash or earthy matter in the Cherra coal would be decidedly in favor of its use.

Marble.

Much of this limestone would produce most durable, and occasionally very handsomely-veined marble. It would answer well for ordinary purposes, chimney pieces, slabs for tables, garden seats and for flooring tiles. Of the latter article, I believe, many hundreds are annually imported, of inferior colouring and beauty to those which could be manufactured out of this Khasi limestone.

Coal.

The existence of coal in the Khasi Hills appears to have been first brought to notice in 1815, when Mr. Stark reported that he had found some beds in the lower hills of Sylhet, from which he forwarded specimens to Government. This coal was examined at the Gun Foundry at Cossipore, at the Mint, &c.; and being favorably reported on, Mr. Stark offered to supply any required quantity to the Government at one rupee and eight annas per maund. This offer was declined, and he appears to have obtained permission to bring to Calcutta any quantity during five years, free of charge. Not finding sale however for the first cargoes brought down, he abandoned the mines.

Mr. Jones, in a paper "on the mineral productions of Bengal," describes the Sylhet limestone, coal, &c.; but he does not appear to have known of the coal at Cherra Poonjee *(a)*.

It does not appear that much further was done (partly in consequence of the disturbed state of the frontier) towards exploring these hills for coal after this, until Mr. Cracroft in 1832 brought to public notice the existence of beds of coal close to the station of Cherra Poonjee *(b)*. This

*(a)* Gleanings in Science, Vol. I., p. 281, 1839.

*(b)* Journal Asiatic Society Bengal, Vol. I., p. 250, and p. 252.

discovery was followed up by the finding of other beds of coal in various places in the adjoining district(*a*).

Regarding this coal, the most important information referring to the few succeeding years is to be found in the Reports of the proceedings of the Coal and Mineral Committee, published in 1838-1846.

During the years intervening between 1840 and 1844, a considerable amount of coal was sent down from Cherra Poonjee, under the superintendence of Colonel (then Major) Lister, the Political Agent for the Khasi Hills, part of which was sent to Dinapore and the upper stations on the Ganges, but the larger proportion was sent to Calcutta.

In September 1844, the Government right in the coal-mines at Cherra (which are held under a lease for ever from the Rajah of Cherra, dated the 20th April 1840, at a stipulated royalty of one rupee for every 100 maunds excavated by Government, reserving at the same time the right of all subjects of the Cherra Rajah to mine on their own account, which "the Government are not to prevent") was transferred on the same terms to Mr. Engledue, then the Agent in Calcutta for the Peninsular and Oriental Company, the mines to be worked by him, either on the part of that Company, or on his own account.

It appears that, from that time, the quantity of coal annually extracted from these mines diminished considerably. In 1846, Colonel Lister reported that "the mines subsequently to this transfer had not been worked with that spirit which was expected from the correspondence prior to their being granted; and that only about one-half the quantity which was formerly sent down from the Agency, had been sent down during that season on the part of Mr. Engledue's Agents, while he thought the cost, instead of being reduced, would be greater by some 30 per cent."

These mines, having thus failed under Mr. Engledue's management, were transferred to the Sylhet Coal Company, or to their representatives,

(*a*) Journal Asiatic Society Bengal, Vol. I., p. 363, &c.

Messrs. Gisborne and Co., and have subsequently been under the management of several different persons. In no year, however, does there appear to have been forwarded from these mines an amount of coal equal to that sent down by the Political Agent at Cherra Poonjee, during the earlier years.

The great item of expense in the transport of this coal being the difficulty of conveying it from the mines at the top of the hills to water-carriage, Lieutenant Yule, of the Bengal Engineers, was ordered to report "on the means of transporting the coal found near Cherra Poonjee to the plains"; and early in the year 1842, submitted a very elaborate and able report on this question. He suggested two distinct means of accomplishing the object required; one, the formation of a road for the whole distance from the level of the plains to the mines having such gradients as would be suitable for the use of ordinary carts: the other a mixed plan, in which part of the distance should be traversed by an ordinary road, and part on self-acting inclined planes, or "railed descents," on which the descent of the loaded trucks should haul up the empty trucks returning; the speed, &c., being regulated in the ordinary way. The former plan of a continuous cart-road would involve the making of $16\frac{3}{4}$ miles of road, and the crossing of a river more than 200 feet wide, to bridge which would cost, by Colonel Garstin's estimate, Rupees 7,000. The total expense of a mixed plan, of railed inclines and road, was estimated by Lieutenant Yule at Rupees 66,584, for the first construction. And this plan he strongly recommends in preference to the other.

I cannot find that any thing further was done to facilitate the transport of the Cherra coal subsequently to the submission of this report. And to the present day, any coal brought down from these mines is carried on coolies' backs, as at the first.

It will be convenient here to investigate the actual cost of transport of this coal.

In 1842, Colonel Lister had excavated at the mines and despatched to Chattuc, 44,350 maunds of coal. Of this quantity the cost at Chattuc was 4 annas $4\frac{6}{8}$ pie per maund; 39,750 maunds were sent to Calcutta at a cost for freight, &c., of 3 annas $2\frac{3}{8}$ pie per maund, making a total cost in Calcutta of 7 annas $7\frac{1}{8}$ pie. Again in the same year, 65,955 maunds were delivered in Calcutta at an average cost per maund, including all charges, of 7 annas $3\frac{1}{2}$ pie. In February 1844, 5,642 maunds were despatched, at a cost on an average in Calcutta, of 7 annas $3\frac{1}{5}$ pie per maund. In November and December of the same year, 90,940 maunds were delivered at a cost (including loss of six boats) of 7 annas $9\frac{1}{2}$ pie per maund. In October, November and December, we find 21,126 sent down, but owing to part of the carriage for these coals having been provided by the Commissariat, I cannot state the average cost in Calcutta.*(a)*

We have thus, on an experience of several years, the *average* cost of this Cherra coal in Calcutta equal to 7 annas $6\frac{1}{4}$ pie per maund, or Rupees 47 per 100 maunds. This was the cost inclusive of all charges for overseers, weighmen, coolies, freight, &c., excepting only any charge for superintendence and general management. I would add here, that all the establishment required for this purpose was temporary, and therefore more costly than permanent arrangements would have been.

Lieutenant Yule estimated that the cost of conveying to Pondua, by his proposed plan, 100 maunds of coal, would be Rupees 22,778. To this add the cost of freight to Calcutta, at least Rupees 21 per 100 maunds, and the cost would be Rupees 43,778 per 100 maunds in Calcutta. In this estimate no allowance is made for cost of storage and re-loading at Pondua.

Further, there is no charge in this estimate for the cost of original construction of the road and inclines, nor any interest on the outlay

*(a)* For this information, I am indebted to the kindness of Colonel Lister in permitting me to examine the contingent bills passed for the expenses attending the despatch of this coal.

calculated. For the more cost involved in repairs, wear and tear of machinery, &c., I conceive that at least 10 per cent. on the outlay should be charged, independently of the interest on the capital invested. Taking this as low as 5 per cent., there must be added to the cost, as estimated by Lieutenant Yule, 15 per cent. per annum on the original outlay of Rupees 66,584. Or, what will come to nearly the same thing, we must consider this capital, or original cost, as to be repaid in not more than seven years; or that to the annual cost there should be added the seventh part of the original outlay, or Rupees 9,500. This sum should, of course, be divided over the whole amount sent down. If we estimate this amount as not less than 200,000 maunds, this would add to the cost per 100 maunds, as calculated above, .047 of a rupee. Or, if only one-half this quantity (100,000 maunds) were sent down, it would increase the cost per 100 maunds by .094 of a rupee.

Taking, however, the more favorable estimate, of the larger quantity, it results that on Lieutenant Yule's plan the cost per 100 maunds in Calcutta would be Rs. 43.778 + .047 = 43.825, or per maund 0.438 of a rupee, equal to 7 annas 0.1 pie per maund.

Even, therefore, estimating on the larger quantity taken above, and without any allowance for re-loading at Pondua, the actual saving is 6 pie or one-half of an anna per maund; or in British money one shilling and nine pence per ton.(*a*) I should state, that I have above taken the cost per 100 maunds as calculated by Lieutenant Yule for 100,000 maunds, and that he supposes that this cost (*viz*, Rupees 43.778) would be reduced to Rupees 41.942 per 100 maunds, were the quantity increased to 200,000 maunds, inasmuch as the "expense of establishment for the railed descents" would remain constant. But I have done so for this reason, that in none of his calculations has Lieutenant Yule

(*a*) Supposing that the whole quantity above calculated for, were sold in Calcutta at 8 annas per maund, thus producing Rupees 100,000, while the difference in the cost of transport would be Rupees 6,250, this would give an additional profit of £ 6-5 per cent.

estimated for the cost of the trucks in which he proposes that the coal should be conveyed.

His calculation as to the quantity of coal which could be readily conveyed down his proposed inclines is as follows:—"Supposing each "truck to measure four feet in length, by 2-3 in breadth, and 1-3 in "depth, three such trucks would carry down 30 maunds each trip, and "supposing only six trips in the hour, we might thus convey 180 "maunds per hour, 1,800 per day, or 54,000 per month."(*a*) Now for such work, at the least, there would be required an establishment of 250 trucks, (*b*) which would require for their construction and repair a considerable outlay. And this consideration justifies, I think, my having taken above the higher estimate of the cost per 100 maunds.

At the same time I am perfectly satisfied that, on other grounds, altogether, a mixed system of ordinary cart-roads, and of railed inclines would be found impracticable. The trucks which Lieutenant Yule proposes would be useless on ordinary roads, while ordinary carts would be equally impracticable on the railed descents. The entire distance must therefore be *railed*, and the trucks travel throughout; and this would be decidedly the best plan: or, the coal must be shifted at the top and bottom of each inclined plane from the trucks to the carts, and from the carts again to the trucks. This would involve six loadings and unloadings of the same coals, and the waste consequent thereon: quite sufficient, in my mind, to prevent the adoption of such a system of work.

I conceive, therefore, that this plan of accomplishing the distance partly by ordinary roads, and partly by railed inclines is quite imprac-

(*a*) This supposes 10 hours unbroken work in the day, and 30 days' work in the month; which is certainly above the average amount that could be obtained.

(*b*) Supposing each truck to make two trips in the day, up and down or, to require for loading, despatch, descent, unloading, and return to the mines, five hours, there would be constantly in motion at the same time 90 of these trucks. The entire distance by Lieutenant Yule's measurements is nine miles, and 702 yards; or for the double trip 18$\frac{4}{5}$ miles. This distance could certainly not be travelled in less time than I have calculated, *viz.*, five hours.

ticable: and Lieutenant Yule has himself shown that the cost of transport by a continuous cart-road, with gradients adopted to the use of ordinary carts, would be greater than the cost under the present system of coolies, independently of any consideration of the cost of constructing such a road. (*a*)

In the preceding part of this Report, I have briefly described the mode of occurrence of the coal-bed at Cherra Poonjee, its thickness and its accompanying rocks. I have also alluded to the irregularity of its development, and to the presence of this character at all the points where coal has been observed in the Khasi Hills. It still remains to estimate, as fairly as can be done under these conditions, the quantity of coal existing in the Cherra ridge.

The importance of this consideration has been most justly and forcibly alluded to by Lieutenant Yule in his Report. He says—"In deciding on the propriety of executing any work for facilitating the carriage of the coal, the first question which arises naturally is, whether "the Cherra seam is sufficiently extensive to justify entering on any "measure of the kind. After having expended many Rupees in "making the coal mine more accessible, it would be awkward to find that "the coal also had been expended in the mean time. I have done as "much to ascertain the extent of the seam, as could be done without "going to a much greater expense than would have been justifiable "without special orders on the subject. And I have connected the "points at which I know coal to exist by a sketch. There is, I think, "no reason to doubt that all these points are portions of an uninter-"rupted bed of coal; and taking this for granted, I calculate the "quantity of coal in the ridge with an average thickness of five feet, "to be 50,000,000 of cubic feet, or about as many maunds."

(*a*) There is a serious objection to this plan, arising from the extremely wet climate. The greater part of such roads should necessarily be paved with stone, to preserve them; and constant travelling on such paved roads would very soon knock up any bullocks.

I have given his words in full, because, although I feel satisfied, from the care which he obviously devoted to the investigation of the questions referred to him, that he was justified in adopting such a conclusion from the facts that came before him, I have been myself compelled to form a very different estimate. By a reference to his map, the three points referred to by Lieutenant Yule are seen; but after a careful examination of the ground between, I can say that, so far from there being an uninterrupted bed of coal uniting these points, a very large portion of the district between them is altogether without coal. And I believe that an estimate of one-third of a square mile of coal, with an average thickness of from 3 feet 6 inches to 4 feet, will be rather over than under the truth. This would give in round numbers from 10,850,000 to 12,400,000 cubic feet, or as many maunds (*a*), or from 387,000 to 447,000 tons.

In connexion with this point, and as a curious instance of the difficulty of arriving at accurate results in such matters, I may briefly state the various estimates of thickness which have been assigned to this Cherra coal. By Mr. Cracroft in 1832 (*b*), it was stated to be six feet six inches, divided into 3 layers: by Colonel Watson (*c*) in January 1834 to be from 10 to 16 feet: by the same gentleman in the same year, but a few months later, as from 16 to 20 feet (*d*). In 1857, in the first Report of the Coal and Mineral Committee(*e*) it is given as "15 feet in places," and in their last Report published in 1846 it is stated to be 28 feet (*f*). And in a short paper communicated to the Geological Society of London, through Mr. Lyell, Dr. McClelland gives

(*a*) This amount would not supply the present demand in Calcutta, for Burdwan coal alone, for more than four to five years, without taking into account at all the prospective increase of this demand; or the large quantity of imported coal used. Or, taking Lieutenant Yule's estimate of the amount capable of being sent down, *viz.*, 54,000 maunds a month, the whole would be exhausted in 16 to 18 years.

(*b*) Journal of the Asiatic Society of Bengal, Vol. I., p. 252.

(*c*) *Ibid*, Vol. II, p. 25.

(*d*) *Ibid*, Vol. III. p. 142.

(*e*) *Ibid*, Vol. III. p. 31.

(*f*) *Ibid*, p. 127.

its thickness as "above 20 or 30 feet"(a). This great difference in statement no doubt arises, in a great degree, from the extreme looseness with which such assertions are commonly made, as when a bed of coal is stated to be of "20 or 30 feet" in thickness (a difference in thickness of 10 feet being apparently considered perfectly immaterial), but I am inclined to think that, in the present case, it has in some degree arisen from another circumstance to which I have referred above, namely that at the part of the hill in which this coal was first examined there is a fault (or rather two or three small step faults combined) which have an up-throw to the West of about 40 feet. It would be very easy to be led astray in estimating the total thickness of the coal in this immediate spot : and it is I think very probable that some of the observers measured the distance between the bottom of the coal on one side of these disturbances, and the top at the other side. A glance at the accompanying Sketch will explain this. (*Fig.* 19). Although not intended to represent the exact conditions of the case, this figure will show the possibility of being misled in a hasty examination.

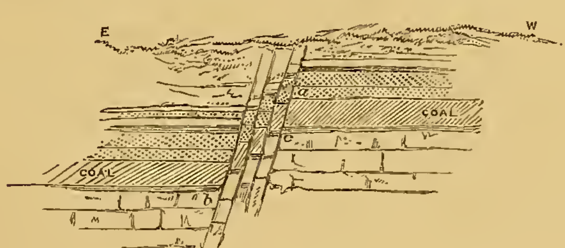


*Fig* 19.

The bed of coal is here represented as broken up and dislocated by four small faults, which are all up-throws to the West. If then this portion of the section were partially concealed by fallen detritus, it would be very likely that the space between *a* and *b* would appear

(a) Proceedings of the Geological Society, London, Vol. II. p. 567, June 14, 1837.

to a hasty observer the thickness of the bed of coal, although the actual thickness is only from *a* to *c*. In this way a bed of only five or six feet thick might assume an appearance of being 20 or 30 feet thick.

In the foregoing estimate I have confined myself entirely to the coal found in the small ridge to the West of the station of Cherra Poonjee, and in which the adits hitherto worked are situated. The coal which occurs at the village of Lairungoo or Surareem is, from the greatly increased distance and increased elevation (some 700 feet), entirely precluded from being profitably brought to market under present conditions, while the small patches of coal which show on the road between Cherra Poonjee and Surareem, are too limited in extent, too much disturbed, and too poor in quantity, to be worth considering at all.

The coal at Bairung has proved very bad and earthy, and is in small quantity; and although possibly useful for lime-burning, brick making or other such local purposes, would not yield any coal, which would repay the cost of transport to market.

The coal which is found to the South of Nonkradem is more favourably placed than any of the others, and there is probably a large amount of it available; but from the way in which it is seen, it would be impossible to form any opinion as to its extent, without expensive boring operations.

As to the quantity of coal existing in the Lakadong coal-field, it is difficult to form anything like a very accurate estimate, owing to the great irregularity of its development. I think we may, however, fairly take the quantity of coal easily accessible as being equal to one-half a square mile with an average thickness of three feet, which would give about 1,500,000 cubic yards or tons of coal or about 40,500,000 cubic feet or maunds. The cost of transport of coal from Lakadong to Calcutta is something less than from Cherra.

The season of the year, and the consequent very unhealthy state of the swampy jungles at the base of the hills, entirely prevented my visiting the various points to the Westward of Cherra Poonjee and towards Laour, where coal is stated to occur; so that I can offer no opinion whatever as to the quality or amount of coal found there. If the statements regarding the occurrence of thick beds of coal in this direction at slight elevations above the level of the plains be credible, the district would reward a careful examination. It could only be visited with any safety, during the cold weather. If coal exist there in any quantity, the probabilities are that it would be found to be very similar to the coal of Cherra Poonjee in quality. And independently altogether of the statements of observers, the general dip or inclination of the rocks, with which the coal is associated, (and to which I have alluded before) renders it tolerably certain that it must occur at a considerably lower elevation than the coal near to Cherra Pocnjee.

I have not entered into the question of the possibility of bringing these Coals *profitably* to market; nor did I feel justified in devoting any of the short time at my disposal in these hills to the investigation of any engineering projects for this purpose, further than was necessary for ascertaining the comparative economy of the various plans hitherto proposed. I was satisfied that any mixed system of transit, partly by ordinary conveyances, and partly by machinery, would fail. I was also satisfied that *no one* of the localities referred to, taken singly, held out a prospect of sufficient coal to yield a fair return on the outlay required for such works for its conveyance. But at the same time I was convinced that, were all these localities in the possession of the same persons, possessed of sufficient skill and energy, and who would work each in succession (the needful machinery for such operations being transferred from one site to the other) it would be possible to render the undertaking a profitable one.

Into the details of any such plan it is not my province to enter; but I am certain that a little experience in the more economical systems of recent mining operations would suggest much more simple and less expensive plans of operation than have been proposed with reference to Cherra Poonjee.

Nor does it at all come within my subject to discuss the probability or improbability of such prices being obtained for this coal, as would yield a profit on its working. The changing condition of the markets; the ever-varying charges for freight, &c., of imported coals; and the constant alterations in the amount of demand and other considerations, all so materially affect the question of profit on such undertakings, that any opinion founded on an imperfect acquaintance with the general commerce of the country would be of little value. I have therefore purposely confined my observations to an examination of the mode of occurrence of the coal, its extent and character, the cost under existing arrangements for conveying the coal to market, and the schemes which have been proposed for its more economical transport.

The quality of the coal at Cherra has been so frequently spoken of, and written about, as being "greatly superior to the Burdwan" (in the ratio of 12 to 10, or even of 5 to 4, it is said), and as "being fully equal in every respect to English coal," that it may be desirable to give a word of caution on this subject, lest some might be misled by such loose statements. The Cherra coal is undoubtedly superior to the coal from the Damoodah valley; and, to the average of that coal, as it has been hitherto supplied to the Calcutta market, after nearly two years' exposure, it is possibly superior in the ratios mentioned before; and it is equally certain that it is equal to *some* English coals, but it is as certainly inferior to others. It is *quick in its action*, and therefore would generate steam rapidly: it cakes well but gives out a large amount of smoke: it splits easily and from the absence of that definite structure, which produces the planes of division known to English miners as "backs," or the joints in the coal, it breaks into unsymmetrical pieces, and consequently would not stow well. From its composition (*a*) therefore, its quick combustion, and its irregular cleavage, I conceive it to be at the least 5 to 7 per cent. inferior to *good* English coal. As a gas-producing coal, it is superior to any English coal imported, both as regards the quantity and purity of its gas. And with proper precautions in burning it might yield a passable coke.

But further, as regards any extensive or systematic working of these mines, there is a condition at present attached to the authority under which they are held, which, if continued in force, must effectually prevent their being economically worked. I allude to the clause in the lease, by which the lessee is prevented from interfering with any of the subjects of the Cherra Rajah, who may extract coal on their own account. So long as such be the case, no general system of operation could be adopted, and no general arrangements for the ventilation and security of the mines could be carried out, as these would be constantly liable to interruption, at the caprice of any unskilled native, who might fancy to work in one part of the hill in preference to another. In fact, almost all the coal hitherto sent down from these mines has been pur-

(*a*) By Mr. James Prinsep's analysis, the composition of Cherra coal was water 7·0, volatile matter 37·1, carbon 62·0, ash 0·9 : while the *average* composition of good English coal imported was volatile matter 31·0, carbon 67·3, ash 1·6. In a rude way these coals may be taken to vary in value in the ratio of the different amounts of carbon contained, or that Cherra coal is to English coal (average) as, 62 : 67·3. Specimens of coals from this district were forwarded to the great Exhibition in London in 1851, and subsequently along with others from India were submitted to very careful examination by Captain Henry C. James, B. N. I., under the superintendence of Mr. Lewis Thompson, an eminent coal consulting chemist, and with the apparatus of Mr. Evans of the Westminter gas works. The results of these analyses, specially directed to the gas-producing qualities of the coals, are given below as submitted by Captain James to the Government of Bengal in January 1854 :—

There is no possibility now of ascertaining the exact locality from which these specimens, given as from the "neighbourhood of Sylhet," and "Cossyah Hills," were obtained, and further, it should not be forgotten that in all probability the specimens sent for exhibition were far above the average quality of the coal which they were intended to represent, being picked and selected masses. But neglecting all these considerations, Captain James' analyses fully prove the value of the Khasi coal as a fuel, and more especially for the production of gas yielding a clear and white flame.

The results of similar trials with the Garesfield coal, from the Newcastle coal-field in England, are given for comparison, this coal being generally considered one of the best coking coals known.

*ANALYSES of various specimens of Indian Coal.*

*London, September 14th* 1853.

| Name of the Place from whence the Coal comes. | Description. | Specific gravity of Coal. | Cubic feet of Gas per ton. | Percentage of Coke. | Illuminating Power of Gas in Candles. | Specific Gravity of Gas. | REMARKS. |
|---|---|---|---|---|---|---|---|
| Neighbourhood of Sylhet .. | Coarse grain and hackly streak, black and shiny. Fuses slightly, does not decrepitate, very bituminous | 1·295 | 10 700 | 61· | 14· | ·462 | The coke of this coal is very fair. It has a metallic lustre similar to the best Newcastle coke, and is remarkably free from sulphur. |
| Singrowlee South of Mirzapore | Slaty, with charcoal bands and iron pyrites parallel to the general fracture, cross fracture, cubical, streak dull black, does not fuse, decrepitates strongly .. | 1·223 | 10·400 | 53· | 15 5 | ·436 | This is very superior coal for gas, it has many of the properties of lignite, and most likely overlays a bed of cannel coal. |
| Cossyah Hills .. | Massive, fracture irregular in all directions streak dark brown, decrepitates slightly, swells and fuses | 1·278 | 10·200 | 58· | 15· | ·424 | A capital coal for Steamers, being difficult to break, and would stow tolerably well, the coke is good, and the gas particularly clear and white. |
| Chota Nagpore ... | Black, and irregular in fracture with thin bands of jet. Slaty, streak blackish brown, does not decrepitate ... .. ... | 1·342 | 9 600 | 72· | 14 5 | ·448 | A very fair coal, but the coke is deficient in metallic lustre. The lowest amount of cubic feet of gas per ton is mentioned. |
| Raneegunge (Burdwan) | Irregular fracture inter-stratified with bands of charcoal and earthy matter, does not fuse .. .. | 1·296 | 9·400 | 59· | 13·5 | ·429 | This coal contains upwards of 10 per cent. of ash, which almost renders it unfit for coking purposes. It contains about 1·8 per cent. of sulphur. |
| Garesfield (NewCastle) | ........ ........ | 1·275 | 10·800 | 73· | 13·4 | ·45 | This is supposed to be the best coking coal in the world. |

(Signed) H. C. JAMES,
*Captain Bengal Army.*

chased from such Khasi merchants, who have raised and sold it. And on a very few maunds indeed has the prescribed royalty of 1 Rupee per 100 maunds been paid by the Government, or its representatives, to the Cherra Rajah, as very few maunds have been raised by persons in their employment. Just at present, while the coal is easily accessible, it can be procured in this way as cheaply, if not more cheaply, than if men had been paid to hew it, and the royalty paid on the quantity extracted. But such indiscriminate and unsystematic working entails an enormous waste of the coal itself. And no precautions being taken to keep open the mines or to support the rocks above the coal, after these workings have been extended a little, all will fall in, and mines and miners be buried in one common grave. (*a*)

There is no such restriction affecting the mines at Lakadong, which are the property of Government; the whole of the Jynteah hills, in which they are situated, having passed into the hands of the Indian Government, together with all the rights to mines, jungles, &c.,

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(*a*) The lease referred to above is in the following terms :—" To the Political Agent Cossiah Hills, Cherra Poonjee. I, Soobah Singh, Rajah of Cherra Poonjee, hereby give a perpetual lease to the British Government of the Cherra Poonjee coal-beds, now being worked, situated within my territories, known by the names of Oosdir, Ooskan and Non-kreem Hills. The terms of the lease, mentioned in the following paragraphs, are to be considered final and binding :—

" 1st. I am to receive for all coal mined by Government servants at the above places 1 rupee for every 100 maunds. I will on no account demand more. The Government are not to prevent my own subjects from working on their own account at the above mines ; and such of my subjects as do so will settle and pay to me direct for all coals they may mine at the above beds. The Government have the power, however, to prevent others than my own subjects from mining at the above places, without their previous sanction and order.

" 2nd. The above terms to be held good for a perpetual period. I will on no account ask for any new arrangement to be made.

" 3rd. Should at any future period any new coal-beds be discovered within the limits of my territories, I hereby agree to make them over to the British Government on the above terms." Dated 20th April 1840.

The lease granted by Beera Singh and Ram Roy, Cossiah Sirdars of Bairung Poonjee, and confirmed by Soobah Singh, Rajah of Cherra Poonjee, was in all respects similar, and bore the same date. It granted the right to work the Coal at Bairung.

previously held by the Jynteah Rajah, who resigned all claim to them in 1835.

On the other hand, the coal which is found to the South of Nonkradem is in the territories, and under the control of Singh Manick, the Kyrim Rajah, who is still independent.

I fully anticipate, however, that the coal of Cherra Poonjee, and of this frontier generally, even though it may not be possible to bring it with profit to the Calcutta market, will turn to great and useful account at some future, and not very distant period. I cannot anticipate that the extensive districts of Sylhet, Cachar and Munnipore, with the prospect of an increasing traffic from the East along this valley, can be much longer deprived of the benefits of steam communication. The noble river Soorma stretches in one continuous course throughout the entire distance, and is navigable for steamers of the ordinary size without the interruption of a single dangerous spot, and at all seasons, as far as Chattuck *(a)*, while ordinary boats of considerable size can proceed as far as Silchar, and smaller boats much further. This unbroken line of water communication, stretching for more than 350 miles from Calcutta, seems specially adapted for such an enterprise; and, if once a steam communication be opened along this river, the coals of the frontier will prove highly valuable for the supply of the requisite fuel, at an economical rate. There may not be at the present a sufficient trade in this direction to render such a project remunerative; but this was equally the case in other localities, and there can be little question that any increase in the facility and rapidity of communication with these districts must tend to develope new and to extend the existing sources of trade. Moreover, such a system of inter-communication would appear to be especially desirable in a district where every road is co-

(a) A rapid, passable however during one-half of the year, prevents steamers from proceeding further than Chattuc.

vered with water for some months in the year and communication can be maintained only by boats.

I have above referred to a great superiority of the Cherra coal over other Indian coals for the manufacture of gas.

Iron. The manufacture of iron appears to have been carried on in these hills from time immemorial; and by all the tribes inhabiting them. Very soon after the British occupation of the Khasi hills, this manufacture attracted attention. In a short notice of these hills *(a)* in 1829, it is referred to; and in the same year Mr. Jones, writing of the mineral productions of Bengal (*b*), recommends Pondua, at the foot of these hills, as an excellent site for an iron mill, for the manufacture of bar, bolt and hoop iron. Mr. Walters *(c)*, in his account of a trip across these hills, refers to this manufacture, and gives a rough sketch of the furnaces in use for smelting. A few years later, Lieut.-Colonel Watson detailed the circumstances which appeared to him to render Cherra Poonjee a favourable site "for the erection of an iron and steel manufactory on an extensive scale." *(d)* And still more recently Lieutenant Yule published a very good account of the processes adopted in washing and smelting the ore; and the manufacture of the iron *(e)*. Mr Cracroft *(f)* had ten years before described the same process, though not so fully, and had published a sketch of one of the Khasi smelting furnaces in operation.

The system at present followed in these hills, both in the extraction and washing, and in the subsequent smelting of the ore, being precisely the same as it was twenty years since, it will be quite unnecessary to do more than refer to the papers quoted above for description of the details of the several processes.

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*(a)* Gleanings in Science, Vol. I, p. 252. | (*b*) *Ibid*, Vol. I, p. 231.

*(c)* Asiatic Researches, Vol XVII, p. 499, published in 1832; excursion made in 1828.

*(d)* Journal Asiatic Society, Vol. III, p. 25, January 1834.

*(e)* *Ibid*, No. CXXIX, p. 853, 1842.

*(f)* *Ibid*, Vol. I, p. 150, 1832.

The principal sites of the mining operations within the Khasi hills are near Molim, Nonkrim, Lailangkot, &c., on the granite district of that neighbourhood; and more to the West near Lungkoi. In other places, where no washings for ore are now carried on, the enormous blocks of granite strewed over the surface, and piled up in gigantic masses, bear evidence to the former existence of workings, of the magnitude of which they remain the lasting monuments. The richest portions of the washings have been generally on the outskirts of the granite area, or near its junction with the rocks that rest upon it.

The only ore worked in these hills occurs in the form of a fine sand consisting of minute crystals of titaniferous magnetic oxide, which are irregularly distributed in the mass of the softer portions of the granite rocks, and also occasionally in some of the gneissose beds. The upper portion of the granite is partially decomposed to a considerable depth, and this soft and easily yielding rock is not quarried, or mined, but simply *raked* into a small stream of water conducted along a little channel formed at the base of the small scarp, or face of rock, from which the ore is obtained. The process of washing is carried on precisely as Mr. Yule described it in 1842. The manipulative skill of some of the Khasi women, acquired by long practice in these operations, is very great; hence a very small proportion of the ore is lost in the washing.

With very few exceptions this ore is not reduced or smelted in the villages, adjoining which it is procured. It is sold in baskets of a tolerably fixed size and shape, seven of which contain about three maunds of the ore. It is carried, often for many miles, to the villages where the smelting furnaces are situated. In most cases the crude iron, as it comes from the smelting furnaces, is again brought to market and carried to other villages, where it is manufactured into tool sand other articles for market.

By much the larger portion of this *cutcha* iron, in the balls or lumps in which it comes from the smelting furnaces, is sent to the plains, where it meets a ready sale. It is brought on the Northern flanks of the Hills to the several marts in Assam, and on the Southern, to Pondua, Lacat, Chattuc, &c., where it is purchased in large quantities, and chiefly, or at least very extensively used in the manufacture of the double hook-like nails, with which the planks of boats are united; and for which there is a great demand at the large boat-building villages on the Soorma River (Azmerigunj, Beetalung, &c.).

Of the iron, which is converted within the Hills, the greater portion is wrought into codalies (or the native form of shovels or spades), or into the large chopper-like knives or *dhows*, which the Khasis use (*a*). In all manufactures of this kind, an almost total division of labour has been established by custom; the making of each being confined to different individuals, and generally speaking even to different villages.

The manufacture of codalies is carried on extensively in some villages, in workshops differing entirely from the huts in which the first smelting or reduction of the ore is carried on. Those in which this manufacture is conducted are generally open sheds, of an oblong shape, the fire being placed at one end. Under this rough cover, formed simply with poles supporting a roof, five men are engaged; one sits at the end of the shed, on a sloping bank behind the hearth, and works the bellows with his feet. Another superintends the fire, and directs the operations. One of the divided lumps, into which the smelted ore has been made, is then placed in the fire, and, being raised to a good red heat, it is roughly but rapidly reduced from its semi-circular form into a more regular and bar-like shape. It is now again fired, and when heated is with a single forcible blow united with the small piece of iron which is to form the handle (Fig. 21 a) and which has been previously

(*a*) The Khasi *dhow* is a straight cleaver-like knife, one edged, from 12 to 15 inches in length, and set in a handle of 10 to 12 inches long. In a Khasi's hands, it is an effective tool, and forms his chief weapon, (offensive and defensive) his axe and his knife. Fortunately of late years it has been used almost exclusively in the felling of trees, &c., and in ordinary labor.

roughly formed. Re-heated, it is then beaten out into the first form of the codalie (Fig 21 b). It is again heated, and an additional change of form given to it. The mass which at first was about two inches thick has now been reduced to about half an inch, or thereabouts; and, about four inches wide at first, it has now become seven or eight. Another heating again reduces this, and gives it more form. This is

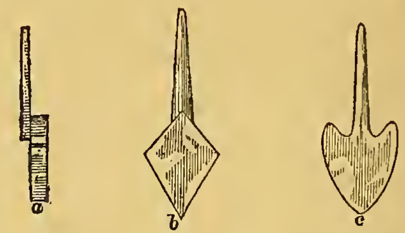

*Fig.* 21.

the fifth time it has been fired, and it is again heated three times more, and each successive time brought more nearly to its finished state. Up to this stage of the process the four men have been all engaged in the forging; now the one man, who has charge of the fire, singly continues to improve the form and complete the fashioning of the codalie.

The hammers used by these smiths appear at first sight very awkward and unwieldy. They are very long in the head, being from 12 to 17 inches, only one-faced, with the handle inserted near to the end of the head. This handle is frequently not much longer than the head of the hammer itself. This peculiarity in the forms of the hammers leads to a marked difference in the mode of using them, as compared with that which an English mechanic would adopt. A Khasi smith never swings his hammer, however heavy, but simply lifts it vertically, and the force of the blow depends on the weight and impetus of the hammer itself, as it falls, rather than on the muscular power of the person who wields it. The general form of the hammers used by the Khasi smiths is shown below (Fig. 22). Few of these exceed 6 lbs. in weight.

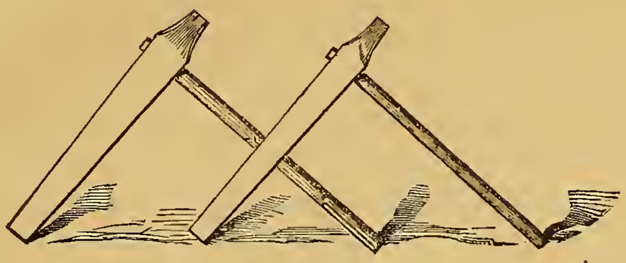

*Fig.* 22.

The anvil on which the work is carried on is simply a rounded block of the hard granite found in the adjoining district, and the ring of the hammers on the stone, as each successive blow is given, produces an extremely musical effect, which at a little distance sounds like the chiming of melodious bells.

The fuel used is entirely charcoal, soaked in water, and kept in a large earthen basin-shaped place next the fire.

The pig iron, as described by Lieutenant Yule, is produced from the smelting furnaces in nearly circular lumps or balls, which are subsequently split or divided into two parts. Each of these blocks or balls makes two codalies, or each half-ball will make one. Each of these balls weighs on an average seven seers, while each codalie weighs not quite two seers. Three seers and a half, therefore, of cutcha iron are required to yield two seers of the manufactured iron, showing a loss arising from the impurity of the iron as it comes from the smelting of about 43 per cent.

The ordinary out-turn of one hearth, or the labour of five men per day, is 10 codalies. The pig-iron is sold at the rate of six to eight blocks for 1 rupee, and the codalies sell for about $3\frac{1}{2}$ annas each, or five for a rupee.

After being formed, and worked-up hot, all these codalies are thoroughly cold-hammered and finished on a smoothly-polished stone anvil. This portion of the work is done by the three men who are not engaged at the fire in the forges during the short intervals of labour while the mass of iron is being heated, or when their services are not required in the forging of the heated mass. And after finally being finished, as far as the forging is concerned, the codalies receive a rough kind of semi-polishing, or brightening, which is accomplished in a most ingenious way. They are carried in numbers by the women or young girls to the bank of some adjoining stream. A common handle is procured, into which each codalie is successively inserted, and then it is for a few minutes rapidly driven into the moist sharp sand of the river. This acts precisely as a grindstone, the sharp-cutting edges of the small quartz grains in the sand soon giving a clean and smooth surface to the spade.

A large number of these codalies are annually sent from the Hills into Assam, in addition to the quantity required for the supply of the Khasis themselves. But I was informed that even in the immediate vicinity of the Hills, English manufactured spades could be purchased at as low a price as these Hill-made tools, and were of a superior quality, being more durable.

The quality of this Khasi iron is excellent for all such purposes as Swedish iron is now used for. The impurity of the blooms, however, as they are sent to market, is a great objection to its use, and the waste consequent thereon renders it expensive. It would also form steel or *wootz* of excellent quality. I have no doubt that the manufacture could be greatly improved, and possibly extended. The great defects in the present system are, the want in the first instance of a means of sustaining a sufficiently high and equable temperature in the hearth, so as to keep the whole of the mass or bloom of metal in a molten state at the same time, and thus more completely separating the slag from the purer metal; and, of some more powerful means of expressing the slag from the spongy metallic mass than the slight hammering it now receives with a wooden mallet or club.

But I do not think (judging of course from the portion of the hills I had myself an opportunity of visiting) that the manufacture of this iron could be very much extended, owing to the scanty dissemination of the ore in the rocks, and the consequent high cost of obtaining it. At present the want of any permanent supply of water prevents the natives from working for more than a few days during the year, whilst the rains are heavy, and they can readily obtain sufficient force of water for the washing of the ore from its matrix.

I would here mention, that although I have never heard that any gold has been observed during the washings for the iron ore, when if it occurred in any quantity it could scarcely have escaped notice, still on amalgamating a large amount of this ore, or rather on agitating it in contact with some mercury, I obtained distinct traces of gold although in very minute quantities; but too trifling to admit of its profitable extraction. It is more than probable that in some other localities it may be found to occur more plentifully, and that these Hills, or the continuation of the same ridge to the eastward, may prove to be the source of some of the gold found in the rivers of the Assam valley. *(a).*

Such is a brief sketch of the various products obtained from the Khasi Hills, and of the purposes to which they are applied. And if this outline should lead to further investigations, and tend to direct the attention of any to this district, and so increase the number of its visitors, I am satisfied, that whether profit may be derived from such investigations or not, much pleasure will result from a sojourn amidst the most lovely scenery and in a most salubrious climate; and among a people presenting many interesting points for study, and many excellent traits of character.

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# APPENDIX.

*Elevation above the Sea of various localities in the Khasi Hills.*

| | Feet. |
|---|---|
| Cherra Poonjee, | 4118 |
| Kala-Pani (Bridge), | 3179 |
| Boga-Pani (road near Bridge), | 4451 |
| Mow-phlang, | 5931 |
| Soh-iong (Synng Bungalow), | 5355 |
| „ (Native Village), | 5901 |
| Myrung (Bungalow), | 5537 |
| Nungklow (Bungalow), | 4585 |
| Bori-pani (below Nungklow), level of Suspension Bridge, | 2380 |
| Bori-pani level of water, | 2339 |
| Shillong Hill, | 6124 |
| Mawm'luh (gate of Village), | 3852 |
| Mahadeo (Rock), | 2623 |
| „ (Guard House), | 2188 |
| Tungwai (Village), | 210 |
| Bairung, | 1242 |
| Kullong rock (top of), | 5684 |
| „ level of top of knolls to the South of the Rock, | 5210 |
| Monai Village on road to Kullong, | 5067 |
| Laidom, | 5205 |
| Lailangkot, | 5703 |
| Nungkreem, | 5406 |
| Pomrong, | 4748 |
| Kala-Pani (ridge to South of), | 5300 |
| Joowai (Jynteah Hills), | 4230 |
| Mentedoo River (at ford on road from Joowai to Lakadong), | 3845 |
| Rombai, | 3578 |
| Oomsatung, | 3234 |
| Lakadong, | 2294 |
| Mooshye, | 3411 |

The following are elevations of places of minor importance, determined for geological purposes;—

| | |
|---|---|
| Top of Greenstone seen under Mawm'luh, | 3222 |
| "Jasper beds," | 2384 |

APPENDIX.

| | Feet. |
|---|---|
| Level of "Fossil beach" of Dr. McClelland, under the village of Mawm'luh, ("Cyrtoma" beds), ... ... ... ... ... ... ... ... ... ... ... ... | 2974 |
| Level of Fossil beds, above Teriaghat, ... ... ... ... .. .. .... | 352 |
| Teriaghat, above Sea, ... ... ... .. .. .. ... ... .. ... ... | 128 |
| Top of Metamorphic Rocks, South end of the Cherra Valley, .. .... | 2155 |
| Ditto ditto ditto, three miles further to the North, .. ... .. ... ... | 2913 |
| Living Bridge, near junction of the valleys of Temshung and Mawsmai, .... | 977 |
| Bamboo Bridge, about three miles to the North in the same Valley, ... | 2311 |
| Maw-ring-rin, (three large stones on ridge North of Cherra), ... ... .... | 4823 |
| Top of Waterfall, North end of Cherra Valley, ... ... .. .. ... ... | 4860 |
| Level of Assam Road, at small toll house, North end of Cherra Poonjee Native village, ... ... ... ... ... ... ... ... ... ... ... ... ...... | 4428 |
| Native village of Cherra Poonjee,... ... ... ... ... .., from 4397 to | 4572 |
| Bottom of zig-zags, on road to Teriaghat, .. ... ... ... ... ... ... | 1428 |
| Level ground below ditto, sandstone abounding in shells, ... ... ..... | 750 |

The above elevations have all been determined from observations made with a mountain Barometer of Newman's latest construction, and obtained from the Mathematical Instrument Department, Calcutta, and observed synchronously with another stationed at Cherra Poonjee. The elevation of the Bungalow which I occupied there (in 1851) was obtained from the average of 112 observations, synchronous with those made at the Surveyor General's Office in Calcutta: the instruments used in my observations having been carefully compared with those in Calcutta, and reduced to the same standard.

The elevation of this point at Cherra Poonjee, having been thus established as 4118 feet above the level of the sea (or above the datum determined for Calcutta, namely 18.11 feet below the cistern of the Standard Barometer there), the elevations of all the other localities have been determined by adding, or subtracting from this ascertained height, the difference of elevation due to the different readings of the Barometer. This has been done in preference to comparing each observation with the Calcutta readings as being much more likely to afford correct results. The greatest elevation reduced from the Cherra observations was 4144 feet; the lowest 4065.

*On the Geological Structure of the Nilghirí Hills (Madras) by* HENRY F. BLANFORD, ESQ., *Geological Survey of India.*

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Geographical position of the Neelgherries.

THE Nilghirí or Neelgherry Hills, well known as the principal Sanitarium of Southern India, form a small lofty table land at the Southern extremity of the wide spreading, but far less elevated plateau of Mysore, and constitute the Southern termination of the Ghats. Like most of the isolated hill-tracts of the Peninsula, *e. g.* the Shevaroys, Pulnies, and Anamulies, the Neelgherries rise abruptly from the lower country around them, and are bounded on all sides by short precipitous spurs, the remains of a former great escarpment, which, in the course of long ages, has been thus broken up by the unceasing action of the numerous streams pouring down from their surface.

Physical aspect.

Their extent.

The greatest length of the Neelgherry plateau is in a N. E. and S. W. direction, or from Rungasawmy's Peak, overlooking the Guzzlehutty Pass, to Sispara, a distance of 48 miles, while their greatest breadth from the Falls of the Pykara at Côt Mullay to the termination of the Mailur ridge does not exceed 20 miles. The Northern and North-Western portions of the great boundary escarpment of the Neelgherries are of less relative height than those bounding the other sides of the plateau, the Mysore country at their foot being itself an elevated tract bounded by the Eastern and Western Ghats, the former of which trend off in a North-Easterly direction from the North-Eastern corner of the Neelgherries, while the latter commencing opposite to Makurty Peak pass off in a Westerly and North-Westerly direction, forming the Northern portion of the magnificent amphitheatre of hills seen from Sispara and Makurty Peak (Plate XI).

The Northern escarpment and the Ghats.

The drainage of the Northern and North-Western portion of the hills flows down towards the Mysore country by numerous small streams, the principal of which is the Pykara, and the large stream (the Moyaar) resulting from these and from the drainage of the adjacent part of Mysore, passing through a deep gorge cut by its own denuding action in the Mysore plateau, flows down near Guzzlehutty to join the Bhovani River at the foot of the Ghats and of Rungasawmy's Peak.

Drainage of Northern escarpment.

On the Eastern side of the hills, and below the Eastern Ghats the low country of Coimbatoor stretches away, a barren sandy tract, dotted over at distant intervals with a few low rounded hills, and, except during the first few weeks of the North-Eastern Monsoon, clothed with but little other vegetation, than a few wiry *cacti* and *euphorbias* and stunted banyans, which rather increase than diminish the desert-like aspect of the country.

Coimbatoor country.

The elevation of Matepolliam, a large village of Coimbatoor, near the foot of the hills, is 800 feet above the sea. From Rungasawmy's Peak, the great escarpment of the Neelgherries trends away in a South-Western direction, following, or rather directing, the course of the Bhovani River which flows at its foot, and receives the drainage of the Southern portion of the Neelgherry plateau. The country to the South of the Bhovani as seen from the summit of the hills near Mailur is shown in Plate XII. It is covered with long ridges of hills for the most part low, and running parallel with the escarpment, with small alluvial plains intervening, through which flow the Bhovani and its principal tributaries. One or two of these ridges, such as that known as Lambton's Peak, (shown to the right of the sketch,) rise prominently to an elevation not much inferior to that of the Neelgherries, but they are either entirely isolated or communicate

S. Eastern escarpment and drainage.

Hill country to South of Neelgherries.

with the great mass of the hills by ridges of much less elevation. These ridges terminate to the South West in a low spur projecting from the South Western corner of the Neelgherries, and forming a portion of the great watershed of the Indian Peninsula. This hill tract, extending from the foot of the Neelgherries to the neighbourhood of Palghat, is covered with a dense jungle through which the villages of the Erulars are sparsely scattered, and which abounds in wild Elephants, Tigers, Bears, Nilghai, Sambur, and such animals as are only found in the wildest jungles of the Peninsula.

Great Western escarpment.

The Great Western escarpment of the Kundahs (a name given to the South Western portion of the Nilghiris) extending from Sispara to Makurty Peak, or rather to the head waters of the Pykara river immediately below Makurty, completes the circuit of the Hills. There is perhaps no scene in Southern India more grand and imposing than this gigantic escarpment. Rising abruptly from the low jungle covered plains of Malabar, to the lofty surface of the Koondah plateau, an elevation of nearly 8000 feet, it presents an apparently almost precipitous hill face covered with dense jungle, furrowed but not broken up by the innumerable hill torrents which course down its surface, and glisten like silver threads amid the dark green foliage of the forest. It would seem at first sight perfectly inaccessible from the plains below, and such it is throughout the greater portion of its extent. It is only at Sispara that with considerable engineering skill, a road has been constructed, forming a communication between the hills and the low country of Malabar, and it is from this road that the finest view of the escarpment is obtainable.

Neelgherry Plateau.

To pass now to the description of the plateau. As might be inferred from the preceding, a great difference in the character of the scenery is perceptible on ascending from any of the hill ghats to the surface of the hill country, a change due, partly to the different aspect of the vegetation, but principally to the different nature of the two great physical agents which have operated in giving form to the hills on the surface, and to those forming the edge of the table land.

Lateral gorges due to fresh-water action.

It has been already mentioned that the gorges which break up the lateral faces of the hills, and up which the principal roads are carried, have been cut out by the attrital action of the streams flowing down from the plateau They have, therefore, the precipitous sides, and are separated by the steep ridges which always result from extensive fresh-water denudation in a mountainous country.

Character of the surface.

The surface of the Neelgherries, on the other hand, is undulating in the extreme, and the streams which carry off its drainage, meander with a comparatively gentle fall through rounded grassy hills, but rarely forming any thing like a large rocky bluff, while the valleys never present the slightest approach to the character of a gorge except in some of the deeper valleys of the Kundahs, where, from causes to be explained in the following pages, the rainfall is far greater than on the surface of the Neelgherries proper, and the denudation produced thereby consequently greater. It might be inferred, therefore, even from a casual glance at the Neelgherries, that the hills on the plateau owe their form to marine action, it being a well established fact, that rounded hills, and an undulating country, are invariably the results of such action.

Due to marine action.

But on the Neelgherries we have a further proof that the sea has formerly washed over what is now the highest portion of the table land, in the existence of a series of escarpments, imperfect indeed in many cases, and much cut up by the subsequent action of surface water, but still distinctly recognizable to the practised eye, and sometimes traceable for a distance of many miles continuously. The most conspicuous of these superficial escarpments crosses the hills in a S. W. direction from the rise of the Pykara near Makurty Peak, and forms the boundary

Old marine escarpments.

of that elevated portion of the plateau to which the name of the Kundahs has been given.

Botanical features.

The hills are, for the most part, but slightly wooded. They are generally covered with a coarse grass, or in the more rocky parts with a low scrub, and the patches of loftier forest, termed Sholas, are, as a general rule, confined to the valleys and water courses, and the more protected portions of the hills. There are, however, many exceptions to this mode of distribution, and numerous isolated patches of various extent are conspicuously dotted here and there over the slopes of the hills. They have a very peculiar appearance, the boundary of each Shola being sharp and distinct, so that the pedestrian passes in a few steps from the open hill side into a dense thicket. The Botany of the hills is a subject foreign to that of the present report, and will therefore not be entered upon here. All those desirous of information on points connected therewith, may be referred to the works of Dr. Wight as containing the most reliable information.*

Previous writers on Geology of Neelgherries.

Previous to the commencement of the present Survey, the Geology of the Neelgherries had attracted the attention of several persons who had visited the hills,

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* In the Introduction to the "Flora Indica" we find the following summary of the flora of these hills given by the Authors of that masterly essay:—

"The ravines and shady slopes near the undulating summits of the Nilghiri hills are occupied by thickets of small trees and bushes, like those of Ceylon, but probably composed of a greater number of species, all of which are equally characteristic of similar situations in the Khasia, as *Ternstrœmiaceæ*, *Michelia*, *Symplocos*, *Photinia*, *Ilex*, *Eugenia*, *Vaccinium*, *Gaultheria*, *Myrsineæ*, *Rhododendron arboreum*, *Pittosporum Laurineæ*, with *Rubus*, *Cotoneaster*, *Desmodium*, *Jasminum*, *Euonymus*, *Indigofera*, *Daphne*, *Euphorbiaceæ*, *Antidesmeæ*, Willow, *Melastomaceæ*, and a vast number of others. Of forms that do not extend to Ceylon, are Willow, *Gnetum*, Viburnum, *Lonicera*, *Rosa*. Balsams attain their maximum in the Nilghiri and Travancore mountains; and amongst European forms are *Alchemilla Potentilla*, *Gentianæ*, and *Labiatæ*; *Agrimonia*, however, which is found both in the temperate parts of India and in Ceylon, is absent from the Nilghiri. *Flora Indica Vol. I p.* 126 *Introd. Essay*.

either for pleasure or with professional views, and a brief notice of the facts published by these observers may fitly precede the present detailed report.

Dr. De Benza.

The earliest description of the Geology of the Neelgherries, and at the same time the most detailed that has hitherto been published, is that of Dr. De Benza, which appeared in Vol. 3 of the Journal* of the Madras Literary and Philosophical Society. In this notice Dr. De Benza gives a very full, and for the most part, accurate description of the Mineralogy and Topography of the Hills, but in his Geological observations, he has fallen into the very natural error (considering the state of Geological Science at the time at which he wrote) of regarding the great mass of the rocks as of Plutonic origin, and has described as Granite, Syenite, &c., rocks which, in point of fact, are of an entirely different nature. In other respects Dr. De Benza's report is very excellent, and it evinces in every page instances of the careful and minute observation of the writer.

Captain Congreve and Dr. Burrell.

In 1844-45 a series of letters descriptive of the topography, ethnology, geology, &c., of the hills by Captain Congreve and Dr. Burrell, appeared in the *Madras Spectator* Newspaper, but never having been reprinted in any more lasting form, there can be but few, if any copies extant. †

Notice in Report on Medical Topography.

Some brief but very excellent observations on the Geology of the Hills are also contained in the Report of the Medical Topography of the Neelgherry Hills, printed by order of Government in 1844. This Report, like those on the Medical Topography of other Districts, is a compilation, and it is not stated by whom the Geological portion of the Report was furnished.

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* This description previously appeared in a less complete form in the Journal of the Asiatic Society of Bengal, Vol. IV., p. 413, August 1835.

† Dr. Burrell, now Superintending Surgeon of the Centre Division, very kindly furnished me, however, with some items of information on the Geology of the Hills, which will be introduced in their proper place (H. F. B.)

Captain Ouchterlony.

In 1848 Captain Ouchterlony, of the Madras Engineers, published in the Madras Journal of Literature and Science* a valuable Memoir containing such information on the Geology and Statistics of the Neelgherries as he had collected during his detailed survey of the hills. This Memoir contains but little geological information, however, except such as is of economic importance, and in his description of the hills, Captain Ouchterlony appears to have fallen into the same errors as Dr. De Benza and some others of his predecessors.

Mr. A. Schlagintweit.

Finally, Mr. Adolphe Schlagintweit published during the last two years† a few remarks on the direction of the faults and joints in the rocks of Mysore and the Neelgherries taken in connection with the foliation and cleavage of the same rocks. Mr. Schlagintweit's stay in the Neelgherries was, however, too brief, to permit of his making any detailed examination of the country.

Objects of the present survey.

Of the details of the hill Geology, therefore, much information had been collected previous to the commencement of the present Survey, but owing to the rapid advance in Geological knowledge generally, and especially in that of Indian Geology during the last few years, it was highly desirable that this information should be re-tested, and the whole, with such new facts as might be collected during the present Survey, brought together into a general report, and recorded in a permanent form in this series. With this preface we shall proceed to the immediate subject of this report.

## Geological Characters.

Rocks principally of foliated structure.

The rocks constituting the Neelgherry Hills, and indeed those of the South Western part of India generally, belong, with a few rare exceptions, to the schistose or

* Old Series, Vol. XV., No. 34.

† Journal Asiatic Society, Bengal, New Series, No. LXXXVI.

foliated class, which have received from Sir Charles Lyell the appellation of Metamorphic rocks. The use of this term is perhaps premature, until the really metamorphic nature of these rocks *in all cases* be clearly established. The evidence of the actual metamorphism of the vast spread of similar masses, forming the bottom rock over the whole surface of the Indian Peninsula, and probably extending far into Central Asia, as well as of the enormous tracts of Gneiss and Mica Schist occurring in other countries* is yet very deficient, and although, as will be fully explained hereafter, certain observations made during the course of the present survey seem to indicate that the schistose rocks around Coimbatoor, and possibly those of the Neelgherries also, are rocks of sedimentary origin, altered and rendered crystalline by heat, it is perhaps better for the present to restrict ourselves to the term Gneissose rocks, Gneiss† being the best known and most typical of the series.

Other rocks of Neelgherries.

The other rocks of the district consist of alluvial deposits, a few small basaltic dykes, and some quartz veins on the hills; and in the plains, of numerous small granite veins, which are especially abundant in the neighbourhood of Sunkerry Droog to the East of the Cauvery. No trace of Granite or of any rock of that class has been discovered on the Neelgherries.

Granitoid Gneiss.

Gneissose Rocks.—The rocks of this class occurring in the Neelgherries and the surrounding country are extremely varied in mineral character, and frequently assume an appearance, which would lead a casual observer, or indeed most persons who have not made these rocks a matter of especial study, to regard them in many cases as rocks of Plutonic origin. A careful and extended examination, however, will show that, however indistinct their foliated structure may be in places, they invariably pass by insensible degrees into those of a more typical

Distinct from true Granite.

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* Darwin on South America; Strzelecki on Australia, &c.

† The term Gneiss is frequently used throughout this Report as a generic, implying the Gneissose rocks in general.

Gneissose character, and in no case do they form igneous veins, or present any appearance of intrusion. It is principally in the elevated country that they exhibit a granitoid appearance ; in the plains generally, the foliation is extremely well marked, a fact which, hereafter, may prove of some theoretical interest.

Mineral Composition.

The minerals principally entering into the composition of the foliated rocks are Quartz, Hornblende, Felspar and Garnet, and these occur in the most varied relative proportions, one or more of them being frequently absent. Mica occurs but rarely throughout the hills, and indeed appears to be an exceptional mineral in this part of India generally. Besides the above there are some few minerals of local occurrence, *viz* :—Magnetic Iron, Hæmatite, Specular Iron, and Graphite, and as the results of decomposition, the various earthy forms of the Hydrated Peroxide of Iron, such as Ochre and Laterite ; and Kaolin.

Accidental Minerals.

Hæmatites.

Of the minerals of occasional occurrence, the Oxides of Iron are the most abundant. They occur forming short irregular bands or masses in the Gneiss, such bands generally running nearly in the direction of the foliation. Hæmatite and Specular Iron are far more common on the surface than Magnetic Iron, but from their massive structure and mode of occurrence, they are probably Magnetic Iron peroxidized by atmospheric agency. The most important masses of Iron ore occur above the village of Karrachola, a mile and a half West of Kotergherry, and on a small spur of Dodabetta, overlooking the Dhobi's village. Dr. Burrell informs me that from the same locality, he has a piece of Magnetic Iron which is sufficiently magnetic to carry a bodkin eighteen grains in weight. Another rich deposit of a similar nature occurs about three miles east of Jackatalla, where the Hæmatite is interfoliated with the gneiss, in broad strings of the pure mineral.

Magnetic Iron.

Foliation.

The foliation, wherever seen, is tolerably constant in its direction over the whole of the Neelgherries; this direction approximately coinciding with that of the great Southern escarpment of the Neelgherries, the Bhovani river, the Eastern Ghats, and many of the principal ridges on the surface of the plateau, especially those to the south of Ootakamund. Its prevailing strike is between N. E., S. W. and E. N. E., W. S. W., the principal exceptions to which occur to the North East of Ootakamund in the neighbourhood of Daversolabetta, where the foliation is somewhat variable; but even these variations are very local.

Its strike.

Is rarely strongly marked on the hills.

The foliation is but rarely strongly marked, and never on the surface of the hills assumes anything approaching to a schistose character. It is most distinct in the neighbourhood of Kotergherry. On descending the Coonoor Ghat a striking difference is perceptible in the structure of the rocks. The foliation becomes strongly and even coarsely marked, and in the neighbourhood of Matepolliam a coarse hornblende schist composed of thick alternating laminæ of quartz and hornblende is seen protruding from the ground in large slabs, resembling the old tombstones in a country churchyard. Passing Southwards towards Coimbatoor, the rock becomes more compact, the foliation still being very distinct, and such is the prevailing character over the whole of the low country between the Neelgherries and the Shevaroy Hills.

But coarsely so on the plains.

Hornblendic variety of Gneiss.

It is in the very hornblendic variety of the Gneiss, such as prevails over the North-Western portion of the Neelgherries, that the foliation is the least marked. In this, which is a hard tough black rock, breaking with an even fracture, and consisting of an intimate intermixture of quartz and hornblende with some garnets, but little trace of foliation is usually perceptible, especially on a freshly

Indistinctly foliated.

broken surface. On weathered surfaces the foliated structure is more apparent. In some localities, *e. g.* at the Seegoor Ghat, the rock weathers into smooth rounded blocks presenting no appearance whatever of Gneissose structure. It is undoubtedly such varieties as this which have been described as Syenite, Greenstone, &c., by Dr. De Benza and other writers. That in reality they are mere abnormal varieties of the foliated rocks is proved by their invariably passing into these latter, and by their never forming veins or exhibiting any appearance of intrusion. A similar hornblendic Gneiss forms the whole of the North-Eastern or loftier portion of the Kundahs, where it is much decomposed, and produces a thick covering of ferruginous clay and lateritic gravel.

Quartzo-felspathic Gneiss of the Koondahs.

Another very striking variety of the Gneissose rocks, and which has been described as Pegmatite by Dr. De Benza, is one occurring near Sispara in the Koondahs. That when seen in a hand specimen only, it bears some resemblance to Pegmatite or Graphic Granite, is undeniable, but when seen in the mass, it is found to pass gradually into the hornblendic Gneiss around, and close examination shows that the peculiar arrangement of the two component minerals, quartz and felspar, is really due to an imperfect foliation, the lenticular threads of quartz being all arranged in the normal direction of the foliation. A somewhat similar rock to this, but of finer structure, occurs near Ootakamund, in the valley to the N. W. of Daversolabetta or Snowdon*, and again a much more extensive spread occurs to the North of Mailur forming a belt about three miles in width, passing from the foot of the Kundahs to the Kaitee valley at the foot of the great ridge of Dodabetta. The last mentioned rock contains, in addition to the quartz and felspar, Garnets in great quantity.

Pegmatitic appearance due to foliation.

Occurs also to North Ootakamund.

And at Mailur.

* So termed by the residents of Ootakamund.

The most common variety of the Gneiss over the central part of the hills, where, however, its mineral composition is extremely variable, is a finely grained rock composed of quartz, garnet, and hornblende, with a variable proportion of felspar. It usually exhibits an indistinct foliation, and almost invariably on the weathered surfaces ; it is very decomposable, except on the large precipitous faces, which occasionally present themselves on the slopes of the spurs of the Dodabetta range, and when so decomposed breaks up into spheroids which scale off as the decomposition proceeds and remain embedded in a mass of quartzose ferruginous clay arising from their decomposition. The cause of this decomposition will be treated of in another place. When large undecomposed faces of the rock are exposed it sometimes shows a tendency to split off in enormous slabs slightly curved to the form of the hill side. The cause of this is not very apparent, but it may possibly be due to the heat of the sun causing the exposed surface to expand rapidly, and thus separate from the underlying cooler portion of the rock. After heavy rains, the earthy decomposed mass becoming saturated with water, frequently rushes down as a great landslip, scattering the embedded boulders, often of enormous size, over the valleys and low grounds. A large landslip of this kind which took place some years since on the side of the Kundahs at a spot near which the road to the Sispara Ghat passes, has given the name of Avalanche, usually pronounced Avalanchy, to the locality. Such landslips are not unfrequent on the great escarpment overlooking the Kaitee valley to the S. E. of Ootakamund, and cause great injury to the Coonoor Road, which is carried along the face of this escarpment. The gaps formed by similar landslips are frequently notice-

Quaternary Gneiss.

Spheroidal decomposition.

Scales off in slabs.

Cause of Landslips.

Landslip at Avalanche

On Kaitee Escarpment.

able on the steeper hill-sides, and in their protected hollows the sholah jungle is very luxuriant.

Gneiss of Pykara.

A variety of Gneiss, very similar to that last described, but containing more hornblende, forms that portion of the hills to the N. W. of the Pykara Bungalow (Fig. 1), and

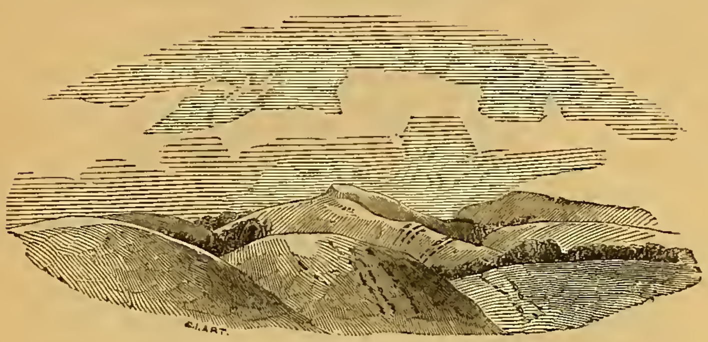

*Fig. I.*—Hard bands in gneiss, near Neddiwuttam.

Hard bands in Gneiss.

Himagala range.

Makurty.

a curious feature of its mode of decomposing is worthy of mention as bearing on the structure of the rock. Bands of hard rock are seen protruding from the hill sides in broken masses, and always running in the direction of the foliation. The same peculiarity is observable in many parts of the Himagala range (so called by Dr. De Benza) which extends from Makurty to Neddiwuttam west of the Pykara River, and it is especially marked around Makurty where the rock is very hornblendic.

Banded structure of Gneiss around Ootakamund.

Traces of banded structure coincident with the foliation of the rock are also observable throughout the central portion of the hills around Ootakamund. In many cases the mineral variations of the rock appear to conform to the strike of its foliation, but it is rarely possible to trace this for any distance, and the mineral bands either become lenticular or break up and die away in the mass.

Coimbatoor Limestone.

Another variety of the foliated rocks, although not occurring on the hills, must be mentioned, both on account of its economic importance, and because it exhibits the banded structure more clearly than any of the other varieties referred

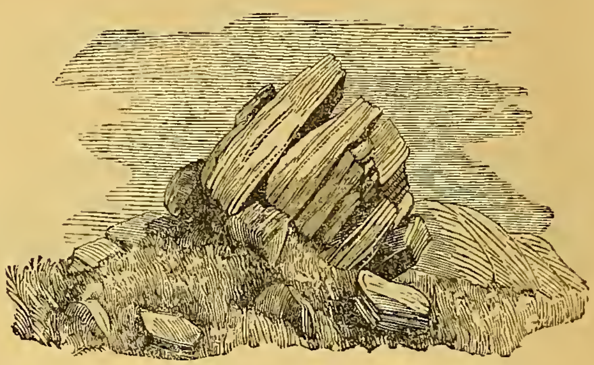

*Fig. II.*—Thin alternations of limestone and gneiss, weathered;—near Coimbatoor.

to. This is the Crystalline Limestone, a notice of which has already appeared in the Madras Journal of Literature and Science.* It occurs about five miles to the South of the Station of Coimbatoor, forming a band of variable thickness which passes in an E. N. E. direction along the foot of the broken range of hills which forms the extreme Southern termination of the Neelgherry hill district. These hills,

Banded structure of adjoining hills.

which run parallel to the limestone band, and also to the foliation of the gneiss in this part of the District, consist of repeated alterations of crystalline limestone and gneiss in bands of from one to a few inches in thickness, and the unequal erosion of the limestone and gneiss has given the hills a jagged appearance, very apparent when viewed in the direction of the bands of structure. Two sketches illustrating this are here given (Figs. 2 & 3).

* New Series, Vol. III, No. V.

The striking resemblance of this banded structure to that seen frequently in limestone rocks, where thin bands of limestone and shall repeatedly alternate, and

Its origin.

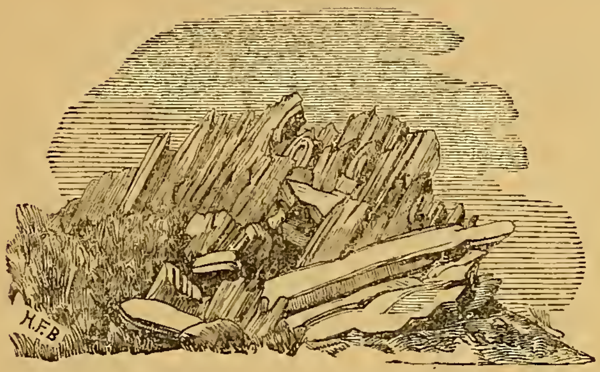

*Fig. III.*—Thin alternations of limestone and gneiss, weathered ;—near Coimbatoor.

the regularity and continuity of this rock for a distance of seven miles and probably even more, render it difficult to believe that it can be other than a really metamorphosed band of sedimentary rocks, and afford the strongest evidence of such an origin that has yet been obtained in this part of India.

Intruded Rocks.—The intruded rocks of the Neelgherries are of one kind only, *viz.*, a compact basaltic Trap, which occurs in small dykes at one or two localities in the Northern part of the Neelgherries, and on the Western edge of the Kundahs. We may however, also consider under this head, the largely crystallized granite veins which are by no means uncommon in the foliated rocks of the low country, and are most numerous in the neighbourhood of Sunkerry Droog in the Salem District. To the East of this locality they become more and more

Trap, the only intruded rock of Neelgherries.

Granite common in low country.

None in the Shevaroys.

scarce, so that in the Shevaroys, and probably also in the other hill groups around Salem, no trace of them is visible. In this respect, therefore, these hills resemble the Neelgherries.

Hornblendic rocks described as Trap really Gneiss.

TRAP.—A large portion of the hornblendic rocks described in the preceding section have been noted as Greenstone, Syenite, &c., by Dr. De Benza and other observers, but careful observations have proved that such are but part and parcel of the great foliated mass, and in no case intruded.

Trap dykes small and rare.

The only rocks which can be really regarded as trap rocks are a few small dykes marked as such in the accompanying map (Plate X.) These, although exceedingly small, had previously been observed by Dr. De Benza

Have been previously observed.

and Dr. Burrell, and afford sufficient proof of the careful and minute observation exercised by both these observers. The dyke marked as passing through Daversolabetta was only seen in two localities, *viz.*, on the Nor-

Trap at Daversola-betta.

thern slope of that hill, about 200 yards from the summit, and again to the North West in the bed of a small watercourse on the western side of the valley, and in both cases consists of several small parallel dykes, varying from two to ten inches in width, and consisting of a tough compact basaltic rock. That

Near Pykara Road.

occurring to the North of the Pykara road is very similar to the above. It is only visible for a short distance, and no trace of it was found elsewhere in the hills. The

Direction uniform.

direction of these dykes is about N. W. or nearly at right angles to the foliation of the gneiss.

Described by Mr. King.

The only other locality at which Trap has been observed is the neighbourhood of Sispara at the South Western extremity of the hills. Mr. King, who examined this part of the hills, describes the trap as follows :—" Between the Sispara Road and the North Western edge of the plateau there are traces of very small trap dykes, which increase in number and extent in the neighbourhood of Sispara, the Gneiss through which these dykes have penetrated being more quartzose and felspathic, and having a more contorted foliation than that on the Neelgherries; its general direction is N. 70·E. At the same time the laminæ of the Gneiss are broader and more distinct, especially those of the quartz, which widen out in some places, so as to resemble veins of that mineral when seen in detached blocks.

Trap on the Kundahs.

Character of Gneiss at Sispara.

A mass of trap, some square yards in extent, occurs on the North side of the road between the first and second mile-stones from Sispara, having a convex surface, the same as that possessed by gneiss, and is only to be distinguished from the latter by the absence of lamination, and its being very much jointed or split up in a direction W. 40. N. It is not very hard, breaking up with plane surfaces, which have a slightly metallic lustre. The boundary between this rock and the gneiss is very apparent, but when masses in which the two occur together are broken up, they do not separate at the junction, but split across it in preference.

Dyke near Sispara.

On ascending the slope on the Sispara side of the gorge called the Devil's gap, the trap is seen cropping out between the beds of gneiss, and sending off branches across the bedding and foliation, or between the laminæ of the latter. The gneiss when in contact with these dykes is coarser, and the laminæ wider than elsewhere in the vicinity, while the dykes themselves are more split at their surfaces of contact than towards their interior. The widening of the laminæ of the gneiss is very well seen at the Southern end of the small plain of New England, where portions of a trap dyke occur inter-laminated with the gneiss. Here the quartz bands attain a width of 10 or 18 inches, but thin out eventually to the ordinary thickness of the laminæ."

At the Devil's gap.

At New England.

From the absence of any evidence bearing upon the age of these small outbreaks of trap, it is impossible to say whether or not they are connected with the great outbreak of the Deccan. Similar dykes have been observed in the Mysore country, and it is probable that an examination of these, and of the country intervening between Mysore and the great trap spread of Central India may enable us to solve the above problem.

Age of Trap not known.

Trap Dykes in Mysore.

GRANITE.—It is remarkable that although veins of this rock are of frequent occurrence throughout the Coimbatoor and part of the Salem districts, with the exception of the Neelgherries and Shevaroys, and perhaps the other hill tracts, that no intruded mass of this rock has been observed. As before mentioned, Sunkerry Droog, to the East of the Bhovani, appears to be a focus where the veins are most numerous, and the hill on which the old fort or Droog stauds, as well as the gneiss of the surrounding country to the distance of some miles is perfectly cut up in every direction with granite veins. (See Fig 4). This granite is

No Granite on the Neelgherries.

Sunkerry Droog.

Mineral composition.

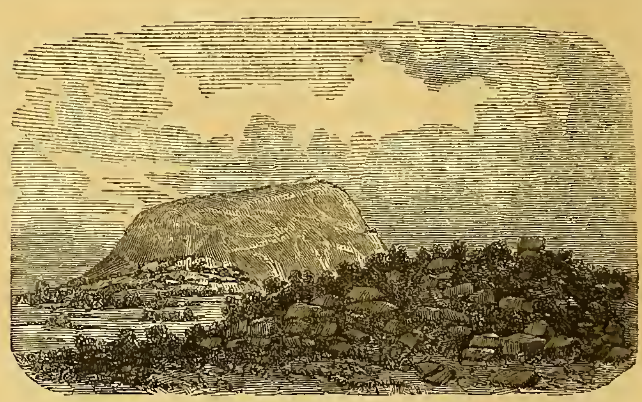

*Fig. IV.*—Gneiss hill pierced by Granite veins near Sunkerry Droog.

a ternary compound of quartz, felspar, and mica, all largely crystallized, and the rock is consequently very easily decomposed and broken up. The only other minerals hitherto observed in it are Magnetic Iron, Garnets, and Beryls, both of the opaque and aqua-marine varieties. These latter occur at Kangyam in the Coimbatoor district, and an excavation was formerly opened by Mr. Heath for the purpose of obtaining them. The works have been now abandoned, and the excavations are filled with water.

Accidental minerals.

Aquamarines at Kangyam.

With regard to the age of this Granite little more can be said than of that of the Trap. To judge from the appearance of the veins at Sunkerry Droog more especially, the gneiss must have been rigid at the period of the intrusion of the granite, and it would seem, moreover, that the country must have undergone some dislocation, since, although tolerably numerous in the neighbourhood of Matepolliam, no trace of them is to be found on the hills, the gneiss of which must, therefore, have been elevated above the sphere of their penetration. It is therefore desirable to defer the further consideration of this subject, until the low country of Coimbatoor and the plateau of Mysore have been carefully investigated.

Age of Granite unknown.

Dislocations and Mineral Veins.—It is necessarily somewhat difficult to establish satisfactorily the amount and direction of the dislocations which have taken place in a country consisting solely of foliated rocks, inasmuch as the only evidences even of the existence of such dislocations are to be found in the effects produced by them on the physical features of the surface, and, in comparatively rare instances, in the presence of mineral veins. Evidences of both kinds are fortunately to be found in the Neelgherry country, sufficient to enable us at all events to ascertain the direction of those great lines of faulting which have determined the form of the principal hill masses under consideration.

Difficult to determine dislocations in Gneiss country.

Remarks by Mr. Schlagintweit.

Mr. Adolphe Schlagintweit in his "Report on the progress of the Magnetic Survey" published in the Journal of the Asiatic Society of Bengal,* has already recorded his observations on this subject, and his conclusions, although rendered somewhat obscure by what is probably a typographical error, appear to be very similar to those independently arrived at by the present surveyors.

Three systems of faults.

There are three principal systems of faulting, two of them probably synchronous, and at right angles to each other, being those which coincide with the lines of the Eastern and Western Ghats respectively, and a third probably subsequent to the above, and contemporaneous with the final upheaval of the Neelgherry plateau.

First System.

The first of the systems of dislocation, *viz.*, that to which the formation of the Eastern Ghats is due, has an E. N. E. direction, varying occasionally to N. E., and therefore about coincident with the general strike of the foliation. To this system belong the great faults with a down throw to the South-East which have produced the Eastern Ghats and the South-Eastern escarpment of the Neelgherries, and those with a North Western down throw, which have given rise to the great Kundah escarpment, and that at Neddiwuttam, both of which face towards the North-West. To the smaller dislocations of this system may be attributed the valley of Pykara at the foot of the "Himagala" range and the great South-Eastern escarpment of the Dodabetta range (See Fig. 7) both on the plateau of the hills, and having a down throw to the South-East.

Eastern Ghats and other line of escarpment.

Second system.

The second system is nearly at right angles to the preceding, and has a W. N. W. direction, varying to N. W., where it meets the former system in the Neel-

* No. II for 1857, New Series No. LXXXVI.

gherries. It comprises the Western Ghats and the smaller Neelgherry escarpment of the Kundah range, or that which, facing to the North-East, commences at the Pykara river, and passing thence behind Avalanche, terminates near the village of Keel Kundah, overlooking the valley of the Bhovani river. These two escarpments, although in precisely the same line, face in different directions, and it is therefore probable that the disturbance which gave rise to the latter was of subsequent date to that which produced the former, but took place along the old line of dislocation, the upheaval being on the opposite side. Another line of fracture belonging to this system is that which crosses the hills from St. Katharine's Falls to the Elk Fall in the neighbourhood of Kotergherry, on the North-Eastern portion of the hills, and it is to this that the gorges below these two falls are originally due.* There does not appear to have been any great amount of disturbance along this line, so far as can be judged from the present aspect of the country, but the evidences are sufficiently clear to warrant the belief that such a fracture exists.

Western Ghats and Kundah escarpment.

Of different age.

Faults near Kotergherry.

The third great system of faults is that to which the Northern boundary of the Neelgherries, the short Southern escarpment of the Kundah range, the extreme terminal escarpment of the hill country of Palghât and probably some smaller dislocations in the hilly country intervening between the Neelgherries and Palghât, belong. The first of these might at first sight seem to ramify from the line of disturbance of the Eastern Ghats, which at their junction has very nearly the same direction, but the existence of parallel lines of faulting elsewhere, all of which are connected with the upheaval of the Neel-

Third system.

Why regarded as a distinct system.

* The description of this line of fault is furnished by Messrs. C. Oldham and H. Geoghegan, who alone visited this part of the hills.

gherries as a group, and the incompatibility of such a series as synchronoús with either of the two systems above enumerated,* induce the belief that it belongs to a separate and subsequent system of dislocations.†

Succession of disturbances as deduced from the preceding.

According to the above, the following is the series of successive disturbances which have mainly given rise to the present physical aspect of the country.

Upheaval of the Ghats.

The first great disturbance which took place was the upheaval of the Ghats, and the intervening plateau of Mysore, the two main lines of dislocation meeting and possibly terminating in the Neelgherries. The great fault, or system of faults, along which the Neelgherry or Avalanche escarpment of the Kundahs was afterwards upraised, probably gave rise to the terminal portion of the Western Ghats, the down throw at that period being towards the South. Many smaller dislocations more or less parallel to the two main lines would be produced during such an upheaval, and in some of these the isolated hill mass of the Neelgherries may have been subsequently upraised to a far greater elevation.

Formation of the Neelgherries.

The second great disturbance which produced the Neelgherries may have followed the former, either after a certain interval, or as the closing act of a long period of elevation, the upheaving force being more concentrated. The area upheaved was bounded partly by pre-existing lines of fracture, and partly by a newly formed series, having an Eastern and Western direction. During the same period, minor disturbances broke up the country for some miles to the South, and also produced some of those escarpments which have been described as occurring on the Neelgherries,

* Hopkins, Geol. Trans. Vol. VII., part 1.

† Mr. Adolphe Schlagintweit, in his paper previously referred to, states his conviction of the existence of a line of dislocation along the course of the Moyaar river, which flows in a deep gorge through the Mysore country, a few miles to the North of the Neelgherries. This part of the country has not yet been examined by the Survey, but if, as is extremely probable, Mr. Schlagintweit's supposition be correct, such a line of fracture would belong to this third system.

and which were subsequently much modified in form by marine action.

Probably subsequent in part to the general upheaval of the country.

It is not improbable that the Neelgherries have been upheaved *en masse* to some extent, since the surface of the plateau received its present form, and since that portion of the country has been raised above the sea, for the mural escarpments which bound the Neelgherries are far more precipitous than we could imagine them to have been, had they been subjected to marine action during a long gradual process of upheaval from the sea.

Geological epoch of upheavals not ascertainable.

Of the Geological periods during which the disturbances just enumerated took place we can learn nothing in this part of the country, there being no sedimentary rocks that can furnish any clue to this important problem.

The Carnatic, and the country through which the Godavery flows, are the districts most likely to afford the much desired information as to the epochs of disturbance in the Indian Peninsula.*

Quartz veins cannot be classed with any system.

In describing the great lines of fracture in the rocks of the Neelgherries, no notice has been taken of the small quartz veins occurring in various part of the hills inasmuch as these minor disturbances can scarcely be referred to any distinct system.

Of no economic value.

They are in most cases of no great length or width, and of no economic value. The vein stone in all of them is a pure white quartz, occasionally

* From the subsequent Survey of the cretaceous rocks to the North of Trichinopoly, it is proved that the Collamullies and Puchamullies, two groups of Gneiss hills between Trichinopoly and Salem, and about 90 miles East of the Neelgherries, have been upheaved during two successive epochs of disturbance. The first of these occurred after the deposition of the lower cretaceous series of Southern India, (a group, which appears to be of newer date than the Neocomian rocks of Europe); the second, at some period subsequent to the formation of the upper cretaceous series of the same district. It is possible that the former of these epochs may have been synchronous with the upheaval of the ghats, and that the latter, during which the disturbance was evidently more local, was contemporaneous with the upheaval of the Neelgherries as a group.

containing a few crystals of Pyrites of tolerable size, and which appear to have the form of the pentagonal dodecahedron.

Pyrites.

In the vein which is seen cropping out on the hill side where the Avalanche road crosses a stream about 7 miles from Ootakamund, there is a small quantity of Brown Hæmatite (Limonite) filling the cavities in the quartz. This is sometimes seen forming irregular pseudomorphs of the Pyrites, and it is evident that it has resulted from the decomposition of that mineral. Captain Ouchterlony mentions having found a speck of copper Pyrites in a loose block derived from one of these quartz veins, but no trace of that mineral has been found by the Surveyors after careful and repeated examination of the veinstones. It is possible the Iron Pyrites, or Mundic above described, may have been mistaken for the more valuable cupriferous mineral.

Brown Hæmatite how found.

No Copper Pyrites.

*Weathering of Rocks.*—Before proceeding to describe the series of physical changes by which the hills have been denuded to their present form, a few words must be said on the decomposition of the rocks. There are many points connected with this subject of a purely chemical character, and which, although of great geological importance, can only be worked out in the laboratory. Thus, without a carefully conducted chemical analysis, it is difficult to assign a reason for the unequal and irregular decomposition which obtains in many cases in rocks of apparently identical mineral composition. This appears indeed occasionally to be due to the varying relative amount of felspar present, and probably also to local variations in the composition of the felspar, but what these differences are, and in what manner they affect the stability of the rock, chemical examination alone can determine. As a general rule, those rocks from which felspar is absent, or in which it is only present in small quantity,

Weathering principally a chemical question.

Dependant on the amount of felspar and hornblende present.

are but little liable to decompose, and, on the other hand, those which contain no hornblende, although much felspar be present, are generally but little affected by the atmosphere.

Spheroidal weathering.

The most decomposable variety of the gneiss is that which has been already described as occurring over the central part of the hills, and weathering into spheroids.

Due to jointing.

This spheroidal decomposition does not appear to be caused by any peculiarity in the intimate structure of the rock, but rather to be the consequence of the jointing by which the rock has been broken up, probably during the upheaval of the hills, as a secondary effect of the great forces which produced the dislocations treated of in the preceding section. The weathering of the rock commences at the sharp edges and angles of the jointed fragments, gradually rounding them off, until the cuboidal mass, throwing off coat after coat of decomposed rock, tends to assume a spheroidal form. The original joints are soon obliterated in the decomposed mass, and the result is a number of spheroids of hard rock, of various sizes, remaining imbedded in a sandy clay more or less ferruginous, and still retaining traces of foliated structure, when such structure has been originally very distinct.*

Highly hornblendic rocks.

When a rock is very hornblendic, such as occurs over the tract marked on the map as "Hornblendic Gneiss," the iron originally contained in the hornblende becomes thoroughly peroxidised and hydrated, and by a species of crystallization forms a mammillated coating of impure Limonite, (Brown Hæmatite) exactly resembling the characteristic surface of laterite. At one locality near the road from Ootakamund to Makurty, and about two miles from the Pykara river, a highly hornblendic band of rock has become thus partially decomposed, and the fragments rolling down a steep hill side,

* See Report on the Coal-field of Talcheer, Pages 41, 42, where two drawings are given, illustrating this peculiarity of weathering.

have accumulated and become cemented together, forming a rock undistinguishable from many varieties of the laterite of the plains.

The probable origin of laterite.

There are no absolute beds of laterite on the hills, but observations made in numerous localities on the plains, where this rock occurs in true beds sometimes even conglomeratic, seem to show that the materials may have been derived from a similar source to the above, and except that they have been probably distributed by water over the surface of the country instead of accumulating by simple gravitation, the mode of consolidation into laterite may have been also very similar.*

Weathering in bands.

The manner in which the gneiss of Makurty weathers, leaving hard bands projecting from the surface of the ground, has been already adverted to, and the phenomenon admits of easy explanation, *viz.*, that the hard bands are more quartzose than the gneiss on either side, and hence they disintegrate far less readily.

Kaolin.

It is unnecessary to do more than mention the occurrence of kaolin, which has been noticed in two or three places on the hills, *viz.*, on the road between Pykara and Neddiwuttam; in the vicinity of Fairlawns, on the road from Ootakamund to Avalanche, and in a valley about two miles South of Ootakamund (See Map). The origin of kaolin, and the chemical theory of its formation are too well known to require comment. That of the hills only differs from the kaolin of other countries in being formed by the decomposition *in situ* of a very felspathic variety of gneiss, instead of being the result of decomposed granite. The masses of this mineral at the localities mentioned do not appear to be very extensive, and the mineral itself contains too much iron to be of much economic value.

Not valuable.

* Subsequent observations on the Laterite of Tanjore confirm this view of the origin of that rock.

Ochreous clays.

The cuttings on the Cantonment road between the Church and the Club-house of Ootakamund, expose a mass of highly ferruginous clay, evidently arising from the decomposition of the gneiss *in situ.* The bands vary in tint, the variation being probably dependent upon the quantity of hornblende in the original rock. Some of this clay is sufficiently colored to serve as a pigment, but it does not appear that it has ever been tried for this purpose.

Hæmatite.

The alteration of Magnetic iron into Hæmatite is a well known result of atmospheric action. The localities on the hills which exhibit instances of this have been already referred to.

*Denudation and recent Geological changes.*—In treating of the denudation to which the Neelgherries have been subject, two different and consecutive periods—the former an epoch of marine action, the latter of atmospheric agency,— may be separately considered.

Physical aspect of Neelgherries.

If the physical aspect of the Neelgherries be compared with that of the lower ranges of the Himalayas, as, for example, the hills around Darjeeling, the difference, notwithstanding their similarity of lithologic structure, of climate and elevation, is so apparent as to strike the most superficial observer. While the latter hills consist of a system of sharp backed precipitous ridges, drained by a corresponding system of ravine like valleys of enormous depth, the slopes of which up to an elevation of 10,000 feet are clothed with a dense luxuriant forest jungle, scarred here and there with the debris and bare rock surface of a recent landslip, the former present an undulating surface of smooth grassy hills, and the ravines and gorge-like valleys, so characteristic of the Himalayas, are in the Neelgherries confined for the most part to the outer precipitous slopes of the plateau. In the Kundah portion of the plateau we have a country of intermediate character, the hills being more whale-backed than on the Neelgherries Proper, and the valleys, especially those of the main streams, assuming more of the gorge-like aspect.

The cause of this variation of physical character in the Himalayas, the Kundahs and the Neelgherries Proper, is to be found in the varying amount of fresh water erosion to which each of these hill tracts has been subject, and this in its turn is dependent on the rain-fall, and the area of the system of drainage in each locality. There is reason to believe that the Himalayas, as well as the Neelgherries, have been originally exposed to marine action, and this at even a later period than the Neelgherries; but the great deposit of moisture, in the form of rain and snow, which takes place over the Southern slopes of the Himalayas during the South-East Monsoon, collecting in streams and glaciers, long ago ploughed out deep valleys through the entire mountain mass, the rock of which, although a gneiss very similar to that of the Neelgherries, is far more rapidly decomposed, owing to the dense vegetation with which it is covered. In the case of the Kundahs, the amount of rain-fall is as great as that on the wettest part of the Himalayas,* the Kundahs being so situated as to receive the full force of the South-West Monsoon, which blows from May to September, and deposits over these hills and the Western Ghats the vast torrents of vapour collected in its passage over the Indian Ocean. The rain-fall on the Kundahs is thus far greater than on the Neelgherries, which are to some extent, protected by the former from the effects of the South-East Monsoon, and where the rain-fall consequently does not exceed about 90 inches, and hence the Neelgherries, although of larger area, exhibit less extensive erosion than the Kundah Subdivision of the same hill-group.

Rain-fall and its results.

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* It has been stated to be as much as 250 inches at Sispara whereas the rain-fall of Darjeeling is only 130 inches. At Khersiong, however, the position of which more resembles that of Sispara, the rain-fall must be much greater than at Darjeeling.

In both cases, the denudation is less than in that of the Himalayas, and this partly because, as already stated, the rock decomposes less rapidly, but principally owing to the comparatively small areas of drainage of the Kundahs and Neelgherries, and the consequent absence of any gigantic river-torrents, such as gush down from the vast range of the Himalaya. Indeed, the drainage of the hills pours down by several independent streams, those of the Neelgherries uniting in the plains below and flowing finally into the Cavery, while the single stream which collects almost the entire drainage of the Koondahs flows down to the Western Coast.

Evidences of marine action.

The country immediately around Ootakamund, which is the loftiest part of the hills, is naturally that which has been least altered by the action of fresh water, and it is here consequently that the evidences of the previous marine action are most clearly seen. The station of Ootakamund is situated in a broad undulating valley, immediately at the foot of Dodabetta, (the loftiest point of the hills,) and is surrounded on three sides by the steep spurs of this range, while on the fourth or Western side of the station, the plateau undulates gently away to the Himagala range, only interrupted by two prominent hills situated immediately to the right of the Makurty road, about 4 miles from Ootakamund. The best view of this part of the hills is obtained from the new Kotergherry road at various points on its Dodabetta ascent. The general outline of Dodabetta as seen from a distance is much rounded; it appears as a prominent mass of hills bounded on the greater part of its circumference by a tolerably distinct escarpment. This escarpment

Escarpment of Kaitce Valley.

is especially visible on its South-Eastern side which overlooks Kaitee valley (See Fig. 5), and again to the North and North-West of Jackatalla, where the projecting terminations of several spurs present a striking resemblance to the rocky headlands of parts of the South Coast of

England. The ground between these prominent spurs has been much hollowed out by the streams pouring down from Dodabetta, and it is, therefore, only by viewing the general contour of these hills from some

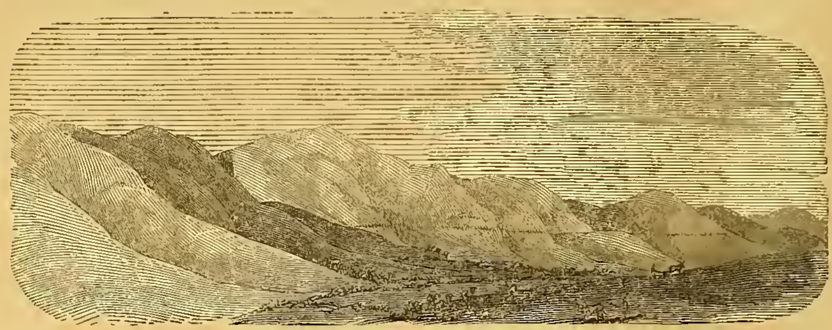

*Fig V.*—View of the Dodabetta and Kaitee escarpment.

little distance that their cliff-like character becomes apparent. Passing from Jackatalla towards Kotergherry, the escarpment may still be traced, although much obliterated by the subsequent formation of valleys. About half way between Jackatalla and Kotergherry, it turns to the West, and seen from any point on the Northern part of the hills it presents a bold rocky face terminating in Daversolabetta, a lofty conical peak a few miles North-East of Ootakamund. At this point, the escarpment cannot be very distinctly made out, but to the West of Daversolabetta, the upper part of the escarpment appears to turn round to the South and join that overlooking Ootakamund, while the lower part, which is extremely well marked, although of comparatively less elevation than that of Dodabetta, and at a somewhat lower level, passes below Marlimund and Seven-Cairn hill, crossing the Seegoor road, and forming the termination of the pass of that name, and finally merges into the great boundary escarpment of the hills. To return to our starting point, the escarpment above Kaitee valley may be traced for some distance to the South-West as seen in the foreground in Fig. 5, and finally dies away, or rather appears to be broken up into smaller escarpments, which, in the course of time, have become nearly obliterated by the erosion of the hill streams.

The other principal escarpment on the plateau of the hills is that of the Kundahs, a prominent feature as viewed from the neighbourhood of Ootakamund. Its position has already been described when speaking of the lines of dislocation in a previous part of this report, and there can be but little doubt that like most large escarpments, it was originally produced by a great fault, but it is equally certain that its form has been subsequently modified by marine action, and that being of nearly the same elevation as the great mass of Dodabetta, it must have been finally upraised from the sea at about the same epoch. Its face has been much furrowed by streams, but less than would have been the case, had the drainage of the Kundah plateau poured down towards the Neelgherries, instead of being collected in one large central stream as already described. The Eastern escarpment of the Himagala range appears to have been originally continuous with that of the Kundahs, but there is now a deep gap between them formed by the Pykara river, which originally commenced at a point much to the South-West of its present head waters, and the ridge, which, at a former period, probably united Makurty hill and Tukulhullybetta at the Northern extremity of the Kundahs, has been washed away by the united action of the Pykara on the one side, and the stream which flows down to the South of Makurty on the other. The annexed sketch is a view of Makurty with the Pykara at its foot, the gap between Makurty and Tukulhullybetta being concealed

Escarpment of Kundahs.

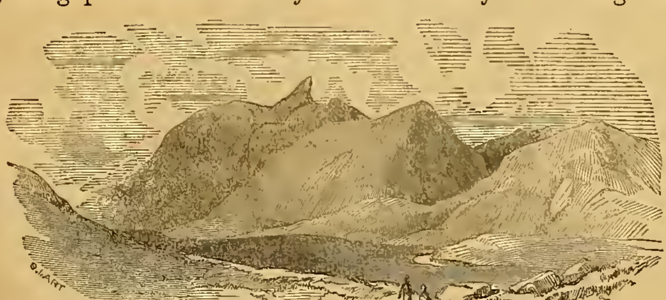

*Fig. VI.*—View of Makurty Peak with part of the Himagala range and the valley of the Pykara.

by the clouds which roll up through it from the Western Coast. Beside the principal elevated masses of Dodabetta, the Kundahs and the Himagalas, there are several small insular outliers, such as that to the North-West of Mailur, the Hoobicul Droog and the adjoining hills, the hills to the East of Coonoor, and the two prominent hills already mentioned to the West of Ootakamund, all which are bounded partly at least by escarpments, more or less distinctly marked. Subsequent fresh-water denudation has much modified, where it has not destroyed, most of the pre-existing features of the hills, in some cases rendering the escarpments still deeper and more marked, in others cutting through them and breaking them up into rounded spurs, so that it is only by observing their general outline from some distance, that an idea can be formed of their original appearance.

Alluvial deposits.

In connexion with the fresh water denudation of the Neelgherries, a feature of much interest as bearing on the origin of certain of the present valleys, and affording strong presumptive evidence, that at least portions of these valleys existed previous to the final changes of level in the hills, is that of the deposits of alluvium, which, as shown on the map, have been formed by some of the larger streams. The largest and most striking of these is on the upper part of the Pykara river, along the course of which it extends for a distance of more than two miles in a direct line, lapping round the spurs of the adjoining hills, and stretching for short distances into the small lateral valleys which debouch into that of the Pykara. At its lower extremity, the hills advance from each side to the banks of the river, and the stream which up to this point meanders gently through a narrow green plain, here gushes with a considerable fall over a hard band of hornblendic rock which connects the steep hill spurs on the opposing banks. This feature is common to all the alluvial deposits in the hills, and shows clearly that such valleys have been originally closed by a natural bund or dam of hard rock, through which the stream has slowly cut its course, and the remains of which exist in the terminal spurs and rocky ridges already alluded to. An instance in which this is especially obvious is on the great feeder of the Pykara, which rises on the Eastern flank of Tukulhullybetta.* (See Fig 7.)

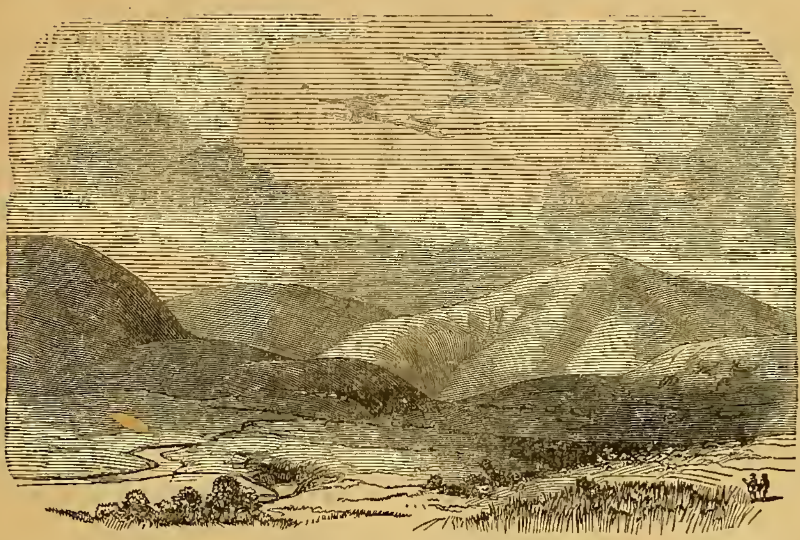

*Fig. VII.*—Alluvial plain on a feeder of the Pykara River near Tukulhullybetta.

On the Mailur road, about 7 miles from Ootakamund, another very good instance is seen, and the gorge which closes the alluvial plain, and down which the Mailur road passes, is very fine and rocky.

Ancient lakes.

From the above descriptions, it is evident that at some period in the geological history of the hills, there were several lakes of a serpentine form occupying what are now drainage valleys, but which were then closed by a ridge of hard rock since cut through. Now it is evident that any obstacle closing a valley excavated by running water must be of subsequent date

* It is proposed by Mr. Fraser to take advantage of these natural bunds, and by filling up with an artificial bund the gap formed in them by the stream, to reconvert the upper part of the valley into a lake or reservoir, such as was undoubtedly its original condition.

to the formation of the valleys, and therefore, if the Neelgherry valleys now occupied by alluvium be really of fresh-water origin, as seems most probable, there must have been, subsequent to their formation, some changes in the levels of the country, which by stopping the drainage converted the pre-existing valleys into lakes. In such cases, the drainage would seek an outlet either by cutting still deeper its old channel, or in another direction by cutting away a low ridge, or through some open fissure, and in course of time, if the rock at its new point of exit be hard, the stream would cut a narrow gorge-like channel such as has been described, and through this the lake would be finally drained. There are indications that something of this kind has taken place in one or two instances. Thus the stream which has been mentioned as flowing down the gorge through which the Mailur road is carried (See Map) may originally have followed the course of the Avalanche road to the South. A slight elevation of the country to the West of the Mailur road, and the simultaneous formation of a small fissure along the line of the present gorge, would convert the valleys now occupied by alluvium into a large lake, until the stream had sufficiently enlarged the present gorge to carry off the water.

The above appears to be the most probable explanation of the origin of these alluvial plains. The form of the valleys which they occupy precludes the idea that the former were excavated by any other agent than the hill streams, and such being the case, it is, as already stated, only by subsequent disturbance that they could be converted into lakes.

*Economic Geology.*—Almost the only article of any economic value furnished by the crystalline rocks of the Neelgherries is stone, whether for the purposes of building or road making. The various forms of the Gneissose rocks are abundantly obtainable for either of these purposes, but for the former they

Building stone.

have been hitherto extremely neglected, the only building in which stone has yet been employed being a private house in Ootakamund, which, from its singularity in this respect, is generally known as Stonehouse. The reason for this preference of brick over stone is undoubtedly its comparative cheapness; and the advantages of the superior durability of the latter material, and what on the Neelgherries is a matter of no small importance—its dryness—have been sacrificed to present saving in cost. Were the bricks employed for dwelling houses properly burnt and vitrified, the most weighty objection to their use—dampness—would not obtain; but they are in most, if not in all cases, of native manufacture, and being made of a very sandy clay, and but slightly baked, they are so absorbent, that except in the dryest and most elevated situations, the houses constructed with them are scarcely ever dry, and many are the fevers, rheumatic attacks, and similar affections to which their valetudinarian residents are consequently subject.

Hitherto but little used.

Its advantages.

Bricks used are very inferior.

Quarrying on the large scale is almost unpractised in this country, and should stone be required for buildings to be hereafter erected on the Neelgherries, some care would be necessary in the selection of a proper stone, and a favorable site for working, in order that the expenses of quarrying and the carriage of the stone be as small as possible. In many parts of Mysore the foliated rocks exhibit a great tendency to scale off in large slabs, varying from a few inches to one or two feet in thickness, and as this variety of the rock is very free from vertical joints, long narrow post-shaped blocks, and slabs of various sizes are readily cut by means of a row of iron wedges driven into holes previously cut with the chisel.*

Selection of Building stone.

Peculiar structure of the Gneiss of Mysore.

How worked.

* In Mysore the electric telegraph wire is supported on stone posts of this description upwards of twenty feet in length, and averaging about nine inches square in section.

On that part of the hills East of Billicul which overlooks the Mysore country, Gneiss of a somewhat similar structure occurs, and again on the Lovedale flank of Elk Hill near Ootakamund ; in the Kaitee valley ;* and very extensively on the Northern escarpment of the Dodabetta range. In these localities, the slabs are in most cases much thicker than those quarried in Mysore, but this would be no disadvantage were blocks required for building purposes. Blocks of any size and tolerably definite in form might be separated by a proper arrangement of blasting holes.

Gneiss on the Neelgherries.

Well adapted for quarrying.

The rocks of the Neelgherries are but rarely well jointed, and when they are so, the stone appears to have a greater tendency to decompose in consequence. There are, however, one or two localities on the Coonoor road where the rock is advantageously jointed for quarrying purposes, and large blocks of a more or less rectangular form might be obtained. The Gneiss of the Kundahs, especially in the neighbourhood of Sispara, is very finely jointed, but the great distance of that locality from the inhabited part of the hills, and the difficulty of transport, preclude the possibility of working the stone profitably.

Jointing rare.

Gneiss of the Kundahs.

By far the most valuable of the crystalline rocks described in this Memoir is the limestone near Coimbatoor,† which was first discovered by Dr. Cornish, the Civil Surgeon at Coimbatoor. This stone might not only be employed for the manufacture of lime of great purity, but moreover, owing to its softness and its non-liability to decompose, might be advantageously used as building stone, except for such parts of a structure

Coimbatoor limestone.

Discovered by Dr. Cornish.

Useful for lime-making, or as a building stone.

* My colleague Mr. King furnished me the notice of these localities.

† The major portion of these remarks were embodied in a Notice of this limestone published in the *Madras Journal*, Vol. III, page 60, new series.

as present sharp angles, and are at the same time exposed to much mechanical wear. Being moreover susceptible of a high polish, and very transparent, it would afford a very beautiful material for internal decorations, the effect of which would be enhanced by the judicious selection of slabs of various tints. Pink and grey, occasionally approaching white, are the prevailing colors of the stone. Perhaps the best locality in which to open an experimental quarry for working this stone would be at the Eastern extremity of the low ridge crossing the Palghat road, and about three quarters of a mile to the East of the road. The stone is here very homogeneous in composition, and appears to be sufficiently jointed to render quarrying an easy process.* The situation of the limestone is very favorable as affording facilities of transport. The trunk road from Coimbatoor to Palghat and the Western coast crosses the band, as has been already mentioned, at about five miles from the former station, and the Railway from Madras to Calicut and Beypoor passes for some miles along its out-crop. Thus by opening quarries at the side of the line the blocks dressed in the quarry might be placed on trucks and conveyed to any point on the line without the expense of reloading.

For internal decorations.

Best locality for a quarry.

Means of transport.

On the plateau of the Neelgherries, there appears to be no limestone, either crystalline, or in the form of kunkur, and for building purposes, this latter material is brought at a considerable expense from the plains of Coimbatoor, where it occurs in occasional patches of varying thickness. The supply for the barracks now erecting at Jackatalla is brought up in the unburnt state, packed in bags carried by bullocks,

No limestone on the Neelgherries.

All lime brought from Coimbatoor.

* As the locality was not within the area to which this report is specially devoted, only a cursory examination of the Limestone was made, and a more minute survey might possibly discover other spots equally, or even better, adapted for quarrying.

and is burnt in kilns erected near the barracks; a mixture of peat and wood being employed as fuel.

Iron ores abundant, but fuel scarce.

The ores of iron are tolerably abundant at several localities on the hills, the most plentiful being the Hæmatite and Magnetic iron, which occur intercalated in the Gneiss (see page 219). The comparative scarcity of fuel renders it however improbable that any of these ores can be smelted with advantage on the hills, and on the Malabar coast where fuel is abundant, iron ores are sufficiently plentiful to render it unnecessary to resort to the hills for a supply.

Quartz plentiful.

Too opaque for optical purposes.

Quartz of great purity occurs abundantly in the form of veins, especially in the valley crossed by the Avalanche road, 7 miles from Ootakamund (see map). It is for the most part very white and free from iron, but not sufficiently pellucid to be of any value for optical purposes.

Earthy iron ores applicable as pigment.

Various earthy iron ores result from the decomposition of the rock *in situ*, and some of these appear to be sufficiently rich to be employed as pigments. The localities at which such occur have been already referred to at page 237.

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John Gray, "Calcutta Gazette" Office.

*On the Geological structure and Physical features of the Districts of* BANCOORAH, MIDNAPORE *and* ORISSA—BENGAL.

Extent of Area.

THE country referred to in the following Report, and included within the limits of the accompanying map, (plate XIII.) was geologically examined during the working season of 1857-58. The province of Orissa, which includes the districts of Pooree, Cuttack and Balasore, was examined by Mr. W. T. Blanford, assisted by Mr. Harry Child; the district of Midnapore, lying north of Orissa, by Mr. Joseph G. Medlicott and Mr. W. L. Willson; and the district of Bancoorah by Mr. Oldham, who also visited a large portion of Midnapore and adjoining districts. The details, given in the following notice are derived from the Reports of these gentlemen, for each of the districts examined by them, and combined into one general review of the structure of the entire area.

To the districts actually surveyed during the season of 1857 has been added, on the map, a portion of the Talcheer field already described in these memoirs. This addition will shew the relation existing between the two districts; while the separate map of the Talcheer district, on double the scale of the present plan, will give the details. It will be seen that the outline of the area, geologically examined, is extremely irregular towards the west, arising from the fact that no topographical maps of that portion of the country exist. It was not, therefore, examined by the Geological Survey. The total area of the districts, now published for the first time, is (exclusive of the part of Talcheer included) more than 14,000 square miles, extending along the right bank of the river Hooghly, and the east shore of the Bay of Bengal, from Burdwan in north latitude 23° 13′ to Ganjam in latitude 19° 22′. The river Damoodah (Damuda) forms the northern boundary of the area referred to, and the Chilka Lake its southern extremity.

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Two distinct portions.

This extensive area may, in a general way, be viewed as consisting of two distinct geographical portions, one a broad expansive plain varying in breadth from a few miles to nearly sixty, and which borders the sea and river Hooghly; and the other a limited area of more elevated ground, studded with numerous hills, and which, in all its geographical relations, is connected with the hilly country to the west.

Alluvial plains.

Almost the entire area of the northern districts of our map is included in the former of these divisions, and with the exception of small patches of hilly ground to the extreme west, the districts of Bancoorah and Midnapore are composed of a great widely-spread plain of gently undulating ground, the elevation of which above the mean sea-level is very trifling. This, plain is, near Balasore, broken up by the range of the Nilghirri hills but again stretches to the West, beyond the limits of our map, along the valleys of the Byturnee and Brahmini rivers. From this, southwards, the more hilly ground gradually approaches the sea-coast until near Ganjam and the Chilka Lake, the hills almost reach the shore.

The eastern portion of this flat ground is almost a perfect plain, chiefly under cultivation, while more to the west and along the foot of the hills the surface is much more irregular and undulating, and is, for many hundreds of square miles, covered here and there with large patches of low scrubby jungle and coppice-wood.

Chiefly deltas of rivers.

The great flat, which we have just noticed, consists mainly of the combined deltas of the large rivers which here discharge into the sea. The Hooghly, the Damooda, the Roopnarain, and Kossye, have combined to form the alluvial flats of Bancoorah and Midnapore, while the Byturnee, the Brahmini, and the Mahanuddee, have produced the flat plains of Orissa. These fluviatile deposits are still going on, and the peculiar outline of the coast seems to be entirely due to their advance.

Form of Coast.

On looking at a map of the shores of the Bay of Bengal, it will be seen that the general line of the western shore from the Chilka Lake southward, for nearly four hundred miles, runs almost due south-west, and is remarkably continuous and straight. A little to the north of the Chilka Lake, Orissa is seen to project some miles beyond this general run of the coast line, while southward also another great projection of the coast line occurs near the mouths of the Godavery and the Kristna; these projections being apparently due entirely to the fluviatile deposits brought down by these large rivers gradually gaining on the sea.

The more northern portion of the flats of Orissa Province, that is, the part extending from the Soobunreekha river to the Boorahbullung, belongs geographically, to the Midnapoor and Hidgellee country, (Bengal) and from Balasore for about twenty miles to the south-west is a district of older alluvium noticed below, similar to much of that which occurs on the skirts of the delta of Lower Bengal. Throughout the northern parts of the Province of Orissa there is much similar older alluvium, but to the South of the Brahminee river this is not seen.

Chilka Lake.

In the extreme south of the province there is a large indentation in the hills, which has formerly been a bay in the sea. The advance of the river deltas has, however, hemmed in this area on the north-east, and a spit of sand from the hills near Ganjam has joined to these delta deposits across the mouth, leaving inside a large expanse of salt water known as the Chilka Lake. This lake, which is about 40 miles long, by about 12 miles in width at the widest parts, has only a narrow passage uniting it with the sea, and is being gradually filled up by the detrital matter brought into it by the few hill streams, and by the small portion of the water of the river Mahanuddi, which it receives through the channels called the Dyah, the Min, and one or two other small streams. It is now in few, if in any places, more than twenty feet in depth, and if an engineering project, lately proposed, be carried out, and a large portion of the flood waters of the Mahanuddi be turned directly into the Chilka Lake, the filling up in future will probably be far more rapid than it has hitherto been.

Its nature and origin.

The spit of sand and mud separating the Chilka from the sea is peculiar. To a certain extent, it may be looked upon as a river-bar upon a gigantic scale, being formed where the tidal current of the Bay of Bengal, coming up in a north-easterly direction from the coast of Vizagapatam and Ganjam, meets the waters of the river Mahanuddi. Moreover, from the prevalence of south and south-east winds in the Bay of Bengal, and the heavy breakers produced by them along this coast, the tendency of the sand and pebbles of this shore is to travel northward. This, doubtless, has been the main cause of the formation of a spit towards the north-east from the end of the Ganjam hills. In illustration of this, it may be mentioned that pebbles of gneiss, granite, conglomerate and sandstones, and even fossils* occur in abundance on the shore near Pooree. These pebbles must be derived from rocks washed by the sea, yet no rock comes down to the shore, to the north of this, nor for many miles to the south. The pebbles must therefore be derived from those localities to the south, where, in the neighbourhood of Vizagapatam, rocks do occur along the sea shore.

Hilly ground.

The hilly ground forms a small part of the western portion of Bancoorah, being a continuation of the broken country of Puralia, on the west. There is no marked ridge of hills, however, but the ground rises irregularly and interruptedly from the alluvial plains. In Midnapore, this hilly country only occurs at the extreme north-westerly corner of the district near to Sildah.

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* Only one species has been found, a *Meroe*, from some beds, the locality of which is as yet unknown. Both valves frequently occur together.

Of Orissa, the hilly part consists of a country dotted over with detached peaks and small ranges, which become more sparse and scattered to the east, being there separated from each other by plains of deep alluvium. Further to the west they are generally surrounded by laterite, which rises to a considerable height above the alluvium; the latter in the more undulating country, although still covering considerable tracts being confined to the neighbourhood of the streams.

From these general facts, we may probably infer that the condition of the whole district before the present deltas commenced forming, was a region, or (if, as is highly probable, it were subaqueous) a sea-bottom, formed by an undulating surface of rock, from which arose numerous rocky islands, large and small, themselves the relics of a former denudation.

Former condition of District.

Insular character of Hills.

An exception to this prevailing insular arrangement exists in a mass of low hills, west and south-west of the town of Cuttack. A small district of sandstone occurs there, in which the hills are massed together in ranges, and seem to have undergone less marine denudation than has taken place in the adjoining areas of gneiss-rocks. On their western edge, they are escarped; to the east they sink down towards the plain. As the rocks composing these hills are comparatively soft, and the hills themselves of no great elevation, it is evident that they have never been subjected to the same marine action which has planed away the mass of the gneiss of Bankee, Khoordah and other districts in their immediate neighbourhood, leaving only a few isolated peaks. Consequently, this sandstone itself must be of later date than that denudation, unless, as is possible, but not probable, it was cotemporaneous.

Sandstone near Cuttack, not so.

Within the area described above, the following classes of rocks are found:—

1. Hypogene and metamorphic rocks; various forms of gneiss, and

quartzites, with associated intrusive igneous rocks, trap and syenite.

2. Sandstones of the Kuttak or Atgurh field.
3. Laterite.
4. (*a*) Older alluvium.
   (*b*) Alluvium of the river Deltas.
5. Blown sands.

With the single exception of the small group of sandstone rocks lying south-west of the town of Kuttak, all the hills of the district included in our map are composed of metamorphic rocks, with associated igneous intrusions.

Metamorphic Rocks.—A reference to the map will shew that within the limits of the area included in it, the metamorphic, or gneissose rocks occur only in irregular patches along the western edge. In reality this area includes nothing more than a few of the more easterly, and projecting headlands of that great extent of gneissose rocks, which cover such an immense space to the westward, stretching from the boundaries of Bancoorah, Midnapore, and Orissa to Hazareebagh and Nagpore, and which form the prevailing rocks over many thousand square miles, regarding even the geography of which very little is known, and concerning the geological structure of which nothing has been ascertained, excepting in the most cursory way.

Great extent.

The detailed examination and description of these rocks naturally, therefore, connects itself with that country, of the ancient shore of which the little projecting promontories which occur within the area now mapped only form the small headlands.

It will, therefore, be both impracticable and useless to attempt any thing more at present than briefly to indicate the general structure and arrangement of these rocks, reserving any general considerations as to their relation until that country to the west has been more fully examined.

Manjia Hill.

The great fault,* which marks the southern boundary of the coal fields of the Damuda, passes immediately south of Manjia or Medjia Hill, just outside the N. Western limits of Bancoorah district. In the northern portion of this district, and across towards Malliarah, the rocks stand up boldly in well marked ridges, or bands, the prevailing character of which is hornblendic, associated with granitoid gneiss. Strong massive runs of the hornblendic varieties stretch across the country in tolerably continuous lines; the general strike of these is nearly east and west, or a little to the north of east. Many of these runs are very highly crystalline. They are traversed by granite veins. The more felspathic varieties have yielded to decomposition more readily than the others, and are generally coincident with slight depressions in the general surface, in which deposits of clay, and sandy clay with kunkur are not unfrequent. The rocks all appear to dip to the north at high angles.

Hornblendic rocks.

Trap dykes.

Two or three small and badly seen trap dykes are observed cutting across these rocks and heading a little to the west of north. They are in no case of any great width, and appear to have exerted a very trifling reaction on the adjoining rocks.

Granitite.

Near to Ramchunderpoor and the Damuda, there is a considerable area of a curious granitite rock composed of quartz and felspar (white) with imbedded crystals (always twins) of a second felspar of a leaden grey colour. It looks

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* This fault passes *south* of the little hill of Manjia, and close to its base. The hill itself is composed of a conglomerate of peculiar aspect, the pebbles are all of considerably rounded pieces of granitic rocks, of felspar, pegmatite, quartzose gneiss &c., in a matrix of sand composed of felspar and quartz, the former being the cementing matter. The bedding is very irregular, but on the whole constant ; the beds strike a little to N. of east, dipping 8° to 10° to the north, forming a bold scarp to the south, within a few yards of which horndeni rocks are seen.

very massive but continues to the west, associated with the hornblendic rocks. It occurs in great rounded bosses which have a marked character and curiously spotted aspect from the darker imbedded crystals. Highly felspathic and rapidly decomposing gneiss is associated, and some beds of hard quartzose granular rocks.

The same prevailing hornblendic character of the rocks, some of the masses or beds having even a diallagic character, continues southwards to the small hills of Kora, or Koro. This hill is sharply scarped to the north and west, and, on those sides, stands up boldly from the flat country around; but on the east it descends gradually into the general level. It is composed entirely of a granular quartzite of light greyish-white colour arranged in flaky, or flag-like, masses or layers, more like a thin-bedded indurated sandstone, than ordinary gneiss. These flaky layers are nearly vertical, underlying about 10° to the north. The rock is in thin layers not more than a few inches thick, all adherent but very easily detached.

Koro hill.

There is a marked jointing, which is vertical and heads nearly due north and south. In addition to the foliation or lamination of the layers in the mass, there is also, although not very distinctly seen, a kind of curved parting or division in the rock corresponding rudely with the outer surface, and giving a curiously rounded, though by no means polished, look to the top of the bosses. This is precisely analogous to the curved lines of division or partings, which are so frequently seen in the more granitoid masses of gneiss through this country.

Jointing.

This small hill of Koro is exactly in the same line as the more marked rise of Susinia to the west in Puralia; and it may not improbably be connected with some line of faulting or disturbance, which may be traceable when the country to the west is examined. There is a marked change in the direction of the rocks north and south of this line, which seems to confirm such a

Probable fault.

supposition. The quartzose gritty rock of Koro is to a limited extent used by the people in the neighbourhood for quern-stones, curry-stones, &c.*

Granite veins.

Close to Koro hill on the S. West, hornblendic schists occur, traversed by numerous veins of pegmatitic granite, all of which have a common direction W. S. W. to E. N. E., and similar veins occur even more abundantly a little further to the south. They seldom exceed one foot in width, and are frequently not more than a few inches thick, but they may often be traced for hundreds of yards, the fleshy-white colour of the felspar contrasting strongly with the dark greyish-green of the decomposing hornblendic rocks about. They form frequently a little sharp ridge, and look like a great white cable stretched along the surface. Schorl is abundant in them, frequently constituting more than a third of the whole mass, and with a pinkish felspar in largely crystalline masses, and pure quartz, forms the entire rock.

Schorl.

Near to a small village called Kendbursa, a little west of Gungajole-ghati, there is seen a thick vein or dyke of porphyritic greenstone, which runs N. W. It is nearly 60 feet wide.

Change in strike.

To the south of Koro hill, the gneissose rocks, which to the north had exhibited a prevailing strike to a little N. of east, all have their strike well marked to a little W. of north, and are more quartzose. Obscurely seen trap dykes traverse them near Moheshpur, and Chandpur. The rocks become markedly hornblendic, and with granite veins very similar to those noticed above, as we approach the town of Bancoorah, by Poorunderpur, and towards Kessurah. To the east, the gneiss becomes gradually covered up with laterite masses, and coarse sandy clays.

* It is similar in composition, &c., to the stone sold in Calcutta as "Burdwan paving stone," which is, I believe, all derived from near Susinia Hill to the west. Koro Hill stands close to an excellent road, and within a short distance of the present terminus of the railroad at Raneegunj, and the stone from it could be very economically obtained.

Bancoorah.

In the town of Bancoorah itself, and to the west of it, gneiss is abundantly seen, shewing in the same way as is common over the country in great rounded bosses, the tops of swelling masses which just peep through the more recent deposits of lateritic and gravelly character.

Epidotic granite.

South of Bancoorah, veins of epidotic granite may be traced cutting through the gneissose rocks, and heading nearly east and west. And here and there, along the western boundary of the district of Bancoorah, gneissose and hornblendic rocks may be seen shewing just beneath the surface of the ferruginous gravel and laterite-clays which there prevail.

Selye stream.

In the Selye Nuddi, at the S. W. corner of the district the rocks are well exposed; there they are seen to be much disturbed, and cut up by many irregular veins of granite. This granite along the edges is highly micaceous, the mica being in large crystalline masses of whitish colour. Felspar is also abundant, and schorl locally so, but not equally distributed. The beds of the gneiss strike nearly N. and S. dipping to the W. at 85°. On the whole they are hornblendic, but are intercalated with many thin seams of gneissose and granitoid character, and also some thicker beds of hornblendic rocks. The granite veins cut across the beds, or occasionally pass along the strike for a little way, in a most capricious way.

These gneissose and hornblendic rocks continue into the district of Puralia, beyond the limits of our map.

In Midnapore.

The most easterly point at which these rocks crop out from beneath the lateritic flats in Midnapore district, is near the village of Sildah, about 30 miles west from Midnapore town. Here, grey and dark-grey micaceous schists with hard gritty bands are seen in a stream close to the village. The gritty bands shew the bedding of these slaty rocks well; they dip to the east, at an angle of about 40°: the slates abound with andalusite in small crystals.

About eight miles west of this, a low ridge of ground rises rather suddenly from the lateritic plain, of which it here forms the boundary.

Schists &c., near Sildah.

This ridge is formed of grey and blueish grey micaceous schists with bands of a more gneissose character, some of the beds being very similar to those seen in the stream near Sildah. The general direction of this ridge is about 30° to north of east, agreeing with the strike of the rocks, which are at a high angle (75°). To the west of this ridge, there is a group of hills, of irregular shape with no general bearing, but occurring rather in isolated masses separated by valleys. These are principally composed of hard grey and greyish white gritty quartzites and large lenticular shaped masses or irregular veins of vein-quartz associated. These rocks form a portion of a series of beds which extend from the commencement of the ridge just noticed for several miles to the west and north.

General section.

The general section (ascending) is as follows: commencing from the rocks of this most easterly ridge, which are the lowest. First, fine grey and blueish grey micaceous schist (with andalusite) and more gneissose bands; then, dull leaden grey slates more earthy and less altered, with hard grey, and greyish white quartzose grits (quartzite in parts); next dark blue schist with bands of hornblendic rocks, of some thickness, sometimes occurring as lumpy masses, and crystalline like greenstone, but more frequently flaky and of an ashy character: then again, deep blue shining and silty slates, with surfaces much wrinkled, and much cleaved, the cleavage planes being at right angles to the bedding; and finally, the uppermost beds here seen, are dull yellowish brown and purple clayey schist, also cleaved similarly to those just mentioned below them.

As a whole these rocks are much twisted and contorted. The bands

Rocks contorted.

of quartzose grits generally form the high peaky and precipitous hills which are dotted over this area; the blue slates, and traps, occurring in the lower grounds and valleys between them. It is not easy to find a steady section of the rocks in any given direction for any great distance—and the general succession as given above, has been obtained from several points. The thickness seems to be very considerable, although it is difficult to form any accurate estimate of it. Before it can be ascertained, the country to the north and west of the Midnapore district must be carefully examined.*

Thickness.

All over these hills, but principally in the northern parts, are scattered masses of iron-slags, the refuse of former iron smeltings. And, at the present time, iron is smelted to a considerable extent by the natives. The system adopted differs in nothing material from that so often described, and which was noticed in the report on Cuttack (*ante*, page 12).

Iron slags abundant.

Commencing from the north of Orissa, the range of the Nilgiri or Balasore Hills, runs just outside the boundary of the province for about 50 or 60 miles. These hills have their northern limit on the banks of the Booraballung River, about 12 miles W. N. W. from Balasore. From this point they run in a broken range, formed by 3 short detached hills, (in a pass between two of which the village of Nilgiri is situated) for about 16 miles, nearly due south. Thence their escarpment runs for 8 or 10 miles to the west, and then continues for 30 miles in a general W. S. W. direction, the hills terminating at the valley of the Byturnee. On the northern part of the range, these hills

Nilgiri Hills.

Nature of the rocks.

* Mr. Willson, whose long experience on the Geological Survey of Ireland entitles his statement to every attention, justly remarks—" I would notice here the close resem- " blance there is, lithologically, between the rocks forming this small group of hills, and " those which occur on the flanks of the granite in the south-east of Ireland, particularly " the purple, and yellowish clay slates with their associated quartzites, which are very " similar to those " Cambrian" beds in Ireland, in which fossils have been found ; " namely, Oldhamia and Annelide tracks."

consist of excessively granitic rock, so granitic indeed, that it is only on viewing the hills on a large scale that the true direction of the foliation becomes evident. Its strike is then seen to be nearly parallel with the escarpment of the range, 10° to 20° E. of N. near Nilgiri, while further S. W. near Jugjuri, it is nearly N. E. and S. W. There are very few indeed of the largely crystalline granite veins generally so abundant in the more compact forms of gneiss. Trap dykes, however, many of them of very great size, are numerous, and most of them, if not all, appear to run parallel with the foliation of the gneiss. The dense jungles on these hills, their steepness and inaccessibility, renders an examination of them exceedingly arduous. They rise to a considerable height, Nilgiri hill, the loftiest or nearly the loftiest peak, being 1,786 feet above the sea, and many other summits are but little inferior in elevation.

Their strike.

Granite dykes.

Trap dykes.

Inaccessibility of hills.

Height.

Interfoliated with the gneiss there are found in one or two places bands of a chloritic rock approaching serpentine in texture, and quarried to a considerable extent by the natives. This rock will be noticed again in reference to its uses. The principal localities in the Nilgiri hills are situated a few miles S. of Nilgiri, and near the villages of Santragodia and Goojadeeha. There is also a quarry about 2 or 3 miles west of Jugjuri, and there are others scattered over the hills.

Serpentine.

Localities of ditto.

A few miles W. S. W. of Jugjuri, and near the village of Paikpada the rocks alter considerably. They become a hard, tough, indistinctly crystallized hornblendic rock resembling in hand specimens a greenstone. The foliation is better marked than to the N. E. in one respect, viz : that its direction can

Nature of rocks near Jugjuri.

be distinctly seen in the large masses of rocks. It continues to strike about N. E. and S. W. with a dip to the S. E. of about 50°. The rock is highly jointed, and in some places presents a structure approaching the columnar.

Ditto near Splundi River.

Still further to the S. W. and near the Splundi Nuddi, quartz schist comes in, well foliated and sharply cleavable. Occasionally it contains a small quantity of talc, and is of a greenish colour, in other places it is slaty. A detached hill near Buquiepūr* is formed of these quartzite rocks, and so is all the range from near this to the S. W. extremity near the village of Rogadi, with the exception of the immediate neighbourhood of the Splundi Nuddi at the spot where it leaves the hills. Here syenite occurs and the same rock also forms a detached hill near Darrapur. All the S. W. portion of the range is free from the trap dykes which are so conspicuous to the N. E. of Jugjuri.

Metamorphics between the Brahmini and Mahanuddi.

There are no hills S. of this within the boundary of the province† till the Brahmini is passed, nor does any gneiss occur. To the south of that river in the killahs of Bulrampoor, Mudpoor, Dinpoor, Kulkullah, &c., and scattered over the country to the east as far as pergunnah Ultee, there are numerous hills more or less isolated, and all composed of gneiss. Along the Brahmini near Bulrampoor, and thence east and south for some miles the rock is compact and occasionally even exfoliating, as in the Nilgiri hills, but, further south, a peculiar form of gneiss, generally more or less decomposed, comes in. It is marked by numerous red blotches, the remains of disintegrated garnets. A steatitic mineral is common in the fissures. This form of the gneiss is occasionally quarried for various purposes, its softness rendering it easily available.

* This name should be Bakipür.

† The mass of the Nilgiri hills is outside the province, but in many places the range forms the boundary.

Strike of rocks.

The strike of the metamorphic rocks in this part of the country is very variable, in places it is 10 or 15 degrees N. of E. to S. of W. in others as much S. of E. to N. of W. The ranges have a general E. and W. run, those tending to N. and S. being composed of several smaller hills with the prevailing E. and W. strike. Many of these are not correctly marked on the published maps, there being no ranges but several detached hills, which are separated from each other by plains of alluvium or laterite; others of the hills here shewn on the maps however are quite erroneous, none existing in the places where they are marked. In the detached hills E. of the Kuttak road, the strike is different from that in those more to the W. thus in Neltigree hill it is S. 40° W. and in the hills just south of Chutteea Bazar S. 10° to 20° W.

Bankee.

The hills near the Mahanuddi W. and S. W. of Kuttak are of sandstone, but the province extends up the river on its southern bank for 30 miles, and includes the estate of Bankee, which contains some fine hills; the main peaks, as usual detached, running in a semicircle from near Bankeegurh to the village of Bydessur. These hills are partly of the garnetiferous gneiss, like those North of Kuttak, partly of more compact and hornblendic rock. Bankee Peak is of very quartzose gneiss. The strike varies in a peculiar manner, the rocks having a general tendency to dip inwards towards the point which might be considered as the centre of the semicircle of peaks. Both strike and dip are, however, very irregular and varying, especially in the two hills South of Bydessur.

Country S. of Bankee.

There is a large undulating plain south of these peaks, partly covered with laterite, through which the gneiss rises at intervals. In the extreme west of the province around Bollghur and Goreallee, there are two very barren ranges of no great height, running east and west, and formed of compact gneiss,* striking in the same direction as the hills run.

* The rock here and elsewhere termed compact gneiss is a granitoid variety very hard and compact, with blotches roughly crystallized of white or pinkish felspar.

The province boundary then returns eastward, and from this point nearly to the Chilka Lake none but detached hills occur, all of which are of gneiss, the plains between them being of laterite and alluvium. The group of hills near Chutterma are composed of compact gneiss, most of the others are of garnetiferous rock with occasional bands of quartzose gneiss. Such are Khoordah hill and the smaller hills about it, and also those east of the Kuttak and Ganjam road between Rammeswur and Monglajuri. Throughout the country south of the Mahanuddi, dykes of all kinds are rare, trap is entirely wanting, and granitic veins seldom seen.

Country from Khoordah to Chilka Lake.

The more compact forms of the gneissose rocks exhibit exfoliation very finely, and this is especially the case in the northern parts of the Nilghiri hills. The strike is shewn by the preceding details to be very irregular, but, nevertheless, the tendency seems to be, throughout the area, for it to conform to a general east and west direction, as is the case in so many other parts of the country.

Exfoliation of gneiss.

General strike.

Sandstones.—As stated above, the only place, within the districts included in our map, where the older sedimentary rocks occur, lies to the S. West of the town of Kuttak, in the district of Atgurh. Here sandstone rocks compose a small cluster of hills, quite uncultivated and covered with dense jungle.

Kuttak or Atgurh sandstones.

These rocks consist of coarse grits, sandstones, and conglomerates, with one band at least (perhaps more than one), of white or pinkish clay which is largely dug by the natives. In this clay a few indistinct vegetable remains have been noticed; none of which, however, were sufficiently well preserved or well marked to be of use in ascertaining the affinities of the beds. At the base, or what appears to be the base of these strata, on their western edge, is a coarse conglomerate, the pebbles being chiefly of quartzite, a few being of an altered and hardened sandstone.

Nature of rocks.

Dip.

Throughout this small area, there is a prevalent dip, to the east and south-east at low angles not exceeding 5° or 6°. The whole area is surrounded by flats of laterite and alluvium, so that very little can be ascertained concerning the relations of these sandstones to the underlying rocks. It is impossible therefore to say whether they are let in by faults or not. Towards the eastern edge, they are generally covered up by laterite.

Age.

It has been already suggested* that these beds probably belong to the Mahadeva group, or, at least, to the rocks supposed to represent that group in the Talcheer basin. They certainly resemble those rocks, in their lithological character, more than any other described beds of the neighbouring district. At the same time, it must be remembered that a similarity in mineral character, in the case of such beds as coarse sandstones is insufficient alone to establish clearly the connection between the rocks, in two distinct areas separated by sixty miles of intervening country, which space, so far as is known, is entirely devoid of any outlying, or detached portions of similar beds. While, therefore, it appears that the information at present in our possession tends to connect the rocks of the Atgurh basin with the Mahadeva series, rather than with any other known rocks, that information is still far from sufficient to warrant the expression of a decided opinion as to their identity. In both places, the rocks are unfossiliferous, and in the absence of rocks in this Kuttak basin belonging to the Damuda or Talcheer age, which would afford evidence of superposition, mineral character alone remains.

Laterite.

LATERITE, &c.—Although the lateritic and associated rocks or sands and gravels, no where within the limits of the district of Bancoorah, assume the same importance as more to the south in Midnapore or Orissa, they still constitute a very marked feature.

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* Report on Talcheer Coal Field—*ante*, page 68.

Physical character of surface.

Passing over the great flats of clay and sandy clay which extend for many miles to the west of the river Hoogly into Bancoorah, the ground gradually becomes more broken, more elevated, and at the same time less cultivated. For the most part these broken swells are covered by low coppice jungle, the hereditary abode of charcoal-burners, whose labours have gradually removed every thing which could be called a tree, and left only the stumps and young shoots where formerly noble sal trees flourished. Around the few villages here and there, some large trees still remain, indices of what was, years since, the condition of almost all this country. The whole surface is composed of long low swelling ridges of this character, interrupted by irregular bays and spits of the more recent sandy and kunkury alluvium which stretch into the higher grounds of the ferruginous gravels and sands, and form stripes of cultivation separating the jungles. This character becomes more marked along the lines of the larger streams, each of which has its own river-alluvial deposits. In Bancoorah these streams are, as compared with the area, more numerous than further south, and the outline of the lateritic deposits becomes therefore more irregular and less continuous. (See map).

Older alluvium.

In the small map, given herewith, no attempt has been made to separate the true massive laterite, that which occurs in hard massive beds and blocks, from the laterite gravels, which have all the appearance of being the result of the decomposition and re-arrangement of this more massive laterite. These ferruginous gravels in some places seem to pass by almost imperceptible changes into the solid laterite, and in a few instances have become re-cemented into a mass not easily distinguished from that rock, and which, in fact, has been and would be called laterite; while on the other hand they pass by equally insensible gradation into a coarse sandy clay containing only a few of the ferruginous nodules of the laterite sparsely disseminated and barely

Varieties of.

sufficient to give a red tint to the whole. In this case also kunkur, that is calcareous kunkur or gootin, is frequently associated.* The two extremes, of a sandy clay full of kunkur, and with nodules of laterite few and sparse, and of a gravelly rock composed almost exclusively of ferruginous nodules, similar to those which constitute the massive laterite, pass into each other, and it is impossible to draw any marked line of separation.

More recent than Laterite.

That this sandy clay and gravel, often ferruginous, often calcareous, is a more recent and a more widely extended deposit than the true massive laterite, is undoubted. But neither the scale of the map at our disposal nor yet its accuracy was such as to admit of a separation of them on it. In most cases therefore, the *older alluvial deposits* (in all probability marine) of the country are included in the area coloured as laterite.

Extent of laterite.

In the northern part of the district of Bancoorah, this laterite does not cover any great area, between the alluvial flats along the river Damuda on the one hand, and the gneiss on the other. It is seen near Barjorah and Shaharjora; southwards near Kharary, resting on gneiss; and in thin patches of no great extent, nearer to the town of Bancoorah. In the higher and more broken grounds extending to Sonamooky, and the Dalkissur, it is seen covering the greater part of the swelling coppice-covered ridges, for the most part gravelly in its character, but here and there forming thick, solid and massive beds. (Bursinghee; Chooa-mussena; Radhanuggur; Puttramara; Kurwan; Ramband, &c.) Toward the west, it becomes thinner and less marked, and gradually more mixed up with the debris of the gneiss.

* The nodular ferruginous rock, which most geologists would call laterite, is generally known to the people of this district as *kunkur*, or *iron-kunkur*, while the calcareous concretions, which are so common, and so universally used as the source of lime, and which a geologist would call kunkur, are universally known as *gootin*.

The flats of the Dalkissur now intervene, and south of this stream, laterite again shews, forming similar long low swelling ridges of broken ground, and covering the greater portion of the district, extending from Bancoorah, south of Bishenpur to Buniapokur, and so passing into the district of Midnapur.

Points of interest.

There are two or three points of interest connected with the mode of occurrence of this "laterite" which deserve a brief notice. In every case, within Bancoorah, where it has been seen, it is detrital; that is, it contains pebbles of quartz and often of other rocks also, but chiefly of quartz. Not unfrequently these imbedded pebbles, and fragments increase in number, until the rock becomes a coarse ferruginous conglomerate. This, however, in most cases, occurs under circumstances which lead to the supposition that it is only the re-aggregation of the surface debris of laterite rocks, and other matters; and that it is, therefore, of a more recent formation than the great mass of the laterite itself. This conglomerate has a peculiar aspect from the fact that the imbedded quartz fragments are generally of clear glassy quartz, the peculiar lustre and transparency of which contrast strongly with the deep dull red of the ferruginous matrix. Layers of sandstone frequently occur with this conglomerate, irregular in their development and arrangement.

Apparently associated with these laterite deposits, there are seen in Bancoorah in one or two places, thinly bedded sandy shaly layers of an ochrey tint and earthy texture, some feet in thickness here and there, but having apparently no extension. These are well seen at the east end of the great tank near Bishenpoor, and further to the east on the road between that and Baniapokur. At first sight these would be taken for small remaining portions of a more widely extended series of beds, different from the laterite, but they seem rather to be instances of the local occurrence of a more earthy, and regular deposit in the midst of the generally gravel-like laterite around.

Near Sonamookhy, to the east, this recent conglomerate, which forms an upper cake-like coating where the lateritic rocks occur, rests upon a bed of loose quartz pebbles forming a coarse clean gravel. Most of the pebbles are well rounded, some of them being as big as a man's head. The same or a similar bed of coarse loose quartz gravel is seen again, south of Birsingha (about 2 miles south).

Gravel beds.

Another point of interest connected with these laterite deposits is this, that in proportion as we approach the gneiss rocks to the west, in the same proportion do the number and the size of the fragments of quartz, felspar, and other debris of those rocks increase, clearly indicating the source from which such have been derived.

Gneiss debris in laterite.

The laterite itself gradually thins out, as noticed above, and dies away toward the west, becoming broken up into isolated patches of smaller and smaller extent and thickness until at last a few loose blocks may be the only trace of its former occurrence. On the other hand the deposit becomes more continuous, and thicker towards the east until it is covered up by the clays.

Over these lateritic rocks, there is widely spread a sandy clay often itself composed to a large extent of the small rounded nodular concretions of the laterite, and passing from this into an ordinary sandy clay with kunkur, (calcareous). In this also, the relative amount of those lateritic nodules steadily increases as the lateritic masses are approached. These older-alluvial deposits are often of considerable thickness, but have not, in Bancoorah, by any means so great a development as in Burdwan to the north, or Midnapore to the south.

In the district of Midnapore, the lateritic rocks cover an immense area. They are here also less cut up by intervening patches of alluvial deposits, along the streams, &c., and therefore form a more continuous sheet of rock. In the majority of

Laterite in Midnapore.

cases the only variety visible at the surface is that gravelly, pisolitic, and nodular rock which has been already noticed. In very few places are any good sections of this rock exposed, and its general appearance is that of a continuous layer spread over the country, swelling here and there with a gently undulating surface, the waving rolls of which are slightly elevated above the alluvial plains adjoining. The rise in the ground is in fact so gradually formed that the difference of level is only noticed when seen from a little distance. These long low swells of lateritic gravel and laterite, are chiefly covered with low coppice, with occasional patches of grassy land ; but their dry, parched, and stony, soil is ill adapted for cultivation.

The same peculiar feature, which may be generally noticed in Bancoorah, is always observable here also, that this great sheet of laterite appears invariably on both sides of these long swelling undulations to dip under the small alluvial flats adjoining, and to rise again beyond. (See below).

All pebbly.

Throughout the whole of Midnapore the surface laterite, or that which we have alluded to above as detrital laterite, invariably contains in more or less abundance small rounded fragments of other rocks. The proportion in which these occur in the ferruginous matrix of the rock is very variable. Occasionally they constitute the mass of the rock, and the laterite then becomes a coarse gritty sandstone of red-colour, and in no lithological character differing from many sandstones of very different geological date. Often the rock becomes conglomeratic, pebbles of quartz, and rounded fragments of other rocks being imbedded, these pebbles being coated, as in other ferruginous conglomerates, with oxide of iron (near Midnapore). About four miles south of Midnapore also, near Jowfulla, the rock, which is well seen, is very conglomeratic, large pieces of quartz and jaspery rock, and well worn fragments of other rocks being of common occurrence. From this coarse conglo-

Or conglomeratic.

meratic variety, every gradation may be traced into a homogeneous pisolitic mass composed of small nearly spherical nodules of sandy ferruginous matter generally speaking arranged in concentric layers, with a black or nearly black central spot, or nucleus. This is occasionally composed of magnetic-iron, but is often decomposed and is then in the state of a yellowish ochre, or has disappeared and left a small cavity.

Nodular or pisolitic.

One of the most remarkable features about this curious rock is the extraordinary regularity or uniformity in the size of these small nodular concretions, or rounded masses. Few of them are so much as one inch in diameter; the prevailing size being from one half to three quarters of an inch, but over many square miles of such a deposit it would be almost impossible to discover a single nodule double this average size.

Uniformity in size of nodules.

Frequently this detrital or nodular laterite is like a loose gravel, each nodule being separate and free, but not uncommonly it has been cemented into a solid mass, which can be quarried like any other rock. Many places may be seen in pits along the road side, where this gravelly laterite is extracted as road-metal for which it is admirably adapted; and in these pits the connection of the more solid variety, with the more loosely coherent, may be traced. In all cases it seems to have resulted from a reconsolidation or subsequent cohesion of the previously free particles or nodules: and this seems to have been produced by the infiltration of water, which decomposing and partially taking up the iron has again re-deposited it, forming a cement between the nodules. This recementing is always seen along lines of jointing or cracks, by which such water has trickled through the rocks, and the solid portions are seen irregularly disposed along the irregular directions of such infiltration.

These re-cemented masses of the nodular laterite (kunkur, or iron kunkur of the natives) formed from the already dried-up and exposed particles, generally fall to pieces on exposure; in this respect as in others, differing from the more moist and clayey varieties of the so-called laterite, the peculiar character of which is to become harder on exposure and desiccation.

Few good sections.

In very few places can the actual contact of this curious rock, "laterite," with the rocks which underlie it, be traced in this district. Close to Midnapore town an excellent section is seen near Gop House and to the west of the station. Here in some places what looks like the decomposed upper surface of the gneissose rocks can be just traced, but no where sufficiently exposed to enable a definite opinion to be formed of their character. This soft and clayey mass with sharp angular pieces of quartz is here and there cemented by peroxide of iron into a mass closely resembling the ordinary laterite of the country. The laterite itself is of very variable thickness, in places not more than a foot or two, while under Gop House more than fifty feet are exposed of solid blocky laterite, arranged in large tabular masses or beds which have a slight dip or inclination to the south. This here rests upon a greyish-white and reddish clay, soft, soapy, and felspathic, and in most respects like the ordinary kaolin clays resulting from the decomposition of felspathic rocks. There is, in this locality, no passage observable between the two rocks. The clay* below is but slightly impregnated with iron, which in fact, only shews in ferruginous patches or stains, while the mass of the laterite above, in immediate junction, is of the most typical character. All this "laterite" contains rounded fragments and pebbles of other rocks, of small size, the clay beneath being quite free from such admixture.

Gop house.

* This non-porous clay, covered by the open and fissured laterite above, forms the water level of the district. Wells sunk through the laterite, north of this, passed through some sixty feet, meeting no water until they had reached the clay below.

Laterite in Orissa.

In the central and southern divisions of Orissa, "laterite" covers a very large area. In the northern part of the province it occurs in a compact form only along the base of the Nilghiri hills, which it generally but not invariably skirts, and from the base of which it in many places extends for from half a mile to a mile into the plains. But around Balasore a peculiar gravelly variety of this singular rock appears forming a bed some five or six feet thick, and at a short distance beneath the surface of the ground. This bed occurs in a tract of undulating alluvium, and is not compact as near the hills, but gravelly and sandy, consisting mainly of ferruginous pisiform nodules, and having generally the appearance of a bed reconstituted from denuded "laterite." It does not follow that this has been its origin, but it presents that appearance. This does not extend far to the south, and it dies away also towards the hills. Further to the south, it occasionally recurs, generally in the dry, gravelly and kunkuriferous soils of the older alluvium; but it is also sometimes found in alluvium quite undistinguishable from the recent delta deposits, as, for example, at the village of Teelochundpur, close to the river Kursooa, the northern branch of the river Brahmini, and just to the west of the Cuttack road.

Terrace-like plain.

South of the Brahmini, and thence to the Chilka Lake, laterite forms a raised terrace-like plain around nearly all the hills, excepting those few which occur far out in the alluvium. It sometimes stretches across from hill to hill, and is covered by alluvium in the hollows, in which it evidently in many cases underlies the more recent deposits. Indeed it probably underlies the whole of the recent alluvium, and seems to have covered the country up to a certain height, as if the undulating surface of the region to a certain altitude had been converted into this singular ferruginous formation. It is seldom seen above this altitude, and its level dips rapidly towards the East, so that the area it covers around the more easterly hills becomes more and more circumscribed, until at length in the isolated peaks far east of the main clusters, no laterite at all appears, and

Dips to east, rises to west.

it seems to be covered up by the alluvium. Towards the west, on the contrary, it rises to a height sometimes of 60 to 80 feet above the plain, and outliers of it occur upon the surface of the gneiss or sandstone. Laterite even caps some of the low sandstone hills upon the Mahanuddi, as is seen near Naraj and Bolpada, yet somewhat further west it recurs in the lower ground forming an extensive plain which bounds the sandstone on its northern and north-western edge. This plain, however, being at some distance from the river, while the previously mentioned localities are on its bank, may not really be lower than they are, although it appears to be so.

The accompanying Sketch section will serve to illustrate the relations of the alluvium, the laterite, and the metamorphic rocks.

*Fig.* 1. Sketch-section shewing the apparent relations of the Alluvium, the Laterite and the Metamorphic Rocks.


*a*, alluvium ; *b*, laterite ; *c*, gneiss, &c.

The depth to which this rock extends is very variable. Frequently 30 to 40 feet are exposed, and there are hills of it at least 80 feet high.

Thickness of Laterite.

Towards the south-west end of the Chilka Lake no laterite occurs although the general form of the country is similar to that further to the north-east. The undulating ground is here composed of gneissose rocks. As this district of Ganjam however has not yet been closely examined, the absence may be accounted for by a closer survey.

Near Chilka Lake.

ALLUVIUM.—Of the two kinds of alluvial deposits to which allusion has already been made, little need be said. The older is distinguished by being more sandy, and probably always containing more or less laterite gravel. The country covered by it is undulating, the surface having been modified by denudation, and the newer alluvium occurring in the river valleys—kunkur

Two kinds.

very generally accompanies it; but this is also, though in a somewhat less degree pretty generally distributed in the more recent alluvium also, and in some places the nodules are very large.

Difficult to separate.

It is extremely difficult to separate the two varieties, as they frequently pass into each other by insensible gradation and in some places laterite may be found beneath the soil in a perfectly flat country, in which every thing induces the belief that the alluvium is recent.

Shells in alluvium.

On the southern bank of the Chilka Lake in one or two places at an elevation of 20 to 30 feet above the present flood level is found a bed of mud with shells.* A similar deposit occurs at some places on the spit between the Chilka and the sea. The shells (*Cytherea casta and Arca granosa*) are marine and do not, so far as ascertained, at present inhabit the Chilka Lake, although one of them the *Cytherea casta* is common in the estuary connecting the Lake and the sea. On the other hand, the shells now abounding in the Chilka, as for example *Cerithium fluviatile* and *Modiola emarginata* do not occur in this deposit. This affords evidence of an elevation of the land, since the recent period, when the Chilka had freer communication with the sea, than it, at present, has.

As a general rule, however, all the alluvial deposits are unfossiliferous; the only shells that are seen are a few fresh water mollusca, common in rice fields and marshes.

Ranges of sand hills.

*Blown sand.*—Blown sand occurs along all parts of this coast which face the south-east. In some cases, these sand hills cover a considerable tract, as near Pooree, where they are two or three miles across. When such is the case, their area is generally bounded on each side, towards the land, and towards the sea, by a range low (60 to 80 feet at the most) but still higher than

* These are collected and burned for lime.

the ground between; other ranges more or less obliterated occurring further inland. On the inner range there is almost always vegetation, and it seems to serve as a boundary for the barren land, which is prevented from being covered with grass, by sand from the sea being continually, in high winds, blown upon it. There can be little doubt, that each range of sand hills marks an old sea coast, and it seems probable that the sea has retired, that is, that the land has been elevated not continuously, and uniformly, but at intervals, and by interrupted lifts.

Mark old coast lines.

The evidences of the gradual rise of land in Orissa are numerous. It is probable that the cliff-like escarpment of the Nilgiri range, and the clusters of isolated hills evidently once islands, which dot the province, have been brought to nearly their present form by denudation of an ancient date. But that a more recent agency has also tended to modify their shape, seems shewn by the laterite conglomerate. But these are no evidence of a recent rise of land. Within the memory of man, however, the tide came further up the rivers than it now does, so much so, that the export salt golahs had to be moved further down the Brahmini. This may, however, be merely due to the raising of the delta by fluviatile deposits. It is said, that the Black Pagoda, when first built, was on the shore; now it is two miles inland, and on the inner row of sand hills, above mentioned; a fact which renders it probable that it was originally built close to the sea. It is also stated by the natives that Balasore was once on the shore, but it seems doubtful if such can have been the case in historical times.

Gradual rise of land.

*Economic Geology.*—The rock most generally employed for building purposes in these districts is "Laterite." This is largely used in the construction of the walls of houses, and in buildings also of greater pretension. Few rocks present

Building stones.

greater advantages from its peculiar character; it is easy to cut and shape when first dug, and it becomes hard and tough after exposure to the air, while it seems to be very little acted on by the weather. Indeed in many of the sculptured stones of some of the oldest buildings, temples, &c. in the district, the chisel-marks are as fresh and sharp as when first built. It is, perhaps, not so strong, nor so capable of resisting great pressure, or bearing great weights, as some of the sandstones, or the more compact kinds of gneiss, but it certainly possesses amply sufficient strength for all ordinary purposes. It is largely used at the present time, but has also been employed from the earliest period from which the temples and buildings of the country date. And the elaborate specimens of carving and ornament, which some of these present, shew that the nodular structure and irregular surface of the laterite does not prevent its effective use for such purposes of ordinary ornamentation, as mouldings, &c. Another advantage it possesses over other rocks is the facility of transport, it being generally found in the low grounds, and often at no great distance from some of the many streams which traverse the vicinity.

Laterite, its uses.

Slabs from four to five feet long are easily procurable of this rock. They are quarried in a rude but effective way; a groove is cut with a rudely pointed pick round the slab: another is made underneath, and then a few wedges driven in split off the block. The more loose and gravelly forms of the laterite are universally used for road-metal for which purpose they are admirably adapted.

Mode of quarrying.

In Orissa, gneiss and sandstone are also quarried in places for building purposes. Ancient sculptures on both are found. The caves of Khundegeree, and the temples of Bobanessur are both of sandstone, while temples with statues of Hindoo deities carved in gneiss are common in many districts as on

Gneiss and sandstone.

Neeltigur hill in pergunnah Ultee, and the large statues at the Black Pagoda of Canarue near Pooree. The variety generally worked is one of the kinds of garnetiferous gneiss. At Neeltigur, millstones are manufactured to a considerable extent, in other places drinking cups are made of gneiss.

Chloritic rock.

The chloritic and serpentinous beds in the gneiss are manufactured into plates and basins, wherever they occur. In Midnapoor district and close to its boundary in Maunbhoom, and in the Nilgiri hills are the principal seats of the manufacture in these districts. The rock yields a beautiful compact and very tough material, though soft and easy to work. It is admirably suited for fine carvings as may be well seen in some of the beautifully sculptured doorways of the Black Pagoda, which are carved from this variety of rock. Blocks of almost any size can be obtained, the only impediment being the difficulty of transport from the high hills on which it generally occurs.

Used for plates, bowls, &c.

The most general use of this rock at present, however, is in the manufacture of plates, bowls, basins, &c. which are in common use all over the country. The tools employed in the manufacture of these are of the rudest kind. A short round bar of iron pointed at one end, and a wooden mallet suffice to procure from the rock a piece, of size sufficient for a plate or bowl. This is rudely cut into the intended form by the quarryman on the spot, and the thus half-finished materials are brought down from the quarries or holes on the hill side, and finished by different workmen in the villages below. This is done partly by hand with finer tools, partly on a simple lathe. The finished plates, &c. are then transported to the markets by merchants who deal in these articles, and who generally have the whole produce of villages secured by contract before hand.

Mode of working.

Under the thick mass of laterite seen at Gop House, Midnapore, a white clay is seen of no great thickness, and discolored here and there with ferruginous stains. Similar clay is also seen to the west in several places. Again southward near Cuttack, on a hill a little west of Kukkur, in another near Naraj, and at some other places in the sandstones, a bed of soft white clay occurs; this is largely extracted and used by the natives in dressing leather, and also mixed with water as a wash to ornament their houses. It might prove a good material for porcelain.

Clays.

Many of the alluvial clays, when not kunkuriferous, make very tolerable bricks, and are generally used for that purpose.

*Note on the* LATERITE *of* ORISSA, by W. T. BLANFORD, *Geological Survey of India.*

Object of the present paper.

IN my notes on the Geology of Orissa, embodied in the preceding paper, I mentioned some of the peculiarities of the mode of occurrence of the "laterite" so widely distributed in that province, and especially in the southern portion of it. Amongst these peculiarities, I remarked on the manner in which it forms a raised terrace-like plain, surrounding the hills, and rising to a greater height above the sea towards the west than to the east; its absence above a certain level in each locality, and its variable thickness, as also the peculiar form it assumes in the northern parts of the province. The object of the present note is to describe more fully the circumstances attending the appearance of this remarkable rock, and to suggest briefly a few theoretical explanations which may account for some of its characteristics. And in so doing, I cannot pretend completely to explain its origin. I confess myself unable entirely to appreciate the causes of its very singular nature and constitution, nor is it surprising that what has proved a riddle to probably every investigator of Indian Geology should still remain unsolved. Neither do I wish the conclusion to be drawn that what may serve to explain the mode of occurrence of "laterite" in one position in Orissa will equally account for its exhibition in other localities; *e. g.* in the enormous masses which cap the Rajmahal Hills in places. I only wish to offer, rather as suggestions than as theories, hypotheses which may partially explain its existence in the locality which has fallen more particularly under my notice; trusting that if my present views should, as they very possibly may, hereafter prove erroneous, they may nevertheless have the effect of drawing the attention of more competent observers to the study of this rock, and that the latter may, by clearly explaining its origin, remove a stumbling block from the path of Indian Geology, and a disgrace from its reputation.

Employment of the term "laterite."

The term laterite has been vaguely applied to many forms of rock, all agreeing in being ferruginous, but varying in coherence and in composition. In Orissa and Bengal, it has usually been confined to the dark reddish brown substance so commonly seen on the surface of the ground; and which, when exposed to the action of the weather, assumes a rough nodular surface, and is frequently permeated by hollows of irregular shape and direction, It also becomes covered with a glaze-like coating of brown peroxide of iron.

Comprises two different rocks.

On a careful examination of this rock in situ, it is seen that it comprises two kinds, essentially distinct in nature and composition, and that one particular form invariably overlies the other wherever the two occur together.

Surface "laterite."

I. The form which generally appears at the surface, (it being rarely that the lower kind is exposed by the denudation of the upper), consists mainly of round ferruginous nodules, about ⅛ to ¼ of an inch in diameter, in a matrix of dark reddish brown clay, which is generally more or less sandy. The nodules have a coating of brown hydrated peroxide of iron, and, when broken, some are seen to be black inside, others appear to be formed of concretionary peroxide of iron, others again are evidently ferruginous pebbles of decomposed gneiss, or of sandstone, if that rock prevail in the neighbourhood. These little nodules are frequently scattered over the country by the denudation and disintegration of the deposit containing them.

Its state of aggregation.

In places this substance is so soft that it may be cut, though with difficulty, with a spade; in other places it hardens into a firm rock, sometimes cohering only in the form of large blocks, the intermediate portion remaining loose and gravelly, but frequently forming a hard mass which covers the surface for considerable areas. It is only at the surface that this rock becomes thoroughly hardened, the lower portion requires exposure to give it firmness and strength; when exposed it becomes cavernous, owing to the washing away of the softer portions, and apparently a chemical change takes place, whereby the iron becomes altered from the state of anhydrous peroxide, (and sometimes perhaps also of magnetic oxide,) into that of brown or hydrated peroxide. To this chemical change the coherence may perhaps partly be attributed; much, however, is doubtless due to the mere thorough drying of the clay by the heat of the sun. The rock passes from this compact form, by insensible gradations, into the gravel like "Laterite" of Balasore and its vicinity.

Effects of exposure.

"Laterite gravel."

In the immediate neighbourhood of hills, and sometimes even for a considerable distance from their base, instances are numerous, in which pebbles and boulders, frequently of considerable size, abound in this deposit. There can be no doubt that these are the result of denudation and transportation, and not of partial disintegration of the underlying rock, because apart from their rounded form, which alone is strong evidence, even if not of itself sufficient to prove that they have been rolled by water, the foliation in different boulders does not coincide, and moreover blocks of many different varieties of the metamorphic rocks lie side by side. Near hills of quartzose forms of the gneiss, the ferruginous deposit sometimes passes into a grit, consisting of the mere detritus of the hill cemented by iron. But "Laterite" frequently extends over flats of many square miles in area, and, at a distance from hills, similarly good evidence of the origin of the rock is wanting.

Evidence of its detrital origin.

In some rare cases, the surface of a rock, either gneiss or sandstone, is exposed, the hollows in which are filled by this form of "Laterite." A beautiful illustration of this occurs in the Máhánadi river, nearly opposite the village of Simlibhánd, 3 or 4 miles above Cuttack. On a small rocky island, on which stands the temple of Deválsur, not only are the small cracks in a conglomerate occurring there, which belongs to the Atgurh basin sandstone, filled by a nodular ferruginous substance, but some of the pebbles have been removed and are replaced by it, so that the conglomerate appears as if containing pebbles of laterite. A little lower down on the opposite (north) bank of the river, the same ferruginous rock is seen to fill the hollows, caused by wear in a sandstone. In both cases it can scarcely be the result of any thing but deposition, in its present form, on the subjacent rock. It may, however, be caused by the re-consolidation of denuded laterite.

The gravel containing ferruginous nodules in great abundance near Balasore also contains pebbles and sand transported from a distance; indeed as before remarked, it is merely a modification of the more ordinary form of the rock. This modification is not, however, confined to the neighbourhood of Balasore, where it appears to rest on alluvium, but occasionally occurs resting on gneiss, in other parts of the province. This gravelly form of the laterite may in some places be contemporaneous with the older alluvium and formed from denudation of the more massive variety.

The underlying variety.

II. The underlying variety greatly resembles the former wherever it is exposed, as it hardens and becomes covered with a brown glaze in the same manner. It is nevertheless of an entirely different constitution, and, where it rests on gneiss, is always found to consist mainly of a true clay, generally more or less mottled, and *much more ferruginous near the surface than below*; it varies in colour in consequence from red above to yellow at a short distance beneath, and, at a greater depth, to nearly white. It contains a few pipes, of small diameter, evidently produced by the percolation of water. Throughout the clay occur irregular pieces, varying in size and shape, but seldom exceeding two or three inches in thickness, of a hard stony ferruginous substance, which sometimes appear, when broken, to consist mainly of concretionary peroxide of iron, with frequently small angular pieces of clear quartz, but more frequently of a mottled rock, which is evidently decomposed gneiss. Probably the more ferruginous concretionary masses are the same, but changed in appearance by being more strongly impregnated with iron.

Its passage into gneiss or other metamorphic rocks.

The deeper the section, the less appears to be the quantity of iron, and the smaller the number of ferruginous lumps, until at length the bed passes into a white clay containing particles of quartz and felspar, foliation then becomes gradually apparent, and no doubt can remain that the formation is the result of the alteration, in situ and by surface action, of a metamorphic rock. Indeed the change only differs from the usual course of conversion of a felspathic rock into kaolin, in the peculiar impregnation with iron, and the tendency to a segregation of that iron, in the less decomposed portions of the mass.*

Sections are occasionally seen in wells, in which the quartzose layers of the metamorphic rocks extend unaltered into the argillaceous mass of "Laterite," which has been formed by the decomposition and alteration of the more felspathic portions, and in one particular instance, near Paikesae, a village a little west of the Dyah river, a section was seen,

* Fresh sections of laterite are naturally not easily found; those available being chiefly wells in process of sinking, and, as the water which usually rests upon the lower and most argillaceous portion of the decomposed gneiss is, in most cases, reached at a small depth, they are seldom of much value. Old sections are of no use, for reasons which are mentioned further on. Many of the above details were first observed at a well and boring at Daltola, near Khúrdah, which was made by Captain Harris, the Surveyor of Cuttack rivers, who very kindly supplied me with specimens taken at short intervals in the depth. The well was dug to a depth of 26 feet, when water was reached, and then a boring was sunk nearly 50 feet further. The upper 6 feet was formed of the nodular and sandy upper deposit, below 6 feet the argillaceous lower form of laterite came in, and was, at the top, dark red in colour, at 12 feet reddish brown, at 20 feet dark yellowish brown in part, light yellow in others, at 25 feet all yellow or white. The boring from below this shewed a gradual passage into gneiss, but the unaltered rock was not reached.

in which unaltered blocks of the subjacent gneiss rock, preserving its foliation, were seen entirely surrounded by a mass of "Laterite."

Or into sandstone.

When sandstone forms the underlying stratum, it is seen to pass into a ferruginous deposit, in a similar manner to that in which the gneiss does. The resulting "Laterite" is generally much more gritty, but sometimes it much resembles that formed above gneiss. This is probably where the sandstone is very felspathic. The rock, when formed by the alteration of sandstone, may however always be distinguished by containing fragments of that rock strongly impregnated with iron.

Irreconcilability of the two forms.

* From the preceding description of these two forms of rock confounded under the name of laterite, it follows:—

1. That the overlying form contains pebbles and boulders evidently transported from some distance, and is consequently the result of deposition from water.

2. That the underlying form is clearly and unmistakeably the result of the alteration, *in situ,* of the rock on which it rests.

These two different rocks are clearly distinct therefore, both in composition and in origin. It is manifestly unscientific to continue to confound them under the same name.

The name laterite was applied by Dr. Buchanan Hamilton in all probability generically. The name (brick-stone) however, was given on account of the employment of the rock in building, a purpose to which the detrital form is far more frequently applied, at all events in Orissa, than is the variety formed by the alteration of igneous or metamorphic rock or of sandstone. The detrital form moreover is that most commonly seen and best known, and to it I shall consequently in the present paper restrict the term of *Laterite.*

* The two forms of Laterite have been remarked by several previous observers, and the difference in their constitution is clearly explained in Lieut. A. Aytoun's account of the

Lithomarge.

The underlying form varies so much in constitution according to the rock from which it is derived, that scarcely any petrological term will include all its varieties. As a rule however, it is, when derived from gneiss or other felspathic rock, a more or less ferruginous clay varying in purity. To such substances the name *Lithomarge* has frequently been applied, and it seems the most applicable in the present instance, it being understood that all the impure varieties derived from quartzose metamorphic rocks or sandstone are here included in the term.

Apparent passage of Lithomarge into Laterite.

Many instances occur in which the Lithomarge appears to pass into laterite, and therefore, despite the clear evidence of their distinct origin, it has been supposed that the latter is merely the result of a further alteration of the former. The small nodules so abundant in Laterite, and so characteristic of it, are sometimes found, though only in small quantities, in the upper part of the decomposed rock beneath, especially where it has been exposed. There is nothing unnatural in the formation of small nodular concretions of iron in a highly ferruginous rock, consequently their presence in both is no proof of the two kinds of rock being identical. And, with regard to the cases of apparent

Its explanation.

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Geology of the Southern Concan, Edin. New Phil. Jour., vol. iv. p. 67. Their relations to each other have however hitherto, so far as I am aware, not been explained and a critical re-capitulation of their differences appears the only method by which to appreciate the connexion between them. Many of the points mentioned above have been noted by other observers, as by Mr. Stirling (Asiat. Resear. Bengal, vol. xv, p. 163.) in the locality described in the present paper. It will be seen that I differ from all previous observers (at least with all with whose writings I am acquainted) in accounting for the iron in the altered clay or underlying form of laterite. This iron has always, I believe, been considered as derived from the decomposing rock beneath.

It is only right to add that this paper was written before reading Lieut. Aytoun's valuable description of the laterite of the Western Coast. It will be seen on comparing the two descriptions that the rock of the Concan is precisely similar to that of Orissa.

passage, all which have come under my notice, and they are very numerous, have occurred in old sections, which are utterly untrustworthy for the purpose of investigating the phenomena of these ferruginous deposits, for water impregnated with iron runs from the upper formation down the sides, and the whole surface becomes, by weathering, hard, irregular, and homogeneous, with the well known appearance of blocks of Laterite, which have long been exposed to the air. Few good sections moreover are seen in Orissa, except in wells, which are difficult of access for the purpose of careful inspection, while excavations for building material are generally confined to the detrital form.

What is the source of the iron?

It remains to ascertain the source of the large quantity of iron in laterite and the underlying clay, and the method by which these rocks have become impregnated.

By what course did it penetrate the rocks?

It is evident that if we can determine the manner in which the iron penetrated the rocks, we shall have advanced a step towards ascertaining its source. Now there seem to be three possible ways of accounting for its presence in the two formations. We may suppose:—

Possible hypothesis.

I. That the Laterite was originally an ordinary detrital deposit, and that it and the underlying rock were together impregnated with iron. In other words, that the source of the iron was extraneous:

II. That the Lithomarge is the source of the iron, and that Laterite is merely the result of its denudation and re-consolidation:

III. That Laterite is an original ferruginous deposit, and that all, or nearly all the iron, contained in the Lithomarge, is merely obtained from the former rock by the percolation of surface waters.

Pro. et con.

Of these three hypothesis, the first is the least probable. From what imaginable extraneous source could iron be supplied, which should, over hundreds of square mile of country, so impregnate the rocks, that they contain at times no less than 24 per cent of iron,* or nearly 35 per cent of the peroxide? But even assuming this to be the fact, the only source of the iron must be ferruginous waters† covering the country, and in that case, in places where the detrital deposit was thin or wanting, the clay beneath would only be more strongly impregnated with iron. But so far is this from being the case, that, where Laterite is thin or only slightly ferruginous, the clay appears to be nearly or entirely destitute of iron beneath, and wherever the latter appears without the former, there is evidence of a denuding action having removed the Laterite.

The following section, from a well which was being sunk at Geringapatna, a village not far south of Chandkar on the Cuttack and Ganjam road, illustrates the poverty of the ferruginous clay, where Laterite is only slightly developed.

| | ft. | in. |
|---|---|---|
| Surface soil, ... ... ... ... ... ... .. ... ... ... | 1 | 6 |
| Ferruginous gravel, (Laterite of the sandy form and poor in iron,) ... ... ... ... ... ... ... ... ... ... ... .. | 4 | 0 |
| Ferruginous clay (Lithomarge), ... ... ... ... ... ... | 2 | 0 |
| Variegated clay, bluish grey with red spots, containing pieces of decomposed gneiss, and evidently the result of the alteration of that rock, ... ... ... ... ... ... ... ... ... ...... | 12 | 0 |

In the neighbourhood, where the Laterite was of the ordinary thickness and coherence, the clay beneath was highly ferruginous to depths of 15 feet or more.

* Laterite from Daltola, Cuttack, gave ... ... ... ...... 24·5 per cent. of iron.
Ditto from Kattiwar, W. India, gave ... ... ... ... 22·8 ditto ditto.
Ditto from Tanjore, S. India, gave ... ... ... ...... 23·4 ditto ditto.

† If from any other source, such as mineral springs, it is incredible that the deposit should be similar over any considerable area.

For these reasons, we may safely conclude that the above hypothesis is untenable.

The second hypothesis by no means explains the fact of laterite being confined to a certain definite level, as is the case in Orissa. Were it true, we might expect to find Lithomarge on the hills, Laterite on the low grounds, and it would only be natural to anticipate, that, in a great number of cases, each rock would be found not associated with the other. This by no means agrees with the facts observed, for so constantly does Laterite occur wherever Lithomarge does, unless there is evidence of the former having been denuded, that it becomes evident that the existence of the latter is dependent on the presence of the former, and all probabilities therefore point to the last hypothesis, *viz.:* the derivation of the iron in Lithomarge from the Laterite, by the percolation of surface waters, as the only theory in accordance with the facts. And the quantity of peroxide of iron which saturates the surface of the clay below Laterite in old sections is good additional evidence of this passage of the iron from the upper into the lower formation.

How would the iron be distributed according to each hypothesis?

But another point yielding valuable evidence upon this question is the mode of distribution of the iron as regards the quantity contained in various parts of each rock.

Assuming the first hypothesis to be correct, we should expect, either that the quantity of iron throughout the two formations, from top to bottom, would be the same; or that it would diminish regularly, from the surface downwards, to the water level of the country.

Assuming the second, the Laterite would probably be the richer formation, since in the process of the disintegration of the mass, formed by the decomposition of gneiss and other rocks and its redistribution by water, the non-ferruginous portion, in consequence of its lower specific gravity, would have been separated from that richer in iron, and would have been carried away to a greater distance; but the Lithomarge beneath might be expected to be of nearly uniform constitution throughout; or, at all events, its richness would be independent of its depth below the surface.

Assuming the third, we shall certainly find a much larger quantity of iron in the laterite than in the lithomarge, and whilst, in the first named rock, the quantity will be uniform throughout, or diminished very slightly from the surface, in the latter it will decrease in quantity rapidly and regularly with the depth, as far as the water level of the country. Below that level it may probably remain uniform.

How it has been found to be distributed.

It has unfortunately only in one instance been found possible to obtain specimens of these rocks, at regular intervals from the surface downwards to a considerable depth. The result therefore must be looked upon as imperfect until confirmed by fresh experiments. So far as they go, however, they completely coincide with the last proposed hypothesis, that of the laterite being the source of the iron.

The locality whence the specimens were obtained was a well and boring near Daltola.* The section there exposed was—

WELL.

| | |
|---|---|
| Laterite, ... ... ... ... ... ... ... ... ... ...... | 6 feet. |
| Lithomarge passing downwards into white and yellow clay, | 20 ,, |
| Water level at ... ... ... ... ... ... ... ... ... | 26 ,, |

BORING.

| | |
|---|---|
| White clay passing downwards into decomposed gneiss, ... | 44½ ,, |
| | 70½ ,, |

* See note, *ante*, p. 284.

The following were the results of assays:

| | | | | | per cent of iron. |
|---|---|---|---|---|---|
| At 4 feet the specimen | (Laterite) | taken contained | ... ... ... ... ... | | 24·53 |
| ,, 8 ,, ,, ,, | (Lithomarge) | ,, ,, | ... ... ... ...... | | 18·71 |
| ,, 12 ,, ,, ,, | (ditto) | ,, ,, | ... ... ... ... ... | | 15·30 |
| ,, 16 ,, ,, ,, | (ditto) | ,, ,, | ... ... ... ...... | | 16·11 |
| ,, 20 ,, ,, ,, | (ditto) | ,, ,, | ... ... ... ... ... | | 10·00 |
| ,, 24 ,, ,, ,, | (ditto) | ,, ,, | ... ... ... ...... | | 8·37 |
| | | WATER LEVEL. | | | |
| ,, 28 ,, ,, ,, | (clay) | ,, ,, | ... ... ... ... ... | | 4·80 |
| ,, 32 ,, ,, ,, | (ditto) | ,, ,, | ... ... ... ...... | | 4·08 |
| ,, 36 ,, ,, ,, | (ditto) | ,, ,, | ... ... ... ... ... | | 5·34 |
| ,, 40 ,, ,, ,, | (clay) | ,, ,, | ... ... ... ...... | | 3·85 |
| ,, 48 ,, ,, ,, | (ditto) | ,, ,, | ... ... ... ... | | 4·47 |
| ,, 57 ,, ,, ,, | (ditto) | ,, ,, | ... ... ... ...... | | 7·16 |
| ,, 64 ,, ,, ,, | (ditto) | ,, ,, | ... .. ... ... ... | | 5·68 |
| ,, 70½ ,, ,, ,, | (ditto) | ,, ,, | ... ... ... ..... | | 5·67 |

These assays shew a sudden change, and a diminution of nearly 6 per cent. in the quantity of iron contained, between the laterite and the lithomarge. Thence downwards, as far as the water level of the country, there is with one exception, a perfectly uniform diminution in the quantity of iron. And when it is considered that lithomarge is far from homogeneous in composition, and that it contains masses far more ferruginous than the rest of the rock, a single exception to the regular diminution, if surprising, is so only on account of its singularity. Neglecting therefore the quantity of iron found at 16 feet, and dividing in proportion the difference between 12 and 20 feet, we have the following decrements in the percentage of iron from the surface to the water level.

| | | | | | |
|---|---|---|---|---|---|
| At 8 feet from the surface | (in lithomarge) | there is 5·32 per cent | less than at | 4 feet | (in laterite.) |
| ,, 12 ,, ,, ,, ,, | ( in ditto ) | ,, ,, 3·41 per cent | ,, ,, | ,, 8 | ,, (in lithomarge). |
| ,, 16 ,, ,, ,, ,, | ( in ditto ) | ,, ,, 2·94 per cent | ,, ,, | ,, 12 ,, | (in ditto). |
| ,, 20 ,, ,, ,, ,, | ( in ditto ) | ,, ,, 2·36 per cent | ,, ,, | ,, 16 ,, | (in ditto). |
| ,, 24 ,, ,, ,, ,, | ( in ditto ) | ,, ,, 1·63 per cent | ,, ,, | ,, 20 ,, | (in ditto). |
| ,, 28 ,, ,, ,, ,, | ( in ditto ) | ,, ,, 3·57 per cent | ,, ,, | ,, 24 ,, | (in ditto). |

This sudden decrease at the water level points strongly to infiltration from above. Below the water level, the amount of iron contained is very nearly uniform, averaging 5·13 per cent.

Therefore the laterite was the source of the iron.

These results coincide exactly with the theory above proposed. They also agree nearly with what might have been expected were the first hypothesis correct, but reasons for dissenting from its conclusions have already been given.

To recapitulate, I have endeavoured to shew that, in Orissa, two formations have been confounded under the name of laterite;—that of these the lower is produced by the decomposition of felspathic rocks near the surface, and the infiltration of iron into them;—that the upper is a detrital deposit, and that it is the source of the iron, with which the lower one is impregnated.

What is the source of the iron in laterite itself.

It only remains to ascertain the source of the iron in laterite, and the mode of formation of this extraordinary deposit. Unfortunately I am obliged to confess that, on this point, the most interesting in the whole history of the formation, I can add little or nothing to what is already known. The only suggestion I can offer towards its elucidation is the following.

Possible source of the ferruginous nodules.

Over many districts of gneiss rocks in Eastern India, and probably in other places, there are found, in variable quantities, scattered through the soil, some of the small ferruginous nodules which form a considerable proportion of the mass of laterite. These, when broken, are mostly black inside, they almost always contain magnetic or some other form of iron ore, and quartz sand. They are generally rough outside, on account of grains of sand adhering to them, but when they have been rolled in streams, and even when shaken together slightly, the sand comes off, and they are then seen to be covered with a crust of brown peroxide of iron.

In sandstone districts, small pieces of highly ferruginous sandstone are similarly found dispersed through the soil in places. They are frequently, as in the Tributary Mehals of Orissa, used as iron ore by the natives.*

And the mode of their formation.

The source of the nodules first mentioned is possibly this. Let us suppose a metamorphic rock of the average constitution of those forming the greater part of the surface of Eastern India to be gradually disintegrating by the action of the weather. It contains felspar, hornblende, quartz, magnetic iron, and a little mica. The felspar and hornblende become, by weathering, clay or a similar substance; the quartz splits up into sand. The violent tropical rains pour down upon the mixture; the fine sand, the clay, and the mica are easily washed away, the coarser sand remains, and, with it, the magnetic iron, in virtue of its high specific gravity, like ore on the washing floor of the miner. This magnetic iron is partly in small lumps, partly in fine particles, and although its indifference to the action of the weather has enabled it to resist the influences which have decomposed and carried away the minerals which accompanied it, it, in its turn, becomes subject to the changing action of meteoric waters. It combines with oxygen and water, and is gradually converted into the hydrated peroxide of iron, and, in the change, it agglutinates the surrounding sand more or less firmly. The nodules which are black and metallic inside are those which, having been originally most compact, have undergone the least change. Those which contain *angular* fragments of quartz, or small pieces of partially decomposed gneiss, are formed by the agglutination of the surrounding sand by the iron oxide in process of change. Those, lastly, which have a concretionary structure, may owe it to the gradual change of the mineral composing them, the alteration having proceeded slowly and uniformly from their surface towards their centre, or they may be true concretions, formed by the peculiar ten-

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* Report on the Talcheer Coal Field. *Ante* p. 71.

dency of some bodies to accumulate substances of a similar structure around them.

However formed there can be but little doubt that these pisolitic nodules are the source of all or nearly all the iron in laterite, the greater portion of the metal being still contained in them. The remainder of the mass is merely sand and clay cemented by iron supplied by the nodules.

Marine action may also have aided.

The laterite of Orissa has undoubtedly been subjected to marine action, as shewn by the boulders which are found contained in it around the hills,—once islands,—which dot the plains of that country. It is by no means impossible that this marine action has carried further the action of rain in separating the lighter sand from the heavy ferruginous particles, and in spreading the latter evenly over the surface of the country. The greater height to which Laterite ascends in the western part of the Province may be due to a greater rise of land in that direction.

But nothing certain can be predicated.

But these ideas are merely put forward as suggestive speculations. I believe that they may serve partially to explain a very remarkable natural phenomenon, but it is extremely probable that they are far from containing the complete elucidation of all the facts. I can only trust that more fortunate observers may succeed in thoroughly investigating and explaining not only the Orissan, but also the many other Indian Rocks, which have hitherto been confounded under the name of Laterite.

Camp near Raneegunge,<br>
*1st February*, 1859.

*On some fossil fish-teeth of the genus* CERATODUS, *from* MALEDI, *South of Nagpur, by* THOMAS OLDHAM, L. L. D., F. R. S., F. G. S., *and Superintendent of Geological Survey of India.*

THE genus *Ceratodus* was originally established by Agassiz,* to receive several varieties of fossil teeth, presenting remarkable peculiarities in external form, while agreeing in their internal structure and texture with other teeth belonging to the genera *Psammodus, Cochliodus, Strophodus,* &c., included in his great sub-division of PLACOIDS.

These teeth are all composed of two distinct layers ; the upper, being of enamel-like texture, composed of closely set tubes, and presenting externally, where worn, a finely punctulated surface ; the other, or lower layer, of bony structure, composed of reticulated tissue, like that of cartilaginous fishes in general, this reticulated tissue being closely set where the bone was thin, and loose and open, where it was thick ; the external surface, where perfect, being smooth.

The form of these teeth was described as presenting on one side a smoother edge or border, straight or approximately straight through a portion of its length and curved in the remainder, while the opposite edge or border of the tooth was marked by several projecting ridges or horns ; whence the name of the genus.

Under this genus, Agassiz separated and gave specific names to fourteen different varieties, stating distinctly, however, that he did so only provisionally, until the discovery of better preserved and more numerous specimens enabled him to determine how far the differences he had noticed depended really on any specific distinctness, how far on the position of the teeth in the upper or lower jaws, or how far on age. And certainly, as has been forcibly pointed out by Quenstedt,† the specimens figured by him seem to demand this caution from their imperfect condition.

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* Agassiz. Recherches sur les Poissons fossiles. Vol. III. p. 129.

† Handbuch der Petrefactenkunde, p. 186-7.

From the examination of all the specimens to which he had access, Agassiz arrived at the conclusion that, in all cases, the comparatively smooth, or unhorned side of the teeth was that which was internal in the jaw, the horns or projecting ridges being external; and that these teeth were not arranged in more rows than one in the mouth of the fish, but that in each side, of the upper and of the lower jaws, one tooth only was fixed making four teeth in all in the mouth. He concluded also that the straighter portion of the smooth side of the tooth was anterior. This being granted, it followed that all the horns of the tooth would be pointed forward, and those which were, in this case, the posterior horns were also the larger, and more marked. Agassiz also pointed out two distinct groups of these teeth, one flat and broad, the other comparatively elongated with more elevated ridges or horns. He alludes to the possibility of one of these varieties belonging to the upper jaw, and the other to the lower, but without fixing the point.

He considered the fish, to which these teeth belonged to have been more allied to the Cestraciont group, than to any other. Subsequent observers, in adding somewhat to the knowledge of this remarkable genus, have referred it to a different position. BRONN places *Ceratodus* among the Chimeridæ, as does also Plieninger, who has described several species from the Muschelkalk and the Keuper. A few other species or varieties have been figured in different works, but little has been really added to our knowledge of the genus. Quenstedt* has recently described another variety (*Ceratodus Cloacinus*) from the beds below the lias, (" the forerunners of the lias"). This was also nearly the geological position of all previously known species. Only one species has been found so high as the Stonesfield slate (*Ceratodus Phillipsii*) all the others being from beds lower in the series, and ranging from the upper " Bunter Sandstein" of the vicinity of Magdeburg to the boundary breccia between the Keuper and the lias.

* Der Jura, 1858, p. 34.

During the present summer, I had the gratification of receiving in a letter from the Reverend J. Hislop of Nagpur, (whose contributions to our knowledge of the Geological structure of the district in which he was located are well known to Geologists,) a sketch of some teeth which he stated to have been picked up by an intelligent native (named Virapa), near to a village called Maledi, about 150 miles S. S. E. of Nagpur, and about 30 miles from Kota. This man, who had some experience in collecting, had been despatched to the neighbourhood of Kota, a well known locality for fish remains, to collect Coleopterous, and other insect exuviæ, which had been noticed some months previously in specimens brought from thence by Dr. T. Jerdon. In this object he was comparatively unsuccessful, but he was rewarded on his route by the discovery of these fish-teeth at Maledi.

The sketch forwarded by Mr. Hislop, I at once recognized as in all probability representing a *Ceratodus* tooth, and pointing out the interest attaching to this discovery, from the well marked geological horizon to which the genus belonged, I requested the favor of his allowing me to see and draw the specimens. To this he at once, and most liberally, consented, and I was soon in possession of the specimens represented on the accompanying plates (Plates xiv, xv, xvi). These were well preserved, although in parts broken, and abundantly supported my original supposition, from Mr. Hislop's sketch, that they were in reality *Ceratodus* teeth.

Of teeth, of different kinds, there were seventeen specimens; accompanying these were two specimens of Coprolites; a mass consisting of several pieces of bones cemented together, principally of the thick bony plates of the head (?) one terminal portion of a bone, and one or two small fragments, which were useless.

The most cursory examination of the teeth shewed that there were representatives of both of the sub-divisions noticed by Agassiz, namely of flat and broad teeth, and of longer and more elevated teeth. A little more careful examination of the specimens shewed that these two groups differed also in another, and very marked, respect. The flatter teeth in all our specimens had five horns, that is, the two terminal points, and *three* intermediate; the more elevated teeth on the contrary had only four horns, that is, the two terminal points and *two* intermediate horns.

This fact at once suggested that these two kinds or varieties might fit into each other ; and on examining further it was found that in several cases these flatter teeth fitted perfectly to the other and more elevated teeth. There remained, therefore, no doubt, that whatever their position in the jaw might be, we had in these two groups the upper and the lower-jaw teeth of similar individuals.

There was, however, no direct evidence as to which belonged to the upper jaw, and which to the lower. In almost all cases the tooth-mass was detached from the bone which originally supported it. One specimen still retained a portion of the bone, and with considerable care I was able to relieve this from the ferruginous clayey concretion which had formed round it, and to discover in part the true form of the bone. This is seen Fig. 1. Pl. xiv.

It also appeared that the bony or lower layer of the teeth was in all cases deeper and stronger and thicker, in the more elevated and more prominently ridged teeth, than in the flatter specimens. From this I was led to conclude, that the teeth having the more massive and stronger osseous attachment belonged to the upper jaw, while the flatter teeth probably belonged to the lower jaw. If this be granted, out of the seventeen teeth which I received from Mr. Hislop nine were upper-jaw teeth of Ceratodus, of different kinds, and eight belonged to the lower-jaw.

Agassiz noticed the curious fact, that out of seventeen specimens to which he had access, no less than eleven had their hornlike projections on one side, or belonged to the same side of the mouth ; and only six to the opposite. In the same way it is curious that out of the nine upper-jaw specimens which we have, six belong to the same side of the mouth (the left, according to our supposition) and only three to the other side: while of the flatter group, which we suppose to be lower jaw specimens, seven belong to the same side, or the left side, and only one to the right.

If our supposition as to the position of these teeth in the jaws of the animal be correct, (and a similar idea was previously thrown out by Quenstedt) an examination of Agassiz's figures seems to shew that he had only six teeth belonging to the right jaw, of which only two were upper-jaw teeth, and four were lower, while he had eight teeth of the left jaw of which all were lower-jaw teeth. At present, these Indian specimens throw no light on these very curious facts; but they appear to confirm very strongly the doubts which have more than once been thrown on the correctness of Agassiz's supposition that there had been only one tooth on each side of each jaw.

Mr. Edmund Higgins, writing in 1853* stated that his collection of Ceratodus teeth at that time amounted to about 140 varieties—and that among this large number he could scarcely say that he ever met with a duplicate! We believe his collection has now extended to nearly 200 varieties with the same result!

No spines have been as yet found in these rocks in India, and we are not therefore able to throw any light whatever on the suggestion of Agassiz that the spines, called by him *Nemacanthus,* belonged to the same genus as the teeth to which he gave the generic name *Ceratodus.*

We do not intend to assert in the following descriptions that the varieties to which we have given names are really distinct species. It is simply useful to distinguish such well marked varieties for future reference. It is highly probable that some of them may prove identical with others found in Europe, but not yet figured or described. Mr. Higgins, as cited above, gives 21 names as of distinct species, but unfortunately no descriptions or figures accompany this list.

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* Morris' Catalogue of British Fossils, 2nd Edition, page 320.

## Ceratodus Hislopianus. n. s.

Plate xiv. Figs. 1—7. Plate xvi. Fig. 1.

Of this marked variety we have three specimens belonging to the same jaw of the elevated class, (or upper-jaw) and two of the more flattened (or lower-jaw) opposite sides.

The outline, in plan, of those which we suppose to have belonged to the upper jaws of the fish, is rudely an isosceles triangle, the two shorter sides of the triangle being slightly curved, the longer side being formed by an imaginary line joining the terminations of the horns, or projecting points of the external side of the tooth. The inner sides are of nearly equal length, that which was posterior being slightly more curved and shorter than the other. Of the ridges of the tooth, the first, or that which on Agassiz's supposition was placed foremost in the mouth, is, as compared with the others, flattened and broad, and in the old and worn teeth becomes worn down into a slightly concave irregular furrow or depression along the middle. Its point or termination is obtusely rounded. The second horn is sharp, and forms a very marked projection separated by a deep bay or furrow from the first. The line of its continuation is marked on the surface of the tooth by a ridge, which passes in a right line to the highest point or summit of the tooth. The third horn or ridge is similar to the second, and is even more prominent, and strongly marked, and the continuation of its line is equally marked by a sharp ridge passing also in a right line to the apex of the tooth. The posterior horn was large, strong, and well marked, being also much sharper, and less obtuse than the first or anterior horn (Pl. xiv, Fig. 2,). Seen in profile, the outline of these upper-jaw teeth rises in a continuous slope from the anterior part of the tooth to the central apex, and gradually falls from that to the posterior point of the tooth also. (Fig. 2. Pl. xiv.) The upper surface of the teeth, where they have been exposed to wear, exhibits in perfection the curiously punctulated surface common to all these teeth: but is also marked by small irregular and partially confluent little pits or depressions, arising partly from some slightly irregular wear of the surface. The outer and nearly vertical edges of the teeth present a highly enamelled and polished surface, crossed longitudinally by numerous striæ, or slight ridges of growth. The edges of the lateral horns or spurs are marked by two or three sharp tooth like serrations or projecting points, formed by these ridges.—(Fig. 1, Pl. xvi., Figs. 1 and 5, Pl. xiv.)

The flat, or lower-jaw tooth of the same species (Figs. 4 and 5. Pl. xiv) is very different in outline. Seen in profile, the upper surface is nearly flat, and parallel with the lower surface of the enamel layer, the very marked and prominent ridges of the tooth projecting above the general level. Of the total thickness of the tooth, two thirds at least belong to the enamel layer, the osseous layer being very thin. The ridges or horns become regularly more marked and prominent from the front of the tooth backwards to the centre or fourth ridge which is the most prominent. The first or anterior horn is in this tooth marked by a slightly convex rise along the middle of its upper surface, corresponding to, and fitting into the slight depression or furrow mentioned as being on the corresponding anterior horn of the upper-jaw tooth. The other projections are sharply ridged and prominent.

The general outline of these teeth is not so triangular as that of the upper corresponding teeth. The inner edges are less curved, and meet at a more obtuse angle: the line joining the ends of its projecting horns or spurs, would also be much curved, and not as in the corresponding upper teeth, nearly straight. The worn surface of the tooth is exactly similar to that of the upper teeth, the whole being finely punctulated, and having also numerous little irregular pits or depressions. The same bright enamelled surface crossed by numerous striæ of growth shews on the sides of the tooth. Projecting from the bony surface of the tooth below, there is a small projecting process for the attachment of the muscles giving motion to the tooth (Figs. 4 and 6, Pl. xiv.) The lower surface of all the teeth is concave and hollow for the entire length of the tooth. (Pl. xvi, Fig. 1). Two teeth are shewn in contact in Figs. 6 and 7, Pl. xiv; but unfortunately the artist has reversed what we suppose to have been their true position and has put the lower-jaw tooth uppermost in both cases.

Among all the specimens the only instance in which the teeth were found attached to the bones of the jaw is shewn in Figs. 1 and 7, Pl. xiv; and although very imperfect the general form of the bone may be made out. The inner curve of the edge of the bone is seen, and gives some key to determine the general form of the jaw. The bone was thin and concave below, a well marked and widely rounded depression or furrow traversing its entire length. Unfortunately the posterior portion of the bone is broken, but it can be seen that it continued to extend for some distance back, and was probably expanded laterally.

This species more nearly resembles *Ceratodus serratus* and *C. Phillipsii*, of Agassiz than any other figured by that author. But the distinctions are obvious on comparison. I am disposed to think that both the species referred to have been figured from specimens of lower-jaw teeth; and it does not seem at all improbable that both may even belong to the same species, but of different ages. One marked difference between our Indian specimens and the teeth figured by Agassiz is the rounded and obtusely blunt point of the anterior horn, which, in his species, is represented very sharp or even bicuspid; unless, as may be the case, the two first points of Agassiz's Fig. 18, Pl. xix, Vol. iii, in reality belong to one horn or ridge, the surface of which has been worn down in the centre, so as to give a somewhat fallacious appearance of division into two points. In our species also the ridges are narrower, sharper, and more prominent, and divided by wider, and deeper furrows.

There is, however, a close relationship between the Keuper *C. serratus* and the Stonesfield-slate *C. Phillipsii* and our *C. Hislopianus*. C. runcinatus (Plieninger), is even more closely allied, but differs in the much more acute (nearly a right) angle at which the two portions of the inner margin of the tooth met, and in the more closely adjoined horns or ridges. It is from the Lettenkohle of Hoheneck (Triassic. Upper Muschelkalk of Thuringia).

The species is dedicated to the Revd. S. Hislop of Nagpur, one of the most successful cultivators of Geology in India and author of some most valuable papers on the structure of that district.

Found in ferruginous clayey beds near Malèdi, 150 miles S. S. W. from Nagpur.

### Ceratodus Hunterianus. n. s.

Pl. xv. Figs. 1—6. Pl. xvi. Fig. 4.

This species is at once distinguished from all figured Ceratodi by the strongly marked, and greatly elevated ridge which bounds its internal border or edge, and which gives it so peculiar a form. The inner edge of the tooth is greatly curved, the larger and anterior portion being about one-third longer than the posterior. These two portions form an obtuse angle (about 125°) at the points of meeting, this angle marking also the highest or culminating point of the interior ridge of the tooth. This ridge or raised edge of the tooth is here so marked that its total height from the surface of the osseous layer is double the total height of the horns or ridges at the other edge of the tooth. In general outline, (looking down on the tooth) the form is an obtuse scalene curved-sided triangle the base or longest side being formed by an imaginary line joining the points of the horns or projections. The anterior portion of the smooth internal edge is slightly and continuously curved, and is considerably longer than the posterior portion, the latter is also curved. In profile, this variety differs materially from *C. Hislopianus.* The edge rises suddenly from the posterior horn (Pl. xv. Fig. 2; Pl. xvi. Fig. 4) to nearly its greatest height and continues to form a most prominent ridge to the point of the curve or apex of the tooth; and thence it gradually drops to the level of the anterior horn.

The first horn, or projecting point is obtuse, and on its upper surface becomes, after use, worn down to a slightly concave or depressed furrow, which passes up towards the apex of the tooth. The second horn is sharper, and more prominent, and the line of its continuation is marked by a blunt ridge, which continues in a slightly curved line towards the apex, until at about half the distance it loses itself in the general concavity of the surface of the tooth. The third spur is similar, but the ridge which marks its continuation on the upper surface of the tooth is more marked and continuous. This ridge, in worn teeth, is separated from the last or terminal ridge, (which terminal ridge is at the extreme edge) by a deep furrow forming a sharp depression between the third and fourth, or last, horn. Pl. xv. Figs. 1 and 2.

The internal edge of the teeth is formed of a nearly vertical surface of bright enamel, marked by numerous crossing striæ of growth, and forming a regular wall of enamel of nearly an inch in height—($\frac{8}{10}$ths). This enamelled surface is continued all round the tooth. (Pl. xvi, Fig. 4. Pl. xv, Figs. 1—4.) Where worn above, the surface is, as usual, closely punctulated, but is also marked by numerous little depressions, which are often confluent, and are transverse to the length of the tooth, thus causing a series of small transverse, irregular, and ill-marked furrows on the surface.

As compared with the great thickness and size of the enamel layer, the bony layer of the tooth is thin and small, not being much more than one-fourth the thickness of the former. It is marked below by a deep furrow, or concavity, passing along the greater portion of the length of the tooth, and by a thickening of the mass, forming a rudely projecting process, just beneath, or in a line with the apex of the tooth.

The lower-jaw tooth of this species is shewn in Pl. xv. Figs 3, 5, 6. As in the preceding species, its outline forms a marked contrast with that of the upper teeth, being almost perfectly flat on the surface, with ill developed ridges and furrows. The first or anterior horn of this is, on surface, slightly convex, corresponding with the slight concavity or depression in the analogous surface of the upper tooth, as mentioned above. The second and third ridges are nearly alike, and are more slightly marked than the first. The fourth is still more prominent and larger, and the ridge of its continuation makes a well marked rise on the general surface of the tooth. The fifth or last spur is broken off in our specimen, but it must have been less prominent, and marked than the fourth. To this specimen. Pl. xv. Figs. 5, and 6, no bony layer is attached ; the under side, as well as the upper, is closely punctulated, and also marked by numerous strongly cut curved fossettes, giving the whole a very worm-eaten aspect.

The two teeth are shewn in contact Pl. xv. Fig. 3.

Among the varieties figured by Agassiz, *C. Kaupii* appears to be the most nearly related to this. It is, however, very distinct. It is not by any means so elevated or thick a tooth, the ridge bounding it, is not so continuous, and the general form of its outline appears to have been more irregular.

The species is named after the Revd. Robert Hunter, for many years the active fellow labourer of Mr. Hislop in his researches in Nagpur.

Found with the last.

### Ceratodus Virapa. n. s.

Pl. xiv. Figs. 8, 9, 10, 11, 12.—Pl. xvi. Fig. 2.

In general outline and form, this much resembles the last described species, but at the same time offers very marked distinctions. The tooth is broader, and more massive, as compared with its length ; the upper face exhibits a much larger proportion of flat surface ; the ridge and furrows are less sharp and defined, but more rounded and open. The anterior inner edge of the tooth (upper jaw) is straight or nearly straight for two thirds of its whole length, when it curves rapidly round to the anterior horn, or projecting point of the tooth. The bounding ridge behind also, though sharp, well marked, and high, is less so than in *C. Hunterianus.* It does not gradually diminish with a continuous slope to the first or anterior horn, but at a little more than one third of the distance it drops by a sudden step to nearly the general level of the surface of the tooth.

These differences appear to be constant in all the specimens we have seen, and to be sufficient to mark a specific difference or at least to be sufficient to justify our separating them under a different name for the present. They may possibly arise from difference of age in the individual, even supposing the supposition, that there was only one tooth in each jaw, be proved tenable.

In the small collection forwarded by Mr. Hislop, we found a very strong, large, and massive tooth, which on trial was found to fit these teeth with tolerable accuracy. It is a flat five horned tooth, Pl. xiv. 8, 10, and, as we suppose, therefore a lower jaw tooth. The general surface of the tooth is flat, or slightly convex, the interior edge, corresponding to the lofty ridge in the upper tooth, being depressed and rounded in this. The ridges and horns are strongly marked and project considerably above the general surface, being separated by flatly concave depressions. Besides the fine punctations on the surface, there are numerous irregular pittings, or little depressions.

The bony layer in this tooth is more massive and stronger than in the others; its thickness being equal to that of the enamel layer. The lower surface is marked by a long furrow, or curved concavity, and on the outer edge there is a well marked projection, or bony process, similar to that noticed in the other species, Pl. xvi, Fig. 2.

The species has been named after the intelligent native Collector, who procured the specimens, forwarded by Mr. Hislop; and who was also the Collector of many other valuable fossil remains from the district of Nagpur.

Found with the last.

Ceratodus Oblongus. n. s.

Pl. xv.—Figs. 7, 8.

The only specimen we have of this variety is unfortunately imperfect. But there would seem to be abundant ground for separating it from all the others already noticed; both from its general form and relative proportions. It is of the flatter five ridged group of teeth. It is broader than any of the others, and is evidently an old, and much worn tooth. The inner edge is peculiarly straight for two thirds of its length, when it suddenly bends outwards at an angle of about 130°. There is a very obtuse, and slightly marked ridge or elevation along the inner edge, and between this and the ridges of the spurs of the tooth, there is a depression. The first horn is blunt, but slightly projecting, and is marked by a continuation of the low ridge or elevation which bounds the tooth on the inner edge. The second horn or spur is sharp, very prominent, and rises by nearly one half its depth, above the general surface of the tooth. The continuation of it forms a ridge which is nearly parallel to the outer edge of the anterior spur; and which does not, as in the other species, converge to, or nearly to, the centre of the inner edge of the tooth. The third horn, or spur, has apparently been very prominent, but in the old specimen before us it is obliquely worn down to an irregular surface, which has removed the elevated projection, of the top or point of the spur. The continuation of its ridge also is nearly in a line parallel with the anterior inner edge of the first horn. The furrows between these horns are comparatively broad, rounded, and depressed.

The posterior portion of the tooth is unfortunately broken off.

The bony layer is strong, massive, and thick, with, as in all the others, a furrow or continuous curved depression along its entire length.

The surface is beautifully punctulated and has besides little, nearly circular, depressions or fossettes, irregularly disposed. In addition the whole surface is beautifully striped in irregular contour lines, giving a damasked appearance to the tooth. These lines seem to result from a slight difference in the closeness of the tubular structure, resulting in a difference of colour in the fossilized tooth. These different layers of colour being worn down on the irregular surface of the tooth, thus shew in curved lines like contours on a map.

Found with the last.

Pl. xv., Figs. 9 and 10. represent a small tooth, evidently totally unworn and young. I have not thought it desirable to distinguish it by any name. It may possibly be the young form of C. Hunterianus.

## Coprolites.

Pl. xv., Figs. 11 and 12 represent two specimens of Coprolites, found along with these fish remains. They are enclosed in a thick concretionary layer of the ferruginous clay, in which they occur, which assumes the general form of the inclosed Coprolite. On breaking off this outer coating the true form, and spiral structure, of the Coprolite itself is seen within. They are composed of a white and powdery substance with some slight ferruginous stains. They still contain a large amount of phosphates, and, if occurring in any quantity, would doubtless prove a valuable manure.

A piece of the rock in which these teeth are found, with several pieces of bone cemented together in it, is shown in Pl. xvi., Fig. 5. The principal of these are large plates, like some of the large bony plates of the head. (? Saurian) There is also a vertebra, long and thin. Figs. 3, 6, 7 and 8 on the same plate (xvi.) represent other fragments of bone found in the same beds. And I think there can be little doubt that the locality from which these teeth and bones have been procured, will, on closer examination, yield many more specimens and varieties, and in all probability many in better preservation, possibly even entire fish.

It is much to be regretted that Mr. Hislop has not himself been able to trace out the geological position, and relations of these rocks. The character of the teeth above described appears however so marked that there can be little doubt as to the geological age of the rocks, in which they occur. And taking this evidence in connection with the previously described *Brachyops laticeps* (Owen)* from Mangali to the North, and with the fish remains of Dapedius and Lepidotus from Kotah to the south, of Maledi ; and also with the general character of the plants as described by Mr. Hislop himself from Nagpur, I see no reason why we should hesitate to say, that there exist in this portion of the Nagpur district, a series of beds, which represent in India the lower mesozoic era of European Geologists.

There is equally little doubt that these beds will yield a rich harvest of new and valuable contributions to our knowledge of the fauna and flora of that period.

There is as yet no sufficient evidence to show how far this group extends, or what its thickness and relative importance may be. Nor can this be hoped for, until the whole country is continuously examined, and the true relations of these beds as to superposition, disturbances, &c., established. In truth, from mineral characters, these beds were by Mr. Hislop at first supposed to be tertiary. And it is by no means improbable that mistakes of this kind may have occurred in other places also, and that some of the plants and other remains supposed to be of more recent date, may prove to belong to very different groups, from those to which they have been referred. A systematic survey of the district, will alone clear away these doubts. Meanwhile, Mr. Hislop has in this, as in many other ways, contributed largely to the final result.

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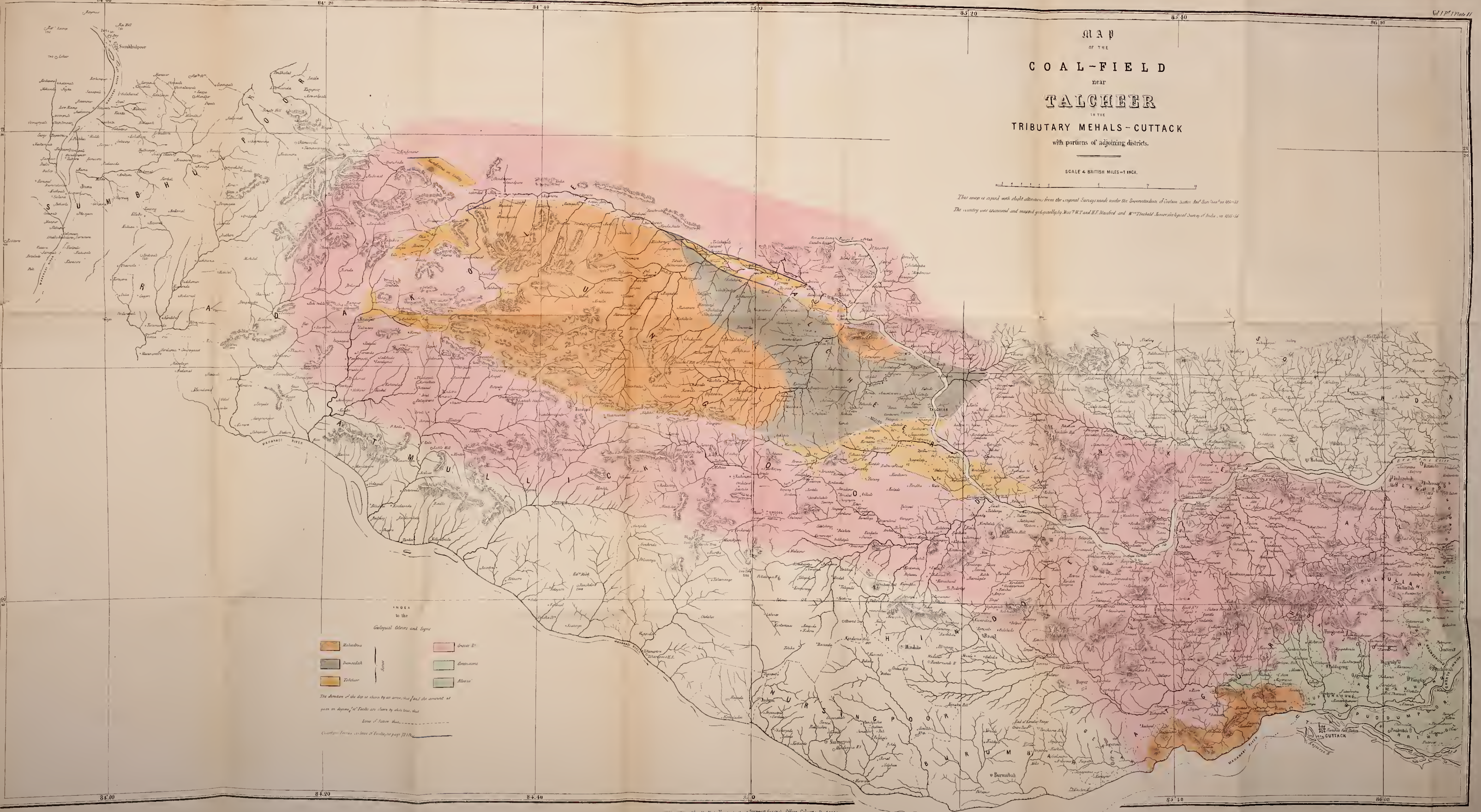
* Quar. Jour. Geol. Soc. London, Vol. xi, p. 37.

" " " " " Vol. x, p. 371.


On Stone by L. Schneeweiss.

Printed by H. M. Smith at the Surveyor General's Office Calcutta December 1856


MAP
OF THE
COAL-FIELD
near
TALCHEER
IN THE
TRIBUTARY MEHALS - CUTTACK
with portions of adjoining districts.
SCALE 4 BRITISH MILES = 1 INCH.
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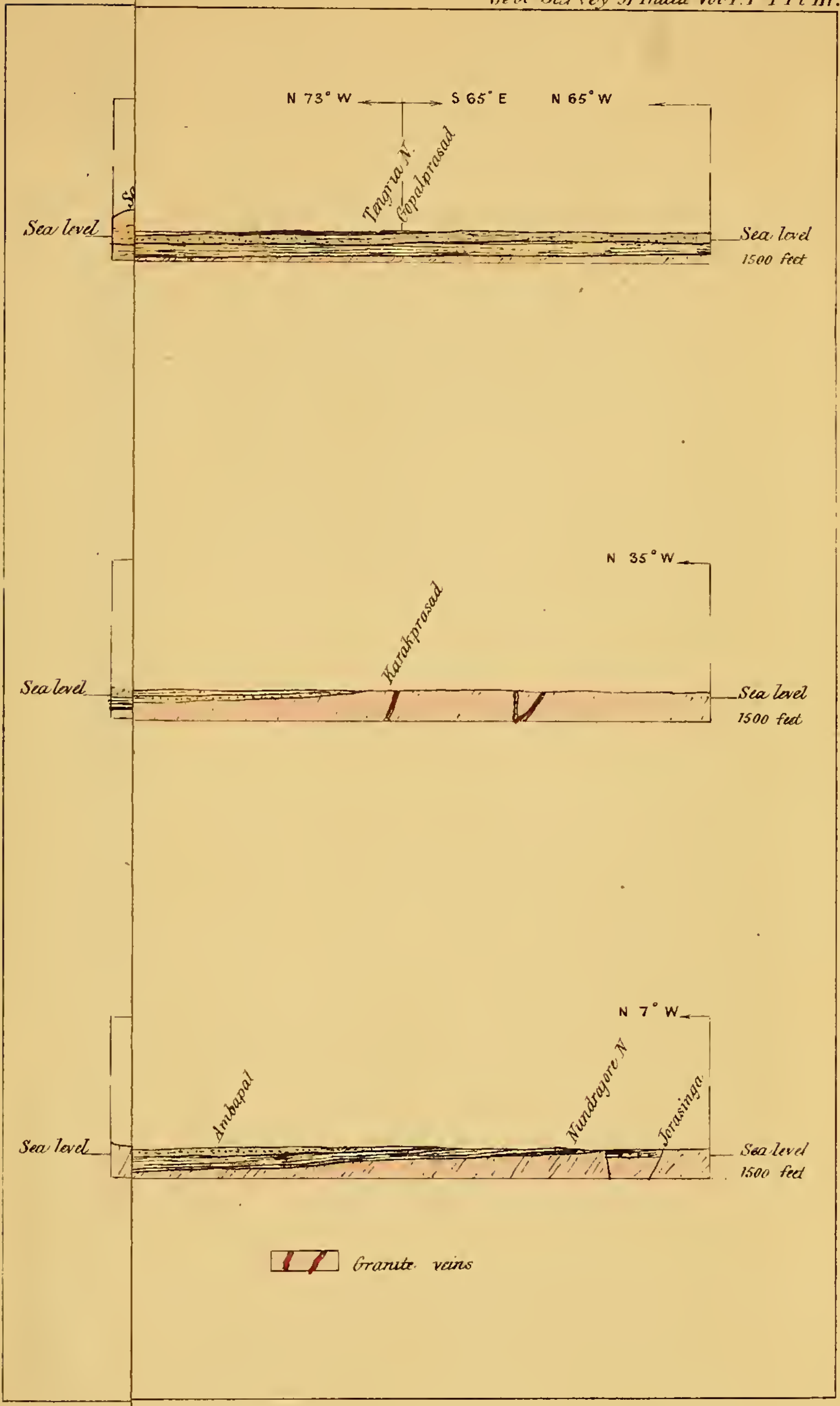
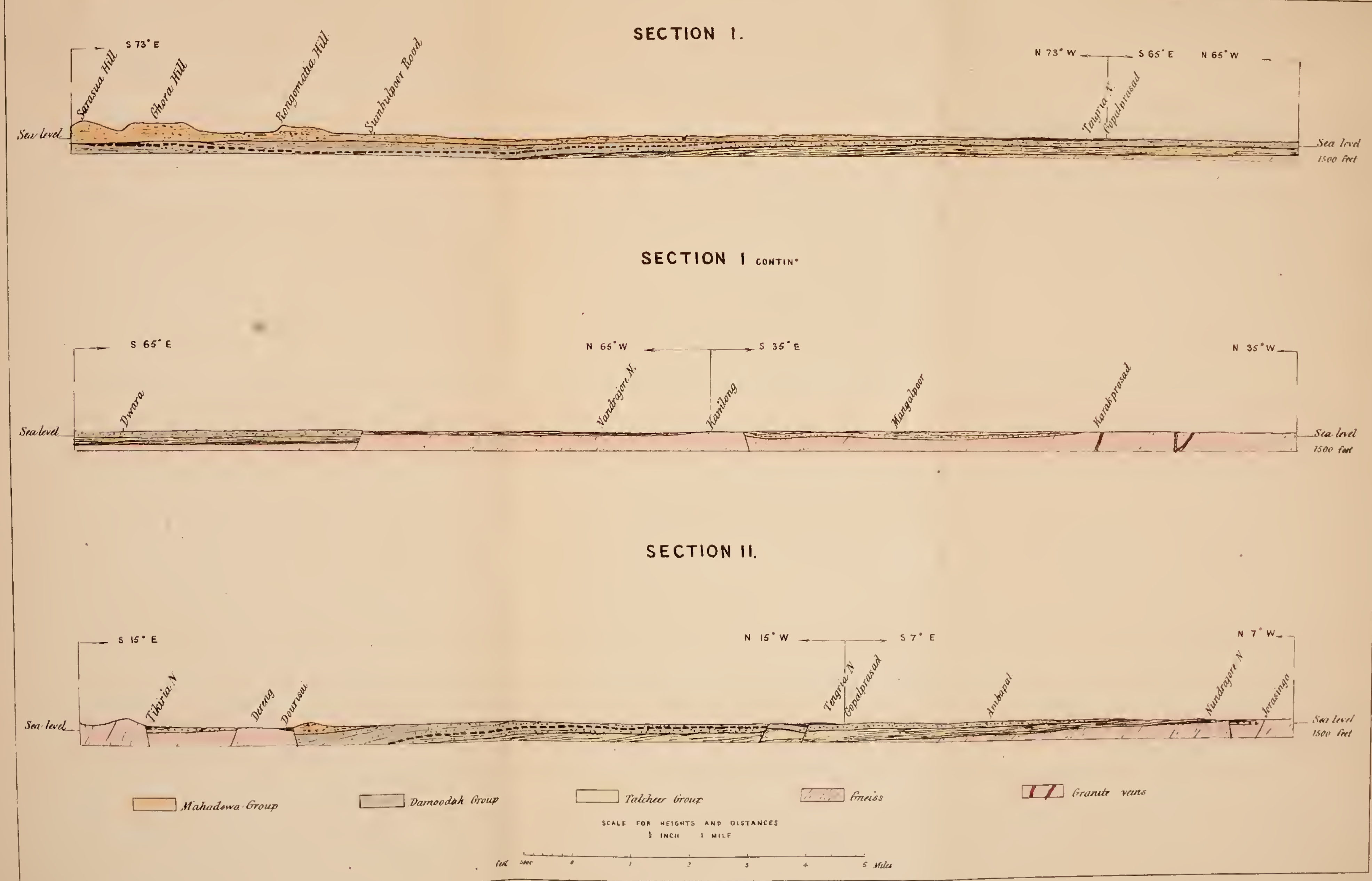
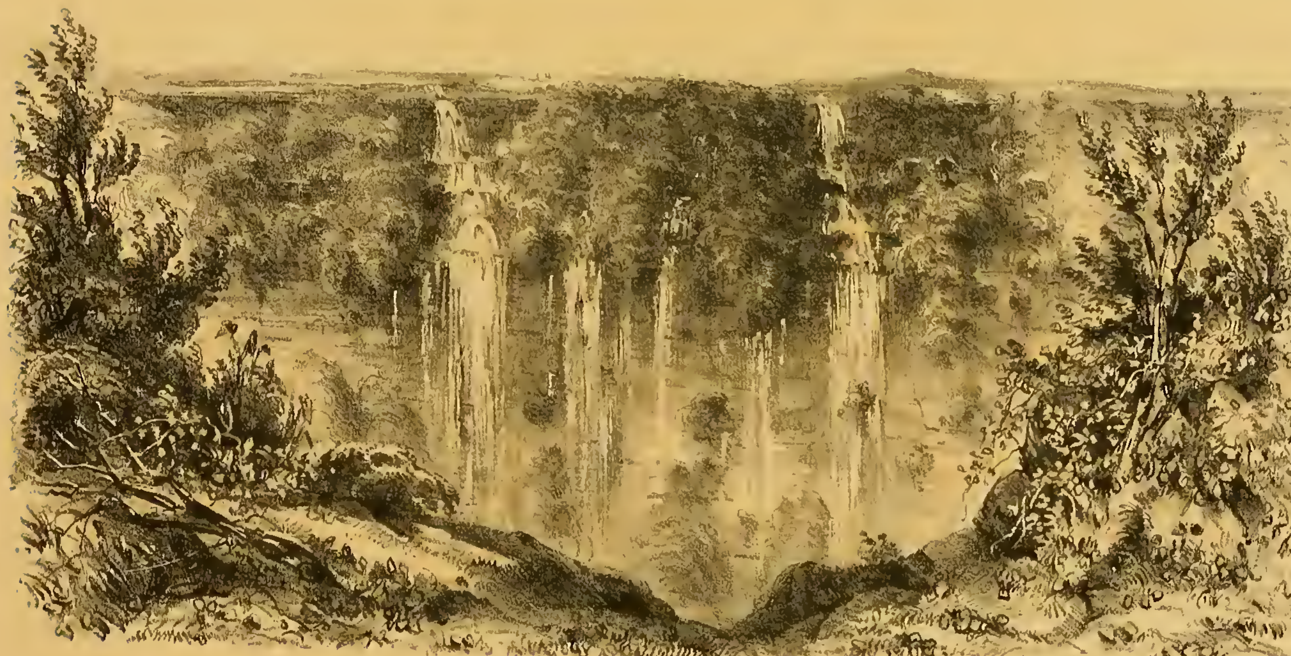

N 73° W
S 65° E
N 65° W
Tengria N.
Gopalprasad
Sea level
Sea level
1500 feet
N 35° W
Karakprasad
Sea level
Sea level
1500 feet
N 7° W
Ambapal
Nundragore N
Jorasinga
Sea level
Sea level
1500 feet
Granite veins



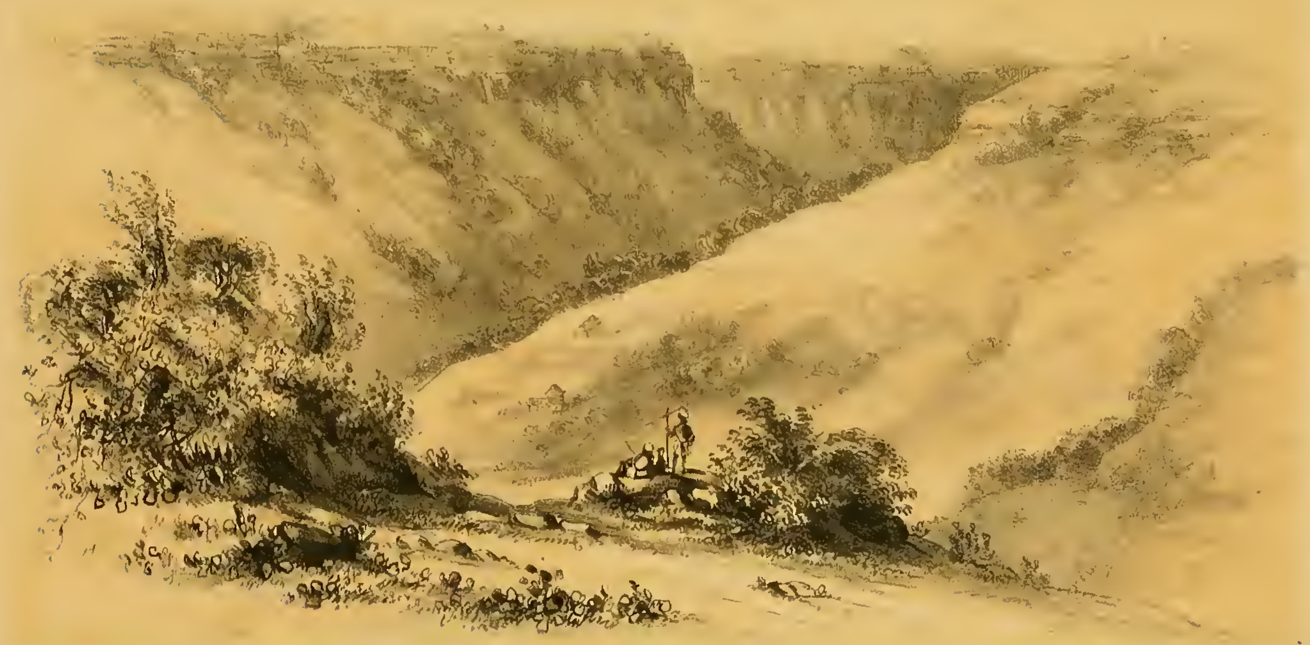

Lith by H. M. Smith Surv^r Genl's Office Calcutta Nov^r 1856



H. L. Frazer Lith.

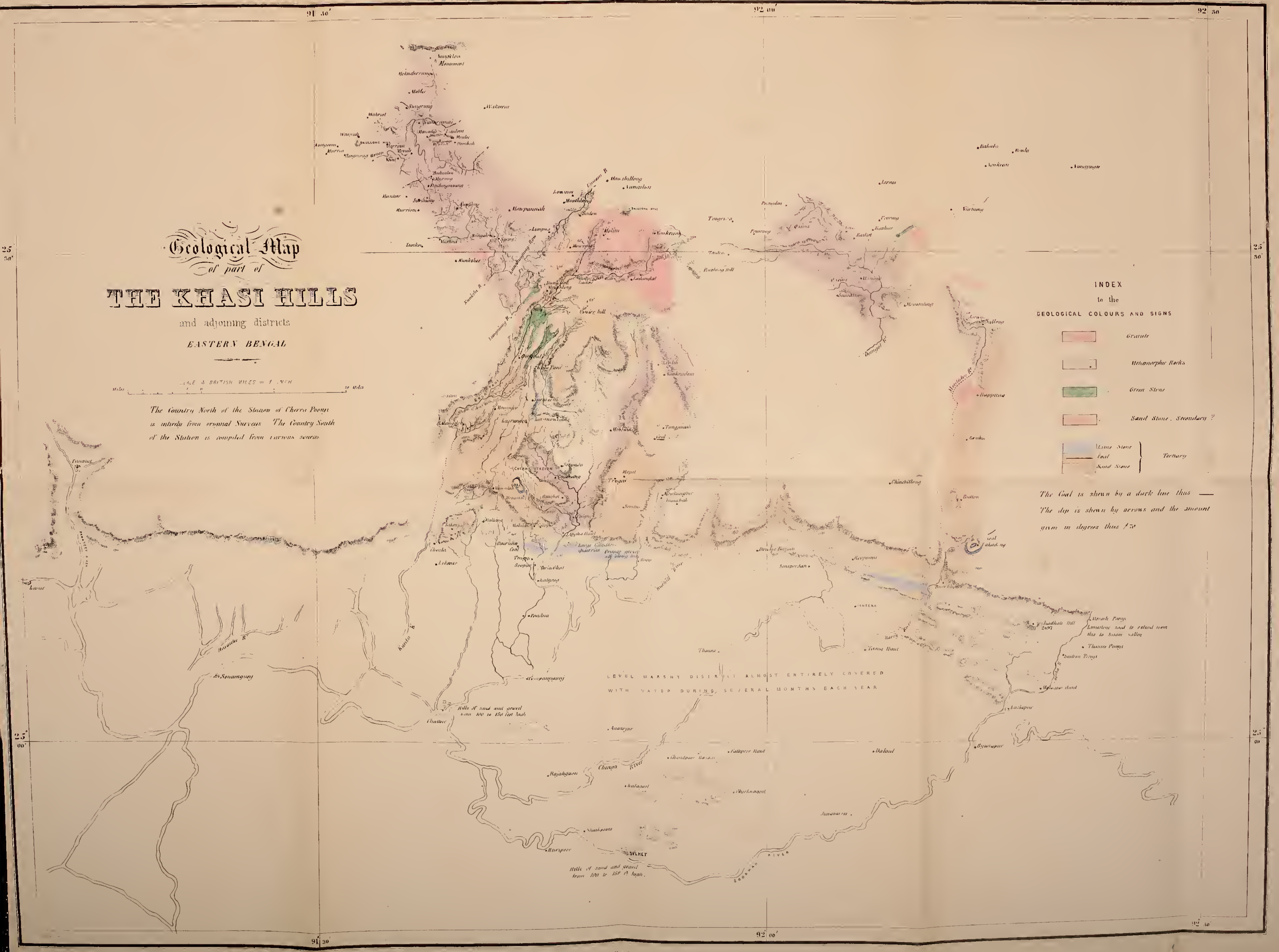
Calcutta 1857.

MAWSMAI FALLS.



H L Fraser Lith

VALLEY OF KALA PANI RIVER.


Geological Map
of part of
THE KHASI HILLS
and adjoining districts
EASTERN BENGAL
BRITISH MILES = 1 INCH
The Country North of the Station of Cherra Poonji is entirely from original Surveys. The Country South of the Station is compiled from various sources.
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Coal
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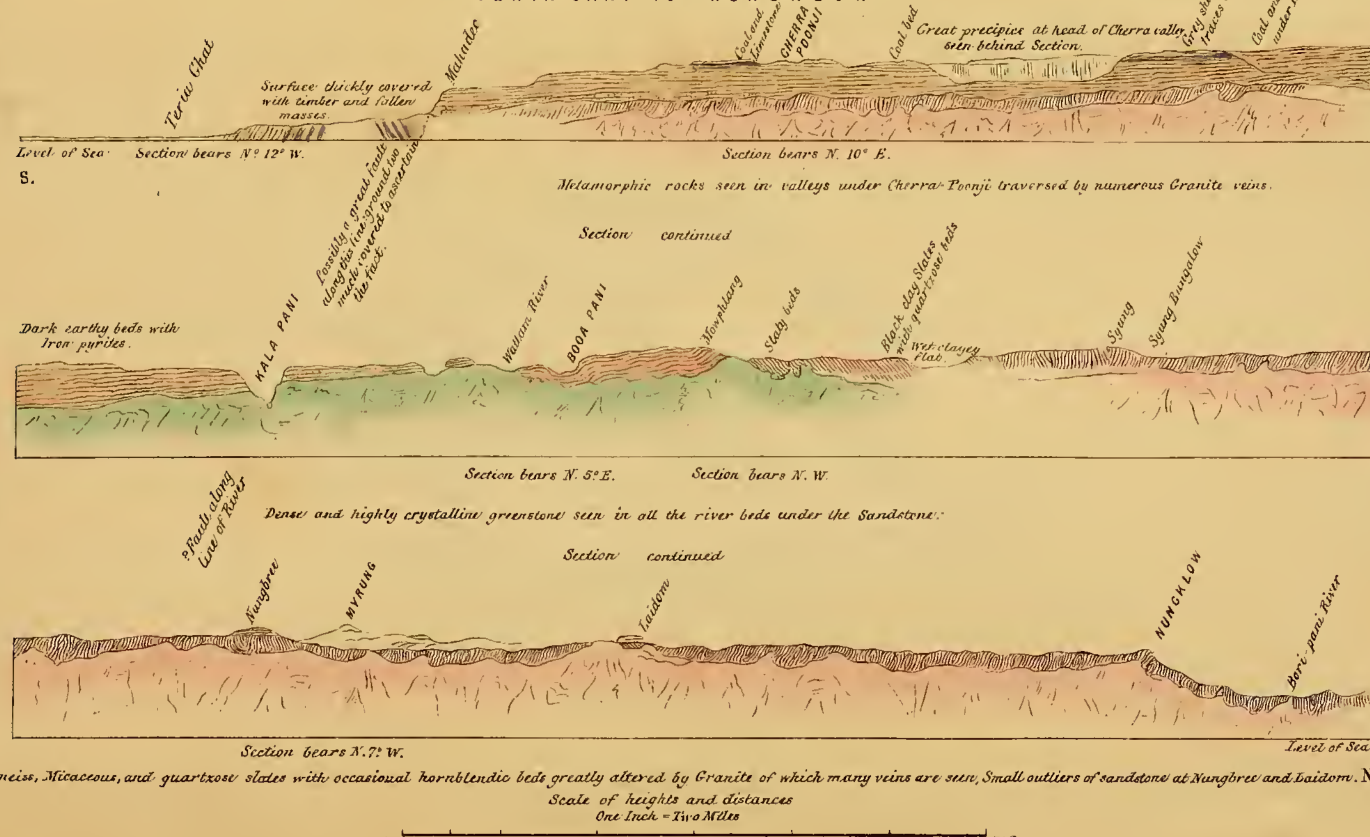
Tertiary
The Coal is shewn by a dark line thus
The dip is shewn by arrows and the amount given in degrees thus
LEVEL MARSHY DISTRICT ALMOST ENTIRELY COVERED WITH WATER DURING SEVERAL MONTHS EACH YEAR
SYLHET
Chinga River
91° 30'
92° 00'
92° 30'
25° 30'
25° 00'

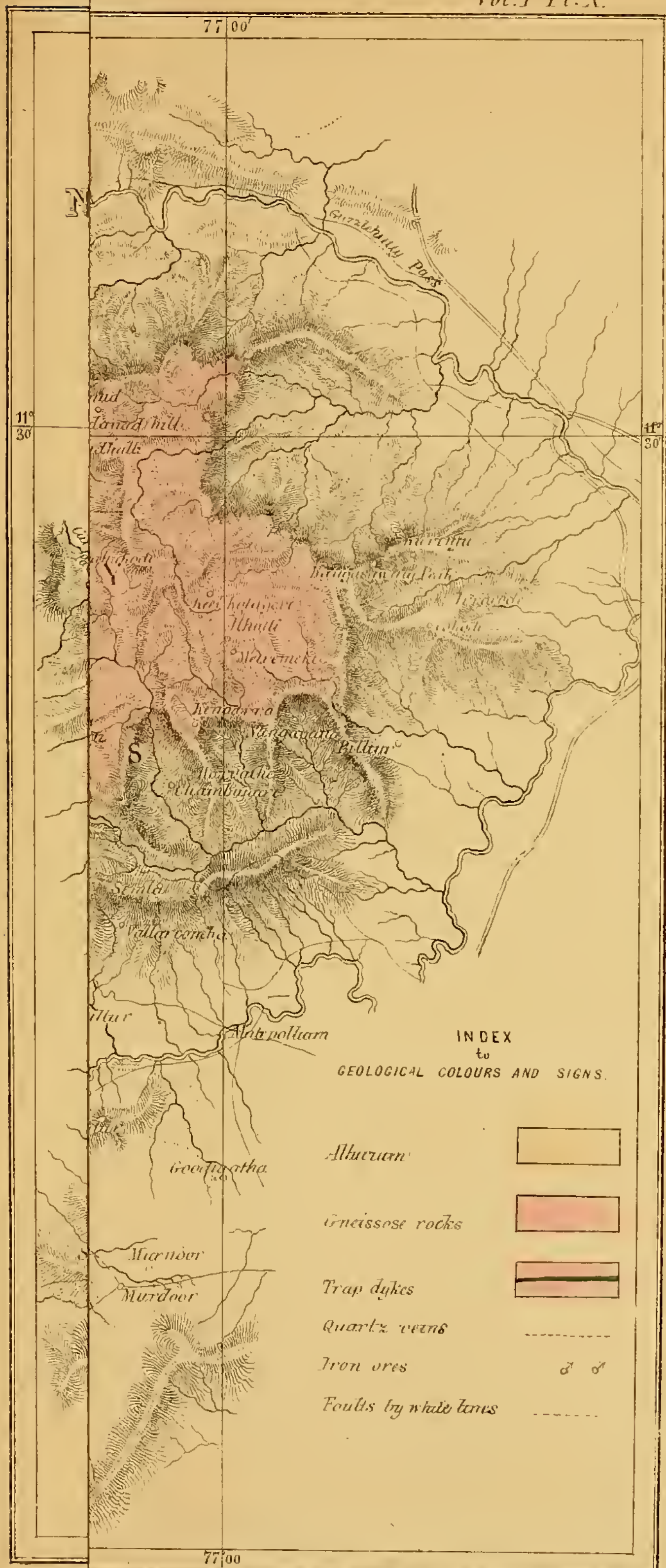
# Geological Section of the Khasi Hills
FROM
TERIA-GHAT TO NUNCKLOW




ON TRANSFER PAPER BY MUNNEEROODEEN & LITH: BY H. M. SMITH SURV: GENL'S OFFICE CALCUTTA FEB: 1858


On Transfer paper by Mohummed Azeem. Lith by H M Smith. Surv Genl's Office Calcutta Feby 1868.

Vol. I Pl: X.


77 00'
11° 30'
Gazzelhutty Pass
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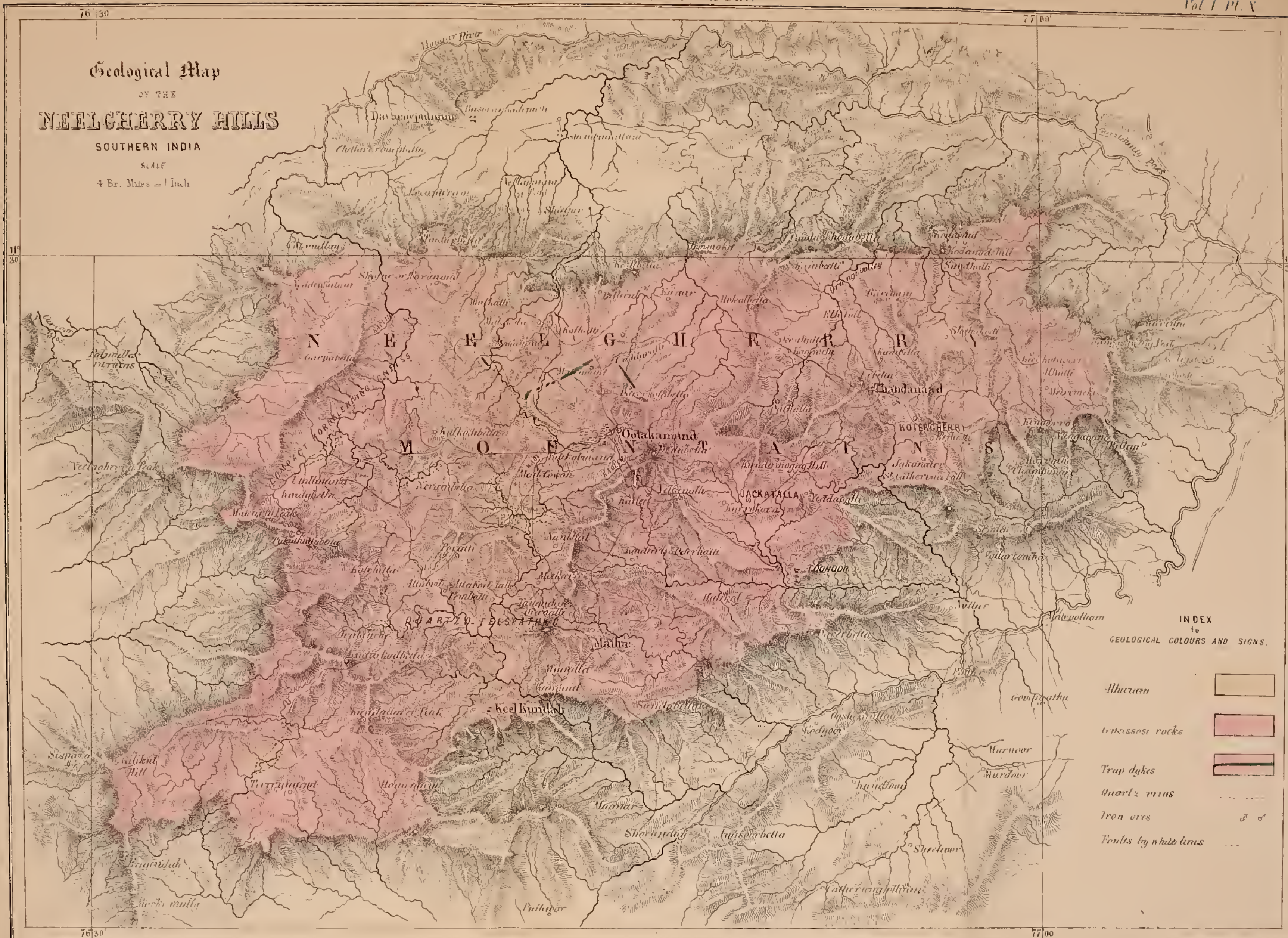
T. BLACK




T. BLACK, LITHR. 4 WATERLOO STREET, CALCUTTA.

On Stone by H.L. Frazer. T. Black Chromo-Lithr. 4 Waterloo St.

WESTERN GHATS AND PLAINS OF MALABAR FROM MAKURTY.

NILGHIRIS.

On Stone by H. L. Frazer.

T. Black, Chromo-Lithr. 4 Waterloo St.

VALLEY OF BHOVANI FROM MAILUR
NILGHIRIS.


Geological Map
OF THE DISTRICTS OF
BANCOORAH MIDNAPOOR AND ORISSA
BENGAL
Scale 8 Br. Miles to an Inch
Compiled from the Revenue Survey Maps of the Districts
The soundings &c. from chart of Bay of Bengal publ.d by Imray & Co.
London.
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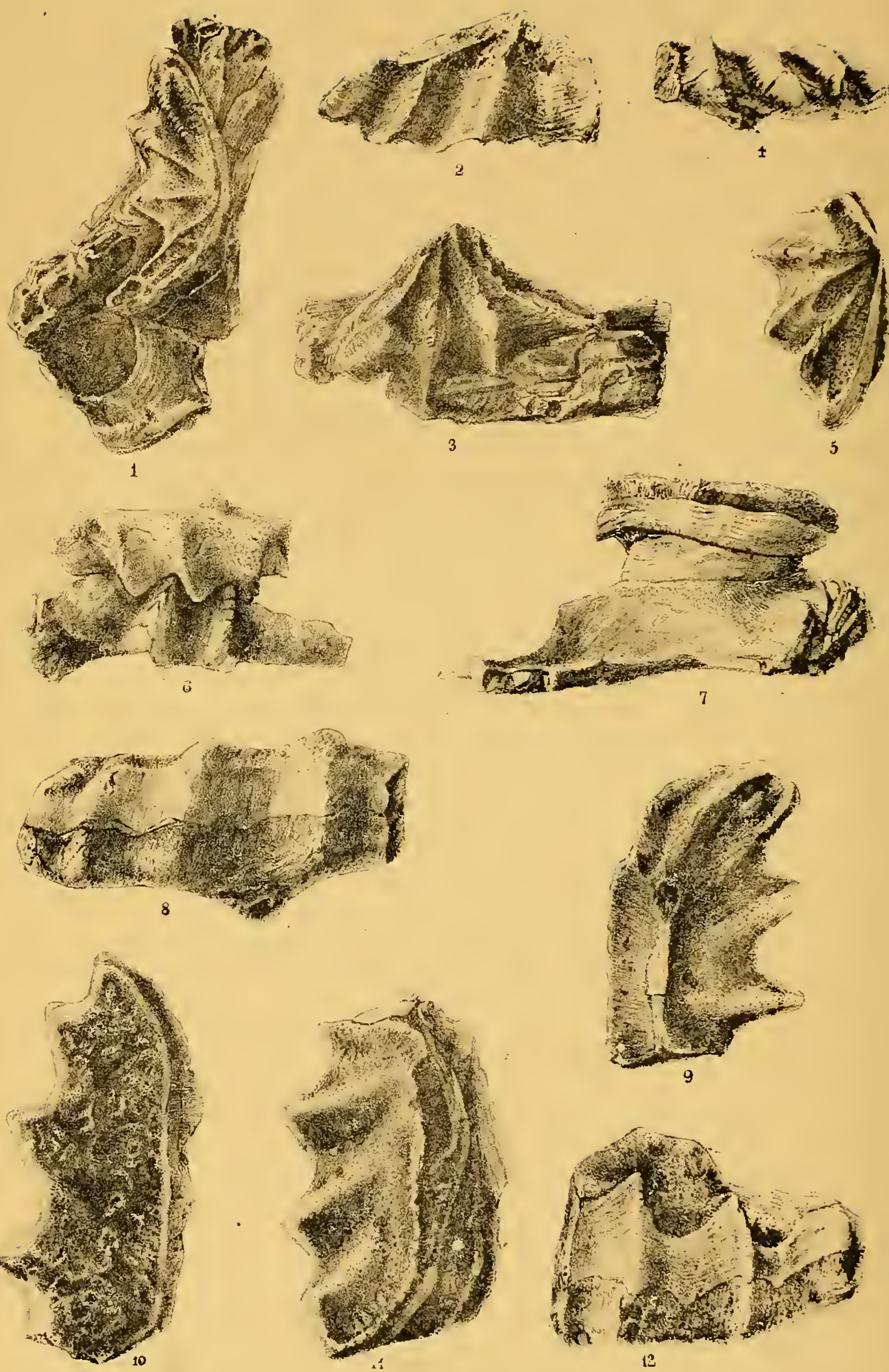


H L. Frazer Lith T Oldham direx$^{t}$ Calcutta

## PLATE XIV.

Figs. 1—7. CERATODUS HISLOPIANUS. N. S.

Fig. 1. Upper-jaw Tooth, with portion of jaw attached.

2—3. Ditto ditto side view.

4—5. Lower-jaw Tooth, top and side views.

6—7. Exterior and interior views of the two Teeth in contact.

The position of these teeth has been, by an error in drawing, reversed; that, which is supposed to have been the upper-jaw tooth, being placed lowermost.

Figs. 8—12. CERATODUS VIRAPA. N. S.

Figs. 9, 11, 12. Different views of upper-jaw Tooth.

Figs, 8, 10. Ditto ditto of lower-jaw Tooth.

PLATE XV.

Figs. 1, 6. CERATODUS HUNTERIANUS. N. S.

Figs. 1, 2, 4. Upper-jaw Teeth in various aspects.

Fig. 3. Two Teeth in contact.

These teeth, by the same error as in Plate xiv, have been erroneously placed, that which is uppermost in the drawing being supposed to be the lower-jaw tooth.

Figs. 5, 6. Lower-jaw Tooth, top and side views.

Figs. 7, 8. CERATODUS OBLONGUS. N. S.

Fig. 7. Side view: Fig. 8. Top view.

Figs. 9, 10. Young Tooth? Ceratodus.

Figs. 11, 12. COPROLITES.

Fig. 11. Shews the Coprolite, with spiral arrangement exposed by breaking off the concretionary mass, with which it is covered as in Fig. 12.

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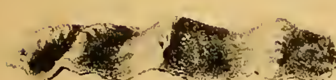

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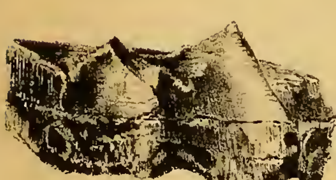

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8

9

10

11

12

H. L. Frazer Lith.   T. Oldham direx[t]   Calcutta

## PLATE XVI.

Fig. 1. End view of Ceratodus Hislopianus, showing the longitudinal furrow along base of tooth.

Fig. 2. Ceratodus Virapa, shewing ditto.

Fig. 4. Ceratodus Hunterianus, ditto ditto.

Figs. 3, 5, 6, 7, 8. Fragments of bones found with the teeth in same beds.

H L Frazer Lith. T. Oldham direx[t] Calcutta

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