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RECORDS

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Part 2.] **1878.** **[May.**

ON THE GEOLOGY OF SIND, (SECOND NOTICE,) *by* W. T. BLANFORD, A. R. S. M., F. R. S., *Geological Survey of India.*

Introduction.—A brief account of the Geology of Sind, so far as the structure of the country had been ascertained by one short season's work, was given in the Records of the Geological Survey for 1876.[1] Two whole seasons, 1875-76 and 1876-77, have since been devoted by Mr. Fedden, and one season and part of a second by myself to the geological examination of the province, and, as might have been expected, several additions of more or less importance have been made to our previous knowledge, whilst in a few cases it has been found that our first conclusions were incorrect. As before, Mr. Fedden's notes are combined with my own, and I am indebted to my colleague for a large proportion of the observations made. Mr. Fedden has also added much to our knowledge of the fossil fauna by his collection and examination of the fossils, but the details must be deferred for the present.

The sub-division of the tertiary series in Sind into Manchhar, Gáj, Nari, Khirthar and Ranikot groups holds good, although the boundaries between the various sub-divisions have proved, in parts of the province, to be less distinct than in the Khirthar range, and there is the same remarkable appearance, that all the different tertiary formations are only of local value, and that all tend to pass into each other at a comparatively short distance from each typical section, which has been already noticed by Mr. Medlicott in the corresponding formations of the Punjab.[2] Some slight modification in the geological horizon

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[1] Vol. IX, pp. 8-22.

[2] Rec. G. S. I., IX, pp. 50, etc.

attributed to the lower Manchhar beds has also been rendered probable, but in general there appears every reason for accepting the views put forward in the former paper as to the correlation of the different tertiary groups in Sind. It has, however, been found that, in the original classification, rocks were included in the Ranikot group, which belong in fact to a much lower horizon, and three small groups have been established beneath the lower tertiary subdivision and referred to the cretaceous epoch.

Errors in previous paper.—Before proceeding to notice the additions since made to the Geology of Sind, it will perhaps be best to call attention to a few statements in the previous paper which further examination of the country has proved to be untenable. The corrected general section will be found below, but there are a few details requiring alteration, besides the entire re-arrangement of the beds included in the first notice in the Ranikot group.

The supposed unconformity between the Gáj beds and the Nari group at Tandra Ráhim Khán, west of Sehwán,[1] appears doubtful. Further examination of the junction between the two groups has failed to show any clear evidence of unconformable overlap.

The basaltic lava flow[2] is now shown to be at the base of the Ranikot group, and not intercalated, the beds below the volcanic rock being of different age.

Another error is in the statement[3] that the Khirthar rocks compose several ridges near the Habb river, the southernmost of which terminates at Cape Monze. It is true that some ridges near the Habb consist of Khirthar rocks, and that the ridge west of the river, not far from the mouth, is composed of that formation, but the range terminating at Cape Monze proves on re-examination to be of Gáj beds resting on Nari. The mistake was due to the rocks having been first examined before the different sub-divisions of the Sind territories had been made out.

General section of rocks in Sind.—The following is the general section of the Sind rocks as corrected, the thickness of each group being estimated, as usual, where the beds are best developed. Very nearly, if not quite the full dimensions given, from the base of the lower Khirthar to the top of the Manchhars, are, however, exposed on the Gáj river, where, below the beds classed as lower Khirthars, nearly 4,000 feet of shales and limestones are seen, which probably belong to cretaceous formations:—[4]

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[1] Rec. G. S. I., p. 16.

[2] *l. c.*, p. 22.

[3] *l. c.*, p. 13.

[4] In some brief notes published in the Proceedings of the Asiatic Society of Bengal for January 1878, pp. 4, 6, all these beds were classed as lower Khirthars, and the thickness of the group estimated at 10,000 feet, but subsequent study of Dr. Cook's descriptions of the Kelat rocks has shown that the unfossiliferous lower beds in the Gáj section may, like some very similar rocks south of Kelat, be really cretaceous.

Name.	Sub-divisions.	Approximate thickness.	Supposed geological age.	REMARKS.
1. Alluvial, &c. ...	......	Unknown ...	Recent and post-tertiary.	
2. Manchhar ...	Upper ...	5,000 ...	Pliocene ...	Apparently representative of the Siwaliks proper.
	Lower ..	3,000 to 5,000	Lower pliocene or upper miocene.	
3. Gáj ...		1,000 to 1,500	Miocene.	
4. Nari ...	Upper ...	4,000 to 6,000	Lower miocene?	
	Lower ...	100 to 1,500	Upper eocene.	
5. Khirthar ...	Upper ...	500 to 3,000	Eocene ...	Nummulitic limestone.
	Lower ..	6,000? ...	Ditto.	
6. Ranikot ...	.....	2,000 ...	Lower eocene.	
7. Trap ...	......	40 to 90 ...	Upper cretaceous...	Representative of Deccan and Malwa trap.
8. Cretaceous ...	*Cardita Beaumonti* beds	350 to 450	Cretaceous ...	
	Sandstones..	700 ...		A bed of trap interstratified with the sandstone.
	Hippuritic limestone ...	320 ...		Base of lower group not exposed.

Cretaceous beds.—The only part of Sind in which rocks of pre-tertiary age are known to exist is in the range of hills running south from Sehwán. Various portions of this range are known by local terms, such as Dharan, Tiyún, Eri, Surjána, &c., but amongst the people of the country there is no name for the range as a whole. By Europeans the northern portion is sometimes called the Laki range, from the town of Laki, near the northern extremity, and for want of a better name this may be accepted. The old fortress of Ranikot is in this range.

The Ranikot beds themselves, it may be mentioned, as was already pointed out in the previous paper, extend over a considerable area to the east of the Laki range, and southward as far as Tatta. They are, however, not exposed anywhere in Upper Sind. The area of the beds beneath the Ranikot group extends northwards from the fortress of Ranikot to within four or five miles of Laki, a distance of about 22 miles. The outcrop, however, is not quite continuous, for the trap and underlying beds are covered up in places by the Ranikot group. The Hippuritic limestone, the lowest rock known to occur, is only exposed in a single locality. The range is very difficult of access, and there is a permanent supply of sweet water at only one spot, the fortress of Ranikot.

The spot where the Hippuritic limestone is exposed is at a place called Barrah, about 15 miles north of Ranikot. The range here consists of three parallel ridges. The eastern of these faces the plain sloping to the Indus, and consists of vertical or nearly vertical Khirthar limestone, on which, to the eastward, Manchhar beds rest unconformably. To the westward, Ranikot beds come in below the Khirthar limestone, but have a reversed dip to the westward; then there is a fault with a considerable upthrow to the west, and, west of this, the cretaceous beds come in with a low western dip. They are exposed in a high scarp and form the second or intermediate ridge. From this point there is a gradually ascending section to the westward, the soft upper cretaceous and Ranikot beds cropping out in the valley between the intermediate ridge and the western or main range, which is formed of Khirthar or nummulitic limestone.

The lowest beds seen are a hard compact white limestone, white or grey in colour, pure below, but becoming gritty above. No nummulites occur: fossils abound, but are only seen in section, and they weather out so badly that only one fairly recognizable specimen has been obtained. This specimen, however, is of importance, as it appears to be a portion of a Hippurite, one of the most characteristic of cretaceous fossils.

The peculiar interest attaching to the discovery of this fossil, if the identification be correct, is due to the circumstance that the principal cretaceous formation in Persia is a limestone containing Hippurites, and that this limestone has been found extending over a large tract of country from Lake Urumiah in north-western Persia to south-east of Karmán. This last locality, however, is about 700 miles from the spot where cretaceous rocks are found in Sind, and the Hippuritic limestone has not hitherto been recognized in Baluchistan, where, however, cretaceous rocks are certainly present. The bed in Sind differs much from the characteristic form of the Persian rock, but the latter is of great thickness; some 8,000 feet at least, in the neighbourhood of Karmán, apparently belonging to the formation, and it includes many beds varying in mineral character.

The gritty limestones on the top of the white Hippuritic limestone pass upwards into a group of dark-coloured sandstones of considerable thickness, and forming the intermediate ridge of hills already mentioned. The dark colour of the beds makes these hills conspicuous from a distance, and enables them to be distinguished at once from the two whitish limestone ranges to the east and west. The sandstones are usually coarse, sometimes conglomeratic and often calcareous, the prevalent colour is dark-brown or purple, and many beds are highly ferruginous, a few bands of dark-red shale, containing much iron, being interstratified. On the top of the sandstones is a thick bed of dark-coloured impure limestone containing oyster shells and some other fossils, amongst which are some large bones, apparently of reptiles, but all hitherto found were too imperfect for identification.

In one place a bed of basalt about 40 feet thick was observed by Mr. Fedden interstratified in the sandstones, and it is probable that this band may exist elsewhere, although it has been overlooked. The position of this bed of trap is about 300 or 400 feet above the top of the Hippuritic limestone, and about twice that distance below the main band of basalt at the base of the Ranikot group.

The highest sub-division of the cretaceous rocks consists of olive shales and sandstones, for the most part soft and fine-grained, but occasionally hard and calcareous. The beds of sandstone have very frequently an "ashy" appearance, as if they contained decomposed grains of basalt or some similar volcanic rock, or fine volcanic lapilli, or they may be an admixture of the products of submarine volcanic outbursts with ordinary sediments. Gypsum is of common occurrence in the shales. These olive shales and sandstones are highly fossiliferous, the most common and conspicuous fossils being *Cardita beaumonti*, the affinities of which are shewn by D'Archiac and Haime to be with a cretaceous form, and a *Nautilus*, which Mr. Fedden has, I believe correctly, identified with *N. bouchardianus*, a Gault species in Europe, but found in the upper cretaceous beds (Arialúr) of Southern India. Another species of *Nautilus* also is allied to some cretaceous types. The first named species may be *N. labechei* of D'Archiac and Haime, from which it only differs in the siphuncle being median instead of interior, but this character sometimes varies with age in *Nautili*. Amongst the other fossils occurring is a species of *Epiaster*, a genus of Echinoderms almost confined to upper cretaceous beds. The only form in the olive shales hitherto identified as common to the Ranikot group is *Corbula harpa*. Besides the above, species of *Cidaris* and of anEchinoderm allied to *Pygorhynchus*, *Rostellaria*, *Cypræa*, *Natica*, *Turritella*, *Cardium* and *Ostrea* occur, with two species of Corals. A few imperfect Reptilian vertebræ have been determined by Mr. Lydekker as belonging to an Amphicælian Crocodilian with distinctly mesozoic affinities.

All the cretaceous beds abovementioned appear to be perfectly conformable to each other and to the overlying trap. It is premature to attempt correlation of these cretaceous rocks, but it may be remarked, that some peculiar olive shales, which underlie the nummulitic limestone of the Salt Range in the Punjab conformably, and which have been classed by Dr. Waagen as probably of cretaceous age, may represent the very similar beds in Sind.

Deccan trap.—Besides the bed of trap just noticed as occurring interstratified with the cretaceous sandstones, the basalt first observed at Ranikot in 1863,[1] and subsequently found further north at Jakhmari and other places,[2] has now been traced throughout the whole distance, upwards of 20 miles, between Jakhmari and Ranikot, wherever the base of the Ranikot beds is exposed. The thickness of the trap varies from about 40 to about 90 feet, the average being 60 or 70. The only rock is basalt, of which, in places, there appear to be two flows similar in mineral character; the upper portion of each flow is amygdaloidal.

In the previous paper on Sind Geology, it was stated[3] that the relations of the trap were obscure, and although this was corrected in a postscript[4] so far, that the interstratification of the trap flow was said to have been clearly ascertained, the most important point, the probable relation of the volcanic rock in question to the great Deccan and Malwa trap series, was left undetermined. The interest of this question and the possibility that the basalt seen for a few feet only in the bed of the stream at Ranikot might be a representative of the Deccan trap, were naturally mentioned in the first notice of the occurrence.[5] The trap series, it may be remembered, has been traced from the Deccan and Malwa throughout Kattywar and Cutch, to within about 150 miles of Ranikot, so that

[1] Mem. G. S. I., VI, p. 5.
[2] Rec. G. S. I., IX, pp. 11, 22.
[3] *Ib.*, p. 11.
[4] *Ib.*, p. 22.
[5] Mem. G. S. I., VI, p. 12.

the representation of this great volcanic formation in Sind is far from improbable. The question as to whether the Ranikot trap belongs to the Deccan series may now be answered in the affirmative. There is conclusive evidence that this rock is interstratified and not intrusive, for it occupies precisely the same position above the highest *Cardita beaumonti* beds, and below the base of the Ranikot group, for over 20 miles, and appears to be conformable with both, whilst not a single vertical dyke has been noticed in the country. The mineral character of the basalt is precisely that of a very common form of the Deccan trap, whilst two mineral peculiarities—the occurrence of amygdala, surrounded by green earth, and of cavities containing quartz crystals, with trihedral terminations—are both characteristic of the trap rocks of Western India. The geological position also at the base of the tertiary series corresponds with that of the trap series in Cutch and Guzerat.

It is clear, however, that the thin flows of basalt in Sind can only represent a portion of the great Deccan trap period, and the lower band in the cretaceous sandstones indicates that all the upper cretaceous beds between the two trap flows were, in all probability, contemporaneous in origin with the Deccan trap series. If now the age of the *Cardita beaumonti* beds has been rightly determined as upper cretaceous, the identification of the Sind representative beds confirms the views previously held by myself, but by no means generally accepted by my colleagues, [1] as to the cretaceous age of the lower portion, at all events, of the Deccan trap series.

Ranikot group.—It was mentioned in a postscript to the previous paper in the Records[2] that the highly fossiliferous brown limestones seen north-west of Kotri and near Jhirak (Jhirk or Jerruck) and Tatta must be classed with the Ranikot group, and not with the Khirthar. A list of fossils obtained from these brown limestones was given,[3] but from this list two species must be removed, viz., *Cardita beaumonti* and *Nautilus labechei*, the species thus identified (the identification is doubtful in the case of the *Nautilus*) being from the olive shales now classed as cretaceous. It was also noticed in the postscript that south of Ranikot there is distinct unconformity between the Khirthar limestone and the Ranikot group, the upper members of the latter being deficient in the Laki range, and there being at one place evidence of the lower group having been slightly disturbed and denuded before the deposition of the Khirthar limestone. The break between these two formations is, however, probably not indicative of any great interval in time, for several of the Ranikot fossils pass upwards into

[1] Oldham: Rec. G. S. I., IV, p. 77; Wynne: Mem. G. S. I., IX, p. 48. I have lately had occasion to go over all the evidence again when writing a chapter on the Deccan traps for the Manual of Indian Geology, and it appears to me that the arguments in favour of considering the traps tertiary are weaker than I at first supposed. Only one fact of any importance, so far as I know, has ever been adduced: the supposed identification of certain freshwater shells in the intertrappean beds of the Deccan with forms found in the lower eocene plastic clay of Belgium. Apart from the question, a very important one, whether freshwater shells afford trustworthy evidence of age, I greatly doubt the validity of the identification.

[2] Vol. IX, p. 21.

[3] *l. c.*, p. 14.

the Khirthar beds. In some cases, it is true, there does appear to be a change of species: thus *Eurhodia morrisi*, a common Ranikot echinoderm, appears to be represented by *E. calderi* in the Khirthar beds, but still there is much evidence of transition, for the lowest Khirthars near Jhirk and Tatta have much the character of the Ranikot limestones, and there is a gradual passage from the one to the other; so much so indeed, that Mr. Fedden has found it difficult to the southward to determine any exact limit between the two, and to map their boundaries.

All the lower portion of the Ranikot group consists of soft sandstones and shales, much variegated in colour. The only fossils found are land plants; many of the shales are pyritous, and gypsum is of frequent occurrence. It appears highly probable that these beds are of fluviatile origin, and their occurrence immediately above the trap may indicate that the latter was of subaërial formation in Sind, as elsewhere.

Cretaceous and lower tertiary beds of Baluchistan.

In 1875, from the top of the Khirthar range in upper Sind, lower beds were seen cropping out west of the British frontier from beneath the Khirthar limestone. At that time, owing to political complications, there was a difficulty in visiting any part of Baluchistan; but in 1876-77, this difficulty having been removed, I was enabled to examine the sections on the upper Gáj, the only river which actually cuts through the Khirthar range. The beds beneath the Khirthar limestone at this spot proved to be utterly different from those seen in the same relative position in the Laki range. The following is a rough section of the beds on the upper Gáj, with their approximate thickness by estimate:—

KHIRTHAR ...	1. Massive nummulitic limestone forming the crest of the Khirthar range	1,200
	2. Shales, marls, and clays, mostly dark olive in colour and abounding in *Nummulites*	500
	3. Hard grey limestone with *Nummulites*	60
	4. Argillaceous limestone, shales, and clays, olive and bluish grey in colour, abounding in *Nummulites*	400
LOWER KHIRTHAR.	5. Unfossiliferous olive and bluish grey clays and nodular shales; no limestone bands	1,500
	6. Pale-brown sandstones in thick beds, with traces of vegetables ...	1,000
	7. Fine greenish white sandstone and shale, some of which is carbonaceous	500
	8. Dark-brown limestone and dark-green argillaceous beds, with *Nummulites*	100
	9. Pale-grey argillaceous limestone, with but few fossils. One band towards the base contains *Nummulites* and *Alveolinæ* ...	200
	10. Fine dark-coloured shales, unfossiliferous	3,000
? CRETACEOUS	11. Very fine grained homogeneous thin-bedded limestone, white, red, grey or ochrey in colour, unfossiliferous, forming a conspicuous range of hills	1,200
	12. Hard grey shales, with calcareous bands, from an inch or two to a foot in thickness	2,500
		12,160

Not a single bed below the Khirthar limestone (No. 1) can be recognized as identical with any of the formations in the Laki range, although the distance between the two localities is only about 90 miles. In the upper Gáj section, there are no fossiliferous brown limestones, no trap, no olive shales with *Cardita beaumonti*, no dark ferruginous sandstones nor hippuritic limestone. The sandstones Nos. 6 and 7 may represent the lower Ranikot beds, but the resemblance is not great, and there is no palæontological connexion between the two.

The examination of the section was hurried, and it is far from improbable that some fossiliferous bands may have been overlooked, but no distinct break in the sequence was detected; perhaps for want of palæontological evidence. The division between upper and lower Khirthar, and between the latter and the supposed cretaceous beds, is arbitrary; the limestones No. 8 contain the same species of *Nummulites* as Nos. 2, 3, and 4, and no fossils were found below No. 9. The sole reason for distinguishing the 6,000 feet of beds, from No. 5 to No. 10 inclusive, as lower Khirthars, is that, as the nummulitic limestone No. 1 is the same bed at the Gáj as in the Laki range, some of these lower beds must represent the Ranikot group. At first it was supposed that all the lower beds on the upper Gáj section were tertiary, and the lower Khirthar beds were estimated to have a thickness of 10,000 feet, but on subsequently reading more carefully Dr. Cook's account of the geology of Kelat,[1] and Dr. Carter's notes on Dr. Cook's discoveries,[2] it appeared to me that the peculiar fine-grained banded limestones No. 11 must be the same as some red and white limestones extensively developed at no great distance to the north-west. These red and white limestones pass down into some argillaceous beds (perhaps the same as No. 12 of the above section), in which Dr. Cook found *Ammonites*, and he consequently classed both rocks as mesozoic.

It is probable that the beds below the Khirthar limestone occupy a large tract in Baluchistan to the west of the Khirthar range, for similar beds are seen to the westward from the crest of the hills as far north as Darhyáro. Again, west of the Habb river, forming the western boundary of lower Sind, the whole Khirthar formation appears composed of shales, marls, and sandstones, closely resembling the lower Khirthar beds of the upper Gáj section, and an enormous mass of similar beds is found to the westward in Makrán.[3] A peculiar banded red and white limestone, so closely resembling that on the upper Gáj that these two are probably identical, forms a small hill at Gadáni on the sea-coast, about 25 miles north-west of Karáchi.

Khirthar group.—The nummulitic limestone of the Khirthar and other ranges in Sind varies much in thickness, and the original estimate of 3,000 feet may have been excessive, though it is doubtful whether it is too high in the northern part of the Khirthar range, where the limestone must be very thick. At the Gáj, as we have seen, this bed does not exceed 1,000 or 1,200 feet in thick-

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[1] Bom. Med. & Phys. Soc. Trans. November 1860. I am indebted to Dr. Cook for a copy of this interesting paper.

[2] Jour. Bom. Br. Roy. As. Soc., VI, p. 184.

[3] Eastern Persia, II, pp. 460, 473.

ness, and farther south it diminishes still further. In the Laki range it is probably not more than 500 or 600 feet, and towards Jungshahi and Tatta it is perhaps even less. Here it rests upon Ranikot beds. But to the westward in the Habb valley the Khirthar limestone disappears entirely, and it appears to thin out within the space of a very few miles. The Khirthar range is composed of the limestone throughout, and terminates to the southward inside the province, near a police post called Karchát, about 50 miles south by a little west from Sehwán. The southern extremity of the range, like several other ridges, is an anticlinal, so that the thickness of the limestone is not seen, but it must be considerable, and can scarcely be less than 500 or 600 feet. About 8 miles west of the Khirthar, the top of the ordinary limestone is seen underlying Nari beds, but in the next low ridge to the westward, only about 4 miles farther, the Khirthars are brought up by a fault, and the typical pale-coloured limestone is found to be completely wanting, and replaced by dark-coloured grey limestones containing *Echinodermata* and *Nummulites*, and interstratified with shales and sandstones precisely like those of the Nari group. A few miles farther west, in the Hamlig range, about 25 miles from the Khirthar, not a trace of the massive Khirthar limestone could be detected. The locality is beyond the Sind frontier, and the examination was so brief, that some fault may have been overlooked, but at this spot, and in some other localities further south, the Nari sandstones appeared to pass downwards gradually into shales and sandstones, with some beds of marl and dark-coloured argillaceous limestones, containing the typical Khirthar nummulites, *N. granulosa* and *N. obtusa*, &c. These beds precisely resemble some of the beds below the Khirthar limestone on the upper Gáj. The brown and yellow Nari limestones, too, are only faintly represented towards the base of the group by thin bands containing *Orbitoides papyraceus.*

Nari group.—No alteration is necessary in the general description of this group. Throughout the Khirthar range, the whole upper portion, 4,000 or 5,000 feet thick, consists of sandstones, with a few scattered beds of shale or conglomerate, and destitute of fossils, with the exception of a few vegetable markings, too imperfect for recognition. The lower sub-division of the group varies in thickness from 100 or 200 feet to as much as 1,500, and consists of shales and thin bands of sandstone, with brown and yellow limestones; the latter chiefly developed towards the base, and containing *Nummulites garansensis*, *N. sublævigata*, and *Orbitoides papyraceus* (or *fortisi*).

It has already been mentioned that in the Habb valley, in south-western Sind, there is a gradual passage from the upper Khirthar into the Nari beds, and there is in the same area an equally evident tendency to a passage between the Nari and Gáj groups. The Nari group in the Habb valley is probably as thick as in the Khirthar range; but although the prevailing rocks are still sandstones, brown limestones with *Orbitoides papyraceus* are found in the middle of the group, instead of being confined to the lower portion, whilst the typical limestone bands at the base of the group appear to be ill developed. Now, Mr. Fedden noticed some time since that bands of limestone, with apparently the same *Orbitoides*, are found in the Gáj group; and in the upper part of the Nari group bands of marine fossils occur, containing Gáj species, such as *Ostrea multicostata* and *Pecten subcorneus.* The boundary between the two groups is consequently, to some extent, arbitrary.

On the other hand, Mr. Fedden has observed at one spot on the west side of the Laki range, a few miles from the northern extremity of the range near Sehwán, distinct unconformity between the upper and lower Nari groups, the sandstones forming the higher portion of the group resting upon the denuded edges of the brown limestones composing the lower sub-division. This is an excellent example of the manner in which the sub-divisions of the tertiary series change, the groups of one locality passing into each other, and new breaks occurring. It should be remembered that the Nari beds are entirely wanting east of the Laki range, and Manchhars, with, in places, a thin representative of the Gáj beds at their base, rest unconformably on Khirthars.

Gáj group.—There is but little to add to the general description of this group also. A measured section of the beds on the Gáj river, where they are especially exposed, shows that the whole thickness of the group is but little less than 1,500 feet at that spot. To the northward the thickness of the Gáj beds must be less, and it is probably smaller in lower Sind also. On the Gáj the greater part of the whole thickness consists of sandy shales and clays, with gypsum, the hard limestone beds, though far more conspicuous, being only subordinate. In the Habb valley however, where the Gáj beds form extensive plateaus, surrounded by scarps in which the rocks of the group are well exposed, the mass of the Gáj strata appears to consist of limestone, and the boundary between them and the Nari, with which, as has just been noticed, bands containing Gáj fossils are interstratified, has been drawn at the base of the limestones. At one spot, a thickness of 500 feet, entirely composed of limestone, was measured (by aneroid) at the base of the group, and this thickness seems to include the greater portion of the Gáj strata in this locality.

It has already been mentioned that the supposed unconformity between the Gáj and Nari groups west of Sehwán at Tandra Ráhim Khán proves, on further examination, to be doubtful. But the Gáj group in the country south of Sehwán completely overlaps the Nari in places, and rests upon Khirthar beds. In this country, however, the Gáj itself is but poorly represented, and frequently is either entirely wanting, or appears as merely a thin band at the base of the Manchhar group.

The passage from Gáj to Manchhar, despite the unconformity shown by overlap, and the presence of Gáj pebbles in Manchhar beds, is locally just as complete as any of the other cases of transition already mentioned. In the paper published in 1876, the transition beds containing estuarine shells in the Khirthar range were mentioned. Some of the estuarine shells are by no means confined to this belt; *Corbula trigonalis*, for instance, occurs in beds near the base of the Gáj group, and has also been found in one band in Manchhar rocks, about 300 or 400 feet above the top of the Gáj. As will be shown presently, there is in the neighbourhood of Karáchi even stronger evidence of the close connection between Manchhar and Gáj beds.

Although the number of Gáj fossils have been somewhat increased, the additions have been less extensive than in the case of many of the other groups.

Amongst the most important additions are, *Vicarya verneuili*, found by Mr. Fedden in some of the upper beds of the Gáj section; a small crab, *Typilobus granulosus*, originally described by Dr. Stoliczka from Cutch,[1] and several of the corals described by Professor Martin Duncan in 1864. All tend to support the opinion that the Gáj beds are miocene, and rather upper than lower miocene.

Manchhar group.—The additions to our knowledge of this group are of more importance. Some of the most interesting have been already noticed in these "Records" and in the "Palæontologia Indica" in the shape of descriptions by Mr. Lydekker[2] of the mammalian remains obtained by Mr. Fedden and myself. During the last season that I was engaged in Sind, Hira Lal, one of the native assistants of the Survey, was attached to my camp, and he succeeded in finding a considerable number of specimens, chiefly small fragments, but including several teeth. Some Baluch shepherds also, living along the Laki range, were induced to collect, and altogether, although the bones and teeth are rare, and but few of those found are recognizable, sufficient material was collected to enable a considerable number of species to be identified by Mr. Lydekker. The comparison of these with the comparatively well known Siwalik fauna has shown a striking difference; most of the species being different, and the general facies of the Manchhar fauna being much older. This distinction is, I think, explained by the geology.

The possibility of a sub-division of the Manchhar group was noticed in 1876.[3] Although it is very difficult to draw an absolute line of separation, there can now be no doubt that the Manchhars may be divided, somewhat roughly it is true, into an upper and a lower sub-group. The lower consists mainly of the characteristic grey sandstone, with occasional red sandstones, and, towards the base, brown or grey and red clays; the latter, however, are of small thickness compared with similar beds in the upper sub-group. Conglomeratic bands are common, and are frequently ossiferous, but they chiefly contain nodules of clay and soft sandstone, and no nummulitic limestone pebbles have been detected in them. It is from these beds that nearly all the mammalian fossils found in the Khirthar range have been derived.

The upper sub-group, where it is best seen in the northern portion of the Khirthar range, is thicker than the lower, and consists principally of beds of orange and brown clay, with subordinate bands of sandstone and conglomerate. The sandstones are usually light brown, but occasionally grey beds occur, like those characteristic of the lower sub-division. The highest part of the formation contains more sandstone and conglomerate, and the whole is capped by the massive conglomerate, which forms the ridge extending along the edge of the Indus alluvium. These conglomerates of the upper Manchhars differ from those of the lower by containing pebbles of nummulitic and Gáj limestone. Bones are rare, and only a few fragments, too imperfect for identification, have been found.

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[1] Pal. Ind., Ser. VII, p. 15, Pl. III, figs. 3—5.

[2] Rec. G. S. I., IX, pp. 91, 93, 106; X, pp. 76, 83, 225; XI, pp. 65, 76, 77, 79, &c.; Pal. Ind., Ser. X, pt. 2.

[3] Rec. G. S. I., IX, p. 17.

In lower Sind, whence a large proportion of the mammalian remains have been procured, this sub-division of the Manchhars has not been traced; the beds are poorly exposed, and it is by no means clear that in this ground, where the lowest Manchhars rest unconformably on the Khirthars, the two sub-divisions can be distinguished by the presence or absence of nummulitic limestone pebbles. Several of the fossil forms, however, are identical with those found in the lower Manchhars to the northward, and there can be no reasonable doubt that the fossiliferous beds are on the same horizon. That the Manchhar beds are probably much less developed in lower than in upper Sind is shown by the circumstance that the section of the group, which can scarcely comprise less than 8,000 to 9,000 feet of beds, west of Lárkána and Mehar, has diminished to about 3,000 feet at Tandra Ráhim Khán, west of Sehwán. The principal localities for fossils are near the Gáj, where mammalian remains were first found by Vicary, and whence Mr. Fedden obtained several good specimens in 1876. Bones have also been found more recently on both sides of the Laki range, south of Sehwán.

It has already been mentioned that an estuarine bed is found at one place some 300 or 400 feet above the base of the Manchhars. This is near the Nari Nai, north-west of Sehwán. In lower Sind, and especially near Karáchi, marine or estuarine bands containing oysters and other shells become of frequent occurrence in the Manchhar beds, and some of these bands contain Gáj fossils; so that there is to the southward the same transition between Nari and Gáj which has already been shown to take place between all the other tertiary groups. It is clear that the lower Manchhars are of the same age as the Gáj beds, and if, as appears certain, the latter are Miocene, the lower Manchhars may be considered as upper Miocene.

This view is in accordance with the fauna, which includes only three living genera, *Rhinoceros, Sus*, and *Manis;* the generic identification in the last case is doubtful, being founded on a single phalange, and both the other forms existed in Miocene times. Besides these, *Amphicyon, Anthracotherium, Hyopotamus, Hyotherium*, some new genera related to *Merycopotamus*, and *Dinotherium*, are found in the Manchhar beds, but not in the Siwaliks, whilst the living types, *Semnopithecus, Macacus, Felis, Hyæna, Ursus, Cervus, Bos, Capra, Camelus, Camelopardalis, Equus, Elephas*, &c., which abound in the Siwaliks, have not been found in the Manchhar beds, so that, although several species, such as *Rhinoceros palæindicus, Acerotherium perimense, Chalicotherium sivalense, Sus hysudricus*, and two species of *Mastodon*, are common to the two, the presence of the much larger number of extinct forms, most of which are typically miocene in Europe, and the paucity of living genera, stamps the Manchhar fauna as of earlier date than the Siwalik.

Now, the Manchhar fauna, as has just been shown, occurs in the lowest Manchhar beds, whilst the Siwalik species are from the upper portion of the group. It is therefore far from improbable that the upper Manchhars represent the Siwaliks. The lower Manchhars may represent the Náhans of the Sub-Himalayas, or some of the lower portions of the Siwaliks themselves. The great distinction between the Manchhar and Siwalik fauna supports Mr. Lydekker's opinion, that the latter is of Pliocene age.

Nothing more has unfortunately been determined as to the relations between the Manchhar and Makrán groups. The former has not been traced to the west of Cape Monze, near Karáchi; at least no such rock could be detected during a traverse of the coast as far as Sonmiáni made for the purpose of endeavouring to trace the connexion between the two formations. The Makrán group, on the other hand, appears not to extend much to the eastward of Hingláj, so that there is a break between the two of the whole breadth of Sonmiáni bay—60 or 70 miles at least. Some of the Manchhar beds near Karáchi closely resemble certain strata in the Makrán group, but the typical whitish marls of the latter have not been noticed in Sind.

General sequence of tertiary beds in Sind.—We have thus in Sind a great sequence of later mesozoic and tertiary rocks, in which, despite the evidence of great changes in the conditions under which they were deposited, and despite local unconformities, there is no proof of any general break in the sequence throughout the province. In some places, as in the Laki hills, where upper Miocene Manchhars rest unconformably upon middle Eocene Khirthars, there is no question that elevation, and in all probability denudation, took place in the interval between the two formations, but elsewhere, as to the westward in the Habb valley, and to the northward on the flanks of the Khirthar, the break which exists in the Laki hills is represented by an uninterrupted sequence of the Nari and Gáj groups. At the close of the tertiary period, however, there is a great break, and the latest Manchhar (Pliocene) conglomerates are as constantly turned on end along the edge of the Indus alluvium as the very similar Siwalik conglomerates are in the Punjab.

The lower portion of the Ranikot beds, the upper Naris, and the Manchhars must have been deposited near land, for they contain terrestrial organisms, and all are probably fluviatile deposits; whilst the upper Ranikot, Khirthar, lower Nari and Gáj beds are clearly marine. Of all the marine beds, the Khirthar nummulitic limestone is the most important, and it is, as a rule, remarkably free from admixture of sand or other indications of the neighbourhood of land, but, as has been shown, this limestone is intercalated with sandstones and shales in lower Sind, and it entirely disappears in the south-western part of the province near the Habb river. The Gáj beds, on the other hand, are interstratified with sandstones and shales in the northern part of the province, but have a much more distinctly marine aspect to the southward, where limestones prevail. It is premature to reason broadly as to the changes in the distribution of land and water during the tertiary period until the rocks of Baluchistan are better known; all that can be done now is to point out the leading facts connected with the evidence afforded by the rocks in Sind itself; but it is impossible to avoid calling attention to the much greater prevalence of marine conditions during later Eocene and Miocene times in Sind than in the Punjab area to the northward, where no marine beds of later date than the nummulitic limestone have hitherto been detected.

On the Origin of the Kumaun Lakes by V. Ball, M.A., F.G.S., *Geological Survey of India.*

In so far as the outer and lower ranges of the Himalayas are concerned, the group or series of lakes described in the following pages is in several respects quite unique.

To many out of the thousands who have visited the beautiful part of the country where these lakes are situated, the question of their origin must have presented itself. Doubtless, it is in consequence of the difficulties which surround the subject, that no one has ventured to publish his observations and deductions in full.

To Mr. H. F. Blanford, I believe, belongs the credit of having first[1] suggested in print[2] an origin for them. But the subject has often been discussed, and three or four years ago it was specially commended to my notice by one who has frequently visited Naini Tal, and whose acquaintance with the Alps and the literature of the subject led him to suspect that that lake might possibly have been excavated by an ancient glacier.

Could I foresee within the next few years any prospect of my being able to carry on my examination of the ground, I should not have presented this unfinished sketch; but as I do not do so, I think the publication of the facts here given desirable, as it may facilitate the speedy final solution of the question, and may also have the advantage of eliciting the opinions of experienced glacialists, who are unable to visit the locality for themselves.

During a recent visit to Naini Tal, I had hoped to have been able to have prepared a detailed geological map of the neighbourhood of the lakes, but circumstances beyond my control arose, which diminished my time for exploration by two-thirds. Though the area is not extensive, the complex and disturbed nature of the beds renders their true appreciation and demarcation a by no means easy task. Owing to landslips, and the fact of so large a portion of the basin of Naini Tal being built over, the accurate mapping of individual beds and of the trap will require much time to accomplish.

Of the age of the unfossiliferous metamorphosed schists in which the lakes occur nothing is certainly known. In the account of the Geology of Kumaun and Garhwal by Mr. H. B. Medlicott[3] will be found such information as exists on the subject. Some casual observations on the geology which bear upon the physical origin of the lakes will be found in their places below; otherwise there is no intention of giving a detailed account of the stratigraphy in this paper. Besides the map on the scale of one inch to a mile, shewing the relative positions of all the lakes, it has been considered advisable to give with this paper a copy of the large scale map of Naini Tal, which indicates very beautifully and with extreme fidelity the physical structure of the neighbourhood.

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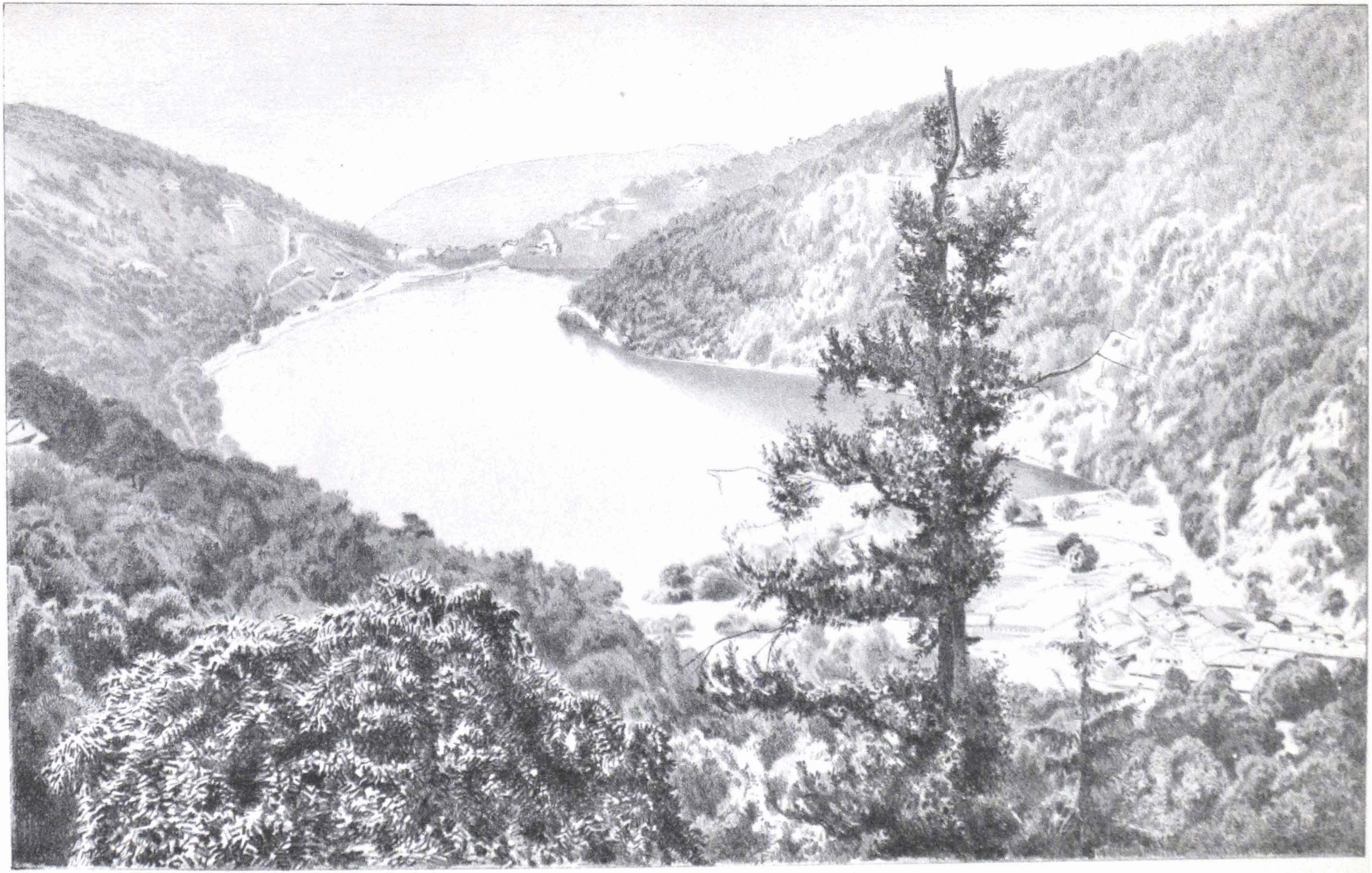
[1] Unless General Strachey's remark, that an outburst of amygdaloidal trap "is associated with the formation of several small lakes," is intended to be read as implying cause and effect.—Quar. Jour., Geol. Soc., Vol. VII, p. 298.

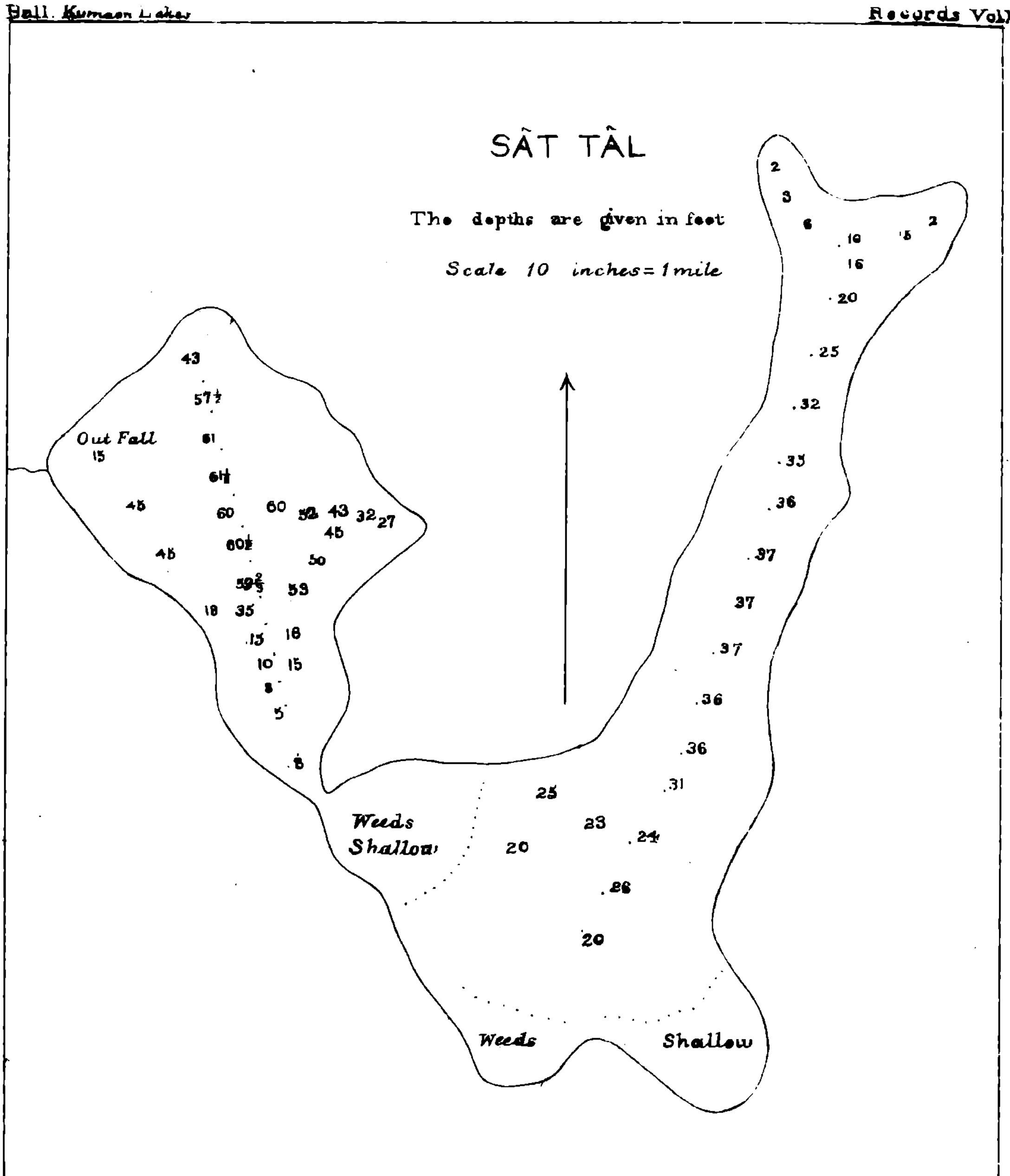
[2] Proc. As. Soc., Bengal, January 1877, p. 3.

[3] *Vide* N.-W. Provinces Gazetteer, edited by E. Atkinson, Esq., C.S.



J. Schaumburg Lith.

GENERAL VIEW OF NAINI TAL.
(From a photograph by Saché)


SÂT TÂL
The depths are given in feet
Scale 10 inches = 1 mile
Out Fall
Weeds
Shallow
Weeds
Shallow

This series of *Tals* or lakes is included in the Chhakata pargana of Kumaun.[1] They are by no means all of equal size or importance. They seem, however, to fall naturally into three classes, the members of each class having certain features mutually in common. So arranged, they would stand as follows :—

Class I.—Naini, Bhim, Malwa.
„ II.—Naukachia, Sat.
„ III.—Kurpa, Dhobie, Saria, Sukha, Khoorea, &c.

NAINI TAL.—This lake, so called after a Hindu goddess, is situated about 10 miles in from the southern slope of the hills. It lies at the bottom of a valley, which runs about north-west south-east, and is surrounded on all sides, except at the outfall on the south-east, by lofty ridges, which serve to give an unusual amount of definition to the limits of the catchment area.

The greatest length of the lake itself is 4,703 feet, the maximum breadth 1,518 feet,[2] and the elevation of the surface at high water about 6,409 feet above the sea. The principal peaks on the encircling ridges are Luria Kanta, 8,144 feet; Sher-ki-danda; Ulma; China, 8,568[3]; Deopathar, 7,989; Iarpathar, 7,721.

The China (Cheena) portion of the ridge at the head or north-west end of the valley is steeply scarped above, with an undercliff much concealed by talus brought down by landslips. It consists chiefly of shales, with which there are some quartzites, and, towards the crest, there are limestones, which, so far as is clearly seen, may partake either of the nature of beds or veins. Passing hence round by north to south-east the ridge is mainly formed of shales and argillaceous schists, which are much contorted and broken ; but the prevailing dip is probably to south-west, the beds striking with the direction of the ridge. An obscurely seen trap-dyke seems to observe the same course. To these two facts, the dip of the beds and the existence of the rigid trap axis, the present form of the slope is, I believe, under the influence of subaërial denudation, to be attributed; and not to the "friction of a glacier," as has been suggested by Mr. H. Blanford (*l. c.*).

It is true that there are no "subordinate ridges and spurs," but such is not uncommonly found to be the case where valleys run with the strike between hard beds bounding softer ones, which have been eroded to form the valleys.

Towards the end of the ridge, overhanging the Depôt, limestones, which are clearly seen in section to occur as irregular lenticular masses, not as beds, become somewhat abundant. I shall have to refer to them again presently. The range, on the south-west of the valley of which Iarpathar and Deopathar are the culminating peaks, is formed of massive limestones, the bedding of which is generally very obscure. There is also some trap, the combined rocks giving a very rigid and steep outline to the range, which contrasts most strikingly with that on the north.

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1 Excepting Malwa Tal, which is just outside the boundary.

2 These figures are taken from a small table in the N.-W. Provinces Gazetteer, Article "Kumaun."

3 The highest point is somewhat in excess of this elevation, which is that of the peak nearest to the lake.

All the rocks of this basin, whether shales or limestones, are singularly unsuited to the retention of the minor glacial marks; and if glaciation did take place, it may be from this cause that no such traces are now found.

From an inspection of the large scale map, it will be at once apparent that the head of the valley has very much the form of a 'cirque,' as defined by Mr. Helland,[1] who argues with considerable force that the cirques of Norway and Greenland are due to glaciers. Mr. Bonney,[2] on the other hand, describes Alpine cirques, which he believes to be formed by streamlets pouring down the sides. It has often been remarked how some forms of our Indian alluvia under the operation of heavy rainfalls exhibit in miniature many of the forms of denudation and erosion. Among these forms, cirques and cirque valleys are not unfrequently met with. Invariably, they are due not to denuding action from above, but to subterranean springs or streams. To a similar cause may, I think, be attributed cirque-like valleys in rocks formed of loose shales and, to some extent, even those where the rocks are limestones.

The accompanying section of the bed of the lake indicates a state of things very different from what might have perhaps been anticipated, but, however the lake has been formed, explanations to account for the peculiarity about to be described can be suggested.

The soundings from which this section has been plotted have been taken from the Revenue Survey map on the scale of ten inches to a mile. In some cases the exact character of the bottom is given, but not in all. A knowledge of this character is, no doubt, a very great desideratum for the discussion of this question. It would be especially desirable to know the nature of the bottom all across the lake transversely to this line at the point where the shallowest sounding occurs. As represented in the section, the lake consists of two basins, with the maximum depth nearly centrically situated in each case. They are separated by what appears to be a barrier. If it really be so, then it would lend considerable support to the glacial hypothesis. Indeed, if consisting of rock *in situ*, it would fairly prove the existence of a true rock basin, thus furnishing a strong argument in favor of the glacial origin. Supposing it to be so, the twin basins might be readily explained by the hypothesis that they had been successively excavated by the retreating end of a glacier. Unfortunately the case is not susceptible of so simple an explanation, as the shallow sounding may be caused, not by a barrier, but by a mere hummock, which, if (as is possible, so far as is certainly known at present) occurring isolated by deep channels from the margins of the lake, would be on the other hand a strong argument against the glacial origin, as such an obstruction must assuredly have been swept away by a glacier capable of scooping out the deeper hollows. Still another view of the nature of the barrier or hummock, be it which it may, is possible. It may be that it is not really formed of rock *in situ*, but is merely the remnant of an ancient landslip.

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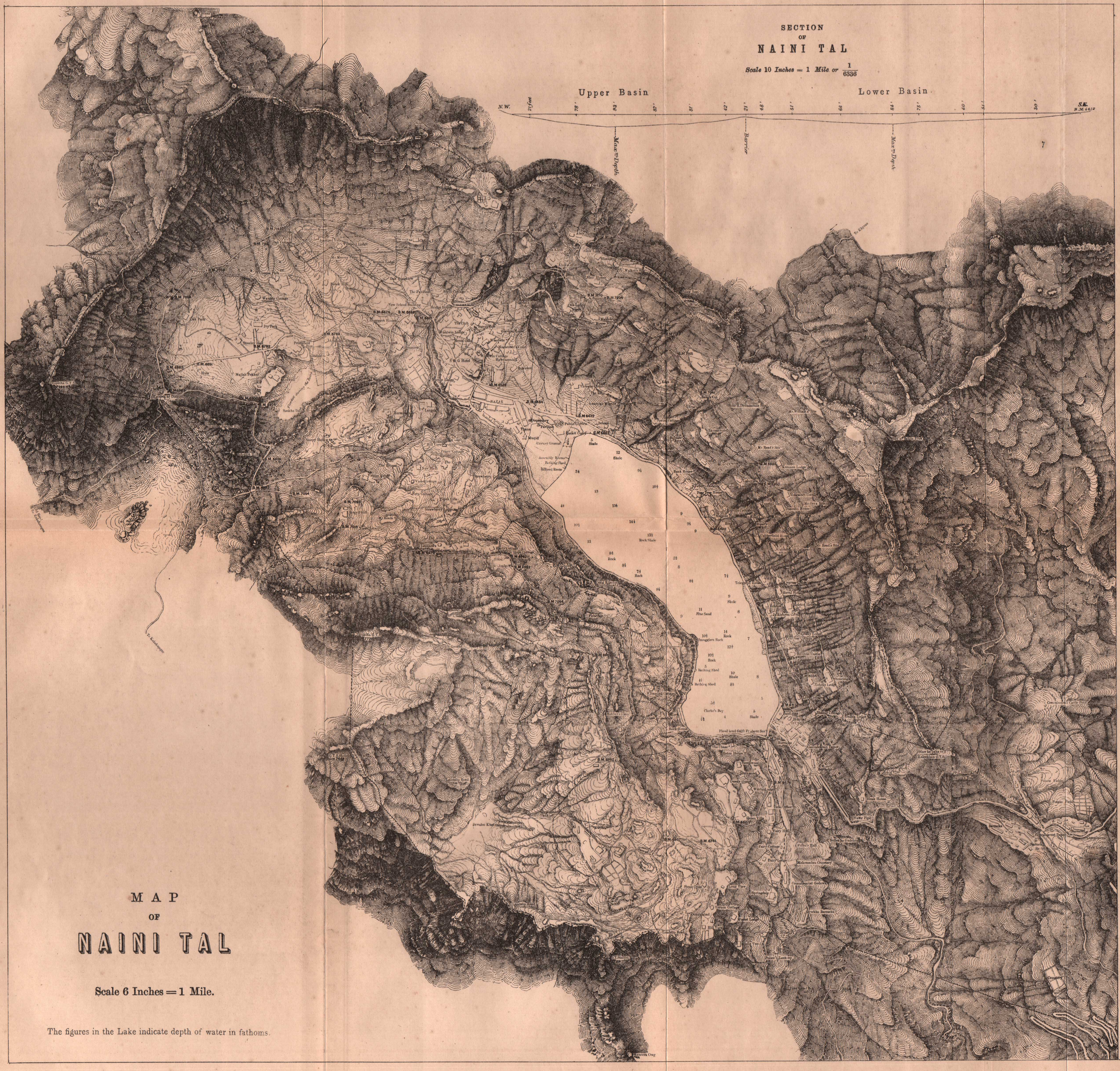
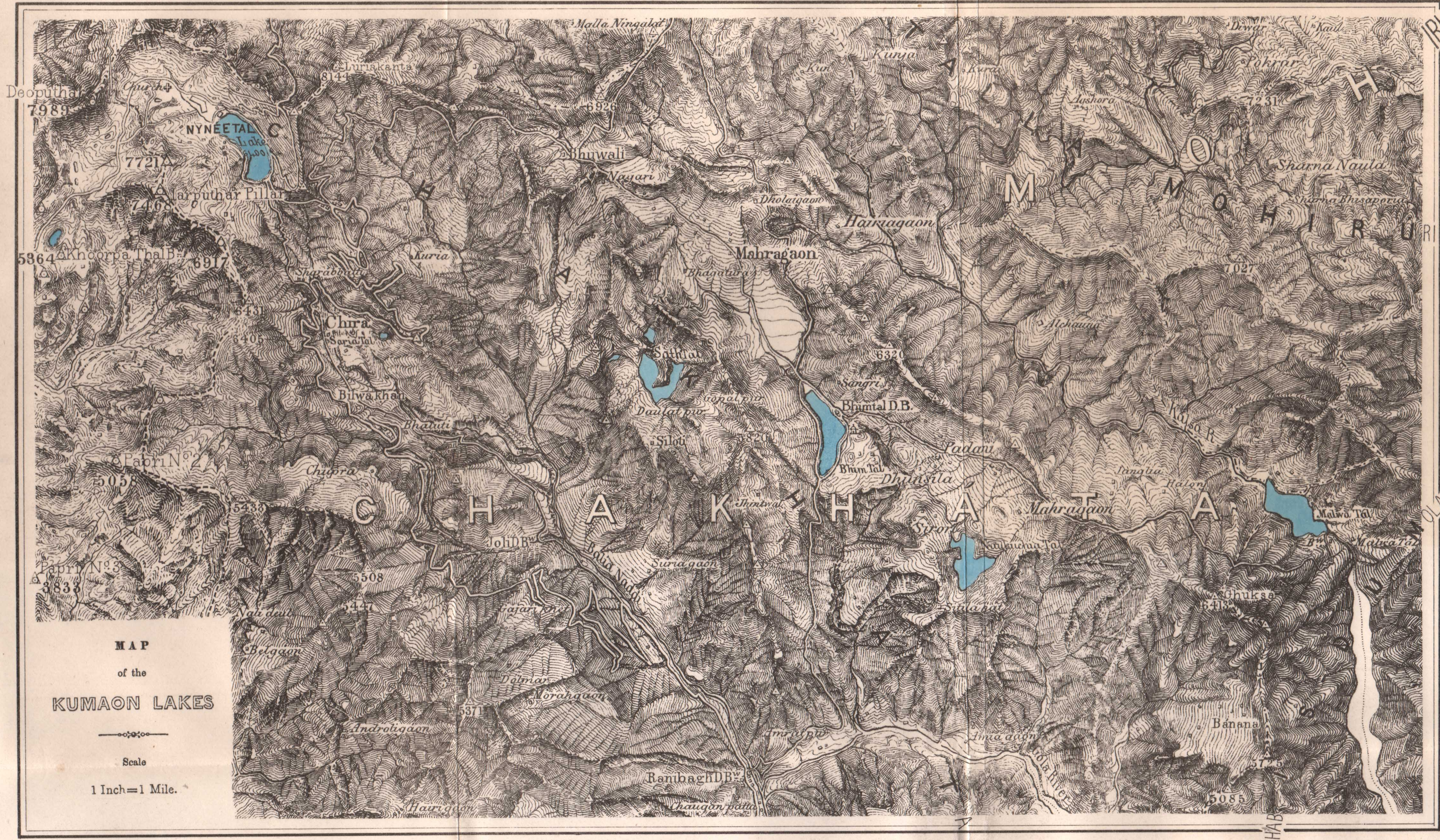
[1] "Cirques are large spaces excavated from the solid rock, bounded on three sides by an almost semicylindrical steep mountain wall, and with a tolerably flat floor."—Quar. Jour., Geol. Soc., Vol. XXXIII, p. 161.

[2] In making these remarks, I labour under the disadvantage of being in camp, away from opportunities of reference to Mr. Bonney's papers.



Photozincographed under the Superintendence of Captn. J. Waterhouse, Surveyor General's Office, Calcutta. January 1878.



Printed from parts of the Negatives of Sheets No. 17 and 25 Kumaun and Garhwál Survey.

In the present state of our knowledge, therefore, no certain conclusion can be drawn from it. But the peculiar character of the basin still remains a subject for some speculation, the more particularly so when it is remembered that the operations of the present day must tend steadily to obliterate these features by the deposition of silt in the hollows.

Passing from the lake itself to examine the nature of the barrier at the outfall, we find that it is formed of a confused mass of debris, in which some very large rock masses, some of them ten feet in diameter, occur. Following down the bed of the stream, rock *in situ* is not met with till near the waterfall, or at a level which must be considerably below that of the bottom of the lake where deepest. I had neither the time nor means for actually ascertaining the elevation of the exact point where rock *in situ* is first met with in the stream. But it is an important point to be determined. The result would, I feel confident, completely dispose of any belief in the existence of a rock basin.

Mr. Blanford (*l. c.*), though he does not expressly state his belief that the large blocks of stone are erratics, suggests that they may be derived from the limestone at the ridge at the head of the valley (Deopathar). He states that his "impression was that the lake was closed by a morraine." The source of these blocks I believe to be much closer at hand. In great part they have, I think, simply tumbled down from the Iarpathar ridge and its eastern prolongation, where not only is similar rock to be seen *in situ*, but similar detached blocks are found on the slopes; one remarkably fine example being seen in the compound of Welham house. Others, on the other hand, may have fallen from the ridge to the north of the depôt, where the already described lenticular masses of limestone occur. The remainder may, I think, have simply been eroded from their envelopment of shales at, or very close to, the positions where they are now found. Though it is convenient to speak here of these blocks collectively as limestones, they vary much in character, and some are highly indurated, but only slightly calcareous, mud stones. From these varying characters it may be possible, hereafter, to trace their origin individually with considerable accuracy. As to the other characters of the debris at the outfall, I in vain searched in it for evidence of a glacial origin, and am unable to point to any feature which is inconsistent with the idea of its having been formed by a landslip.

Further down the valley, near Joli, some 3,000 feet or so below Naini Tal, I observed, when on the road to Ranibagh, that the river has cut through an accumulation of boulders and finer debris to a depth of 200 feet or so, which at the time seemed to me as possibly of morraine origin. On reading Mr. Campbell's opinion of the same kind of deposit near Kalka, which I have also seen, I fear it would require stronger facts than I am in possession of to prove it other than diluvial. I merely mention it here in order to draw attention to the fact of its existence, with a view to its future examination.

BHIM[1] TAL.—This lake is situated about 6 miles, in a direct line, to the east-south-east of Naini Tal. Its elevation is about 4,500 feet above the sea, or 1,900 feet lower than Naini Tal. It lies at the bottom of a valley between two ranges, which strike from north-west to south-east. The northern one is largely

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[1] So called after Bhim, Shib or Mahadeo, to whom there is a temple.

made up of greenstone, which I traced from the neighbourhood of Bhuwali, through Bhim Tal, up to Malwa Tal. According to General Strachey's geological map, a continuation of the same outburst extends northwards up to Bhujan on the Kosi. The southern range consists chiefly of quartzites and shales, and rises to a height of 1,300 feet above the lake.

At the entrance to the lake, in the very throat of the gorge, occurs a small hill, about 80 or 100 feet high, which deflects the in-flowing stream, and the existence of which, if it really is, as it appears to be, a stable prolongation of a spur, presents a serious obstacle in the way of a glacial theory. No one can deny, I think, that a glacier capable of scooping out the lake could not have passed over, or on one side of, such an obstruction.

The determination of the fact, whether this hill consists, and to what extent, of rocks *in situ*, is a point, I believe, of crucial importance in this enquiry. Bearing in mind the vast size of the landslips which take place in this region, no one should hastily venture an opinion on such a point. My examination of the ground was of too cursory a nature to admit of my coming to a final decision.

The maximum dimensions of this lake are, length 5,580 feet, breadth 1,490 feet, and depth 87 feet. It is, therefore, the largest, but the shallowest,[1] of all the series herein described.

Whether it be a historical fact or not I cannot say; but it is clearly, I think, *a fact* that the present outlet of the lake was not the original one. The waters now only escape through a sluice close to the temple, which is situated about midway on the eastern side; but that originally the water found its way out at the southern end, an inspection of the map alone is almost sufficient to determine.

This southern end is now stopped up by what appears to be the debris of a landslip. I was unable to examine the valley below, and the position and elevation of the highest rocks there remain to be determined. At the present outfall, the rocks *in situ* are apparently at a higher level than the bottom of the lake; but this, if it be the case, is a fact of no importance, if my supposition as to the position of the original outfall be correct.

Towards the southern end of the lake, on the eastern side, there is a boulder deposit, which extends along the bank up to a level of perhaps 10 feet above the water. The rounded blocks which it includes were possibly rounded by the waters of the lake when they stood at a higher level, but its appearance suggests a morraine origin. The most remarkable feature about it, however, is, that it is backed by no high range on the east, so that, if derived from a landslip, the materials must have come from the west, and, of necessity, temporarily filled up a portion of the bed of the lake. As elsewhere, my examination here was very hurried, and I therefore commend this deposit to the notice of future visitors.

MALWA TAL.—This lake is situated about five miles, in a direct line, to the east of Bhim Tal; it lies in a deep valley, which strikes north-west and south-east, and is traversed by the Kalsa river, a tributary of the Gola.[2]

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[1] Sat-tal being excepted as regards depth.

[2] It is perhaps worthy of note that the drainage of all these lakes is into the Gola river.

The elevations of the parallel bounding ranges on the north-east and south-west average upwards of 3,000 feet above the level of the lake, the height of which above the sea has been approximately estimated at 3,400 feet.

The range on the north is formed chiefly of white and purple quartzites, with which there are some slates and shales. The dip of these beds is variable, but north-west at a low angle seems to be the prevailing direction. Much of the higher face of this range is steeply scarped, but landslips abound, and have, to a great extent, concealed the character of the lower portions.

The range on the south consists primarily of an axis of greenstone, which stretches continuously hence from the neighbourhood of Bhim Tal. Associated with this greenstone are quartzites and shales, the beds in immediate contact often showing signs of much alteration and induration. Occasionally the effect of the former has been such as to cause the affected beds to assimilate to the characters of the greenstone, and to be almost inseparable from it, by mere examination of their outward lithological structure.

What the exact nature of the physical relations of this greenstone may be, has not yet been fully ascertained; but that it does not exist merely as a single simple dyke is amply testified by the fact that branches from it cross the valley at both ends of the lake, and are cut through by the infalling and outfalling streams.

At the head of the lake is a boulder bed through which the river cuts to a depth of eight or ten feet. This deposit consists chiefly of subangular fragments of trap and quartzite. At first I was inclined to attribute it to the effects of a retreating morraine. Temporarily this view was supported by the discovery of boulders of granite and gneiss—no *known* source for which exists within the present drainage limits of the Kalsa. It was impossible, however, to overlook the fact that there were no signs of polishing on any of the blocks, and that those which have come furthest (the granite, &c.) are well rounded and water-worn. Taking into consideration the professedly general character of the only existing geological map, it would be clearly unsafe to adopt the view that no source for these boulders exists within the watershed ; and this the more especially as in the adjoining basin of the Gola on the north the occurrence of gneiss and granite is indicated on the map.

The importance of determining the source from whence these boulders have been derived is sufficiently obvious. If they have not come from within the limits of this catchment basin, then indeed it might be necessary to invoke the aid of an ice cap to account for their transport; but in the meantime it is impossible to assert that this accumulation of boulders at the mouth of the gorge is other than a delta of diluvial origin.

Now as to the character of the lake itself. Its maximum dimensions are, length 4,480 feet, width 1,833 feet, and depth 127 feet. Unfortunately, as was the case with Bhim Tal, no series of soundings are available, and the form of the basin is, therefore, uncertain. The bounding ranges and their slopes, however, indicate the **V** (river) rather than the **U** (glacial) type of valley denudation.

Looking up the lake towards the course of the stream, the view just beyond the gorge is quite shut out by projecting spurs, which a glacier could have scarcely failed to modify, if not remove.

At the outfall, no rocks are seen *in situ*. The barrier, now modified by a sluice, appears to be mainly formed of debris thrown down by landslips. The first rock which I detected *in situ* in the bed of the stream was the already mentioned greenstone, which will, I believe, prove to be at a lower level than the bottom of the lake.

As I only had a single day to spend at this lake, I was unable to examine the characters of the wide and unusually straight valley below the village of Malwa Tal (*vide* map); its examination may throw some light on the subject.

NAUKACHIA TAL.—This curiously irregular-shaped lake has received its name from its nine corners. It is situated about one mile and a half to the south-east of Bhim Tal. It occupies a hollow on the slope, and is surrounded by low hillocks, not by pairs of distinct ranges, as are the previously described lakes.

With a very narrow outfall on the north-west, its appearance, as seen from a mile distant, suggested its being little more than a shallow pond. And it did not seem to me to be advisable to curtail my already too short time at the other lakes by paying it a special visit. On returning to Naini Tal, I found, very much to my astonishment, that its depth is recorded at 132 feet, thus being the deepest of the series. If this be the correct depth, it renders the lake one of the most singular of all. Its shape, the nature of its surroundings, and the narrow winding course of the outfall, all seem inconsistent with the view that it is of glacial origin.

Its length is given at 3,120 feet, its breadth 2,270 feet, and its approximate elevation above the sea 4,000 feet.

SAT TAL.—The so-called Sat Tal, or seven lakes, are situated about the same distance to the west of Bhim Tal that Naukachia is to the south-east. They are surrounded on all sides by steep hills, a narrow valley, 100 yards wide, at the outfall of the principal lake serving to carry off the drainage. What the maximum depth may be, I do not know; but two soundings, which I took in the western arm of the principal lake, gave depths of about 58 feet. The artificial dam and sluice somewhat increases this depth over what it would be naturally.

At the outfall there is a landslip, and I do not think any rocks are seen *in situ* till a much lower elevation is reached than 58 feet below water-level.

It is scarcely probable that this group of the seven lakes was in any way formed by glaciers. I have seen in parts of the Central Provinces, where no question of glaciers can arise, denuded hollows among hills, which, if closed by landslips, would form very similar lakes.

Since writing the above, I have received from Mr. Yule, of Bhim Tal, the accompanying plan of soundings, which he has kindly taken in the principal of the Sat Tal at my request.

When it is remembered that this curiously shaped lake has but one narrow outlet, and that it is otherwise surrounded on all sides by hills, but without any considerable catchment area for a glacier to be formed and fed, the difficulty in the way of a glacial theory of origin becomes strikingly apparent.

The maximum depth, it will be seen, is given by Mr. Yule as $61\frac{1}{2}$ feet, so that I must have failed to hit off the deepest part.

Of the smaller lakes enumerated above under class III, I have nothing to say at present. They have not yet been specially examined. Very possibly, there may be in connection with them various points of interest to be yet discovered.

CONCLUSIONS.—Reviewing the whole of the facts which are enumerated above in reference to each of the lakes, and considering the limited zone in which they occur—the probability that they are all the result of one general series of operations impresses itself as being an hypothesis of primary importance. If one of the lakes then exhibits indications which seem to connect it with one particular mode of origin, while others of the lakes do not show such or similar indications, it becomes all-important to submit the former to the severest scrutiny. In this way, I think, the appearances suggestive of a glacial origin, which are perhaps strongest in the case of Naini Tal, lose much of their force when we find that other lakes exist of generally similar character, but in which the special indications are wanting. In the single character of the outfall barriers all the lakes agree; opinions may differ as to the origin of these barriers, whether they are remnants of morraines, or have been formed by landslips; but it is almost certain[1] that not one of them consists in any degree of rock *in situ*, and we therefore have not the positive aid of a rock basin to determine a conclusion.

There is one point geologically which links the three larger lakes together, and that is the occurrence of trap dykes in the vicinity of each. Now, I do not think it at all probable that the lakes are due to the original outburst of trap. Indeed, the above described fact in reference to Malwa Tal, where both the inflowing and outflowing streams cut through trap, renders such a view untenable. But it seems not improbable that, when the great upheaval and disturbance of the rocks of this area took place, the existence of comparatively rigid lines of trap may have been largely instrumental in determining the form which the surface assumed, and that on their flanks the soft shales, &c., may have been so much crushed and broken, as to yield more easily to the subsequent operations of denudation, thus affording an abundant supply of material for landslips, which ultimately served to close the valleys, and form the lakes.[2] Or even supposing the outburst of trap to have accompanied the upheaval and disturbance, its effect in determining the subsequently established lines of denudation could not fail to make itself felt.

This explanation, in part suggested by Mr. Medlicott's observations in his well known paper on the Alps and Himalayas,[3] seems to me more in accordance with the known facts regarding the whole series of lakes, than any glacial theory can be.

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[1] Careful levelling can only decide this point.

[2] It is possible that the basin of Naini Tal may be connected with some local faulting, the existence of which is implied by the sulphur spring at the outfall. That a fault occurs all along the centre of the valley is, however, scarcely probable, as, did one exist, it would show in the scarp of China, the beds forming which appear to be continuous across the head of the valley.

[3] Quar. Jour., Geol. Soc., February 1868.

Before commencing examination, I was myself inclined to believe in the probability of a glacial origin; but as my observations have accumulated, I have been constrained to adopt the view, that the balance of evidence available at present is against such an explanation. At the same time, I have indicated that there still remain several points for determination, which are of almost crucial importance. Future observers will, probably, give a large portion of their attention to some of these questions, and, with the aid of the maps, soundings, &c., here given, will be able to add considerably to the above data, thus affording fuller material, by which it is to be hoped a sound and stable conclusion may be finally arrived at.

I have only to add that it appears unadvisable at present to refer particularly here to the debated question, as to the evidence of the former existence of glaciers at low elevations in Kangra and elsewhere.

For the present, the two series of observations had best, perhaps, be kept quite separate, but their ultimate connection and relationship is, of course, none the less obvious.

NOTE ON A TRIP OVER THE MILAM PASS, KUMAON, BY THEODORE W. H. HUGHES, A.R.S.M. F.G.S., *Geological Survey of India, with a* DESCRIPTION OF THE FOSSILS BY DR. WAAGEN, *formerly Palæontologist to the Survey.*

Early in August 1873, an opportunity being afforded to spend a few weeks in Tibet and the higher regions of the Himalayas, my colleague, Mr. Hacket, and I undertook to strike across from Àlmóra to Milam, and return by the Niti pass. I had once before, in 1869, been through the Milam pass, but I was so distressed by constant pains when at high elevations, that I made no observations worth recording. A judicious preparatory training enabled me on the present occasion to enter the lists, and fight with fair success, against the trials of high-region travelling, and my note-book was brought more into requisition.

The time of year at which we started was too unfavourable to make any other than road-side observations among the lower hills. We were in almost constant rain during our first ten marches, and, however enthusiastic our aspirations in the cause of geology at the outset of each day's journey were, they could not withstand the depressing effect of recurring downpours of water, and we hurried to shelter as the most prudent course to pursue. It was not until we reached the Bhótia village of Rilkót, that we passed out of the region of rain.

We were fortunate enough to secure a small collection of organic remains, which, on examination by Dr. Waagen, afforded evidence of the presence of several formations not hitherto detected in this region, and bringing the section here more into correspondence with the sequence of fossiliferous strata established by Dr. Stoliczka in the North-Western Himalayas. To this extent our trip was a satisfactory one; we failed, in that we made no attempt to fix accurately any geological boundaries.

It is easy, however, to reduce within narrow limits the debatable border-land of the fossiliferous and non-fossiliferous rocks, and certain localities can be

referred to their true palæozoic horizon. The main interest of this paper is embodied in Dr. Waagen's remarks; so, after a brief account of the azoic region from Álmóra northward, I will quote them in full, adding a few comments of my own.

Tákli; Bágéswar.

We left Álmóra on the afternoon of the 3rd August, and encamped for the evening at Tákli, and on the following day got into Bágéswar, a distance of 30 miles from Àlmóra.

Slates.

The rocks traversed belonged to the metamorphic series, and consisted of quartzites and schists, a few slate bands and some limestones, with a general dip to the north. Good slates occur in the rise of the hill near Billári, and capping the hill is a great mass of limestone.

Soapstone.

Where the road slopes to the Sarju river, about four miles south of Bágéswar, soapstone appears. It cannot fail to be noticed in the "rains," from the circumstance that at every step you take down the hill, your feet slip from under you, unless great care be exercised.

Kapkót.

Graphite.

Between Bágéswar and Kapkót—the next halting-place, 12 miles distant—similar rocks to those already passed over occur. An impure bed of graphite crops out in the left bank of the first tributary of the Sarju beyond Bágéswar, where the roadway is carried over on a wooden bridge.

Sháma.

From Kapkót we went on to Sháma, a distance of 13 miles. The road leaves the valley of the Sarju at its junction with the Réhra, and follows the course of the latter river. The rocks are of the same character as those seen during the past marches, and have still their northerly dip. Deposits of recent limestone are very prevalent; and at Khar-baggar, where the road to the Pindra glacier leaves the one we were travelling, there is a sulphureous spring.

Tézam.

Dolomitic limestone.

Our march to Tézam was only 7 miles, but a great deal of climbing had to be done, and we did not arrive until the afternoon. In addition to the ordinary quartzites and schists, and superficial deposits of calcareous tufa which were very numerous, there is a considerable thickness of white dolomitic limestones, compact and very fine-grained. A splendid cliff-section of them occurs at the mouth of the Jánkúli river, which falls into the Rámganga, opposite Tézam. Another short journey of 4½ miles brought us to Girgaon, situated high up a hillside. For the first 5 miles the road runs along the right bank of the Jánkúli, and more dolomite is exposed. Near Girgaon talcose quartz-schists replace it.

Girgaon.

Múnshiari.

To Múnshiari,[1] our next halting-place, was 8 miles. The route was a very trying one, owing to the number of heavy ascents and descents. For some way beyond Girgaon the most pro-

[1] Múnshiari is not the name of a village, but the term applied to the whole of the villages that are clustered around Jallat and Súring.

minent rocks are the talcose quartz-schists; but, beyond the ordinary breakfasting place, the name of which I have forgotten, highly garnetiferous micaceous schists are common, and garnets may be picked up in hundreds in little depressions and amongst the roots of trees and shrubs.

We halted one day at Múnshiari, in order to pay a visit to the localities whence are obtained the ovoid stalactites, sold as curiosities to travellers by the people of Múnshiari. The guide took me down to the Góri river, and pointed to places in the cliffs forming the banks, and said they were found there; but I failed to procure any, and I question very much whether I was shown the right spots.

Change in character of rocks.

Lélam.

In the neighbourhood of Múnshiari we began to notice a change in the character of the rocks; and on our next march to Lélam we saw some typical gneiss between Dalkót and Tala Dúmár; dip north, at 25°. Opposite Tala Dúmár black mica-schists, in some instances highly garnetiferous, and hornblende schists occur above the gneiss.

Bághdúar; Rilkót.

Central gneiss.

From Lélam we marched to Bághdúar, and thence to Rilkót. The road keeps in the valley of the Góriganga, and a magnificent section is exposed of what Dr. Stoliczka terms his central gneiss.[1] It is traversed by granite veins, in the manner described by him.

Búrfú.

Still keeping to the valley of the Góriganga, our next halting-place was Búrfú, where we were forced to remain several days until a sufficient number of jabbús (half-bred yaks) had been collected to carry our camp stores and equipage. Búrfú is beyond the ground of the central gneiss, and the rocks between it and Rilkót are quartzites, slates, and schists. Near Tola I noticed an immense number of crystals of iron pyrites in almost all the beds that I examined.

First fossil found near Shilong.

Our first discovery of a fossil was beyond the village of Milam, near Shilong, one of the halting-places of the Bhótias, in some fine silicious sandstone. I think that the *Strophomena aranea*, Salter, which is the only silurian form in our collection, is the specimen referred to; but I am not quite sure, the label having been lost. Along the remainder of our route to the snowy passes, and especially at the foot of Únta Dhúra, we made several additions to our bag of fossils; and each day's journey to the frontier, and through Tibet, enabled us to increase our stock.

Dr. Waagen says of our collection:

Cretaceous fossils.

"The fossils brought by Mr. Hughes from the Milam pass can be attributed to at least five formations, which are indicated with more or less certainty by the different species. I consider as very probably of cretaceous age some pieces of a flaggy yellowish grey limestone, filled with fragments of shells intermixed with entire specimens, which,

[1] Memoirs, Geol. Surv., India, 1866, vol. V, page 12.

though the species could not be determined, yet, by the association of the genera, indicate with great probability the cretaceous formation. I worked out of those rock specimens—

"*Corbula*, sp., allied to, perhaps identical with, *C. cancellifera*, Stol.; as, however, only one specimen has been found, the determination could not be made with sufficient certainty.

"*Astarte*, a middle-sized species, rather oblique in shape, with concentric folds near the apex, nearly smooth on the other parts of the shells; could not apparently be identified with any of the hitherto described species. This shell seems to fill whole beds with hundreds of specimens.

"*Pectunculus*, sp., a large, smooth, rounded shell, found among the *Astartes*. The species could not be determined, but the occurrence of this genus together with a true *Astarte* indicates nearly with certainty cretaceous beds.

"*Cucullaea*, sp., fragmentary.

"The jurassic formation is represented in the collection, by a tolerably large number of fossils, preserved much in the same way as those found in Spiti.

Jurassic fossils.

"I determined—

Belemnites cf. *kuntkotensis*, Waagen (fragments of the guard).
Oppelia acucincta, Strachey.
Perisphinctes frequens, Opp.
,, sp. (*triplicatus*, Stol. *non* Sow.)
,, *sabineanus*, Opp.
,, *stanleyi*, Opp.
,, sp.
Stephanoceras ? wallichii, Gray.
Cosmoceras theodori, Opp.
,, *octagonus*, Strachey.
Aucella leguminosa, Stol.
,, *blanfordiana*, Stol.
,, sp. *nov*.
Pecten, sp.
Rhynchonella, sp. (*varians*, Blanf. *non* Schloth.)

"The genus to which *Ammonites wallichi*, Gray, belongs is rather doubtful, as no sufficiently well-preserved specimen has been found to make this point certain. *Perisphinctes stanleyi*, Opp., is a very good species, and easy to distinguish from *Perisphinctes cautleyi* and *spitiensis*, with which it has been identified. The new *Aucella* is a large rounded shell, with very few concentric striæ, but it is represented only by a single specimen. Nevertheless I thought it worth mentioning; as the occurrence of a new (a third) species in the Himalayan Jura shows yet more clearly the intermixture of European and North Asiatic types in these jurassic districts. In Kachh already species of the genus *Aucella* are exceedingly scarce, whilst north of Milam some of the rocks are filled with hundreds of *Aucella leguminosa*."

Almost all the jurassic specimens just described are from the neighbourhood of Laptél. They occur mostly in concretions, in dark-looking slightly carbonaceous shales, that constitute the most distinctive rocks of the formation. At

Laptél the shales overlie limestones, and they form a trough, which has a north-north-west south-south-east strike. They extend southward as far as the halting-place at the foot of the Kíngrú ghát.

Triassic fossils.

"The different formations of the triassic period are very poorly represented in the collection, but nevertheless the materials are sufficient to state with all certainty the existence of these formations. To the upper Trias very probably belong some hard, flaggy, dark-grey limestones, with millions of fragmentary shells imbedded. However, only on the weather-worn surfaces some species can be recognised, it being impossible to get anything out of the interior of the rock. I am able to recognise one species of *Monotis*, and two species of *Pectens*, on three different rock specimens. The only species determinable, however, is *Rhynchonella austriaca*, Suess.

"There are yet two other divisions of the Trias indicated by fossils in two different kinds of rock. The one is represented by two fragments of Ammonites of the group of *Ammonites semipartitus*. They are preserved as black nodules in a hard, dark-grey, silky, slaty shale, which very likely belongs to the 'Muschelkalk' formation. The other division of the Trias is indicated by a small specimen of a badly preserved *Ceratite*, somewhat like some species of the Salt Range, and thus possibly out of some 'Bunter Sandstein' beds. The rock in which it is preserved is a hard, red, crypto-crystalline limestone.

"These few fossils, though badly preserved, and specifically not determinable, yet show beyond a doubt the existence of a rather complicated group of triassic rocks."

There are two geographical zones of this and the underlying series, one being south of Laptél, and the other north of it, in the direction of Kanchégo.

Permian and carboniferous fossils.

"The next older formations, permian and carboniferous, are represented in the collection by a somewhat better suite of fossils. The most fossiliferous bed is a white limestone with a great number of fragments of crinoid-stems, and the following determinable species :—

" *Terebratula himalayensis*, Dav.
" „ *subvescicularis*, Dav.
" „ sp. *nov. ?*
" *Athyris roissyi*, L'Ev.
" *Spirifer* cf. *glaber*, Martin.
" *Camerophoria*, sp. *nov. ?*
" *Productus semireticulatus*, Martin.
" „ sp.
" *Bactrynium* sp.
" *Cyathophyllum* sp.

"It is very interesting to trace how much this fauna resembles that of the lower carboniferous limestone in the Salt Range; and even the preservation of the specimens is such, that they could be mistaken as coming from the Salt Range. *Productus semireticulatus* occurs of its typical size, whilst the small form from Spiti, which is found also here, and quoted by me as "*Productus*, sp.," is very likely a different species. The latter, however, has been also obtained, though rarely, from the Salt Range.

"The *Camerophoria* quoted above is a beautiful large species, which I could not determine for the present. The *Bactrynium* also is interesting, which is found plentifully in identical specimens in the Salt Range. The genus has been described by Gümbel after a very small species out of the 'Kössener' beds of the Bavarian Alps. The zoological relations of the genus, however, are as yet thoroughly unknown.

"Other beds, possibly also of carboniferous age, which, however, could not be ascertained by the few fossils obtained from them, have furnished:—

Rhynchonella, sp.

allied to *Rh. acuminata*, Martin, preserved in a black hard shale, and

Spirifer cf. *striatus*, Martin,
Stringocephalus ?? sp.
Rhynchonella ? sp.

all bad specimens, preserved in a dark liver-coloured limestone."

The dark-coloured limestone is very probably of carboniferous age, as it came from the same locality as the rocks which furnished the fossils of undoubted carboniferous affinities.

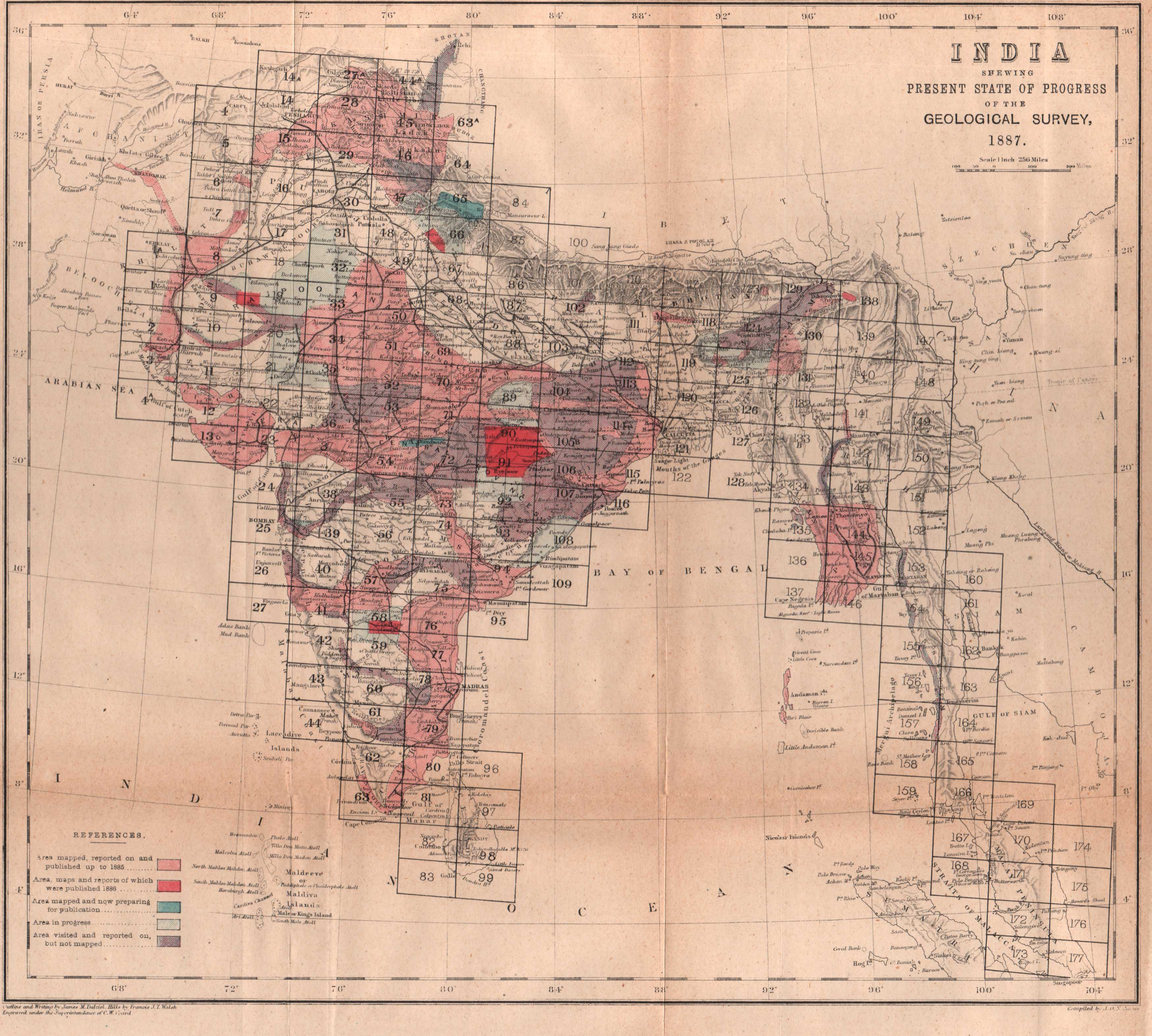
Silurian fossil.

"Of all the silurian formations, there is only one specimen of rock in the collection, consisting of a bit of white not very hard sandstone, with manganese specks, upon which several casts of *Strophomena aranea*, Salter, are observable."

The sandstone in which this brachiopod occurs comes, as well as I can remember, from the neighbourhood of Shilong, as already mentioned.

The following list of halting-places and distances from Álmóra to Milam may be useful:—

Name of halting-place.	Distance.	Remarks.
1. Tákli	16 Miles.	No resting-house.
2. Bágéswar	14 "	Dák bungalow.
3. Kapkót	12 "	Dharamsála.
4. Sháma	13 "	Ditto.
5. Tézam	7 "	School-house.
6. Girgaon	6½ "	No resting-house.
7. Múnshíari	8 "	Dharamsála.
8. Lélam Thánkót	6 "	Cave.
9. Bághdúar	8 "	No shelter.
10. Rilkót	8 "	Ditto.
11. Milam	8 "	Ditto.
TOTAL ...	106½ "	



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Glacial traces on the south slope of the Hindu Kúsh.—The descent from the Chahárdar pass to the Deh-i-Tang lies down a narrow valley of much the same character as the one just described. But the most interesting feature in connection with it is, that in this valley there are some small glaciers still remaining. Near the head of the valley, just south of the Chahárdar pass, at an elevation of 12,050 feet above sea-level, several small side ravines join; I noticed three of them were still filled with glaciers, and though they were very small, the moraine accumulations near their lower ends were enormous. Especially the one from the right side shoots off an enormous cone of large fragments, amongst which there are some very good examples of ice-scratched blocks.

Recent conglomerates.—Both in Túrkistán and the neighbouring South-western Badakhshán deposits of recent and sub-recent conglomerates, sands and clays are largely developed. The hills which skirt the cretaceous anticlinals between Haibak and Dahána Ghori are formed by these deposits which attain there a great thickness. Similarly the valley of the Súrkh-áb is partially filled by them.

The valleys belonging to the Kabul river drainage south of the Hindu Kúsh are to a large extent lined with terraces of conglomerates, as, for instance, the wide terraces of Siáh-Gird, Chahárdeh, etc.

These conglomerate terraces form quite a feature in the landscapes of the road east of Kabul, amongst which I may mention the terraces of Gandamak and Nimlah Bagh.

I believe these accumulations belong to the same age as the Indus gravel beds, which are seen to skirt the hills the whole way from Peshawar to Sind.

In the next number of the "Records" I intend giving a geological map of Afghánistán and part of Persia with a summary of the geological structure and mineral resources of Afghánistán.

CALCUTTA, *23rd December 1886.*

Physical Geology *of* West British Garhwal; *with Notes on a Route Traverse through* Jaunsar Bawar and Tiri-Garhwal, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

PART I.

Introduction.

In Part 2 of the Records for 1885 I described a fossiliferous zone of pre-tertiary age amongst the old mountain-building rocks which form part of the Lower Himalaya of British Garhwal. When that preliminary notice was published I had only been working for a short time in the district, and consequently the area treated of was confined, and no generalizations could be made. Since then, having spent another field season there, I am able to make some additions to our knowledge of the stratigraphy of those parts. But, inasmuch as this part of the Himalaya is divided from ground which has been already geologically surveyed in Jaunsar Bawar by a broad strip of almost completely unknown country, *viz.*, part of Tiri-Garhwal, I am still compelled to put aside for the present all definite correlation between the rock systems displayed in Jaunsar and those upon which I have now been engaged. In consequence of this I shall still adhere to the method observed in my preceding paper of naming the series, when fossils are absent, after their prevailing lithological character; trusting to time, and a wider experience, to eventually make them one with the old established Himalayan formations.

British Garhwal has been topographically surveyed on the one-inch scale, and the principal object of my first season's work there was to settle down on some part of it where the strata showed signs of falling into a natural order, and then work from that point as closely as the advantages of a large-scale map would admit.

But, before doing so, I went through Jaunsar Bawar (the next British possession west-north-west of British Garhwal) for the purpose of making myself as thoroughly acquainted as possible with that already mapped district. From its no great distance from Garhwal it was thought that it might have many points of similarity, and so give one new to Himalayan work a useful basis to go upon.

From the northern extremity of Jaunsar Bawar I rapidly crossed by Tiri through native territory until I struck my own working district at Srinagar in British Garhwal.

Before coming to the main object of this paper I shall therefore briefly set down a few somewhat disjointed notes referring to my route traverse: not because they have any intrinsic value, but because of their possible bearings on past or future work.[1]

Jaunsar Bawar.

The southern parts of Jaunsar Bawar were examined by me in some detail with especial regard to the position of the Mandhali series in its numerous unconformable appearances near Chakrata. It is not my province to describe these rocks, with the questions arising from which Mr. Oldham is now engaged, but the numerous examples about which I have notes, from their containing clear blebs of quartz, fragments of felsites and a great deal of felspar and felspathic material scattered about in the matrix, gave me the idea of a rock produced by the degradation of felsites or granitic rocks and produced perhaps during a time of intermittent volcanic activity. North of Chakrata, the high Deoban ridge up to Mandhali, and some way beyond, was wrapped in deep snow, the product of a late storm, at the time of my visit; and work was therefore curtailed in a great measure. What I saw of the Mandhalis there left no doubt in my mind as to their identity with the rocks classed as the same a little south of Chakrata.

At Tiutar (near the Tonse) I made a careful examination of the Chakrata series to the east of the Konain-Mudhaul fault,[2] in order to solve, if possible, the question of inversion, and whether the igneous rock was intrusive or inter-bedded. From

[1] To make these route observations more intelligible it may be noted that Mr. Oldham's Bawars are taken by him to be about on the horizon of the base of the infra-Krol group of the Simla section, the Mandhalis being older still, but newer than the Deoban limestone (see Vol. XVIII, p. 4).

[2] See R. D. Oldham's "Note on the Geology of Jaunsar and the Lower Himalaya." Rec. Geol Surv. India, Vol. XVI, 1883, p. 193.

the presence of what appeared to be thin ash beds, associated with the igneous rock, I at first felt sure both must be inter-bedded, but until microscopic sections are cut there is a possibility that they may turn out to be merely crushed and pressure-foliated diorites. With regard to inversion, the lie of the beds as contrasted in deep gorges, and on the neighbouring mountain spurs south-west of Tiutar, inclined me in favour of the supposition of inversion; for to the eye there seems to be a steepening of the beds in towards the mountain; but, on the other hand, the limestone which lies apparently immediately below the igneous rock is a very whitey-grey, compact, and marble-like rock, such as could have been produced by the contact metamorphism of the igneous rock. In addition, south-west of Tesar Khera, where the limestone contains some magnetic iron in small crystals, the contact of the igneous rock has in places altered the latter, so that it now lies as amorphous lumps filling lacunæ among the joints of the limestone. From these facts the limestone must be older than the igneous rock, and, if the latter is inter-bedded, their present position must be the original one, and the inversion theory cannot be maintained.

From Tiutar I rounded the north end of Jaunsar Bawar and left British territory at the head of the Khunigadh river which divides Jaunsar from Tiri-Garhwal.

Tiri-Garhwal.

From the Khunigadh pass I descended, in a south-east direction, to Porohla. Except for a mile or so from the pass, where there were some diorites and ash (?) beds, there was nothing met with but Bawar quartzites during the whole descent. They lie dipping slightly towards the north-east and never exceeding an angle of 20°. Their colour is white, and, when seen through a lens, they appear to be made up of little angular fragments of clear quartz and apparently nothing else. They form the exceedingly precipitous ridge west of Gundalho, lying between the two branches of the Kamalada river, which meet at Porohla. The steep bare walls into which they weather utterly barred my progress at a point on the map above the *l* of Gundalho; but, with their low dip towards the north-east, they appeared to continue much higher up towards the main range running parallel to the Tonse. I have no doubt that these are identical with the Bawar quartzites of Mr. Oldham. Porohla lies in a widened and flattened valley, given over to cultivation, and called the Rama Serai, lying to the north-north-east from the village along the present line of the river.

Bawars.

Gneissose rock.

Along its bed there must be an unseen junction between the Bawar quartzites just mentioned, and another rock which is petrologically a gneiss. Unfortunately both it and the Bawars themselves, in this region, have so weathered at the surface that in the few exposures that I could examine in a hasty march I found no reliable junction that gave me a clue as to the nature of the boundary. This excessive weathering into a fine gravel of the separated crystals of the gneiss and the disintegrated grains of the quartzite, is probably the cause of the flat cultivated stretch of the Rama Serai, the valley of which has become in this locality choked with the products of disintegration. I had the gneiss with me, gradually emerging from its weathered covering, up to, and beyond Kumalo; but, when the position indicated on the map by the *l* in Kumalo was reached, it came to an end, and Bawar quartzite and some schists continued up to the ridge, trending north from Saulda peak. The eastern boundary of this gneissose rock runs a little east of north to beyond Dokri, from the point just mentioned. This boundary is as difficult to unravel as the western boundary, for the uniform Bawars show but little dip, except where they rise in escarpments, or when schists come in among them, and even then the results are discordant.

With regard to the gneiss itself, its foliation planes, when visible, are roughly horizontal just as the Bawars are. It will thus be seen that stratigraphically no position can be assigned to it from the evidence before us, for it is not known whether the boundaries are natural or faulted; and, from the nearly horizontal dip found in every exposure, an average actual dip cannot be deduced. Then again, I have no evidence to bring forward as to whether the rock, provisionally named a gneiss, is by origin a gneiss or a granite. Petrologically it is identical with the rock of the Chor mountain, which has received much attention from Indian geologists. That rock, by Colonel McMahon's microscopical evidence, and by the still more convincing evidence of large and numerous included fragments of schist and quartzite found by Mr. Oldham and myself during the season's work of 1883-84, is by origin a granite; but whether the same can be said of this rock depends on how far an exact likeness between two rocks of this kind is to be deemed conclusive of their identity. At the same time, though willing myself to withhold judgment until more extensive mapping has been done, there is no doubt that the two rocks in so far as their mineral characters go *are* the same. There are the same quartz and felspar, with sometimes a predominance of the former; there are pale and black micas; and there are schorl crystals, developed here and there, and occurring abundantly in cracks and veins, just as they did in the gneissose granite of the Chor. In some places I found a decomposed greenstone, probably a dyke of diorite, in the gneissose rock.

From the east edge of the gneiss I crossed the ridge north of Saulda peak and followed a tributary of the Banale river, west of Kanal. The whole of the west side of this ridge was chiefly composed of the Bawar quartzites, showing no evidence of dip, except a general horizontality. At the summit of the pass, and on the east side, schistose beds came on, and continued until some inter-bedded diorites and dioritic ashes appeared below them. Then came more schists, and finally I struck in the stream bed a massive limestone of the Deoban type.

It will thus be seen that, on the east side of the gneiss, we have a set of outcrops inversely arranged to those of the west side. The following will illustrate this:—

WEST. Deoban Limestone.	Schists and igneous products.	Bawar quartzites.	GNEISS.	Bawar quartzites.	Schists and igneous products.	EAST. Deoban Limestone.

Now, the steep descent from the ridge into the tributary of the Banale, leaves the impression that the approximately horizontal beds to the east of the gneiss rank in order of superposition from the limestone below to the Bawar quartzite above; that is, we may assume an ascending series on that side of the gneiss from the limestone upwards. The west side of the gneiss is not so clear, but, from the undoubted identity of the quartzite with the Bawars there is the exact appearance there also of an ascending series towards the gneiss.

A seemingly absurd corollary follows from this: We appear bound to believe in a gentle synclinal along the valley of the Kamalada, with the gneiss as the uppermost member of the series! Those readers who have followed the history of the geology of the Chor mountain will see that we have here exactly the same apparently unsolvable problem that at first proved too much for every one in the case of the Chor. It is true that we now have a partial answer in the case of that mountain, inasmuch as it is certain that its material has been in a condition of aqueo-igneous fusion sufficient to allow of its tearing off fragments of the neighbouring rocks among which it was intruded, and enclosing them in its substance, but we cannot assume the same explanation here until the same proofs in this case of included fragments, and the evidence of the microscope have been brought to bear on the question in this locality. Later on, I shall have to mention Kalogarhi mountain in British Garhwal, an isolated peak, also composed of this gneissose rock, and presenting in its neighbouring relations very much the same features. It also, at first, appears to lie in a synclinal, as a capping on the summit of the hill, and in many ways it may be looked upon as a miniature Chor. The explanation of the Kalogarhi rock rests, however, on the proved great age of the schistose strata amongst which it lies: although the schists there have the appearance of being the highest of the neighbouring formations. The proving of this involved much labour and time, neither of which could be given to the Rama Serai section on account of my rapid movements.

Deoban limestone.

Returning to the section down stream in the Banale river, we have the spur from the main ridge running towards Shishalu and dividing the upper branches of the Banale river, showing distinctly the various outcrops of the schists and the limestone as they appear to dip in towards the mountain and at a much higher angle than met with heretofore. The bed of limestone is not by any means thick, but between Shishalu and the ridge running east from Saulda peak, and between the last point and Palaita the thickness varies very much, becoming less as the outcrop is traced south by the last-named places to the Jumna. Beyond Palaita I could not see where it went to, but its line of strike from that place would carry it very well to join up with the Deoban limestone of Jaunsar near Lauri.

Shaly slates.

At Bigrar village (not marked on the map), which is half a mile above Deltu, the limestone beds have come to an end, and we come upon grey shaly slate dipping about 20° north-west. After a short thickness of these there comes beneath them a thin bed (not more than 60 feet) of a dark, micaceous, gneissose rock, finely foliated, and of very different aspect to that on the other side of the Saulda ridge.

Another gneissose rock.

Of this, and other rocks collected during last season, I hope to make a thorough microscopical examination later on; I can now only say that the quartz is present in large quantities, showing the polysynthetic structure so common in gneiss of other parts of the Himalaya examined by Colonel McMahon.[1] No fluid or other cavities can be seen. The felspar is not so abundant as in a typical granite or gneiss, occurring in less quantity than the quartz; it is decomposed almost beyond recognition. Biotite is fairly represented, and there are a few needles of apatite. Whether the rock is an intrusion, or is metamorphosed *in situ*, is a question I cannot answer

[1] See Records, Vol. XVI, p. 144.

by any direct evidence. Its regular appearance bedded with the other rocks, and its lateral continuity between the stream and the ridge east of Saulda peak along the strike of the rocks, favours the idea of its being a true gneiss, and not a foliated granite; but, on the other hand, the selective metamorphism required to pick out a bed 60 feet thick and make it a gneiss without altering the surrounding rocks relatively at all, seems incredible.

Quartzites and slightly schistose slates.

Between Kanal and Goldar there come beneath this gneissose bed olive-grey quartzites, blue-grey quartzites, and finally slightly schistose slates, all dipping about north-north-west 50°. From Goldar to Jeshtar, and the ridge east of Saulda Peak I re-crossed over the same set of beds. I then descended towards Cheli; the latter part of the descent being entirely upon the slightly schistose slates, which in some cases became very micaceous and soft.

Gneissose granite.

Having crossed the Jumna at Barkot I took up the stream south-south-east from there, and for the first mile I passed over much the same kind of rocks, but not very schistose, the dip being irregular. Then came fragments of a granitic rock for about half a mile, though the nature of the country prevented any good exposures being seen. It appeared to be a rock related to the gneissose bed last described, but the foliation was not much marked. Then came rather gritty, close, blue-grey slates, dipping 60° west-south-west. On getting to the pass, about 6 miles from Barkot, which pass is north-52°-east from Bouk station, looking south into the tributary of the Bhagirati river there is still the gritty slate dipping 20° west-north-west. Beyond the pass, in an easterly direction, the ridge rises into a mass of the granitic rock, which also keeps to the higher parts of the spurs running down into the tributary of the Bhagirati river as far as a point east-south-east from Bouk station, where there is a sharp line of junction (probably a fault) running north-east between it and a massive blue-grey limestone. The lower parts of the same spurs are composed of the slaty rock, and some few gritty beds, with a general dip 30° or 40° west-north-west near the pass. The dip gradually veers round more to the west, and finally becomes south of west as Darng is approached. The limestone, which resembles the Deoban, only crosses the stream bed a little way, and is then cut off in another direction by a fault striking south-east almost in a direct line between Bouk station and Darng.

Returning to the granitic rock, the quartz in it is abundant, in large grains, and with no polysynthetic structure. Numerous strings of liquid cavities, and dust of opacite ramify through the quartz grains. The felspar is in the same condition as that of the Banale river gneiss. The mica is biotite as before, sometimes dark brown, but often quite black, and opaque in thin slices. The granitic mass in its upper parts seemed to change somewhat in nature and take on a rather more dioritic appearance. I was disposed at the time to think that it was indeed a gradual change in the minerals, but I had not time to stay and work all round the mountain. Specimens from the top of the ridge due east from Bouk station are almost certainly a diorite though the rock has not been sliced yet.

Continuing down the tributary of the Bhagirati near Gewla and Darng we find the same gritty slates and quartzites of dull grey colour dipping towards the south-south-west, at 45°.

It is near where the stream enters the Bhagirati that a change takes place, and the dull coloured slates and grits give way to a set of shivery slates of purple and green colours. These weather into a violet, or pale green powdery rock, which forms steep taluses on the river banks. There are some quartzite beds incorporated with them, and a few conglomerates near Upu (sheet 66). How this change sets in I did not observe, as the structure of the lower parts of the valley is much obscured by recent gravels extending up to a height of 300 feet or more on each side of the Bhagirati, and through which it has cut its course. The general dip is south-west or north-east, apparently rolling about a good deal, first in one direction and then in the other. The appearance of the beds, the nature of the conglomerate, their colouring, and especially the way they weather, forcibly reminded me of the beds seen on the road to Chakrata, near Kalsi, in Jaunsar. The whole of the fair valley of the Bhagirati down to Tiri, and probably beyond, is likewise composed as described, the uniformity being due to the recurrence of the same beds by repeated foldings.

Purple and green shivery states and quartzites.

At Tiri I left the Bhagirati river and turned east up the Bheting river, making as direct a line for Pauri as possible. As far as Nurni there does not seem to be any material change in the rocks, but looking north across the Bheting towards Kytiba and Kireh trigonometrical stations, a set of thick-bedded quartzites can be detected constituting the rugged sides and summits of those peaks. Half a mile or so north of Nurni and Koti, the same beds were traced by me running up from Ushunna along the ridge south-east and east towards Maniknath. In their lower part there is a limestone, dark blue, and resembling those already mentioned in this paper. It is only a hundred feet or so in thickness. A mile and a half east of Koti the junction between the slaty beds and the quartzite is seen on the pass leading over into the affluent of the Alaknanda river. Here, too, are some diorite and dioritic ash near the junction, and no limestone. There is also a change in the lower slaty series at this place; they lose the bright tints hitherto possessed and become more like the sombre tinted rocks that we had before entering the Bhagirati; that is to say, they are grey, and slightly schistose. They also have a nearly vertical dip south or south-west. On the left bank of the affluent, some distance above the road, the limestone and the quartzite were traced as far as Kunnali, but below this, on account of the dense vegetation of creepers, &c., nothing more could be seen of them. I should mention that this quartzite is of exactly the same type as the Bawars, a strong clear-grained quartzite, approximately horizontal, and apparently capping the heights and the ridges unconformably. It is evident, however, that having lost touch of the Bawars so long since, no reasonable correlation can be made in this case. The whole of the south-west side of the stream bed east of Chandabadni mountain down to Gar (Gur), is remarkable for the effect that the vertical or nearly vertical dip has had on the carving out of the hill-spurs: they are like a number of sharp pyramids rising one behind the other in very beautiful succession. The rest of the way to Jarkni on the Alaknanda is over the same kind of beds.

From Jarkni I crossed the Alaknanda, and arrived in British Garhwal, where I at once set to work to find a place suitable for commencing systematic mapping operations.

British Garhwal.

PART II.

It will now be useless, or at least unnecessary, to continue the narrative form of this paper. Instead, I shall endeavour to put in a somewhat brief manner the results of numerous traverses, and counter-traverses, over a geologically compact bit of country, lying north and south between the Sub-Himalayan boundary and the Nyar river, and east and west between the Ganges at Hardwar and Ghungti mountain.

This portion of the Himalaya has proved interesting geologically in two ways. In the first place, it was there that I came unexpectedly upon outliers of nummulitic and mesozoic strata, which I traced, as stated in my previous paper,[1] into conjunction with beds of the same age, long ago noticed by Mr. Medlicott as existing in the Tal and Bedasni rivers.[2] In the second place, the remarkable positions which they had assumed with reference to other rocks of the district raised momentous questions in physical geology, very much akin to what have been satisfactorily answered of late years in the Durness-Eriboll district of West Scotland.[3] These for some time proved a stumbling block to me: for, much as the solution of the Highland question tempted me to readily interpret this district by a similar line of reasoning, I felt that no real knowledge would be gained unless I could prove the case here on its own merits alone. This I have been able to do.

The small-scale map (¼ inch to the mile) accompanying this paper gives the nearly completed results of my mapping of the ground, whilst the large-scale map (1 inch to the mile) of the north-west corner of that district is the one to which I shall refer for proofs of the interpretation which I shall submit.

In my previous paper I have already indicated the petrological characters which the rocks present. With regard to their chronological order I will at once anticipate what I shall subsequently prove, by giving a table, which differs from what I previously drew up by the relative positions of the Tal (mesozoic) and the massive limestone being interchanged.

Table of formations (in descending order) in W. British Garhwal.

SUB-HIMALAYAN .	Upper Tertiary .	Soft, yellow, micaceous sand-rock and sandstone, few conglomerates, and purple clay bands.
NUMMULITIC . .	Lower Tertiary .	Sombre-tinted purple and olive and grey shales, with bands of earthy limestone, containing fossils, and soft dark brown sandstone.

[1] A fossiliferous series in the Lower Himalaya of British Garhwal, Rec. G. S. I., Vol. XVIII, pt. 2, 1885.

[2] Mem. G. S. I., pt. 2 Vol. III, p. 69, 1863.

[3] See Prof. Lapworth's "Secret of the Highlands," *Geol. Mag.*, 1883. Also Messrs. Peach and Horne "On the Geology of Durness and Eriboll with special reference to the Highland controversy." *Nature*, XXXIII, 1885, p. 558.

Table of formations (in descending order) in W. British Garhwal—contd.

TAL . . .	Mesozoic . .	*Upper Tál.*—Indigo coloured calcareous grit, usually oolitic; full of broken fossils. The rock might often be called a limestone, but it is never without the sandy basis *Lower Tál.*—Strong sandstone of millstone-grit type; quartzites, &c., few quartzose conglomerates; a black carbonaceous shale, 1 foot thick, with plant impressions, occurs in the Sour-gadh.
MASSIVE LIMESTONE	Age unknown . .	Dark, blue-grey, fairly pure limestone; thick bedded; without fossils. It resembles either the Krol or Deoban limestone.
PURPLE SLATES AND VOLCANIC BRECCIA.	Ditto . .	Slates, bedding and cleavage coinciding, usually coloured a ruddy or inky purple, but sometimes grey. The volcanic breccia is an angular clastic rock, with no rounded fragments. The material is coarse or fine, and is made up of slates, quartzites, and limestone, with very rare fragments of igneous rocks and schists.
SCHISTOSE SERIES .	Ditto . .	Phyllites, quartzites, quartz-schists, schists, and garnetiferous schists, with intrusions of gneissose granite.

Without perplexing the reader by detailing the array of difficulties which presented themselves to me at different stages of my work, I will at once come to the main difficulty, in the right understanding of which all other minor questions are bound up.

If reference is made to the ¼ inch map, the eye will at once grasp the fact that there is a central elongated area composed of the schistose series and which may be called the "Inner formation;" whilst surrounding it on all sides is a zone of all, or some, of the formations from the nummulitics down to the purple slates and volcanic breccia. These may be called the "Outer formations," in contradistinction to the schistose series. Now the belief which is at present so rapidly gaining ground that metamorphic strata are presumably older than unmetamorphosed strata makes one at the first glance assume a strong probability in favour of the inner schistose series being of much greater age than the outer zone of formations. But no sooner has this *à priori* probability obtained a firm hold of the mind than a rude shock is given to it by the discovery that at every point round the schistose area the Outer formations appear to dip towards and under the schistose series at steep angles (50°—60° generally); whilst the schistose series itself is disposed apparently in the form of an elongated quaquaversal synclinal upon the top of the Outer formations, and culminates in a capping of gneissose rock on the summit of Kalogarhi mountain (locally known as Kalan Danda), the highest point of the neighbourhood.

In other words, the observer after a hasty examination is almost driven to the conclusion that there is an upper metamorphic series lying normally upon the comparatively unmetamorphosed zone of Outer formations (a counterpart of the opinion long held with regard to the strata of the Scotch Highlands).

But in one respect the geological structure in this part of Garhwal is unique, so far as I know. The appearance of the Outer formations underlying the schistose series is not confined to one line of country, but is equally noticeable at nearly *every point round the margin* of the Inner formation, whilst up the Huil and Rausan rivers offshoots of the Outer formations appear among the schistose series, fitting in with them more like a piece of gigantic inlaid work rather than lying as unconformable outliers upon them.

When I commenced field-work last season, I was in a complete state of uncertainty as to which way to interpret the sequence of the rocks. On the one hand, I was exceedingly loth to believe that an enormous thickness of phyllites, schistose slates, schists, and even garnetiferous schists could normally belong to an era subsequent to the deposition of the ordinary slates, limestones, and sandstones of the Outer formations; whilst, on the other hand, I was equally averse to straining what then seemed to be the plain facts of the case in order to draw up a more plausible stratigraphical table. Besides, Mr. R. D. Oldham's work in Jaunsar Bawar[1] and Mr. H. B. Medlicott's[2] at Simla had already shown the extreme probability of an upper and comparatively younger schistose series normally overlying slaty and calcareous strata; and I could not of course neglect telling evidence of this kind, although so great a span of country lay between their working grounds and mine.

I was also in a state of uncertainty with regard to the Outer formations themselves; for they by no means preserved a uniform relation to one another; so much so that my first statement that the massive limestone overlaid the Tal beds has had to be discarded and reverse positions assigned to them.

The most pressing difficulty then was that of stratigraphical succession. Although the superficial relations of certain rock-series to one another had been made tolerably clear, it was not manifest which of them was really the newer, and which the older; inasmuch as sometimes they appeared in one order of superposition, and sometimes in the inverse order. In other words, the problem before me was to unravel their order of deposition in time, from conflicting appearances, due to disturbance of the strata; for, in a region of true mountains, it is not enough to see one set of beds dipping beneath another set; but in every case the question must be put—is this the normal order, or is it an inverted order?

The presence, or absence of fossils, makes all the difference in the ease with which such a question is answered; though a single fossiliferous series is not sufficient by itself. But when two or more definite fossil horizons are fixed, among a set of formations roughly coinciding in dip; the sequence in time, evinced by those horizons, will necessarily proclaim the true time sequence of the whole.

Applying this principle to the comprehension of the problems before us, it was imperative to find out how the presence of the two distinct fossil horizons of the nummulitics, and the mesozoic Tal beds, in a region where the other formations are unfossiliferous, would help in settling the true order of those associated unfossiliferous rocks: whilst it was extremely probable that if the Outer formations were once chronologically arranged, a clue would be obtained which would fix the age of the schistose series. Until recently, the unfossiliferous formations had not been met with in such fortuitous conjunction with the fossil-bearing series as to enable me to

[1] Rec. G. S. I., Vol. XVI, 1883. [2] Mem. G. S. I., Vol. III, 1863.

rightly deduce their true stratigraphical order, but the time has now come when I can speak with certainty on this point, and I can throw the whole of the strata of Western British Garhwal into comprehensive groups, arranged in true historical succession (see table of formations).

Within the confines of this paper I shall merely endeavour to show how I have arrived at my conclusions, by reference to the geology represented by the accompanying maps and sections.

Referring to the 1-inch map, it will be seen that within the general curve made by the Ganges there are a set of boundaries, marked as faults, each roughly parallel to one of the reaches of the river, and, in result, giving a compound boundary somewhat resembling the course of the river. Within this boundary, except for a narrow band up the Huil river, the rocks composing the Inner formation agree in being very compact purplish quartzites, without much granular structure visible; glossy-surfaced slates, generally slightly purplish, or considerably metamorphosed into schistose slate, and schists. On the other hand, outside the boundary there are fairly regular groupings of the Outer formations, *viz.*, the nummulitics, the Tal (mesozoic), the unfossiliferous, massive, blue-grey limestone and the purple slates and volcanic breccia.

The first point to which I would call attention is that the order of superposition (whether a true order or not) of the Outer formations, up the Ganges valley, is from the purple slates and ashes below, up through the massive limestone and the Tal to the nummulitics, which are brought to a check by the boundary (see sections AA, BB). Now, in order to discover whether this order is a normal or inverted order, we must reason in this way. The nummulitics being by their fossil contents of later age than the Tal beds, which are mesozoic in age, it follows that the apparent position of the latter, dipping underneath the former, represents the true original sequence in which they were deposited. That being so, the dip of the massive limestone beneath the Tal beds must also be an original true dip; and likewise that of the purple slates and ashes beneath the limestone.

Thus, the present arrangement of the group of Outer formations, as seen near the bend of the Ganges at Lachman-jula, from the purple slates and ashes up to the nummulitics, must be the original historical one; and so part of the previous difficulty is solved once for all.

Coming now to the nature of the boundary between the Outer and Inner formations, and the question of their relative positions: it is certainly, at first sight, a most astounding coincidence that the Outer formations in nearly every locality should persistently dip towards the presumably older schistose series; especially when we have just learnt that the Outer formations, among themselves, are in a natural order. This occurrence, so marked in many places, and the lie of the Outer formations completely encircling the schistose area, make it difficult to get rid of the first impression already alluded to that the whole is a synclinal trough, with the Outer formations below, and the Inner above. One seems almost driven to conclude that if a boring were sunk through the centre of the schistose area, we should inevitably strike the Tal beds below. The very often curved direction taken by the boundary between the Outer and Inner formations, whereby it wanders irregularly, sometimes even V-ing inwards with the inequalities of hill and valley after the manner of a moderate dip-plane outcrop, further enhances this belief; whilst the apparent synclinal, into which the schistose series itself is thrown, seems to clinch the matter. Indeed, if it were not for certain facts, which are at the same time pure stratigraphical accidents, and some elementary reasonings, which might be passed over, I venture to think that the above would be the natural and most plausible interpretation of the features. But nevertheless these facts, not only render the above interpretation unacceptable, but emphatically negative it; whilst I hope I shall be able to show that, owing to the exigencies of mountain structure, apparent anomalies of the above kind are certain to present themselves.

First, as to the facts: in numerous instances, as the map testifies, the Tal beds, dipping down against the schistose series, are not in direct contact with them; but there is an intermediate deposit of shales, clays, and earthy limestones of nummulitic age, which also, in like manner with the Tal, dips down against, and apparently under the schistose series from several sides. And I wish it to be understood that this statement is no general one; but the two widely distinct rocks, namely, soft shales, and highly metamorphic schists and quartzites are in *actual contact*, without any semblance of what could be called a transition rock. Thus, if the Tal beds in reality continue beneath the schistose series, the nummulitics, where present, also do the same: that is to say, a soft, shaly, tertiary rock, not only must lie as a foundation on which the schists are piled, but also must be beneath them in direct contact. To satisfy a condition of this kind the most glaring case of selective metamorphism would be totally inadequate; it results then that the schistose series must be older than, and therefore normally below the whole of the Outer series, including nummulitics, Tal, massive limestone, and the purple slates and ashes. The preservation of the thin deposits of nummulitic age may be called a stratigraphical accident, but the key it gives to the chronological order of the Outer formations, renders any other interpretation of the above impossible.

But if this is so, the false position of the Tal beds and the other Outer formations, where present, cannot be looked upon as nothing but a coincidence; there should be some inherent necessity for such a steadily anomalous position, a position of being, so to speak, tucked in all round under the margin of the inner and older formation, a necessity due, probably, to the exigencies of mountain structure. I think the following considerations will make clear what this necessity is. During the deposition of the nummulitics, the whole of that portion of the Himalaya where they now exist, must have been beneath the sea. Between then and the present time they must have been raised into a mountainous tract; and from the inclined position of these same tertiary beds we conclude that the cause which tended to raise the hills into existence was a lateral compression, acting chiefly south-west and north-east, though complicated to a certain extent by compression in other and opposite directions. Whatever be the immediate cause of this lateral compression, into a discussion of which there is no call now to enter, it is sufficient for present purposes to notice that its effect was to urge the crust of the earth to take up less horizontal space than before. This could only be brought about in two possible ways; namely, by corrugation and by faulting. That the former actually took place, we have abundant evidence; and that the latter, *viz.*, the snapping and tearing of the strata, whereby faults would be produced, also happened, we can well believe.

But if we now enquire as to what sort of faults would be produced, we shall be obliged to own that only such as could enable the strata to take up less horizontal space, in compliance with the lateral pressure, would be of any service in relieving the state of strain. From this we see that a vertical fault, having no effect of this kind, would be of rare occurrence. On the other hand, a reversed strike-fault, inclined at some angle with the vertical, would not only relieve the constant strain and bending of the rocks, but would directly contribute to the horizontal compression of the region by allowing the rocks on one side to work up over those on the other side; thus increasing the vertical thickness of the earth's crust at the expense of its horizontal extension. There being such a manifest relief accruing from such faults as these, it is but natural to suppose there would be a strong tendency to their formation. But their direct consequence is to bring about stratigraphical complexities of precisely the kind we have to deal with, by forcing older beds over the top of younger formations. On the other hand, a fault with the down throw towards the hade would obviously increase the horizontal extension of the rocks, and there could be no predominating tendency to its formation in a tract of country subject to great lateral compression. It seems, indeed, impossible to imagine them occurring in any mountainous tract, other than some few mountains due to great vertical elevation; except as dip-faults, or as secondary results due to local and intermittent relaxations.

There is thus a good *à priori* reason for expecting to find reversed strike faults, and them alone on a large scale, in the district under discussion. But that the boundary of the Tal beds with the schistose series should be so persistently a reversed fault on the dip side, an uninjured synclinal of the younger rocks scarcely ever (in only one instance that I know of) being preserved, does seem a little remarkable, until we remember that the Tal beds, save for the slight capping of nummulitics, must have been the uppermost rocks at the time when the elevation consequent on the lateral pressure began, and therefore it would only be in very favourable conditions that any trace of them would survive from the rapid denudation consequent on emergence from the sea and subsequent atmospheric waste. Simple folding would no doubt tend to bring this preservation about by allowing the anticlinal folds to be swept away whilst the synclinals were saved by being depressed below the action of the denudation agents; but it would not give results so decisive as that ultimate phase of a synclinal[1] (in combination with an anticlinal) developing a thrust plane, or reversed strike fault; whereby the Tal beds, and in some cases the nummulitics, would be actually thrust and buried under a capping of older beds; and so protected by them from all subsequent wear and tear of denudation. We are obliged to admit, from the evidence before us, that the synclinal, except in one instance, was found insufficient, and the sigma-flexure and reversed thrust plane sufficient, for their preservation; and in believing this we shall do no violence to thought, and the apparent remarkable coincidences become reasonable necessities.

A certain additional weight is given to these conclusions, when we remember that the position of the Siwalik and other upper-tertiary rocks with regard to the Outer formations, where they front the plains, is exactly what that of the Outer formations is

[1] Called a sigma-flexure, folded flexure, reflexed fold or overfold. See Heim's Atlas "Untersuchungen über den Mechanismus der Gebirgsbildung," and Lapworth's "Secret of the Highlands." *Geological Magazine*, 1883.

with regard to the schistose series. It has long since been shown by Mr. Medlicott and others that the later tertiary rocks (about the age of which there is no doubt) dip down against older Himalayan rocks, from which they are separated by a reversed fault; and there seems every reason to believe that the causes which produced this condition were simply a repetition in more recent times of a similar type of earth-movement to that which I have advocated above. In ages to come, when the Siwaliks have been worn away at their outer edge more completely by denudation, there will be left a narrow band of rocks analogous to the present reduced state of the Tal; and presenting the same phenomena of persistently dipping beneath much older beds.

It has now been proved: first, that the apparent order, among themselves, of the Outer formations near the Ganges, is their natural historical order; and, secondly, that the Inner schistose series is of older formation than the whole of the encircling Outer series.

It is satisfactory to note as a favourable issue that the complete proof now established shows that the chronological succession of the rocks as here interpreted, is a natural, and not a strained one: for, first, the more highly metamorphosed rocks are found to be the oldest; whilst decreasing age is similarly marked by a commensurate decreasing metamorphism. Secondly, the non-fossiliferous formations pose naturally as older than those which display fossils, whilst the latter, as we should expect, are together and the youngest; and, thirdly, the difficulty of the Kalogarhi gneissose mass is overcome; for since the schistose series, among which it appears, are the oldest beds, its presence whether it prove to be an archæan gneiss, which under pressure and high temperature, at extreme depths, has at some period been liquified, and so merited the name of granite; or whether it be an intrusion of subsequent date, *i.e.*, a granite in which contemporaneous or subsequent foliation has been superinduced by pressure—in either of these cases there is nothing so abnormal as to be improbable.

In this paper I have only touched on the main difficulty, ignoring for the present all less prominent questions, which a close scrutiny of the maps will suggest, *e.g.*, the unconformability of the members of the outer series amongst themselves and the marked unconformability indicated near the Sour and Kotedwar glens between the Tal beds and the schistose series. The map there shows the great thrust plane absent, and the Tal beds and nummulitics in an undisturbed synclinal. Hence the Tal beds are disposed indiscriminately on the schistose series, the purple slates, &c., and the massive limestone; a condition implying contortion and denudation such as to expose the schistose series at the time when the Tal beds were deposited. I have also refrained from going into more descriptive detail than was absolutely necessary to bring out the points of chief significance.

Above all, it seems to me that the foregoing results afford a useful lesson in enjoining the utmost caution and accuracy of mapping; in order that, amongst such intensely folded rocks, a right distinction may be drawn between ordinary dip planes and thrust planes; especially when the latter have a perfect parallelism in strike with the strike of the rocks, and hence cannot readily be recognized as differing in any way from ordinary dip planes. Extreme circumspection in this matter is a *sine quâ non* if good work is to be done in mountainous regions.

In conclusion, a few remarks may be made with regard to the connection between the district just described and other parts of Garhwal and Kumaun visited by me in the course of last season.

From the point where the east and west Nyar rivers meet, I went north-east up to the head of the east Nyar, finding nothing but the schistose series the whole way until Kainur was reached. There, the presence of more decided schists, and garnetiferous schists, heralded the incoming of more of the gneissose granite. Dudatoli, the culminating peak of the neighbourhood, like Kalogarhi in the district just described, is composed of that rock; and from it in a westerly direction extend bedded bands, strongly developed at first, but dying out gradually. All details are out of place here, as the work is still only half mapped; but I would wish to point out the exact correspondence between the gneissose granite, both in composition and in habit, here and at Kalogarhi. The only difference is, that it comes on more strongly, but at the same time more gradually: some of the first bed-like intrusions alternating with schists, as though the result of direct metamorphism. By tracing the beds laterally, however, it is seen that they die out away from the central mass of Dudatoli, and close in towards it; so that they are in reality but elongated "fingers" protruding from the Dudatoli massif.

Further north, beyond the head of the west Nyar river, we have a faulted junction, bringing in purple slates and the massive limestone along the Dobri-Danpur ridge; beyond which a thick set of diorites and quartzites make a first appearance. From here in a south-east direction towards Naini Tal we cross a similar set of formations.

One may then say (roughly generalizing) that the schistose series and gneissose granite about Ranikhet and Dwárahath are most probably representatives of like beds described in the foregoing paper; whilst the slates and massive limestone displayed about Naini Tal are, with equal probability, representatives of the purple slates and limestone also there described. It is to be noted, however, that the Tal beds, or at least the fossiliferous portion of them, are not seen near Naini Tal, and the nummulitics, though said to have been found by Messrs. Schlagintweit [1] are almost certainly absent also.

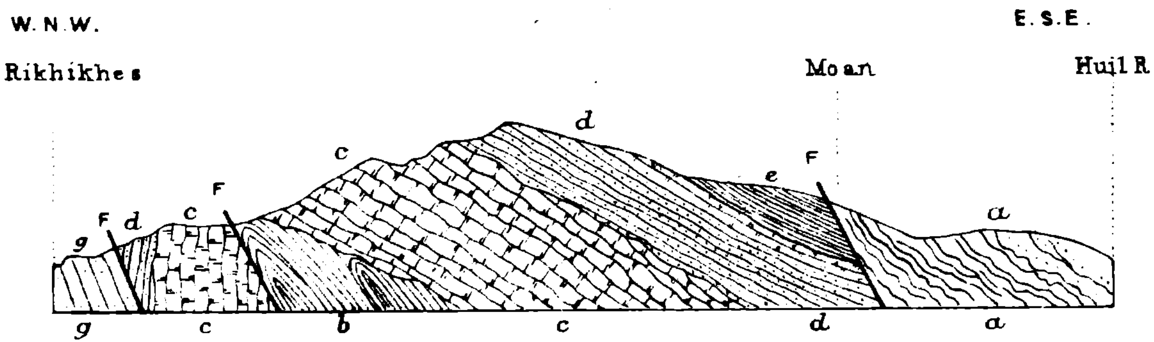
Notes on the Geology *of the* Garo Hills, *by* T. D. LATOUCHE, B.A., *Geological Survey of India.*

The main features of the geology of the Garo Hills have been known for several years and described in the Records and Memoirs of the Geological Survey,[2] but the valley of the Sumesary, where considerable fields of coal exist, is the only portion of the hills that has hitherto been examined in detail.[3] During the past

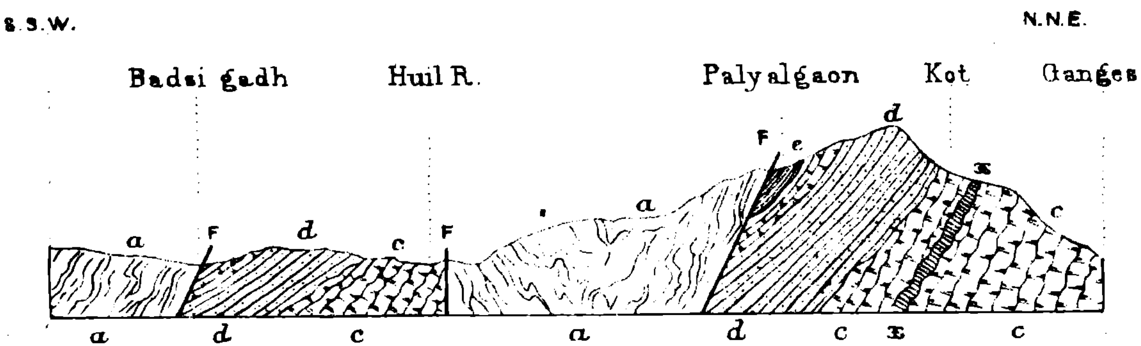
[1] See Manual of Geology of India, p. 609; also Journal, Asiatic Society of Bengal, Vol. XXV, p. 118.

[2] Records, Vol. I, Pt. 1, p. 11. Vol. VII, Pt. 2, p. 58. Mem. G. S. I., Vol. VII, p. 151.

[3] Records, Vol. XV, Pt. 3.



Section along AA.



Section along BB.

INDEX.

g. Siwalik.

e. Nummulitic. }
d. Tal: Mesozoic. } Outer Formations.
c. Massive Limestone. }
b. Purple slates &c. }

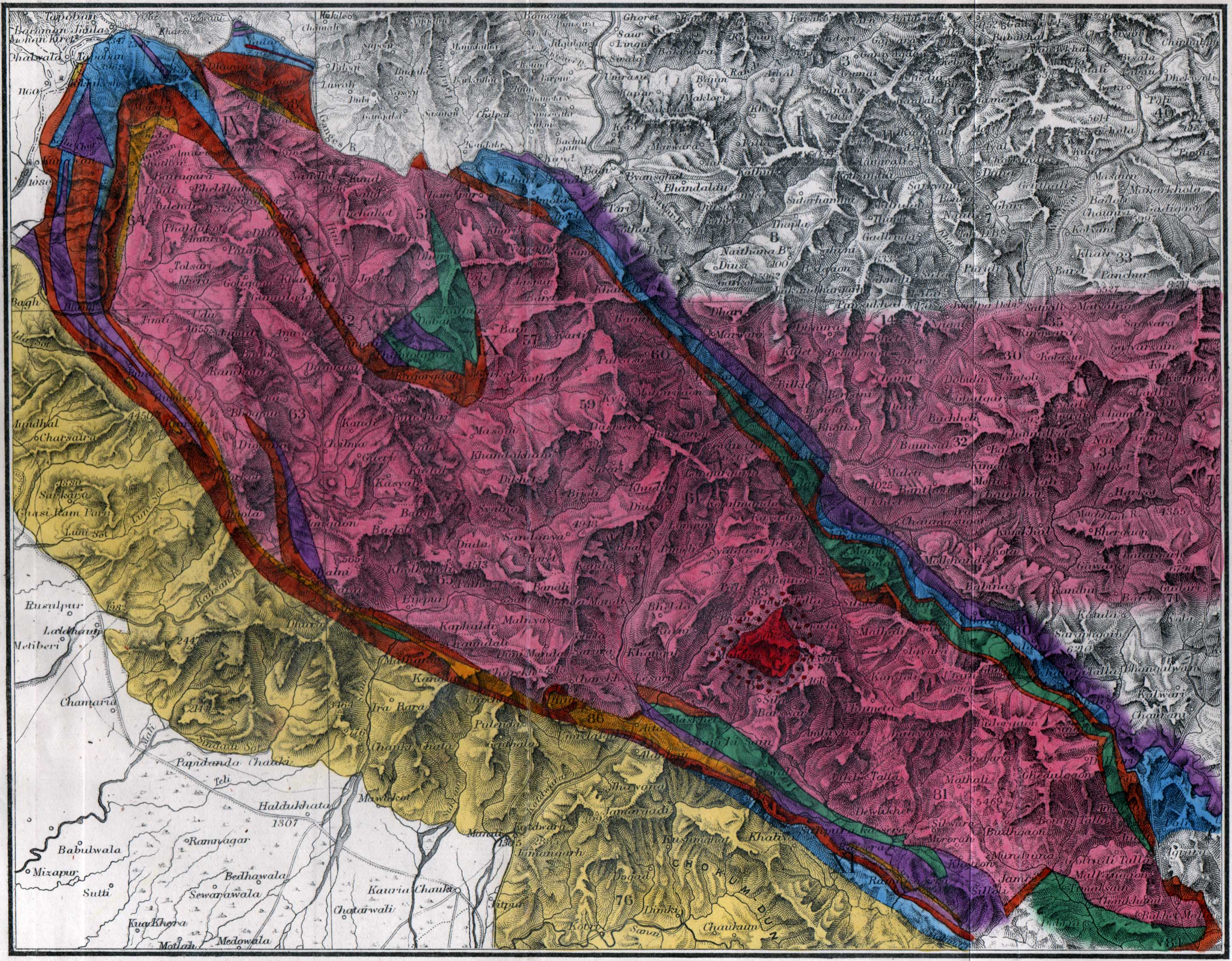
a. Schistese Series. Inner Formation.

x. Diorite.

F. Fault.

A MINULLAH

PART OF BRITISH GARHWAL: SECTIONS. *See the 1-inch Map*.



INDEX.

- Sub-Himalayan (U. Tertiary).
- Nummulitic (L. Tertiary).
- Tál (Mesozoic).
- Massive Limestone.
- Purple slates, &c.
- Volcanic breccia.
- Schistose series Garnitiferous.
- Diorite.
- G Gneissose granite.
- Fault lines.

Taken from portions of Sheets Nos. 48 and 66 of the Atlas of India.

Scale 1 Inch = 4 Miles.

5 4 3 2 1 0 5 10 Miles.

Lithographed at the Survey of India Offices, Calcutta, July 1886.

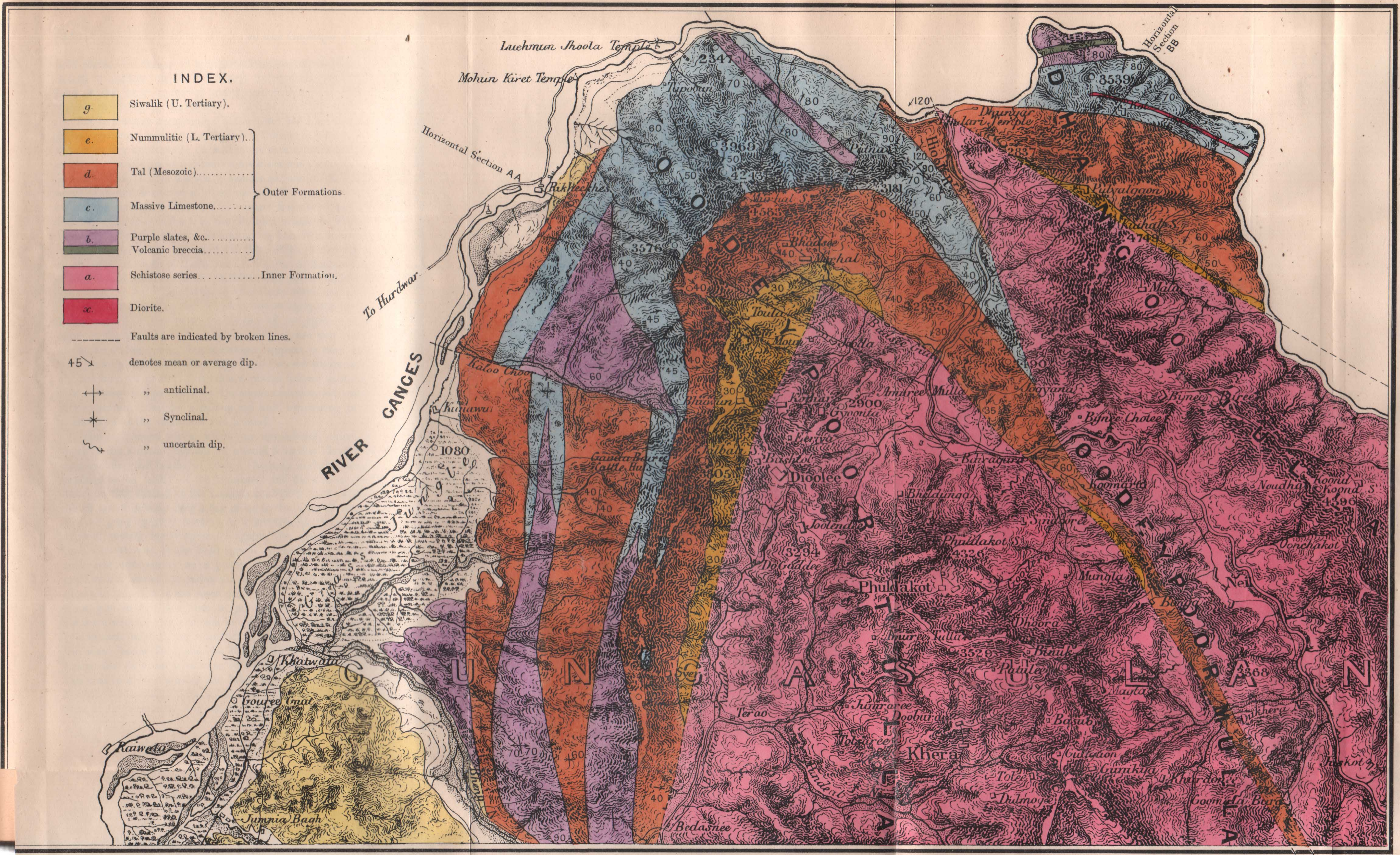


Photo-Lithographed at the Survey of India Offices, Calcutta, June 1886.

Scale 1 Mile = 1 Inch

1 ½ 0 1 2 3 4 5 Miles

Dry and cold north and north-east winds are the prevailing air currents during the dry seasons (summer and autumn); they absorb moisture, even such moisture as the soil may receive from rain and snow during the remainder of the year. This accounts for the rapid destruction of the cretaceous and tertiary sandstone, the decomposed material of which is carried away by the air currents of the dry seasons and re-deposited in the deserts of the Oxus and Sir-Dariyá.

Crystalline *and* Metamorphic Rocks *of the* Lower Himalaya, Garhwal, and Kumaun. Section I, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India* (with map and plate).

INTRODUCTION.

Although much has been done recently, by Colonel McMahon, to bring to light the structures of the gneissose and other crystalline rocks of the N. W. Himalaya, and to frame reasonable hypotheses as to their cause, it must be admitted by every one who has looked into the subject that much yet remains unaccomplished. Microscopical work of high order, and detailed sections carried along one or two lines of country, are of the greatest service to geology; and the value of the papers which Colonel McMahon has from time to time contributed to this journal cannot be over-estimated. But for the rational account of an expanse of crystalline rocks something more is wanted which the above cannot supply; I refer to the actual tracing, step by step, of their relations in the field, or in other words, a patient mapping of the district on an adequate scale. Petrography at the present day is in such a state of transition with regard to many of its most vital principles, that the reading of any one district by the petrographical alphabet made out in another should be supplemented by deliberate endeavour to ascertain how far that alphabet can apply to the district, and by how much it falls short. With this end in view, it seems to me that fairly detailed descriptions of the arrangement, internal structure, lie, and associations of the crytalline rocks of this part of the Himalaya, drawn from exhaustive field observations, will constitute the safest and most impartial evidence attainable in the great questions always pressing for solution among crystalline and metamorphic rocks. I therefore propose to describe here and subsequently a series of localities where these rocks appear to show to the best advantage, the descriptions in all cases being based on a thorough mapping of the area on the one inch scale. There will then be no need for elaborate argument and careful balancing of probabilities; each locality will tell its own tale, so far as structure, lie, and behaviour of the rocks can tell it; each district will depend entirely on its own internal evidence alone, and I shall endeavour as much as possible to banish the risky proceeding of generalizing over large areas. Detailed field exploration is the basis of geology, and sooner or later will extract the secrets from the rocks; and that without recourse to interpretations borrowed from other countries, which may be, but are equally likely *not* to be, applicable, and without appeal to principles and theories supposed to be universally accepted, but which may be after all only partially true.

DUDATOLI MOUNTAIN, BRITISH GARHWAL.

I will begin these descriptive notes by an account of Dudatoli Mountain and its surrounding spurs. I have already mentioned it in a previous number of the "Records," but without giving any details.[1] This mountain, which rises to the height of 10,188 feet, constitutes the source of the Ramganga and the east and west Nyar rivers, all of which are tributaries of the Ganges. It is by far the highest mountain in the neighbourhood. Most of its upper slopes are covered with dense forest of pine, with an undergrowth of Ringall reeds; snow lying for a great part of the year among its sheltered and rocky fastnesses. Without implying more than is directly stated, I may say that it bears a very strong resemblance to Kalogarhi Mountain[1] (Kálandanda) situated further to the south-west and near the plains and also to the Chor Mountain near Simla; both in the way it rises above the surrounding country and in its geological structure.

Geological structure.

Speaking roughly, Dudatoli and its neighbouring hill spurs may be said to be composed of two sets of rocks, namely, mica schist and gneissose granite. These vary among themselves and shade off into different varieties which will be mentioned in due course. Their general surface arrangement will be seen from the accompanying map. The structural features are those of a quaquaversal synclinal elongated in the direction north-west—south-east. The uppermost and lowermost beds are schists of varying character; whilst the gneissose granite appears at numerous horizons insinuated among the schists, seemingly bedded with them, but in lenticular beds which expand or thin out with extreme rapidity. On the east, south, and west sides these lenticular beds are very prominently developed, whilst on the north there is only one thin but continuous band. The Dudatoli ridge itself is very nearly uniformly composed of the gneissose granite, the one or two thin bands of mica-schist which intervene being very unimportant. East of a line between the two Dudatoli peaks, the gneissose rock rapidly breaks up into a fringe of thin beds whose foliation planes dip roughly towards the south-west. They ultimately thin out altogether. West of the two peaks there is one blunted protruding mass in the direction of Gulek, whilst the long thin band alluded to above passes from Dobri trigonometrical station by Tarakakand, Banjkot, and Kotkhandia trigonometrical stations, and the villages Sountee and Hartur. Near the last mentioned place it is interrupted by a fault, but apparently was originally continuous into re-connection with the Dudatoli massif by means of the band

[1] Records, XX. pt. 1, p. 40.

which now runs along the Bandhia ridge. This tongue of gneissose granite has thus almost completed an ellipse of outcrop, and from the quaquaversal dip can only indicate a continuous sheet beneath the schistose strata of Naori which are the highest beds visible of the series. Apparently below this continuous bed there are several more lenticular masses of the gneissose granite inserted between the schistose strata, but only outcropping on the south side of the synclinal. They rapidly thin out towards the north-west beyond Dujukatoli and gradually coalesce for the most part towards the east-south-east and join the south extension of the Dudatoli massif. South of Kainur there are one or two very thin beds which run for a short distance and thin out both ways. If they have any connection with the main mass of the rock it must be a subterranean one.

I have already called attention to the like disposition of the similar rocks at Kalogarhi Mountain and at the Rama Serai,[1] and I here lay especial stress upon the fact, because in a line of section from the Sub-Himalayan boundary to the snows running through Kalogarhi, Dudatoli, and Kedarnath, the only regular apparent synclinals of any importance are connected with the gneissose and schistose series. Nowhere except on the north side of a mass of gneissose granite is there ever a prevailing south dip of the strata. This may be either a coincidence or a necessary relation. I leave the question at present to be afterwards returned to.

Schistose series.

I now come to some of the most marked features in the schistose series, which forms as it were a groundwork for the gneissose granite. Over a large area these rocks consist of the more arenaceous, or quartz-schist type with thinner dividing beds of more argillaceous schists; the schistosity being not very marked. Foliation takes place in the majority of cases along the original bedding, as is well demonstrated, where the arenaceous and slaty types interbed. In some few cases however I found it crossing the bedding along incipient cleavage planes, especially in some quartz-schists; whilst films of mica were often visible along joint planes. In addition, wherever the rocks had been much crushed and cut by nearly parallel divisional planes and by slickensides their surfaces were also coated with a thin micaceous glaze. In some cases among the quartz-schists laminæ more or less micaceous had been cleaved across, and the mica plates re-arranged perpendicular to the laminæ where they occur. To whatever cause this regional metamorphism be due, it is certain that it begins imperceptibly and continues with a minor degree of intensity over a large tract. The section from Shánkar on the Ramganga due north to near Hansuri on the east Nyar plainly demonstrates this. About a mile from any outcrop of gneissose granite as we approach the Dudatoli massif, in no matter what direction, there is a rapid, but gradual change sets in in the metamorphism of the schistose beds. The faint films of micaceous material assume by degrees the aspect of distinct layers of mica plates of considerable thickness. Vein quartz appears ramifying along the foliation planes. Garnets gradually assemble in the schist; first showing as minute pin-heads under a coating of what one may call mica-leaf, and gradually increasing in size and definiteness concomitantly with the mica until they reach an average size of peas, and rarely as large as filberts. On every side of the Dudatoli area can these most

[1] Records, XX., pt. 1, p. 30.

striking changes be observed. In the present paper I am only offering evidence collected in the field, and consequently confine my observations to what is visible under a pocket lens or to the eye.

Varieties of the schists.

The more intensely crystalline schists may, as a rule, be divided into two kinds from a structural point of view. The more common type is one in which the planes of foliation have a wavy or blistered appearance, and are completely covered with mica of a pale silvery hue. The leaves of mica are, as it were, welded together along the wavy irregularities of the foliation planes, forming an uninterrupted layer of the shining mineral. Under the lens the garnets are of a dull claret colour, and when not mere grains are of a more or less distinctly crystalline form. The break of continuity along the foliæ, caused by a garnet, is always overcome by the mica plates waving round it on both sides. Nevertheless, I also found other plates which ran undisturbed towards the garnet, and then stopped abruptly (see fig. 1). The quartz, which in this type is very subordinate, is of necessity present in lenticular layers between the waving sheets of mica. Secondary quartz, in large lenticular or nodular strings, enwrapped in a thin tissue of mica, is frequently met with. The other type of schist is a much more quartzose rock, and is regularly bedded with the former. The mica in this case does not cover in, in a complete manner, the foliation planes. Instead, it is disseminated in small flakes, and is of silvery hue, and also brown. At the same time, their arrangement is always parallel with the bedding, causing a genuine foliation. Garnets are scarcer than in the former rock.

The first of these two types is only rarely puckered or corrugated. Near Malkori pass south-east of Dudatoli there is a variety in which the mica plates, with a leaden sheen, have the appearance of shrivelled tea-leaves. A rather singular structure arrested my attention in the schistose beds as they are advancing from the widely spread slightly schistose kind to the more intensely metamorphic border round the gneissose granite. The foliation surfaces, which were very regular, straight planes, shewed a set of parallel ridges and furrows running in the direction of the dip. They were very minute, and a good idea of the effect to the eye may be obtained from the aspect of a corrugated iron roof.

I may here emphasize two points—first, the schist found near the gneissose granite is entirely a thorough crystalline schist, a fact needing no microscope to demonstrate; and secondly, along a line of country, where rock is exposed at every step, it is seen that this culminating intense form *graduates* into a wide-spread less intense form, and that in turn *graduates* into ordinary slates and quartzites.

From the universality of the changes as the gneissose granite is approached, it is only reasonable to conclude either that the extra schistosity and the development of garnets were brought about by the introduction of the gneissose granite (in whatever way the latter was produced), or that they and the gneissose granite were the joint result of some more remote and subtle cause. In any case, the two rock states are so inseparable that they may be classed as contemporary. It follows that whatever can be proved concerning the geological age of the one may be taken as evidence for the age of the other. The importance of this will be noticed in a paper to follow.

I was unable to gather any clue from the manner of occurrence of the garnets.

The bending round of the mica plates does not satisfy me as an argument for the priority of crystallisation of the garnets.[1] I may, however, say that the latter in all their stages, from the minutest speck to the fully crystallised form, were always intact: there was no sign of crushing or drawing out of them with the foliation. Perhaps a microscopic examination may yield more decisive results.

Gneissose granite.

Turning now to the gneissose granite of the Dudatoli neighbourhood, it is necessary to say something of its mineralogical composition. In this I shall be brief, partly because the rock seems to answer perfectly to much of the allied rock already so luminously described by Colonel McMahon, and partly because the object of this paper is rather to draw attention to the larger aspect of the rock in the field than to its microscopical character. At the same time, I may point out that its coarsely crystalline condition makes the examination under the lens not so hazardous and superficial a matter as it might otherwise appear. It must be borne in mind that I am speaking at present of the rock in this locality of Dudatoli only.

The rock as a whole may be said to be eminently felspathic, and distinguished from an ordinary granite or gneiss by the presence of schorl crystals. These latter occur in all manner of conditions, from large to small, from perfect prisms to others which are manifestly severed portions of a single prism, and held together like a string of beads. The schorl is the most completely crystallised of the minerals; the micas, black and white, come next, often constituting the only perfectly crystallised minerals in the rock. Orthoclase, in rectangular prisms sometimes twinned, is not typical in the rock, but usually appears as in an "augen" or kernel gneiss. The quartz as in all granites is always without crystalline form and fills the interstices between the other minerals. In many cases minute granules of quartz and small portions of schorl are contained in the larger porphyritic orthoclase crystals and "eyes." Garnets occur very sparingly, sometimes singly and sometimes in nests. Kyanite, Beryl, and other accessory minerals I am confident are not present in this locality.

This outline is sufficient to shew the general mineralogical resemblance between this rock and others described by numerous writers on other parts of the Himalaya.

In themselves the minerals are not so important as in their mode of arrangement which varies so conspicuously in different parts of the same mass of gneissose granite that it requires very special mention. In describing these I may add that they are paralleled nearly always in the Chor and Kalogarhi Mountains; but at Kedarnath we come upon rocks of an altogether different structure, and none of the remarks to follow will consequently apply to the gneissose rock of the snowy range where I have at present seen it. The latter better agrees with Stoliczka's "Central gneiss"[2] or what Fouqué and Lévy call "gneiss granulitique."[3] I hope to describe it later.

Varieties of the gneissose granite.

The Dudatoli gneissose granite for the purpose of classification easily divides up into three types—(A) FOLIATED, (B) SEMI-FOLIATED, (C) NON-FOLIATED. These three all graduate one into the other.

(A) may be sub-divided into (1) *Tabular foliated*, (2) *Lenticular-Tabular foliated.*

[1] See Minéralogie Micrographique, Fouqué and Lévy, Manche III., fig. 2.

[2] See Mem. G. S. I., V., pt. I, p. 12.

[3] Minéralogie Micrographique, p. 175.

(A) (1) is a variety not often seen in this part, and then only near the junction with the schists. It is the most decidedly fissile of any of the varieties. It is built up of continuous straight foliæ of felspar and quartz, with intermediate foliæ of mica in continuous films. These each run their own course at least for a great distance without coinciding, the mica being very generally muscovite only. To the weather and to the hammer this rock behaves more like a schist than a granite (see fig. 2).

(A) (2) is much more common, especially in the thinner bands of the rock, which occur near the outskirts of the gneissose granite area. In it the felspar is still undifferentiated into eyes or crystals; but the foliæ of felspar and quartz swell out and thin again (see fig. 3), foreshadowing the perfect eyes of the prevailing forms of the gneissose granite (see B). In using the words "undifferentiated" and "foreshadowing," I by no means imply that the lenticular-tabular is necessarily an embryonic condition of the augen. It seems as likely that the reverse is the case, for in some quartzites of coarse grain, between Rudarprayag and Agastmundi, I have seen the grains, originally rounded, absorbing smaller portions of quartz at each end and so taking on a lenticular appearance, which with the mica films developed coincidently gave the appearance of a lenticular-tabular quartz schist (see fig. 5).

(B) may be sub-divided into (1) *Augen*, (2) *Porphyritic-augen.*

In (B) (1) the different mineral layers are no longer distinct. On the contrary, the mica plates of two layers unite with each other on each side of an "eye," thus cutting up the felspathic layer into a number of isolated eyes (see fig. 4). The long axes of the eyes being parallel give the semi-foliated character to the rock. Connected with this sub-division is a rock, which on the foliation planes shews eyes of felspar blotched and drawn out in the direction of dip. It and the lenticular-tabular quartz schist mentioned above seem to indicate differential movements of the particles of the rock, and are paralleled by structures in other basic rocks, which I hope to describe in another number.

(B) (2) only differs from (B) (1), by containing, in addition, larger, more blunted eyes at intervals, very often turned in directions other than parallel with the foliation and sometimes approximating to a rectangular outline. This sub-division is the most developed of any at Dudatoti, the Chor and Kalogarhi.

(C) in all respects resembles a normal granite, and is usually porphyritic, the porphyritic crystals being always sharply rectangular and often twinned. They are oriented in all directions.

General facts of distribution.

The result of a careful examination of the Dudatoli area is to shew that the sub-division (A) (2) is nearly always found in the thinner bands of the rock, and in the thicker ones near the junction with the schists. The division B is found impartially in all but the thinnest bands. The division C is only found in those parts where the bands of gneissose granite have united together to form a wide continuous mass, and then only in small quantities compared with the division B. These results may be shortly stated by saying that the more the rock loses its bedded appearance the more it approaches a massive and perfectly granitic form; whilst wherever it alternates rapidly by interbedding with the schists, the foliated and semi-foliated types predominate.

Inter-relations between the schists and the gneissose granite.

I must now advert to a consideration of the inter-relations between the schists and the gneissose granite. These are of such great importance in understanding by how much the latter has acted functionally as an intrusive rock, are so amply demonstrated by close work with the hammer, and may hence be said to be the field-geologist's speciality, that I make no apology for treating them fully in this place. The gneissose granite of Dudatoli, in no case that I know of, breaks through the schists, disturbing them: no violent contortions, no puckerings of the foliation planes ever take place as distinct results of the intrusion of the gneissose granite. The difference between this rock and a genuine intrusive granite with large masses of muscovite, which very rarely occurs in the Dudatoli area, and which by the fact that it has no passage forms towards the gneissose granite may be considered to be entirely distinct and doubtless of another geological age, is most marked. A block of mica-schist containing the latter is penetrated irregularly by an amœbiform mass of it which at every thrown-out process or vein has crumpled and tortured the schist into utter compliance with its own irregularities of shape. Compare this with the thin band of gneissose granite near Hansuri, thoroughly exposed in the river section. Its upper and lower surfaces are perfect planes fitting in with similar planes in the mica schist. If the former rock had been sawn in a mason's yard and fitted in with artistic precision, it could not present a more composed aspect, both in its own regular structural planes and in those of the mica schist among which it lies. And yet the two rocks are so unlike that a pencil point may be placed precisely on the junction line. Or consider again what looks on the map a contradiction to the statement of its non-eruptive character, *viz.*, the blunted process near Gulek. At Burari the dip of the foliation of the gneissose granite is S.-W. 30°; and that of the schists in contact is perfectly parallel. Following the junction boundary north-west, there is, near Risti, a more westerly dip in the gneissose granite; and this is also conformed to by the schistose beds. East of Gulek the dips of both have worked round towards the north-west, still retaining their concordancy. Similarly, if the boundary line be further examined, turning towards the north and north-west below Dobri trigonometrical station, it will equally be seen that there is no sudden intrusion, no erupting of the one rock among the other, but on the other hand that each has its foliation planes perfectly parallel with the other, and there is no contortion or puckering of the mica-schist whatever. Without going into detail over the whole map, I may summarily state that everywhere, except where a fault is manifest, the lie of the one rock coincides completely with the lie of the other: such an event as the foliation lines of one crossing at right angles the foliation of the other is unknown.

That the foliation represents true bedding, is placed beyond a doubt by the numerous river sections where from a great height the interbedding of the two rocks can be traced conforming to the trend of the foliation planes. Thus the gneissose granite is *insinuated* among the schists; and if it is intrusive from a foreign source, and not inborn, it must have acted on the principle of the wedge and parted the schists with wonderful precision along very great distances. At Kalogarhi the same remarks apply.

Junction exposures.

The individual beds of the gneissose granite are, as a rule, sharply marked off from the mica-schist, although a large bed nearly always splits up into numerous smaller ones near the schistose margin. These cannot be rendered on the map. An exception to this rule at Eera village is very striking. There the schists merge into the gneissose granite by the gradual acquisition of felspar. This takes place in such minute quantities at first, in the form of small veins, that it is impossible to say where the one rock ends and the other begins. The same conditions are repeated numberless times; so that only diagramatic mapping can be attempted there.

The junction section at Marwara needs a few special remarks. The gneissose granite of (B) (2) type does not fade away into the schist, but it stops abruptly and is followed by a pure mica-schist composed of bronze-coloured mica and quartz. But among the mica-schist next the gneissose granite there are thin beds, 3 or 4 inches across, of fine-grained gneissose granite, very sharply cut oft from the mica-schist. There may be a dozen or more of them (see fig. 6). Notwithstanding their thinness, porphyritic crystals of orthoclose are developed, often filling up the whole of the breadth of the band, and even where too large slightly bulging out the walls of mica-schist.

One more junction structure, well marked at Byansi, is that of a mica-schist as a ground-work, in which large porphyritic eyes of orthoclase are developed singly or in strings. The schist is fine-grained and the eyes of orthoclase stand out in bold relief. In other parts of the Himalaya I have seen this doubtful form prevailing almost to the exclusion of any other.

Inclusion in the gneissose granite.

I have only seen one included fragment of rock in the Dudatoli gneissose granite. This was in a large torrent boulder in the stream below Kainur. The boulder was of the porphyritic augen type, and the included fragment of mica-schist of the more arenaceous kind (see fig. 7). Doubtless more exist, but I am inclined to think they are by no means plentiful. A cursory examination of the Chor in 1884 revealed several examples of inclusions of schist and quartzite; whereas more detailed work at Dudatoli has only been rewarded by one find.

Geotectonic features.

Returning to the geotectonic features of the area, the problems expressed in the present synclinal arrangement of the beds are many. The certainty that at some period there must have been a folding of the rocks leading up to the synclinal, provokes the question whether this earth-movement took place before or after the introduction of the gneissose granite. If before, then we have to account for the latter choosing a widespread synclinal oasis as the place at which to escape from its plutonic confinement; if after, we must seek for the influence, which the gneissose granite possessed, in holding in check the waves of flexure, which setting in from all sides seem to have subsided so conspicuously before the gneissose granite, here, at Kalogarhi and at the Rama Serai. One other alternative, that they were contemporaneous, remains. Can the waves of contortion, meeting at this point, have neutralized one another's sensible movements and thereby induced the movements of particles and of molecules, causing cleavage, heat, and metamorphism?

In endeavouring to look these questions in the face we have the following facts to go upon:—

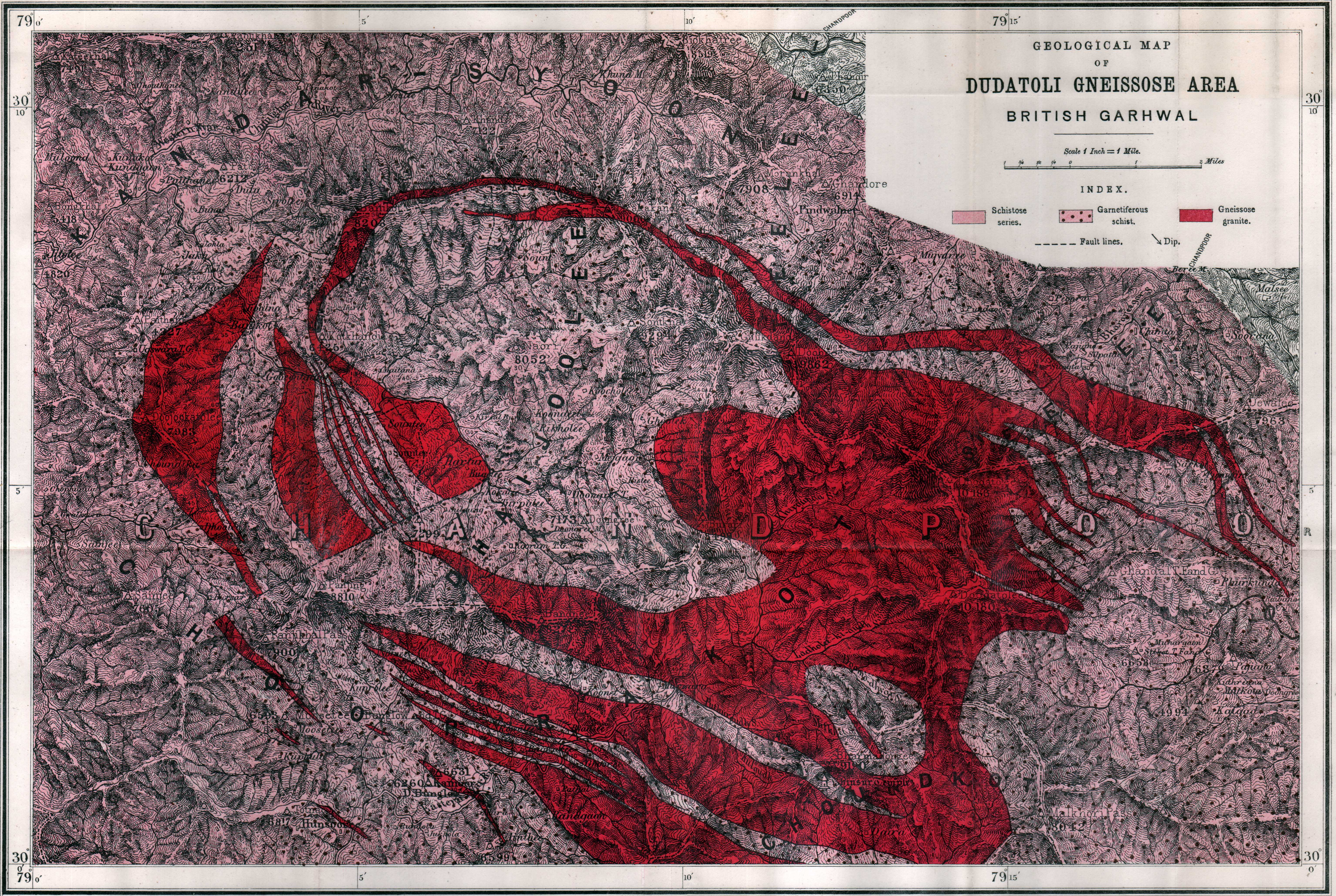
(1) Plutonic and metamorphic action by their deep-seated nature cannot be said to be influencing the Dudatoli area at the present time, nor to have done so in the immediate past.

(2) A wave of contortion of the strata, resulting in a quaquaversal thrust plane round the Kalogarhi centre, in post-nummulitic times, was proved in my last paper (Rec., XX, pt. I); whilst successive waves of longitudinal flexure, at still more recent dates, involving last of all the Siwaliks, have long been acknowledged as affecting the whole of the Himalaya.

From these considerations it seems that the crystalline rocks of Dudatoli must have long ago finished their metamorphism, whilst they have continued to suffer tangential pressure all through tertiary and recent times, if not from a more remote period. I am aware that Colonel McMahon holds to the late tertiary age of the gneissose granite of other parts of the Himalaya; but speaking of the parts of Garhwal and Kumaun with which I am acquainted, I fail to see how a rock of *deep-seated origin*, like that of Kalogarhi at a present elevation of 6,000 feet, can by any possibility be later than tertiary strata *in the same locality*, prominent for nothing so much as their uniform restriction in height to between the 3,000 and 4,000 feet levels. (See map, Rec., XX., pt. I.) And further, from their forming that prominent feature on the plain-ward side of the hills, to which the name Sub-Himalayan has been given, out of which they stray markedly neither in an upward, downward, nor lateral direction, it would be unreasonable to urge that they might have once covered much of the Himalayan region, and that their present state is but an infinitessimal relic of their former wide extension, dropped or forced low by faulting. That reversed faulting has in a manner tended to preserve them when they would otherwise have perished much more by denudation I have no doubt; but looking at the tertiaries in a broad comprehensive light, it is manifest that their position on the plain-ward edge of the hills at a uniform height and extending for hundreds of miles thus, is analogous on a large scale to a raised beach or high level gravel only *modified* by subsequent faulting. This is in substance what Mr. Medlicott has always advocated.[1] Pushing home the argument still further there is a step-like arrangement among the individual members of the tertiaries; for the oldest is usually in the highest position and reaches further into the Himalaya, whilst succeeding younger members stand at lower levels and nearer the plains, the last of which the Siwalik fronts the plains and rises out of them to a comparatively low elevation. Hence it is clear that each lateral thrust of the mountain area since nummulitic times caused, or was accompanied by, a further rising of the margin of the hills; and the tertiary deposits were stranded, one after the other, in positions varying in height according to their age.

To urge that the gneissose granite of Kalogarhi, at 6,000 feet, could have been formed during this tertiary period of steady periodical rise, is akin to claiming a sea-cliff as younger than the sandy shore at its base. There is also good reason to think that if the country had been depressed in tertiary times sufficient to allow of the

[1] Mem. G. S. I., III., pt. 2, chap. III.



Taken from Sheet 14, Kumaon & Garhwal Topographical Survey.

Photo.-chromo-lithographed at the Survey of India Offices, Calcutta, August 1887.

Fig. 1.

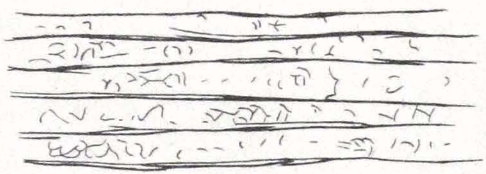


Fig. 2.

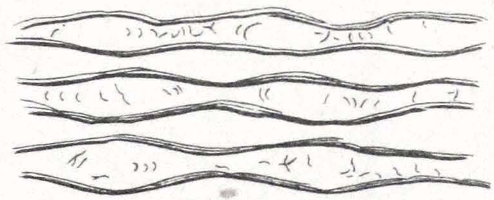


Fig. 3.

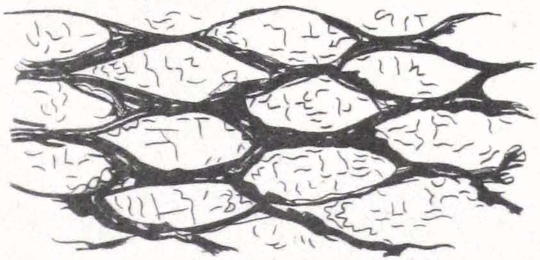


Fig. 4.

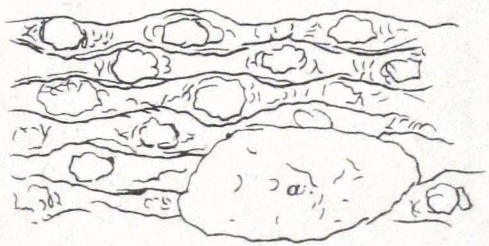


Fig. 5.

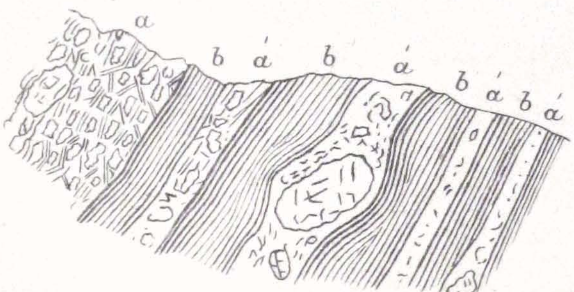


Fig. 6.

DIAGRAMS.

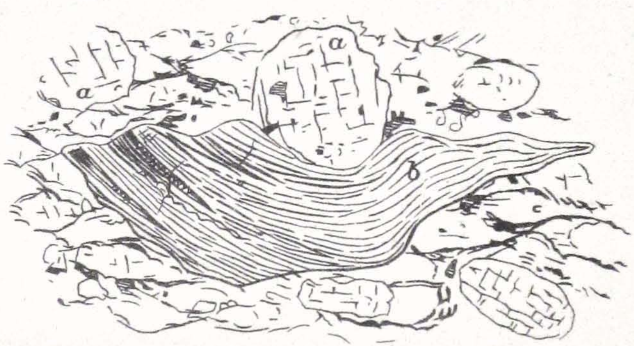


Fig. 7.

Aminullah.

formation of the gneissose granite where Kalogarhi now is, there would have been some phenomena of metamorphism exhibited by the tertiaries themselves, especially since in the Kotedwar glen they are only distant 5 or 6 miles from the intrusive boss of Kolagarhi.

On the whole, it would seem that Plutonic action first, followed by mechanical strain due to tangential pressure as the Himalaya continued and continue growing, must be considered the order in which the agents of change have acted on the Kalogarhi and Dudatoli areas. That this lateral pressure acting on slates and schists should bend them to its will, is not surprising; but we can also imagine that wherever they were stayed by ribs of massive granite, they would have strength to resist largely the contorting pressure, which would then spend itself producing re-arrangements of the particles and of the crystalline texture of the rocks, thus imprinting on them a foliated or semi-foliated character.

REFERENCES TO PLATE.

Fig. 1. Garnet in schist, shewing mica films folding round it.
„ 2. Gneissose granite, FOLIATED: *tabular*.
„ 3. Ditto ditto *lenticular-tabular*.
„ 4. Ditto SEMI-FOLIATED: "*augen*."
„ 5. Quartz schist shewing lenticular-tabular foliation *a*=pebble.
„ 6. Section at Marwara, near Kainur: *a*=gneissose granite mass. *a'*=thin bands of gneissose granite *b*=mica-schist.
„ 7. Inclusion of mica-schist (*b*) in gneissose granite (porphyritic "augen" near Kainur. *a*=porphyritic orthoclase crystal.

Preliminary Sketch of the Geology *of* Simla *and* Jutogh,[1] *by* R. D. OLDHAM, A.R.S.M., *Deputy Superintendent, Geological Survey of India.* (With a map.)

The geological structure of the Simla hill station, if regarded in detail, is one of extreme complexity of varying dips and innumerable faults, but on the large scale it is on the contrary simple to a degree, as may be seen on the accompanying map.

The oldest rocks are exposed along eastern and north-eastern limits of the map and all along the road to Mashobra; they consist of fine-grained micaceous grey slates with occasional quartzite bands, originally described by Mr. Medlicott as the infra-Blaini or Simla slates. On the spurs either side of Annandale the prevailing dip is south-west-by-south which further east bends round to west-south-west. Near the upper limit of these slates there are some bands of a very trap-like sandstone or grit which I have only seen on the spur between Annandale

[1] The observations on which this account is based were made during a brief stay in Simla while preparing to start into the interior: the main features will be found fairly correct, but the boundaries of the rock groups have in many cases been sketched in without having been followed in detail.

and the glen and again near Sanjaoli, though it would probably be found in a corresponding position elsewhere. When weathered it is impossible to tell this rock from a decomposed trap, and even the unweathered rock has a very trap-like appearance, but its detrital origin is shown by the presence of rugged scales of mica arranged parallel with the bedding.

At their upper limit these beds become impregnated with carbonaceous matter, and in consequence the colour becomes darker and the streak changes from pale grey to black. They are succeeded by a remarkable and important set of beds, called the Blini (since changed to Blaini) by Mr. Medlicott, from their occurrence in the valley of the Blaini stream hich flows westwards from Solon.

The group was described by Mr. Medlicott as consisting of a pure hard limestone, generally pink, composed of thin beds aggregating 15 to 20 feet thick, and a conglomerate consisting of a matrix of fine-grained slates through which pebbles of quartz or slate were scattered. As applied to the group in the Simla neighbourhood, this description must be amplified, for, underlying the limestone and "conglomerate," there come carbonaceous slates, which usually weather white on the bedding surfaces, and below these comes another "conglomerate," the whole being probably about 200 feet thick.

As this group is one of great interest and, owing to its marked characteristics, great importance, it will be well to clear the ground by explaining that what has been called a conglomerate in the foregoing passage is not a conglomerate at all in the usual acceptation of the term. The rock consists of a fine-grained matrix through which are scattered blocks of slate and quartzite, as a rule angular or sub-angular, in some cases containing 8 or 10 cubic feet of stone. It is evident that a current sufficiently violent to move these blocks would have swept away the fine silt in which they were imbedded, while, *per contra*, any current sluggish enough to allow of the deposition of this silt would be impotent to move the small pebbles, to say nothing of the larger blocks which the now indurated silt encloses. The only possible explanation is that these fragments were dropped into a comparatively tranquil sea in which the silt was being gradually deposited, but there are only three known agencies by which this could have been affected, *viz.*, volcanoes, floating trees, or floating ice.

The rock in some respects resembles a volcanic breccia, and the resemblance is occasionally far more marked than appears in the Simla rock, but the steadiness with which the rock preserves its character over large areas, the frequent occurrence of well-rounded pebbles, the comparative absence of actually angular fragments, and more especially the absence of associated lavas or volcanic ashes, tell against this hypothesis. Floating timber is known to transport fragments of rock often of considerable size, but it is difficult to imagine how the enormous number of stones found in the Blaini boulder slate could have been thus transported, nor why the boulders should be confined to certain well-defined horizons; it would be strange too if out of the vast number of trees that would be required to transport all the blocks found in the Blaini group, all escaped fossilization, and the absence of carbonaceous matter from the boulder beds is very marked when they are compared with the associated slates.

The only hypothesis that remains is that of floating ice, which presents no difficulties: floating ice is as capable of transporting waterworn pebbles as angular fragments without any limit of size; it melts away and leaves no trace beyond the fragments it may have carried with it, and, though the exact causes are not satisfactorily determined, it is a known fact that icebergs have formerly floated where none are now to be seen, and that regions now covered with perpetual snow and ice were once free from both. There is, consequently, no difficulty in accounting for the restriction of the transported blocks to certain definite horizons. Besides being the only hypothesis which does not land us in a difficulty there is a certain amount of corroborative evidence, for in 1884 Mr. C. S. Middlemiss discovered, in the Blaini group of the Naira (Neweli) valley in Eastern Sirmur, a pebble which was scratched in a manner very similar to that which is due to the action of glaciers, and I have myself seen in the neighbourbood of Simla several fragments which shew the same in a more or less obscure manner: in particular I may mention one block situated on the spur between Chadwick's falls and the glen which measures 4′ × 2′ × 1′ exposed; on one face it is smoothed and scored in a manner that can hardly but be due to glacial action. Taking everything into consideration we may, therefore, decide that when the Blaini group was being deposited, the spot now occupied by Simla was a sea on whose surface icebergs floated, melted, and dropped the stones, which they carried, on their surface or imbedded in their substance.

Returning now to the description of the rocks, the Blaini group, as defined on the accompanying map, consists at the base of a boulder slate; above this come carbonaceous slates which differ from those above and below by the manner in which they turn white on the weathered surfaces. The same feature is occasionally seen in the other carbonaceous beds, but in this particular band it is, so far as I know, universal. Above this again comes the original Blaini group of Mr. Medlicott. At the base it consists of a dark red slate which passes upwards into grey, occasionally blackish and carbonaceous, slate through which boulders are scattered, and above that there comes a thin-bedded pink limestone. It is this group of beds, not more than 60 feet thick in all, that is most easily traced (many of the exposures having already been recorded by Colonel McMahon[1]) and has been followed more completely by me than any other boundary. It enters the map in a side ravine flowing into the main stream below the Chadwick falls and can be traced over the spur into the Chadwick ravine; up the east side of this ravine it cannot be traced continuously, being hidden by surface debris; it may be cut by a small fault here, but this must be of later small throw, for the beds reappear in their proper position on the crest of the spur; they can be traced down into the glen, being hidden near the top and again near the bottom by soil cap, but, for the greater part of the way, can be traced practically continuously and closely follow one of the native footpaths. In the bed of the stream flowing through the glen the limestone is seen and is cut by a small fault which brings it into immediate contact with the red slates. It is again seen on the ascent from the glen and can be traced over the spur separating the glen from Annandale and runs down to where the road round this spur passes the spring which supplies the village of Gowai (of the map) with water. Here the limestone disappears, being apparently cut off by a fault; it cannot be traced across the Annandale valley owing to the rocks

[1] Records, G. S. I., X.

being hidden by sub-recent stream deposits, but may be seen in the stream bed and on the road which leads up the spur. East of Annandale it suddenly reappears, being evidently brought up by a fault. As the road rounds the end of the spur to turn back on itself, the red slates appear overlaid by the boulder bed and the limestone, here only represented by a few weathered blocks, the greater portion having apparently been removed by solution. The limestone and conglomerate can be traced with fair continuity over this spur along its western side, where again a native footpath follows it very closely into the ravines below the ridge. I did not follow it here, but it reappears below the ridge and can be traced up, passing below the Lakar Bazaar, on to the road round the north side of Jacko, where it crosses a spur and appears to run down into the valley west of Snowdon, but the ground is so covered that I was not able to trace it. Going along the North Jacko road the Blaini comes in once more, rather suddenly, as if brought up by a small fault, and runs past Snowdon, where there is a very characteristic exposure of the conglomerate just outside the guard-house. The limestone appears to run down under shady dell, but where not built on the ground is so covered with surface debris or spoil that has been tipped in levelling ground for roads or buildings, that it is impossible to follow the beds. However this may be, the Blaini is not again seen till just beyond the ravine where the upper and lower roads round Jacko separate. The beds are here brought up by a fault which shows itself as a line of springs. From here the Blaini can be traced across the upper road and up the spur to below the summer house in the grounds of Holly oak; here it appears to be again cut by a fault and is next seen just above where the road turns round the end of Jacko; there is only a small patch here, the beds cannot be traced in either direction, nor do they shew on either of the roads along the south side of Jacko. The limestone and conglomerate may however be found in the ravine below the Simla Rifle Club's range, west of and about level with the village of Sangati (Sanguti). I did not see it again till just above Shâman (Chaman) village where it can be traced practically continuously past Balahi, beyond which the limestone has been quarried. It runs down the west side of the Chota Chelsea spur and is seen near the Dhobi ghât below Chota Simla: hence it can be traced at intervals along the east slopes of the continuation of the Chota Simla spur till it runs out of the limits of the map.

It is noteworthy that the limestone is always well seen on the hill sides facing southwards, while on the northern face, which is covered with forest, the outcrop is always thin and often wanting. It is a known fact that the air contained in the interstices of the soil of a forest contains a larger proportion of carbonic acid gas than that of open ground; the water which percolates this soil would consequently become more impregnated with the gas and would be a more active solvent of the limestone than that which percolated the soil of the southern slopes. To this fact seems attributable the thinness or absence of outcrops of limestone on the northern slopes.

The lower conglomerate I did not trace with the same continuity as the upper one. It is seen in the Chadwick stream and again on the spur separating that from the glen. I next saw it where the road from the glen to Annandale passes over the spur, and it can be traced round the spur east of Annandale. On the Elysium spur it crops out where the path leads up to the Elysium Hotel and again immediately above the house called Sylvan Hall; it is seen below Snowdon and again in the stream east of the forest, but whence it runs round towards the Mayo Institute. It appears on the Mall just above this place and can be seen running at first along, then below, the Mall till it crosses the ridge where the lower road rounds the end of Jacko. Southwards from here I did not trace it, but have no doubt that it continues in the same position relative to the upper conglomerate, and have consequently drawn it as doing so.

Above the Blaini comes a band of slates or schistose slates characterised by being more or less impregnated with carbonaceous matter: these were regarded by Mr. Medlicott as the same as some very similar beds called by him infra-krol, owing to their occurrence beneath the limestone of the Krol Mountain, which rises above Solon. But as it is not certain whether these or some similar beds seen at Jutogh represent the beds of the Krol Mountain, it will be better to describe them as the lower or Jacko carbonaceous slates. The upper limit is very indefinite, being only determinable by the presence or absence of the carbonaceous ingredient, and as this appears to be very capriciously distributed, it is probable that beds of the same age may have been mapped in one place as belonging to this and in another to the next group. Owing to the indefiniteness of the boundary I did not pay much attention to it, and as drawn it is for the most part conjectural; but, apart from some such explanation as is given above, or faults which I have not detected, it is impossible to account for some peculiarities in the boundary, which do not appear to depend on the dip of the beds and contour of the ground.

The essential characteristic of this rock is the presence of an appreciable proportion of carbonaceous matter. Occasionally, more especially where the rock is crushed, this is very conspicuous, gives the rock a sooty appearance, and produces a blackness of the hill sides which can be recognized from a distance as at Chadwick's falls and on the road along the south face of Jacko between the convent and Sanjaoli Bazar. Where the carbonaceous matter is in so large a proportion, the rock often assumes bright colours on its surface due to the efflorescence of various soluble salts produced by the decomposition of some of the mineral constituents of the rock. As a rule however the carbonaceous element does not make itself so conspicuous and is only recognizable by the black colour and more especially the black streak of the slate. It is also noteworthy that where these beds are exposed on a ridge and have been much weathered, the carbonaceous element appears in many cases to have been almost if not entirely removed.

The Jacko carbonaceous slates follow the Blaini very closely, except that they run over the ridge and down the Combermere ravine where they extend to near the Brewery, but are ultimately covered up by the general south-south-west dip of the beds: immediately below the first waterfall is some dark limestone which may belong to these beds.

Above these carbonaceous slates, which are about 300 feet thick, there comes a thousand feet or so of quartzites and schists for which I cannot do better than adopt Mr. Medlicott's name of Boileauganj quartzites. It is these beds that are seen for many miles along the cartroad, along the whole of the Mall, except near the bazaar and the road to Jutogh, as well as on all the southern and western spurs. The greater bulk of the beds is quartzite, usually somewhat impure and schistose, but there is no small proportion of what must be called schist, occasionally garnetiferous. On the Boileauganj hill it has frequently a peculiar corrugated structure consisting of small rolls or larger rolls and giving the surfaces along which it breaks off an appearance which bears a distant resemblance to a bundle of sticks; hence the structure is called *bacillary*. These beds present very little of interest, so I shall pass on to the next group.

The upper or Jutogh carbonaceous slates and limestones are the newest rocks within the limits of the Simla station. They occupy three isolated patches—one, the largest, on the Jutogh hill, one on Prospect hill, and one small patch on the spur intermediate between these two. Like the Jacko beds, these are characterised by the presence of carbonaceous matter, but they differ in the prevalence of limestone: in the Jacko beds I have only seen limestone in one place, on the spur east of Annandale, while large quantities of limestone have been quarried, both for burning and as a building stone, from the Prospect and Jutogh hills. At Jutogh there appear to be three distinct bands of limestone, separated by schists and quartzite, but on Prospect hill only the lowest band seems to be left; this is overlaid by thin-bedded quartzite, and the hill is capped by a peculiar garnetiferous hornblende rock. Occasionally the garnets are absent, and it forms an intensely tough almost black rock, but usually a greater or smaller proportion of garnets are to be seen, which in places form fully a quarter of the substance of the rock: they occur for the most part as crystals of all sizes up to half an inch across, but where abundant there are also veins of garnet penetrating the rock. It is difficult to account for this rock; it has not yet been examined in detail, but the most probable explanation would be that it is an altered impure volcanic ash; if so, the absence of any similar or related rocks either on this hill or in a corresponding position at Jutogh is peculiar: the rock may be intrusive, but to the naked eye it has not that appearance.

The most marked feature in the geology of Simla and one that has been remarked on before now is the metamorphism of the higher beds accompanied by the absence of metamorphism in the lower beds. The grey Simla slates, though indurated, shew no signs of what could be called metamorphism, while on Jacko and the Boileauganj hill there are well-developed mica schists, and the limestones of Prospect hill and Jutogh are crystalline, and in the latter case contain well-developed crystals of graphite. [The rocks all down the southern slopes of the Simla hill shew more signs of metamorphism than the Simla slates, but less than the similar rocks of the ridge.] To a certain extent this is due to selective metamorphism, that is to say, the same, or a less, degree of heating has, owing to difference of composition, produced greater change than in the Simla slates, but this hardly seems enough to account for all the facts. In an unpublished paper by Mr. Medlicott on the geology of the Punjab, intended to be published in the Punjab Gazetteer, it is suggested that the heat may have been applied from above by the intrusion of a sheet of granite, since removed by denudation. This hypothesis has a *primâ facie* probability, for such sheets of granite have been observed in other parts of the Himalayas, and there is the remnant of one left on the very top of Hattu, where a very little more denudation would remove all trace of it, as Mr. Medlicott supposed it to have done at Jacko. The hypothesis is however not free from difficulty, for there is no known outcrop of granite in the neighbourhood of Simla, and all round Jacko the rocks do not shew that metamorphism one would expect them to shew had a sheet of granite been pushed over them and retained its heat sufficiently to account for the metamorphism of Jacko. A third hypothesis would be that the metamorphism was due to a core of granite or other igneous rock having been intruded into the rocks but not yet laid bare by denudation. This is not impossible, for the porphyritic granite of the Himalayas appears usually to have eaten its way into the rocks by a process of fusion or solution by which the rock became incorporated with and replaced by the porphyritic granite. This is not the place to give the detailed observations on which the conclusion depends; suffice it to say that there are many facts which render it the only explanation possible in the case of the Chor and other intrusive masses, and granted this conclusion it is easy to see that there might be a great core of granite occupying the centre of the Simla hill without betraying itself either by actual outcrop or any conspicuous disturbance of the beds. Still the hypothesis is an improbable one.

Among these conflicting hypotheses it is impossible to pick out the true one, and probably the safest course will be to fall back on the first as a provisional conclusion. In any case, I do not doubt that selective metamorphism has had great influence, for I have noticed, in other parts of the Himalayas, that the rocks of the same age as those of the Simla hill are especially prone to metamorphism. Still this alone will not explain how the beds on the ridge have come to be distinctly more metamorphosed than those in the valley to the south of Simla, though they must originally have had practically the same composition.

The surface geology of Simla is of considerable difficulty, and I have not had time to make any but the most superficial observations of it. Almost everywhere the hillsides are covered by a soil cap consisting of a mixture of fragments derived from the underlying rock and of soil formed by the further decomposition of these fragments. This soil cap is in a state of progression down the slopes; part of this movement is cataclysmal in its nature, and takes place in the form of what are known as landslips, where a portion of the soil cap is suddenly carried a greater or less distance down the hillside and there rearranged; but besides this there is a slow though sure creep of the soil cap down the hill, which to a certain degree affects even what might be called live rock. This movement of the slightly disintegrated rock can be seen in almost every road-cutting. The rocks are all cut by more or less vertical joint planes, known as master joints, along which the rock splits off, as may be seen in any quarry. In the road-cuttings, however, it is seldom that these master joints shew a smooth face; as a rule, there are a series of smooth surfaces of various size, the upper projecting more or less beyond the lower where the rock has shifted along a bedding, or slightly inclined joint, surface. Where the rock has not been much split up, it is easy to see that these surfaces were originally continuous and have been broken only by the shifting of one part of the rock over the other without their evident relationship to each other having been obscured; but, by a gradual repetition of this process, the joint planes become completely obscured, and the rock gradually passes into an irregular aggregation of fragments constituting the typical soil cap.

It is to this gradual movement of the rock without any great breaking up, as well as to a cause presently to be mentioned, that the dip of the rocks appears to be always into the hill, and even into the minor spurs. It is a well known fact that, on the whole, hills are formed by synclinals and valleys along anticlinals, and the Himalayas are no exception to this rule, but it does not hold good to anything like the extent a casual observer might conclude from the fact that almost every dip he could observe pointed more or less directly into the hill, whatever the actual direction might be. This is in part due to the natural tendency of the broad, flat, rock fragments to arrange themselves at right angles to the direction in which they are slowly moving. In this way a weathered rock may be seen to dip into the hillside, though the true dip of the unweathered rock may be very different to that observed, and consequently it is never safe to trust to a dip observed in weathered rocks.

But even dips observed in solid rock that shews no signs of weathering and shews the true dip of that small portion of the rock, may give a very false idea of the true dip of the beds as a whole. Often along a hillside outcrops of rock are scattered, and all indicate a dip into the hill, though the actual direction will vary with the direction of the slope, while the form of the geological boundaries may shew that the general dip is fairly steady in direction and amount. The explanation of this may be seen in any deep cutting or stream bed: here the beds will be twisted about and contorted on the small scale to such an extent that whatever may be the general dip it will be easy to find some places that will give a dip in any selected direction. Now if this same rock is exposed on a hillside, in all places where the dip is down the slope or neutral (*i.e.*, at right angles to the direction of the slope), the rock will more readily weather into the soil cap than in those places where, owing to the dip being into the hillside, the fragments are able to give each other a more efficient support. In consequence of this we may naturally expect that it will generally be where the dip happens to be into the hill that the rock will be able to resist denudation so as to stand out from the general slope of the soil cap. In other words, the apparent dip into the hillside may be due to the direction of the slope and not the direction of the slope due to the dip. The Simla hill affords a very good instance of this. The general structure of the hill, as shown by the boundaries, is a very shallow synclinal whose axis bears north-east and south-west and is elevated to the north-east. In consequence of this the general dip is south-south-west or west-south-west, but, in spite of the assistance rendered by the numerous road-cuttings, the general impression left is that the rocks will everywhere be found dipping into the hill, whatever that direction may be. A careful consideration of the facts has, however, convinced me that this is only because it is to a very large degree only those dips which happen to be in that direction, which have a chance of being observed, the others being almost all obscured by soil cap.

In the valleys round Simla there are some sub-recent river gravels; they are not extensive in the area included in the map, but there is a large stretch of them extending beyond the limit of the map, in the stream which drains the southern slope of the ridge between Prospect hill and Jutogh. On the eastern side of the stream which forms the eastern boundary of the map, south from Sanjaoli, the same beds are seen not in very great quantity, but shewing their nature very well: they may also be seen in any of the khuds, and the road along which the sewer is laid down to the waterfall shews very good sections of them. They are seen to consist of a *melange* of fragments all more or less angular and varying from some feet across to fine gravel, in fact showing many of the characteristics often considered peculiar to morraines. There is not however any reason to consider them of glacier origin, as they invariably show distinct stratification, a structure which, though not always wanting, is more conspicuous by its absence than by its presence in a true morraine. Stratification is essentially the mark of flowing water, and there can be no doubt that these deposits were formed by streams ; the angular nature of the debris being easily explained by the short distance it has travelled, while the mixture of large and small fragments is due to the steepness of the slope of deposition and the varying quantity of water which would flow at different times.

A point to be noticed is that these gravels extend in many cases right down to the bottom of tbe valleys, showing that these latter had been excavated to their present depth and then filled up by a deposit which is now being removed.

In the valley which leads southwards from Sanjaoli there is sufficient of the deposits left to form some idea of the original form of the surface which is now being destroyed. In the main valley there was a long sloping tract, the slope of this being somewhat steeper than that of the present stream bed. This " bottom" sent tongues up the small side valleys, the surface of these tongues having a slope steeper than that of the bottom and increasing up stream till at the summit it becomes 30°, as steep a slope as ordinary debris will lie at. This gradual steepening of the slope so as to form a concave surface is very conspicuous in the side ravines flowing from the east into the stream which flows south from Sanjaoli and is best seen from either of the roads round Jacko, as Sanjaoli is approached.

The explanation of the curve is not difficult. The slope is formed by debris deposited by the stream when its velocity is reduced below the limit at which it can transport the debris; but a large volume of water will acquire a given velocity on a smaller slope than a small volume; consequently, as the volume of the stream increases, the limit of velocity at which the debris must be deposited is reached on a gentler slope, and therefore the slope of the surface of the deposit diminishes as the stream increases in volume, *i.e.*, down stream. It is in the small side streams that the increase of volume is most rapid, relative to the volume of the stream, and consequently there that the curvature of the surface of deposit is most conspicuous, and in these side streams the effect enhanced by the fact that the large fragments are the first to be deposited, while the smaller fragments which are carried on require a less velocity and consequently a smaller slope to allow of their transport.

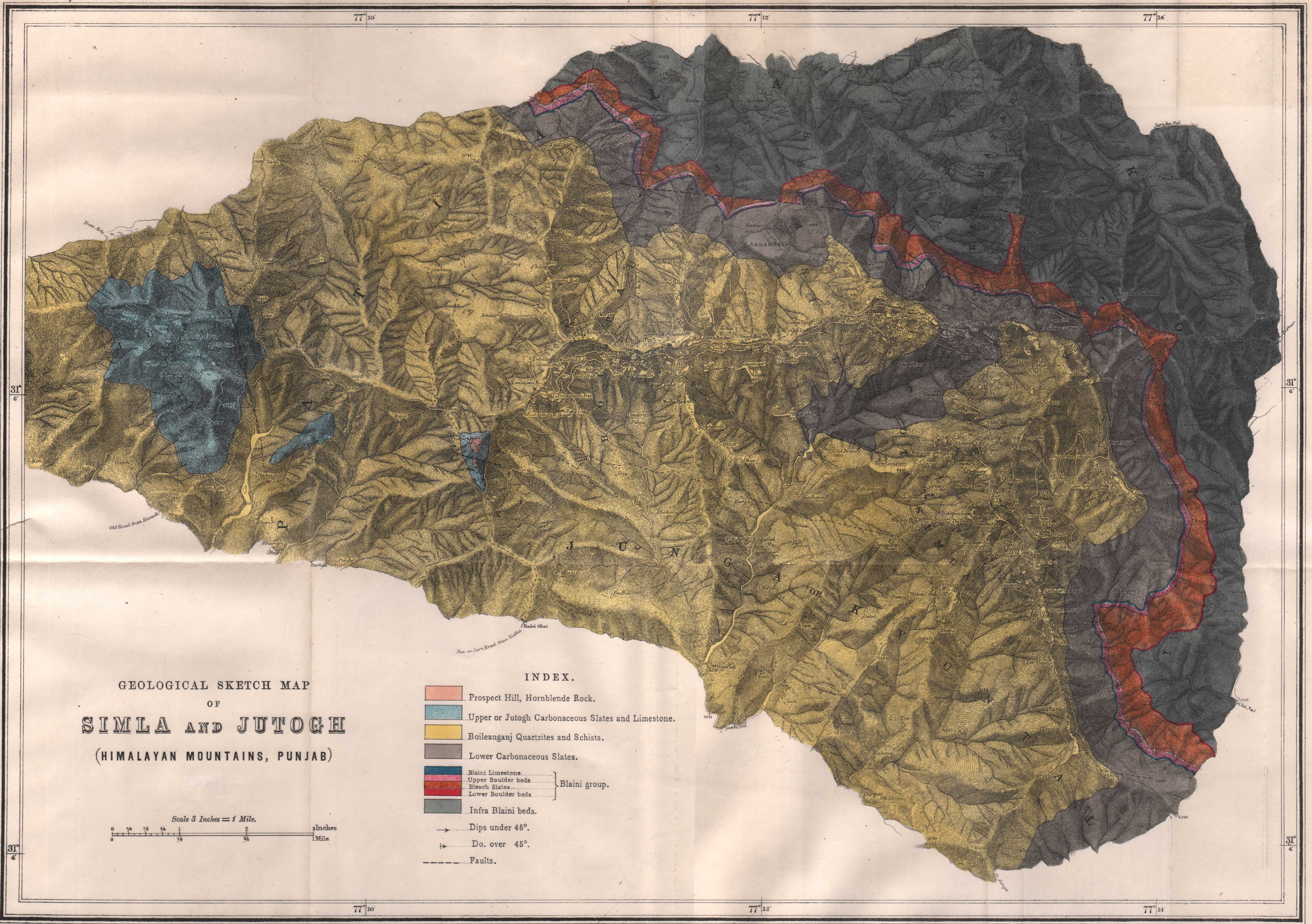
In trying to account for these high level gravels the most obvious explanation would be to suppose a change of level which caused the stream that had originally been eroding its valley to commence depositing debris in it, and then another change of level by which it was once more set to work at excavating. But similar deposits may be found in almost every valley throughout the Himalayas, and where not observable it is more probable that they have been entirely removed than that they never existed. It is impossible to suppose to suppose that every valley had its own special set of movements, and no general movement will account for all the deposits, nor for the greater steepness of the surface of the old gravels than that of the recent stream beds and gravels.

When the gravels were being deposited the streams which flowed over their surface must have had a lower maximum velocity than the present stream acquires on a smaller slope; its maximum volume must therefore have been less or it must have been so loaded with debris as to be spread out in a shallow sheet and prevented from acquiring the velocity it otherwise would have done. In other words, the conditions then differed from those of the present day in that either (1) the rainfall was less or less unevenly distributed through the year, or (2) the disintegration of the rock was greater than what now takes place.

Taking the first of these, it might be supposed that the cutting down of the stream beds was due to the clearing of the hillsides by human agency. It is known that clearing the forest diminishes rainfall, but makes what does fall more unevenly distributed in time; moreover this effect is exaggerated by the increased rapidity with which the water flows off the hillsides. It cannot however be to any such cause that the observed facts are due, for they are just as conspicuous in the streams draining from the forest clad northern slopes of the hills as in those which flow from the bare grassy slopes with a southern aspect. Besides this as far as can be judged from the appearance of the stream beds the increased disintegration caused by the removal of the protecting forests has more than counterbalanced the increased volume of water at the maximum discharge, and in nearly every case of streams draining the southern slopes it will be found that, not far from their sources, deposition is outbalancing erosion and the stream has become on the whole a depositing rather than an eroding agent, so far as its lower reaches are concerned.

Apart from the clearance of forests we know of no change in the rainfall which would account for the alternation of conditions shewn by the river gravels, but we do know of a cause which would greatly increase the rate at which the rocks would be disintegrated, and at the same time would probably have some effect in diminishing the rainfall. There are many reasons, which need not be entered into here, for believing that the glacial epoch was felt in India as in Europe. There is no certainty as to the extent to which the snow line was lowered, but there is good reason for believing that in places glaciers descended to 4,000 feet, if not lower. If we only suppose the snow line to have been depressed 5,000 feet, the whole of the Simla hill would have been cleared of forest, and disintegration proportionately increased; at the same time this great accumulation of snow could not but have had some effect in diminishing if not abolishing the monsoon rains, but as this may have been counterbalanced by the supply of water derived from the melting of the snow in summer, we cannot be sure, though it is very probable, that the maximum volume of flood was less than now.

The hypothesis that the formation of the gravels dates from the glacial epoch has the merit of explaining all the facts and of not conflicting with any other known facts. It allows of a mild climate during which the valleys were excavated to their present depths, then a period when disintegration was increased, both directly by the increased cold and indirectly by depriving the hillsides of their protecting forest; during this period possibly the actual volume, and certainly the volume of the streams relative to the burden cast on to them decreased, and in consequence



Surveyed and drawn by Capt. George Strahan, R.E., and Assistants, of the Topographical Survey of India.

Reproduced in Heliogravure, Surveyor General's Office Calcutta, April 1883.

Printed from a transfer to stone in the Lithographic Office, Survey of India Department, Calcutta, August 1887.

deposition commenced. Then came an amelioration of climate during which disintegration gradually decreased both directly and indirectly, while the maximum volume of the stream increased, if not absolutely at any rate proportionately to the load it had to carry, and in consequence erosion once more set in, which has continued to the present day.

This filling of the valleys has not caused any considerable hydrographical change in the area under consideration, but the two waterfalls in the Combermere glen are both due to a small diversion of the stream. In both cases the old river bed ran west of the present one, but is now filled up with gravel, the stream when it began once more to erode choosing a slightly different channel to that it had originally occupied cut down to a saddle on the buried spur from which it could not work down to the old course; at the same time the more rapid removal of the soft gravels below the spur caused those spreads of gravel with a rapid drop over a rocky barrier at their lower end which are now known as the first and second waterfalls.

The economic geology of the Simla hill is very limited: building stone is naturally in abundance and of a quality good enough for rubble masonry; where dressed stone is required the limestone of Prospect hill or Jutogh is used.

A certain amount of pottery clay is found on the slopes, some of the spurs running north from Simla: it appears to be confined to the neighbourhood of the carbonaceous slates and to be largely composed of the insoluble residue of the limestones associated with them. A large deposit existed on the north slope of Jutogh, but has been almost entirely removed to make bricks and tiles for the new offices in Simla. Another large deposit appears to exist on the Summer hill spur beyond where the road rounds its northern end, but at present it is only dug to make a few gurras, flower pots, &c. Another place where clay is found and worked is on the eastern slopes of the spur east of Annandale. Here there are several potters' houses dotted along the hillside.

The water-supply of Simla has for many years been a source of difficulty, and water is now brought in by pipes from the Mahasu ridge.

Note on the "Lalitpur" Meteorite, *by* F. R. MALLET, *Superintendent, Geological Survey of India.*

We have received from Colonel J. Liston, Deputy Commissioner of the Lalitpur district, in the North-West Provinces, several pieces of a meteorite which fell in the district during the present year, together with such information as could be collected about the fall. It appears that the meteorite fell at 10-30 A.M. on the 7th April, on the boundary line between the villages of Jharaota and Nyagong, in parganna Maraura; approximately, therefore, in latitude 24° 27′, longitude 78° 39′.

Two boys, who saw it fall, said they were startled by a report like that of a gun, looked up, and saw the stone just before it reached the earth. After it fell "a grumbling, like thunder, went on for some time." The meteorite fell on a stone and was broken into pieces: the boys did not go near them for some time from fear: when they did the fragments were cold. The direction of the fall is said to have been from west to east.

"The noise was heard in, and reported from, two places at a distance from the spot where the meteorite fell. Mr. Sturt, Assistant Commissioner, wrote to me from Mahroni, where he was then encamped, that, at 10-30 A.M. on the 7th April, he heard a sound like thunder, went outside his tent to find a clear sky and no signs of a storm, and found the people about wondering what the noise meant. Mahroni is 9 miles 2½ furlongs north-east of the spot where the meteorite fell. The police officer of Dudhaie, 10 miles 2 furlongs due west, reported that at the same time (he says 10 A.M. but had no watch) he heard a sound like a heavy cart going over a rough road; went outside his station to see what the matter was, and could see nothing. He reports the sky to have been perfectly clear at the time."

The Deputy Commissioner remarked that as the meteorite fell on a stone the fragments were scattered and many have probably not been found. Seven were secured by him, one of which subsequently broke in two, making eight in all. These have been sent to the Geological Museum in Calcutta: they respectively weigh—

A.	128·04	grammes.	
B.	82·23	,,	
C.	56·40	,,	
D.	38·21	,,	
E.	28·77	,,	
F.	22·32	,,	
G.	13·78	,,	
H.	2·09	,,	
TOTAL	371·84	,,	(about 13 ounces avoirdupois).

The fact that there are but two pairs that admit of being joined together shows that, as surmised by Colonel Liston, many fragments are wanting. Those sent have the usual black crust on the original exterior, and are composed of a fine-grained, grayish-white stony mass, through which a small proportion of substance with metallic lustre is disseminated, chiefly in very thin seams, but partly in minute grains. The examination of a few milligrammes of this showed that riccoliferous iron is the main constituent, but troilite and schreibersite are both, apparently, present also. The specific gravity of the largest fragment of the meteorite is 3·546.

ERRATA.

Records, Geological Survey of India, Vol. XX, Part 3.

Page 121, line	8	from top,	for *thirty* read *thirty-three.*
„ 122, „	15	„	after *canals* add *Jour. Roy. As. Soc. Lond. XX,* 326, 1863.
„ 123, line	3	„	for *Tovla* read *Toula.*
„ 123, bottom		line,	„ *first* „ *this.*
„ 136, line	2	from top,	„ *Bandin* „ *Bandni.*
„ 137, „	25	„	„ *Matkori* „ *Malkori.*
„ 137, „	42	„	„ *slates* „ *states.*
„ 144, „	5	„	„ *rugged* „ *ragged.*
„ 145, „	35	„	erase the word *later* between *of* and *small.*
„ 147, „	4	„	for *forest, but* read *forest hut.*
„ 148, „	5	„	„ *or* read *on*, and erase the word *and.*
„ 148, lines 36 &	38	„	erase brackets.
„ 150, line	15	„	for *dips* read *a dip.*
„ 153, „	20	„	„ *slopes, some*, read *slopes of some.*
„ 154, „	3	from bottom,	for *riccoliferous* read *nickeliferous.*

denudation. On the summit of the peak above Dugána there is a limestone conglomerate, cemented by calcareous mud, which resembles some of the conglomerates in the Mandháli series on the Deoban ridge. This fact, combined with the occurrence of carbonaceous slates in the upper part of the Naira valley, where they appear to overlie the limestone, led me at the time to regard the latter as of Deoban, rather than Krol age.[1] Subsequent consideration has, however, led me to doubt this

[1] I shall show later on that the two limestones are distinct in age.

conclusion, the superposition of the carbonaceous slates may well be due to disturbance, for the beds are very much disturbed in the upper Naira valley, while the limestone conglomerate is a rock which might naturally be expected to occur as the bottom bed of a formation resting unconformably on massive limestone.

The Blaini group in the Naira and Bangál valleys.—Below the limestone there come grey slates in which the Blaini limestone and boulder bed occur; it was traced from the crest of the ridge south of the Naira valley into the Bangál valley, being much cut up by faults; it is carried up one side and down the other of the ridge which separates these two valleys by a series of step faults, which are especially marked on the south side of the ridge. These faults run in the direction of the boundary of the massive limestone on the Juin hill, and in that rock seem to die out as faults, and become converted into a uniclinal fold.

The group is of the same type as that first described in the Blaini valley, consisting of a single band of pink limestone and conglomerate, the latter containing many fragments of volcanic rock derived from the volcanic series which will presently be mentioned. In the bed of the stream which flows east of the village of Bombhil, close to its junction with the Naira there is an exposure of the boulder bed which distinctly marks its mode of origin. The matrix is laminated and the laminæ are seen to be bent down under, and to arch over, the larger included fragments, showing that these must have been dropped into a tranquil sea in which the fine silt of the matrix was being deposited.

It is not necessary to recapitulate here the reasons why I regard the boulders as having been dropped by floating ice, but I may mention that where the boulder bed crosses the Naira valley we discovered a pebble (now in the museum) showing striations similar to those usually ascribed to glacier action. It is, however, necessary to notice the extraordinary similitude to a volcanic breccia exhibited by the Blaini "conglomerate" on the Juin ridge: not only are the included fragments mostly of volcanic rock, but the matrix itself very strongly resembles an impure volcanic ash. It is not natural to suppose that this rock should here be of volcanic origin, while elsewhere, and in general, such an origin can be shown to be untenable, so we must look to some other cause for the resemblance. This I imagine to be the same as explains the other features presented by the rock, *viz.*, a severe climate. Under the climatic conditions which now prevail even at an altitude of six or seven thousand feet, the volcanic beds disintegrate, principally by the decomposition of their constituent minerals, but it is conceivable that, under a climate severe enough to produce floating ice at the sea level, the disintegration of the rock would be more rapid than the decomposition of its constituent minerals; in this case it would be difficult to distinguish the sandy material so produced from the ash directly produced by a volcanic eruption. I know of no observations confirmatory of this hypothesis or the reverse, but it seems a possible one, and at any rate does not conflict with conclusions arrived at on independent grounds.

The volcanic beds and "lower Chakrata" quartzites of the Bangál and Naira valleys.—Under the Blaini beds, but separated from them by slates, comes a series of volcanic beds, consisting of felsitic lavas and ashes, underlaid conformably by purplish red and mottled quartzites, with interbedded schistose slates. This series of beds I have no hesitation in correlating with what I have described as the Lower Chakratas, and overlying volcanic beds of Jaunsar, as they resemble each other, not only in lithological character, but in the order of superposition of the beds.

Regarding this, the most important fact to be noticed is that part, at least, of the volcanic beds is of subaërial origin. In proof of this statement, I appeal to a specimen, preserved in the Imperial Museum at Calcutta, where portions of two distinct lava flows are seen to include between them a string of well-rounded, water-worn pebbles. Were these only of lava, it would not indicate more than an isolated volcanic island, which need not have been raised more than enough to bring its summit within reach of the breakers, but the majority of the pebbles are of vein quartz, which must have been derived from some land surface of non-volcanic rocks.

On the north side of the Bangál valley below the village of Lána there occurs, far below the volcanics, a bed which, like the Blaini "conglomerate," can hardly but be of glacial origin. It consists of rounded, waterworn boulders of quartzite, imbedded in a fine grained, red coloured, subschistose matrix. This rock was not seen *in situ*, so there is some doubt attaching to its geological position, but it occurs in large fragments just where a continuously descending section of the red quartzites and volcanic beds is faulted against the Deoban limestone. It is important to note that this is not a volcanic bed; it is separated from the volcanics by the "Lower Chakratas" and a considerable thickness of schistose slates that underlie them; and the well-rounded condition of the boulders, which range to over a foot in diameter, shows that they have been waterworn.

In northern Jaunsar I have seen a very similar bed at about the same horizon; its position is represented by the southernmost of the two blue patches in Jaunsar on the map illustrating Col. McMahon's paper on the Blaini groups and central gneiss of the Simla district.[1]

Relation of the Blaini beds to underlying rocks.—On the north side of the Bangál valley the volcanic series is overlaid by about 1,000 ft. of subschistose grey slates. On the south side there are at most a few hundred feet of slates between the Blaini and the volcanic beds, and these appear to belong rather to the Blaini than the volcanics. On the crest of the Juin ridge the volcanics do not seem to have thinned out appreciably, but down the slope into the Naira the thickness of them lying between the purple quartzites and the Blaini slates diminishes, till in the Naira valley the volcanics have disappeared entirely.

It is possible that this may be due to faulting, but the recognizable faults are almost all dip-faults, which would not affect the apparent thickness of strata between the purple quartzites and the Blaini group, while the beds lie too flat for their appearance to be due to a squeezing out of the rocks in consequence of contortion; nor, were such to take place, would one expect the volcanics to be squeezed out rather than the overlying slates.

It might be supposed that the thinning out of the volcanics represented their original limit of extension, but that is hardly probable, for a band of limestone is inter-stratified with them throughout Jaunsar, while, as I have already shown, they are of subaërial origin in Bangál valley. It is reasonable therefore to suppose that this locality marks the neighbourhood of a focus of eruption, and a sudden thinning out in its neighbourhood is not what would be expected.

[1] Records, G. S. I., X, p. 222.

A more natural explanation is to regard the thinning out of the volcanics and overlying slates as due to their removal by denudation, previous to the deposition of the Blaini. This view derives some support from the presence in the Blaini boulder bed of angular fragments of volcanic ash, which must have been indurated and converted into solid rock previous to their transport to the locality in which they are now found.

Termination of the ridge between the Naira and Bangál valleys.—Along the termination of this ridge, where it slopes down to the Tons, and in the Naira valley, there is exposed a grey slate series containing a band of blue limestone about 300 feet thick. These resemble the slates and interbedded limestone of Southern Jaunsar which were described by me as "Upper Chakratas." West of the Tons they appear to pass under the "Lower Chakratas," and the section upwards from the latter is a normal one. This apparent reversal may be due to disturbance, but there is every possibility that the section in Jaunsar on which I based my conclusion was inverted. The question of which of the two, the slates and limestone or the red quartzites, is the newer, remains to be decided by further survey.

Unconformity at the base of the infra-Krols in the Valley of the Minas gádh (Suinj R. of map).—The whole northern side of this valley appears to consist of limestones; possibly near the top some other series may come in, for I did not examine the hillside, but certainly the greater part of the northern side of the valley, near the Tons, is composed of a limestone series, which I see no reason to doubt is the same as that of the Deoban hill. The limestone extends south of the stream and can be seen faulted against the purple quartzites of the "Lower Chakrata" series. At the head of the valley both limestone and quartzites are overlaid by a band of black carbonaceous slates and limestones, which is also seen in the Gerwáni hill, resting on the grey slates that overlie the volcanics. This carbonaceous series can be very distinctly traced along the hillside, and, though it appears to be faulted in the Minas valley, does not seem to be cut by the fault which separates the limestone and quartzite series lower down, at any rate not to the same degree. This would point to the boundary fault being of great age, and to a complete removal of the Deoban limestone south of it previous to the deposition of the black carbonaceous slates, and consequently to a great unconformity at their base. These black carbonaceous slates can be traced into continuity with similar beds in the Chepal valley, where there can be little doubt that they represent the infra-Krols of the Simla region.

The Mandhâli beds of the Chor and Chepal.—On the eastern side of the Chor mountain there are several exposures of a boulder bed, very similar to the Blaini conglomerate in physical characters, but without the characteristic associated limestone. The most southerly exposure is on the north side of the Minas valley a little below the hamlet of Dím (Demi). The boulder beds are here interstratified with blue limestone, a feature also noticed in the Mandhális of Jaunsar, and lie between the massive, presumably Deoban, limestone and the carbonaceous slates. This "conglomerate" is not continuous in this position, as it is wanting near the village of Deothali (Thotali), but it is present on the Cheti (Baiti) ridge.

Between this and Chepal the rocks are too disturbed for their structure to be determinable in a rapid survey, but east of Chepal the boulder beds recur in the same position as further south, *viz.*, between the massive limestone and carbonaceous slates. The beds are a good deal cut up by faults, which, added to their variable nature, renders it difficult to determine a really characteristic section. One which was roughly measured by me gave a band of conglomeratic slates, underlaid by 100 feet of non-conglomeratic slates, below which were conglomeratic bands occurring with quartzites through 200 feet, while 50 feet below these came a band of pink limestone, resembling the Blaini limestone.

This exposure is referred to by Col. McMahon, who declared that "it is beyond all reasonable doubt that the rocks here seen are the Blaini rocks."[1] I think it is beyond all reasonable doubt that they are the same as my Mandhális of Jaunsar, which they resemble very strongly in physical character and in their superposition on a massive limestone series.

Whether the Blaini and Mandháli rocks are of the same age or not I shall leave for a separate paper on the boulder-bearing slates of the Himalayas, but it is necessary here to remark that I could find no proof of unconformity between the boulder beds and carbonaceous slates; but the irregular appearance of the former points to an unconformity of both on the Deoban limestone. The same is proved by the presence of fragments of the latter rock in the former, and in this it agrees with the Mandhális of Jaunsar.

Before leaving this subject I must notice that in the exposure east of Chepal there is a small patch of a rock which very strongly resembles a volcanic ash. The rock is exposed on the very crest of the ridge and is almost immediately cut off by a fault; what remains is very much decomposed, but I notice it, as this is the only case I have seen where a rock associated with the boulder beds has presented more than the most superficial resemblance to a volcanic rock.

The volcanic rocks of the infra-Krol series.—On the spur south of the Minas gádh, leading east from the Chor, in the Deora valley of Jubal, on the Narkanda-Sungri ridge and on the Lambatách ridge between the Tons and the Pabar, I found volcanic beds associated with the black carbonaceous slates. These beds differ in age and character from those of the "Lower Chakrata" series; the specimens have not yet been examined in detail, but, speaking broadly, it may be said that they are of a more decidedly basic character than the Lower Chakrata volcanics.

These are the same beds as are described from the Sutlej valley[2] by Col. McMahon, who correlates them with the volcanics of Dalhousie and Cashmir.

The gneissose granite of the Chor.—As the Chor was deeply covered in snow when I was in that neighbourhood, I did little more than take a passing glance at the eastern margin of the granitic intrusion. The intrusive nature of the gneissose granite having been proved already, it is not necessary to consider this point in detail, but I may say that the manner in which the boundary of the granite cuts across the bedding of the adjoining sedimentary rocks, as well as the numerous inclusions of schist and quartzite, make it very evident that the rock of the Chor is a granite by origin.

I was, however, able to make one observation which has an important bearing on the mode of intrusion of the granite. On the spur south of the Minas gádh the

[1] Records, G. S. I., Vol. X, 210. [2] Records, G. S. I., Vol. XIX, 67.

black carbonaceous slates are overlaid by the volcanic beds noticed above, here changed by contact metamorphism into hornblende schists and mica traps. On the spur north of the Minas gádh no trace of these rocks can be seen, but in their place is an exposure of a rock which only differs from the porphyritic rock of the Chor generally, in that the matrix is highly hornblendic, and consequently dark coloured, thus throwing up the porphyritic crystals of orthoclase with great distinctness.

I do not see any possible explanation of these facts unless we suppose that the granite dissolved and absorbed the rocks, whose position it now occupies. On this supposition its locally hornblendic nature, where it replaces hornblendic rocks, is easily explicable, while the very slight disturbance of the surrounding beds, as well as the steady dip towards the Chor, are inconsistent with the supposition that the granitic intrusion was either the cause or consequence of disruption of the sedimentary beds.

The gneiss series of the Upper Pabar valley.—In the upper reaches of the Pabar valley and its affluents there is exposed a series of beds which, whether we have regard to their lithological structure or their mode of origin, must be classed as a gneiss series. For the most part the beds are gneiss, but they vary in one direction to nearly pure felspar, in the other to a very slightly felspathic mica schist; some beds are schistose greisen, and there are a few of metamorphic quartzite whose sedimentary origin is easily recognizable. The foliation is parallel to the bedding planes, and the whole is most palpably metamorphic, using that term as opposed to intrusive, and without reference to whether these rocks ever were or were not ordinary sediments, such as those the slates have been formed from.

Many of the beds of gneiss contain porphyritic eyes of orthoclase, sometimes two or three inches in length. As regards internal structure, they resemble the porphyritic crystals of the gneissose granite, being composed of a single twinned crystal of the Carlsbad type, but they differ in their external form, which is lenticular, and in their invariable arrangement, with their greatest diameter along the plane of foliation. Doubtless it was by fusion of this rock that the intrusive porphyritic granite originated.

The position of this rock is very clear, for the beds lie very flat for the Himalayas. It unconformably underlies a series of red quartzites, which, near the Búran (Borenda) pass, are overlaid by beds containing hornblende schist. I have little doubt that these represent the "Lower Chakratas" and overlying volcanic beds, the lithological similarity between the quartzites being especially striking.

Arkose beds of the Lambatách ridge.—On the Lambatách ridge there is exposed a series of beds presenting many points of interest which, owing to the coming on of the monsoon, I was not able fully to investigate. The beds consist in part of the fine grained felspathic quartzites which extend into Bawar, and were there described by me as the Bawar quartzites. But below these comes a great thickness of more or less schistose beds containing granules of felspar. In the Kotigadh (Kunjado R.) the rock is at first sight difficult to discriminate from the porphyritic granite, which it resembles also in its mode of weathering. But on closer examination it is seen to decompose more readily, and a close examination will generally show that the felspar consists of broken crystals, while not infrequently small pebbles may be detected. Another feature which separates it from the gneissose granite and unites it to the felspathic grits is the abundance of granules of pale blue transparent quartz.

These rocks pass upwards into black carbonaceous slates and limestones, associated with volcanic beds, which in all probability are the same as the *infra*-Krol carbonaceous slates. If this be so, the arkose cannot have been derived from the porphyritic granite, which is found intruded among carbonaceous slates on the Chor and in the Deora valley, but must have been derived directly from the archæan gneiss.

It seems probable that these arkose beds indicate a severe climate, as it is evident that the disintegration of the rock from which they were derived must have been more rapid than the decomposition of its constituent minerals. This view receives some confirmation from sections exposed in the road cuttings in the Deota forests; some of these beds of coarse grit have scattered through them boulders of quartzite, ranging from a foot and more in diameter. With so coarse-grained a matrix this does not prove glacial origin, unless it could also be proved that the beds were not of subaërial origin; for large boulders may often be rolled along the surface of a much finer deposit, where the latter is formed by shallow streams. But, as there is no direct evidence of a subaërial origin of the felspathic grits, it seems natural to take these boulders, combined with the undecomposed felspar, as indicating a severe climate.[1]

It may be noticed that the arkose beds appear to hold much the same relation to the carbonaceous slates as the presumably Mandhâli boulder slates do to the carbonaceous slates of the Chor and Chepal. The latter, there is every reason to believe, are of glacial origin.

Crystalline *and* Metamorphic Rocks *of the* Lower Himalaya, Garhwal and Kumaun, Section II, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

In the last number of the "Records" I described Dudatoli Mountain from a petrological and structural point of view. The present paper will be devoted to a short account of some ancient Rhyolites and associated rocks which adjoin the Dudatoli area on the east. Their geological importance depends partly on the fact that they are the first representatives of an acidic type of lava that I have met with in British Garhwal, partly on their situation among a set of formations sharply marked off from the neighbouring schistose area, and chiefly on the circumstance that among them exists a transitional form, connecting petrologically these ancient acidic lavas with the gneissose granite of the Dudatoli ridge. This is the first time that any of the gneissose granites of the Himalaya have been shown to be connected with a subaërial lava flow: and the coincidence seems to finally clinch the argument and set at rest the controversy concerning the eruptive character of the gneissose granite. Strictly speaking however, it only demonstrates that a portion of the gneissose granitic material was drawn upon by volcanic vents; and, as this

[1] I have found that gneiss and granite disintegrate into felspathic sand, in which the felspar is undecomposed, at elevations of 14,000 feet and over in Ladák. I have never seen a material which could consolidate into arkose at the lower elevations, up to 10,000 feet, of the outer Himalayas.

material may have come from a source vertically far above where the Dudatoli ridge now is, the deeper-seated magma now represented by the Dudatoli rock may never have had much of a demand made upon it by the volcanic action above, to rush into eruption, and so may never have possessed much motion relatively to the intruded rock. I will describe these erupted lavas, and the formations among which they occur, by reference to a locality where I first hit upon them.

LOBAH VOLCANIC ROCKS.

The map facing page 142 of the last number of the "Records," at its east margin, is contiguous to a great faulted boundary running nearly north by west as far as the Dewalikhal pass, and then veering further west as it skirts the north-east portion of the Dudatoli massif. This fault can be traced for 20 or 30 miles forming a great dividing line between the old schistose series among which the gneissose granite is insinuated, and the younger set of lavas and more nearly related formations with which the gneissose granite is approximately contemporary. A few miles from the fault these younger formations, in the vicinity of Lobah, have a fairly steady dip towards the east-north-east; but near the fault they are forced into a few close folds, with subordinate faulting, nearly parallel with the great fault itself.

The strike of these rocks may be put down as very nearly N.N.W. to S.S.E. They, therefore, cut directly across the strike of the schistose series, which is roughly W.N.W. to E.S.E.

The lowermost of the younger set of formations, east of the fault, is a limestone of dark blue-grey co'our, and massive appearance; only differing from previously described limestones of this type by the presence of nodules of chert in some of its upper layers. This formation peeps out from underneath the volcanic rocks in longer or shorter anticlinal domes, and is well exposed in the stream beds which join the Ramganga from the east. I hazard nothing at present concerning its age. A short thickness of glassy looking quartzite is superposed in some sections.

A great unconformability, with attendant conglomerate, ushers in the volcanic rocks. The conglomerate, which it will be convenient to call the Lobah conglomerate, varies considerably within a few miles of outcrop; and vertically also it changes very rapidly. Its strongest feature is a large, well-rounded, torrent-boulder bed; the pebbles being from a few inches to a foot in diameter. They are chiefly quartzite, of that hard and glassy kind found immediately beneath the conglomerate. I found no pebbles whose constitution could be called a quartz-schist. A few limestone pebbles were occasionally present. The whole is coherent, as a massive and exceedingly hard rock, with a little cementing material of coarse quartzose and slightly calcareous substance. In certain localities the pebbles are scarcer, and the basal conglomerate is then a conglomeratic, faintly schistose slate, or ashy slate. It is sometimes absent altogether, and the limestone is directly overlaid by the faintly schistose slates. South of Lobah, however, the section is complicated by the introduction of a more decided volcanic element. Along with the larger pebbles there appear angular fragments, and the matrix of the rock changes and assumes a hard dark-green compact aspect suggestive of a felsitic nature. This gradually frees itself from the rounded pebbles, the angular fragments remaining, and more and more resembling brecciated portions of a flow similar to that of the matrix, but of a lighter tint. Further south, near Suini, purer rhyolitic rocks set in; the whole series tending to become thicker in this direction. There are now displayed several varieties of a compact type, and others slightly vesicular. In the small stream $\frac{1}{2}$ mile N.E. of Marwara village, near Lobah, I found the rock mentioned above as intermediate between the ancient rhyolites and the gneissose granite of Dudatoli. The whole of these volcanic rocks, together with some subordinate beds of dark grit, ashy grit, brown and yellow non-schistose quartzite, and some steatitic slates, cover the massive limestone as a skin, down the face of the hills on the east side of the Ramganga river. Owing to this position, modified by faulting, it is sometimes difficult to trace their exact stratigraphical relations; but they seem to merge upwards, with sometimes an intervening thin band of cream-coloured limestone into slightly schistose slates and schistose ashes. The latter, in many places high up in the series, become very basic in character; whilst the whole of the series is entirely different from the schistose series west of the great fault. I may here mention that N.W. of the Dudatoli massif another set of acidic lavas are found along the ridge 3 miles west of Dobri trigonometrical station. There seems no doubt that they are of the same age as the Lobah flows.

At this point it will be convenient to close the description of these rocks, so far as their field relations go, and to describe them more minutely by means of a set of specimens. These and their accompanying microscope slides will be referred to by their registered number. Thus labelled, they are now in the Geological Survey Museum, Calcutta.

Specimen No. $\frac{7}{756}$.—This rock was found near Sainji, about $\frac{3}{4}$ mile on the pathway to Suini M., Sp. gr. 2·70. Contains 79 per cent. of silica. Before the blowpipe it fuses with difficulty on the edges of thin splinters. In the hand it is a compact rock of a pale grey-green colour, sometimes flesh-white, and altered much by weathering. It breaks with a flinty fracture. It appears dotted over in many place by white spots about the size of pin-heads. These, which I first thought were spherulites, are small gas-pores, filled with an alteration product in the form of amygdules.

Microscopical.—Under the 1 inch objective the field of the microscope is filled by an almost structureless ground-mass, containing no porphyritic crystals, or included fragments of any kind. There is only a faint indication, here and there, of a gathering of the material of the ground-mass into hazy clusters. The gas-pores appear merely as round holes in the slice. Under the $\frac{1}{4}$ and $\frac{1}{8}$ inch objectives the ground-mass is seen to possess a clear base, which, with ordinary transmitted light, cannot be split up into grains, but appears uniformly amorphous. Through it are scattered in the wildest profusion and without any order a countless number of microlites, very small, and of irregular shape. They are sometimes more or less rounded, sometimes elongated needles; but more often of an irregular form longer one way than another. There is no spicular arrangement, as in the Arran pitchstones, no dendriform structure, and no trace of spherulites. The only thing noticeable is that in some places the microlitic groupings are denser than in others. The microlites are pale yellowish green in colour. Minute specks of opacite are only sparingly represented, except in connection with the gas-pores, which are more or less lined by them. The microlites cannot be regarded as having any claim to a crystalline structure; for when the nicols are crossed, they have no influence on polarized light. Their outline can then only dimly be seen through the base, which becomes divided up into irregular polygonal patches of light, and dark blue-grey colour, whose boundaries are very uncertain. These outlines are quite independent of the position of the microlites, a fact indicating that it is the base alone in which the microlites lie, which has been altered molecularly, and which behaves under crossed nicols something like a crystalline aggregate. It is necessary to note, then, that the visible structure under ordinary light is replaced under crossed nicols by a previously invisible structure; and the microlites, though not absolutely vanishing from view, can only be seen with difficulty. They have only a negative influence on the light. They seem to run in among the petrosiliceous material which now, in contradistinction to the microlites, shews its inherent differences of molecular constitution by its positive effects on the light.

The rock would seem from this to be a petrosiliceous rock, with a confused devitrified base, crowded with minute microlites. The mottled or mosaic-like appearance of the base under crossed nicols seems to indicate that quartzose and felspathic minerals are separating out, though they have not done so so entirely as to be visible under simple transmitted light. The question arises, what was the destiny of the microlites; would they have been absorbed, or would they, if progress had not been arrested by solidification (as seems indicated by their yellowish colour), have become some other mineral, such as mica or hornblende?

Specimen No. $\frac{7}{756}$.—This specimen is taken from the crags above Rheetheea Tea Factory, near Lobah. Sp. gr. = 2·65. I at first overlooked this rock in the field, taking it for a quartzite, as it weathers on the surface exactly like one. A freshly broken specimen shows it to be entirely different, with a dark green ground-mass, vaguely showing flow-structure and full of angular fragments of compact, lighter tinted rocks, flesh-coloured, and sometimes pale greenish grey. It is a very beautiful rock, and undoubtedly forms a portion of the same flow as No. $\frac{7}{755}$. It appears to pass into the Lobah conglomerate by the fragments becoming more and more rounded, and the petrosiliceous matrix becoming less pronounced, or replaced by fine clastic material. (See above.)

Microscopical.—Under the 1 inch objective the rock is seen to be as much clastic as volcanic. The ground mass is of an olive green colour, showing very distinct flow structure. The fragments of other petrosiliceous rocks included are angular and of all shapes. Their intimate structure is very like that of the previously described specimen; and they probably represent caught up dust and fragments of older flows which have become brecciated. No doubt both the included fragments and the enclosing rock were practically of the same age. Quartz is also present in small grains, all of which are angular and the remains of more or less perfect crystals. There is a certain amount of black and dark brown opacite. Small cracks in the rock are lined by secondary quartz, chalcedony or "quartz grenu." Under the ¼ inch objective the ground-mass can be discerned as having a clear base like the last described rock; but it is more thickly crowded with pale green microlites, which are clustered together in irregular patches, as well as being generally disseminated through the base. These green microlites have apparently but little effect optically, except that their density prevents so much light passing through under crossed nicols as there would otherwise be. The mosaic appearance of the base is consequently to a large extent shrouded. I could not see any, or very little polarization colour due to the microlites, as the stage was revolved, such as can be made out in the rock next to be mentioned. Doubtless the microlites in this case were just too small. The flow-structure, which is very prominent, is manifested by differences in the amount of colour and in the fineness of the bands of microlites.

Altogether, the rock exactly resembles a brecciated, devitrified rhyolite, in which a considerable quantity of fragments of other flows have become mixed or caught up.

Specimen No. $\frac{7}{157}$.—Loose block in the stream east of Saliana near Lobah and found *in situ* ½ mile N.E. of Marwara near the road to the Dewalikhal pass. Sp. gr. = 2·73. This rock links the gneissose granite of Dudatoli with the ancient rhyolites and brecciated rhyolites just described in detail. It seems to have a matrix very similar to that of the rhyolites themselves, and dispersed through it are large eyes and more or less rounded crystals of felspar, which give it a porphyritic augen structure. It has also plenty of free quartz in large irregular grains. I take the following extract from my field note-book :—"Matrix, a dull pale greenish grey, perfectly compact so far as the eye can see, save for a flow structure and faint banded appearance, dividing it into sinuous lines of paler and darker colour. The contents distributed in the matrix are a smaller set of granules of somewhat dark quartz, and small rounded eyes of felspar. Its porphyritic nature is given to it however by the presence of large eyes of felspar, rounded and oval, between which, as well as between the smaller particles, the matrix appears to have flowed. In some cases the eyes of felspar, especially the larger ones, have become cracked and partially displaced, and the matrix seems to have flowed in between the adjoining portions and so encompassed them."

Microscopical.—This rock, so far as its ground-mass is concerned, is very slightly coarser than No. $\frac{7}{156}$, the green mineral being rather more strongly represented by somewhat larger microlites. Like it, however, it is of an olive green colour, and by small differences in tint and in the density of the microlites, flowstructure is manifest among the petrosiliceous material which has found its way between the porphyritic crystals and included fragments scattered through it. Under the higher powers of the microscope the evidence of its having flowed is added to by a vaguely linear arrangement of the microlites, indicating that they had become turned more nearly parallel to the direction of flow, as they were swept on in the molten current. Of the porphyritic elements in the rock the large orthoclase crystals are the most conspicuous. They are of an opaque porcellaneous appearance under a low power, and have a very ancient look, disfigured by a corroded outline, and by the ramifying of innumerable veins of secondary quartz through them, and also by portions of the ground-mass, full of microlites, being similarly thrust in between widely open cleavage cracks at right angles to one another. The secondary quartz was introduced last of all, for it cuts through the ground-mass in the matrix and through the tongues of the same which penetrate the orthoclase. The free quartz is usually arranged in hexagonal groupings of three or more crystals, with some of their outlines fairly intact and with others corroded away and jagged, indicating that, though the quartz had crystallized out originally, it had suffered considerably during its transit in the molten flow. In one place a portion of the compound crystal was very nearly separated from the rest by inclusions of the ground-mass along parallel cracks; which gave the nearly separated portion the aspect of being connected by threads with the remainder, and ready to part at any instant. Secondary quartz along lines of infiltration invades the crystalline quartz also. Innumerable minute cavities throng the quartz, but they are unresolved under the $\frac{1}{8}$ inch objective.

Besides porphyritic orthoclase and quartz, there are also portions of other petro-siliceous flows in rounded fragments, a few sharply marked off from the ground-mass, but mostly appearing as half fused up and amalgamated with the ground-mass. Distinct irregular clumps of opacite are present in fairly large quantities.

Under crossed nicols, as in the previous cases, no undifferentiated glassy base can be satisfactorily made out. The grey-blue mosaic indicates at once devitrification structure, which is not quite so much obscured as in the previous rock slice. The general effect is not quite so dark. The embryonic quartz and felspar appear to have gone a little further towards separating out into distinct granules. Without the crossed nicols, however, this separation is quite invisible. Under the $\frac{1}{4}$ and $\frac{1}{8}$ inch objectives the microlites of the green mineral are seen to be rather larger than in the last rock, and to have a decided effect on polarized light, so that when the nicols are crossed, the somewhat parallel microlites light up the field of the microscope with multiform coloured brush-like aggregates.

From all points of view this rock must be considered akin to No. $\frac{7}{756}$, save that it contains crystals of the "first consolidation," *viz.*, porphyritic quartz and felspar. It may therefore be called a devitrified porphyritic rhyolite. Had the rock solidified under a pressure of super-incumbent rock and cooled slowly, it seems probable that it would have resulted as a microgranulitic rock or elvan, with the porphyritic addition of quartz and orthoclase. It would be difficult, therefore, to deny it an intermediate position between the gneissose granite of Dudatoli and the purer rhyolitic lavas.

Specimen No. $\frac{7}{758}$.—This is from the same locality as No. $\frac{7}{755}$. Sp. gr.=3·03. It is undoubtedly a vesicular variety of the purer rhyolite. In the hand it is pale whitey green in colour, splitting with some difficulty along the direction of original flow. Under the microscope its only peculiarity, as distinguished from No. $\frac{7}{755}$, is the large number of gas-pores, which are filled with reddish iron oxide. These account for its high specific gravity; for another fragment taken from the same piece of rock, but less full of amygdules, has a specific gravity of only 2·66.

Specimen No. $\frac{7}{759}$.—Sp. gr.=2·63. This rock is not from the locality of Lobah, but from the stream-head running west to Peera from the Dobri ridge. It is mentioned here because it links the thoroughly brecciated and clastic forms of the rhyolite with the amorphous compact varieties. It is pale grey or whitey green in colour, showing a distinctly banded structure, which has in places become interrupted by one of the bands becoming distorted and brecciated, and by the interbanding of minute rounded quartz grains, suggestive of a fragmental origin. This structure clearly evinces that partial cooling had been followed by further flowing of the semi-solidified mass.

These few examples are sufficiently typical of the acid lavas and their allied forms, as developed in the neighbourhood of Lobah. Others from localities N.W.

of the Dudatoli massif will be described in due course, and also some allied compact red porphyrites, or ancient rocks, of a less acidic character, found near Charmarguri trigonometrical station. There also remain to be considered the basic lavas which seem to replace or overlie the acidic lavas at some parts of the margin of the Dudatoli area. Though far more abundant than the ancient rhyolites, I have deferred their examination until later, because their connection with the gneissose granite seems to be inadmissible. It is indeed difficult to account for the plutonic representatives of these lavas; nevertheless, until the district is completely mapped, it is unsafe to say that they have no such representatives.

I will conclude these petrological notes by a reference to the differences in metamorphism between the old schistose series west of the great fault near Lobah, and the very slightly schistose rocks which lie to the east of it. The garnets, and well developed plates of mica, which characterize the old schistose series end abruptly at the fault. Now, as was shewn in my last paper, the production of garnets in the schist and the appearance of the Dudatoli gneissose granite must have been contemporaneous, and probably inter-dependent. It therefore follows that the argument for the great age of the gneissose granite previously founded on other and more general grounds, is now buttressed by this additional fact concerning the distribution of the contemporary metamorphism.

The Iron Industry *of the* Western Portion *of the* District of Raipur, *by* PRAMATHA NATH BOSE, B.Sc. (Lond.), F.G.S, *Deputy Superintendent, Geological Survey of India.*

Literature.—The notice taken in the article on "Raipur" in the *Central Provinces* Gazetteer (published 1870) of the iron-ores of the district is very poor. Only two localities are mentioned, and not a word is said about the mode of occurrence, the extent, or the working of the ore. It is no wonder, therefore, that Mr. Ball, the accomplished writer of the "Economic Geology of India," should have summarily disposed of the iron-ores of the Raipur district by saying, "Little or nothing is recorded as to the iron-ores of this district."

In Appendix III, G. (Mines and Quarries) of the last number of the Central Provinces Administration Report (1885-86), half-a-dozen iron-ore localities are mentioned as occurring in the district of Raipur, *viz.*, "Kondkasar, Bhindo, Lahora, Dalli, Sambarsingha, and Magarkund." The history of several of these names is not without interest. In the Administration Report for 1868-69 the names given are "Condkusar, Bhindo and Lohara, Dallee, and Muggurkund." Two years later we find "Lohara" separated from "Bhindo" and joined on to Dallee as "Lohara-Dullee;" it was subsequently again disjoined from Dallee, and transformed into "Lahora." But I know of no place of that name in the Raipur district where iron-ores occur.[1] "Lohara-Dalli" would be more intelligible, for the hill of Dalli,

[1] There is a Lohara hill in the Chanda district where iron-ores of good quality are known to occur.

Some remarks on Pressure Metamorphism *with reference to the Foliation of the* Himalayan Gneissose-Granite; *by* COLONEL C. A. McMAHON, F.G.S.

A few years ago the theory found favour with some geologists that granite was the product of the extreme metamorphism of slate, sandstone, and other rocks of sedimentary origin, and that this metamorphism was the result of the heat developed by the compression of strata in the course of mountain formation. As there were serious chemical and other difficulties, however, in the way of the acceptance of this hypothesis, it gradually lost its hold on the geological mind, and another one, the converse of that above alluded to, now holds the field and seems likely to acquire especial prominence in the future in connection with the geology of the Scotch highlands.

The application of the first theory to the Dalhousie rocks I considered in my paper on the geology of that region (Records, XV, 39, 45, 46), and I came to the conclusion that the granitic structure of the gneissose-granite was not due to heat produced by pressure. The principal argument on which I relied was, shortly stated, as follows; if the heat which produced the granite structure were the product of local pressure, one would expect to find the greatest thickness of granite, and the most perfect granitic structure, developed at the point of greatest pressure; whereas, in the Dalhousie region, the contrary is the case, and at the point of greatest strain the gneissose-granite exhibits its minimum thickness and maximum amount of foliation.

In my previous papers, however, I did not consider whether the ascertained facts could be explained by the pressure metamorphism theory, and I now propose to offer a few remarks on this subject.

The pressure metamorphism hypothesis, shortly stated, may be said to consist of two parts. It is known as a fact that solid bodies such as lead, limestone, ice, &c., can, under the influence of great pressure, be made to flow; and from this fact the advocates of the pressure metamorphism hypothesis infer that many square miles of solid crystalline rocks have flowed with the plasticity of treacle under the influence of enormous pressure. This theory further supposes that when rocks are set in motion in this way the shear, and friction, develope sufficient heat to fuse, or dissolve, the minerals of which the rock is composed and that recombinations of the chemical constituents, and recrystallization, take place on cooling. This hypothesis, it will be observed, is a very comprehensive one and likely to be very useful to the puzzled geologist in the field. The conversion of a granite into a mica-schist can be accounted for by the application of the first part of the theory; whilst the conversion of a mica-schist into good granite can be explained by the second branch of the hypothesis.

I have no present wish to enter the lists against this theory, as a theory; indeed I have myself called in the aid of pressure to account for the foliation observed in the Sutlej diorites and lavas and the production of hornblende schists in that locality (Records, XIX, 80—83); all that I propose to do is to consider whether the facts ascertained regarding the gneissose-granite of the N. W. Himalayas, and recorded in my previous papers, harmonize with the theory that the foliation of that rock was produced by pressure applied *after* its consolidation *as a granite.*

As I have discussed this question in an article on the gneissose-granite of the Himalayas recently published in the Geological Magazine (p. 212, May 1887), I think it will suffice to give an extract from this publication. It may be convenient to the future student of the Himalayan gneissose-granite to have his attention directed to this branch of the enquiry in connection with these papers—

"The cause, or causes, which result in the foliation of igneous rocks is a subject which at present occupies the attention of many geologists, and seems likely, in the near future, to lead to some discussion. In view of this, a short account of the foliated granite of the Himalayas may be of interest. It may be as well, however, to preface my remarks by saying that I believe that foliation may be produced in several distinct ways, and the explanation which I offer of the mode in which the foliation of the Himalayan granite has been brought about is only intended to apply to the case of that granite.

* * * * * *

"*Cause of the Foliation of the Gneissose Granite.*

"A realization of the eruptive character of the rock described in the above pages removes many difficulties from the way of the Himalayan geologist. "Despite the wonders performed by flexure of strata in mountain regions," wrote Mr. Medlicott, the Director of the Geological Survey of India, in his Annual Report for 1883, "the structural features presented by this rock in certain cases were impossible of satisfactory explanation on the supposition of its being a really stratified gneiss." But if the eruptive origin of the gneissose-granite be admitted, the further question arises whether the foliation observed in it was produced prior, or posterior, to the consolidation of the rock. In considering this question, I leave out of sight altogether evidence of fluxion structure as being really irrelevant to the question at issue, though I think it material to state that the rock does show very decided evidence of fluxion. Without laying any stress on this fact, however, I think the following considerations prove that the foliation was not produced by pressure acting on the rock after its consolidation.

"First, the granite is not always foliated at its contact with the rocks into which it has been intruded; on the contrary, though still porphyritic, it is not unfrequently decidedly granitic along its margin. This fact presents no difficulty to the acceptance of the hypothesis advocated below, but I think it offers an insuperable barrier to the acceptance of the view that the foliation was produced by pressure. Simple pressure will not do: that would not explain the crumpled micas and the very decided evidence of flow or fluxion. Pressure resulting in shear motion, the development of heat and concomitant chemical and mineralogical action, might possibly account for the fluxion structure; but if shear and motion were established on the grand scale required after the consolidation of the rock, the granitic portions along the margins could not possibly have escaped the effects of this action.

"Secondly, the apparently capricious passage from a granitic to a foliated structure in the main mass of the granite is another serious impediment in the way of the acceptance of the theory of dry pressure.[1]

"Thirdly, the conjunction of the outer band of gneissose granite at Dalhousie with the carboniferous series presents another almost insuperable difficulty. The outer band is the most intensely foliated of all the Dalhousie granite. Parts of it look as if it had been rolled under a gigantic steam roller. Unquestionably it has been subjected to very great pressure, and to either traction or shearing; and yet this rock is chock and block with little altered black carboniferous rocks. He who would apply the dry-pressure theory to explain the intense foliation of the outer band of granite, would have to invent a new set of conditions out of his inner consciousness and bring some other rock into position next the granite before he applied the squeeze.

[1] I use this expression as a short term to indicate pressure appled *after* the consolidation of a rock though of course, I am aware that pressure so applied may produce heat and even fusion

"Fourthly, the condition of the long tent-peg-like splinter of schist included in the granite, alluded to above,[1] shows conclusively that the granite at the point where the inclusion was found was not subjected to extreme pressure of the character under consideration after its consolidation. Had it been, the splinter of schist would have been flattened to a wafer. A mere glance at the plate, a photograph reproduced by the heliogravure process, will show this at once.

"Fifthly, neither the crypto-crystalline mica, nor the fish-roe quartz, described *ante*, can possibly have been produced by the grinding down of the mica and the quartz in the consolidated rock, or by any analogous process; for, besides the crypto-crystalline mica, and the fish-roe quartz, we have very numerous *large* crystals of muscovite, biotite, and quartz. The muscovite and biotite are large and beautiful specimens of these minerals, and they orient in all directions and at every angle up to a right angle to the strings of crypto-crystalline mica. Mechanical action potent enough to have reduced mica to the pulpy condition of the crypto-crystalline mica would not have left the larger micas untouched. Similarly, the fish-roe quartz not only fills cracks in felspars, and forms a sort of setting to quartz grains, but it meanders about in the interior of large quartz grains, and terminates abruptly inside them, in a way that does not suggest to the observer that he is looking at cracks stopped with micro-crystalline quartz, but rather that the crystallization of the quartz was brought to a comparatively rapid termination towards its close.

"Indeed, properly considered, I think the crypto-crystalline mica, and the fish-roe quartz, furnish a clue to the riddle. I may mention in passing that I have observed in a felsite patches of material closely resembling the crypto-crystalline mica mixed up with the quartz and the ordinary felsitic base; but I desire more particularly to refer to a series of rocks which occur in the peninsula of India about eighty-five miles nearly due west of Delhi. We have there a very interesting group ranging from felsites, quartz-porphyries, and granite-porphyries to almost true granites. The felsites appear to be true lavas; and the others, though merging gradually into rocks of plutonic character, are probably more or less directly connected with them. These rocks never show any trace of foliation, or give any indication of crushing. But what is important to note is, that the gradual genesis, so to speak, of the fish-roe quartz may be observed in these rocks. The quartz gradually becomes more and more developed in the felsitic base; it begins to crystallize out in grains of microscopic size, and the grains increase in number, until at last the whole base, or ground-mass, of the granite-porphyries partakes closely of the characters of the fish-roe quartz of the Dalhousie granite. The true explanation of the foliation of the latter rock I believe to be briefly as follows:—The rock had partially consolidated before it was moved into place; large porphyritic crystals of felspar, and numerous micas and quartz grains had formed; it was very much in the condition of a felspar-porphyry, or a granite-porphyry; when, in the course of the earth-movements that were contorting, crumpling, and folding the strata of the Himalayas, this imperfectly consolidated granite-porphyry was forced through the faults that had been formed along the axes of over thrust-folds; the semi-plastic mass was subjected to enormous pressure; the mica was crumpled; the crystals of felspar were cracked and ruptured; and so much of the micaceous siliceous materials as remained unconsolidated were forced into the rents made in the already formed minerals. The final consolidation took place under conditions of continued strain; but before it was actually accomplished minor and subsidiary eruptions took place which forced new supplies of the granitic material into fissures formed in the previously injected rock, and this fresh material consolidated under conditions somewhat different from those of the first eruptions.

"I think this view meets all the difficulties of the case, and that the intelligent reader will with its aid be able to harmonize all the facts stated above without detailed exposition on my part."

[1] See Records G. S. XVII, p. 168.

A list *and* index *of papers on* Himalayan Geology *and* Microscopic Petrology, *by* COLONEL C. A. MCMAHON, F.G.S., *published in the preceding volumes of the Records of the Geological Survey of India.*

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