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RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1883. [August.

On the microscopic structure *of some* Dalhousie rocks—*By* Colonel C. A. McMahon, F.G.S. (*With two plates.*)[1]

The gneissose granite.

In order to avoid repetition it will be convenient to describe the following sample specimens of the Dalhousie granitic rocks together. An account of their macroscopical and lithological aspect has already been given in my paper on the geology of Dalhousie (*supra* Vol. XV, p. 34).

Specimens described.

No. 1. Porphyritic gneissose granite. Bakrota Upper Mall, Dalhousie.
„ 2. Ditto from the same locality.
„ 3. Fine-grained granite from the summit of Dainkund.
„ 4. Granite from the same locality.
„ 5. Another specimen from the same locality.
„ 6. Gneissose granite on the road from the church to the brewery, south-west side of the Dalhousie ridge.
„ 7. Porphyritic variety on the same road.
„ 8. Another porphyritic specimen from the same locality.
„ 9. Gneissose granite on the road from the church to the water-works, south-east side of the Dalhousie ridge.
„ 10. Another specimen from the same locality.
„ 11. Fine-grained granite near Chil on the Dalhousie and Chamba lower road.
„ 12. White granite on the same road about two-thirds of the way to Chil.
„ 13. Prophyritic variety with very fine-grained matrix, having a superficial resemblance to a felspar porphyry. Between Dalhousie and Chil, on lower road to Chamba.
„ 14. A light-coloured gneissose granite from the same locality.
„ 15. Gneissose granite in actual contact with the slates on the road to Bakloh (above the slate quarries), Dalhousie.

[1] It is due to Colonel McMahon to state that this paper has been in my hands since the 15th March, and was in type for the May number of the Records, but had to be deferred on account of delay in obtaining the heliogravure copper-plates. This was particularly unfortunate when there is so much discussion going on regarding gneissose granite.—H. B. Medlicott.

All the above specimens are rich in quartz, and, as is usually the case in granites, this mineral polarises with great brilliancy. The polysynthetic structure is extremely prominent, and is very characteristic of the quartz of these rocks.

Dr. Sorby[1] states that "the quartz of *thin foliated* gneiss and mica schist differs from that of granite in having a far less simple optic structure;" * * * "instead of the larger portions of quartz being made up of a few comparatively large crystals, they are frequently composed of very many closely dove-tailed together, as if formed *in situ*." On the following page he goes on to state: "I have been unable to detect anything that would serve to distinguish the quartz of *thick foliated* schists from that of true granite."

An attempt has been made at fig. 1, plate I, to depict the appearance of the quartz, as seen in slice No. I, in polarised light. The quartz is seen to be composed of a number of large crystals and of congeries of microscopic grains suggestive of the roe of a fish. The small grains polarise as brilliantly as the large ones, and they add greatly to the beauty of the slices under the polariscope.

The fish-roe grains for the most part divide large grains of quartz from each other, forming a brilliant setting to them; sometimes this setting is thick, as in my illustration, but at others it is limited to a single line of crystals. Cracks in felspars filled up with these micro-crystals are common, and occasionally irregular branches meander into the interior of large crystals of quartz.

Some specimens of granite collected by me on the Grimsel pass, Switzerland, contain exactly similar fish-roe grains intermixed with larger grains of quartz.

On the whole I do not see sufficient grounds for regarding this polysynthetic structure as affording evidence of the original clastic origin of the Dalhousie rocks. This structure, as seen in these rocks, seems to me rather to suggest that the large grains were the result of slow cooling; whilst the fish-roe micro-grains appear to indicate either a comparatively rapid ending of the process, or conditions of strain towards its termination.

The quartz in all the specimens contain liquid cavities with movable bubbles. They exist in prodigious numbers in some specimens, whilst in others they are sparse; in most, however, they are abundant. Air, or gas, cavities are also present.

There are apparently some stone cavities. These appear to have either deposited a second mineral on cooling, or to have caught up opacite or other similar substance in the act of crystallization. Some of them appear to contain fixed bubbles. These enclosures, however, are so exceedingly minute that they cannot be satisfactorily determined with the highest powers applicable. Some microliths contain internal cavities, running with the length of the microliths for a portion of their length, which undoubtedly indicate shrinkage on cooling.

All the specimens, without exception, contain more or less triclinic felspar. In some it is rather abundant; in others sparse. It appears from its optical characters to be oligoclase.

Eight out of the 15 slices contain typical microcline, and in some of them it is abundant.

[1] Anniversary Address, Q. J. G. S., XXXVI, 48.

Zirkel at pp. 45, 47, of his Microscopical Petrology of the 40th Parallel, describes the occurrence of a fibrous orthoclase in granite. A similar felspar is very abundant in these rocks. It occurs in all but three of the specimens, the slices in which it is not present, namely, Nos. 3, 12, and 14, being those in which typical microcline is also absent. In every slice in which typical microcline occurs, the fibrous felspar is present. It also occurs in three slices in which the typical mineral is absent. The fibrous appearance is only observable in polarised light, and the felspar in which it occurs seems to me to be a form of microcline. In some an incipient cross hatching can be made out; whilst in one, at least, it is distinctly visible in parts of the fibrous structure.

Orthoclase is present in all the slices, though, if the fibrous felspar be included under the head of microcline, the latter mineral is more abundant than orthoclase. The triclinic felspar (oligoclase) is very subordinate to the orthoclase and microcline taken together.

Much of the felspar is very opaque and has a white glistening appearance in reflected light owing to the presence in it of a multitude of extremely minute gas or air cavities. Liquid cavities with movable bubbles also occur here and there in the felspar.

Some of the felspars are studded with numerous microliths of silvery mica, which occasionally, in polarised light, impart to the portion of the slice in the field of the microscope the appearance of graphic granite. Zirkel, in his work on the rocks of the 40th Parallel (p. 46), notes the occurrence of a similar structure in the granites of Nevada.

Many of the orthoclases and microclines contain the usual intergrowths of plagioclase and occasionally grains of quartz. Some of the microcline exhibits a tendency to inter-laminated structure resembling that of perthite, only it is finer grained and less pronounced. The intergrowth of felspar alluded to is quite distinct from the ordinary twinned structure.

All the specimens contain muscovite, and in all but three biotite is present. The muscovite polarises in delicate but brilliant colours, and some of it is twinned. Some of this mica contains inclusions in the line of basal cleavage of a substance that is absolutely opaque, and black, in transmitted light, and shines with a bright silvery lustre in reflected light.

Muscovite is present in all these slices, not only in good-sized plates and packets, but in a form for which I propose the name of crypto-crystalline mica. In this form no definite crystals can be made out, the leaflets, under polarised light, fade and melt into each other and exhibit no definite shape; whilst no signs of cleavage or lamination are visible.

In transmitted light the crypto-crystalline mica varies from a pale buff to a pale grey colour, and has a superficial resemblance to the base of some felsites and rhyolites. In a specimen in my collection, labelled "Banded felsite, Glencoe" (I did not myself collect the hand specimen from which the slice was made), I find a precisely similar structure present, along with quartz, and the ordinary felsitic base of felstones.

The felsitic matrix of felstones is believed to be an intimate mixture of quartz and orthoclase; and I suspect, from the appearance of some of my specimens, that the crypto-crystalline structure of the mica now described may be due to an admixture of quartz with the mica.

The crypto-crystalline mica passes imperceptibly into a condition that would require, strictly speaking, the use of the term micro-crystalline, but in the following pages I purpose calling it all crypto-crystalline mica.

This crypto-crystalline mica is present in all the slices. It traverses them in ropy masses; sometimes it is extremely attenuated and drawn out into thin strings; at other times it widens out into comparatively broad expanses. It frequently encloses, or leads up to, crystals of muscovite, and of quartz, and more rarely embraces other minerals. It meanders through some large crystals of felspar; whilst isolated patches of it are caught up in other felspar crystals. In both these last cases it represents, I apprehend, the residuum left after the separation of the constituents of the felspar.

All the slices contain magnetite grains and garnets, but in some of them both the garnets and the magnetite grains are very minute.

Six of the slices, namely, Nos. 3, 4, 7, 11, 12, and 13, contain schorl. It is in a rather fragmentary condition, and is much cracked, the cracks being filled with quartz. In some cases the fragments appear to have floated some little distance from each other.

No. 15, a specimen of the gneissose granite in actual contact with the slates above the slate quarries, is a very interesting and instructive slice, for it exhibits in a typical way what appear to me to be decided indications of fluxion structure consequent on traction. Both the biotite and the crypto-crystalline mica are drawn out into long strings in the direction of the flow. This structure is not confined to the larger bands, which can be discerned with the aid of a pocket lens, but even the microliths of muscovite in the quartz are seen, under the microscope, to point in the same direction, and to be drawn out into long trains or strings.

Even more characteristic are the gas cavities. Some of these are themselves elongated and drawn out in the direction of the flow, and they are arranged in lines pointing in the same direction. Some of the gas cavities have deposited granular matter on cooling.

There are also stone cavities, the longer axes of which point in the direction of the flow.

This slice seems to me to exhibit, as far as a granite can do so, as decided fluxion structure as that to be seen in rhyolites and obsidians.

An attempt, to give an idea of the appearance of this slice under the microscope, has been made at fig. 2, plate II, where the bands of crypto-crystalline mica and biotite are represented drawn out into strings.

The quartz, though hyaline in transmitted light, is seen between crossed nicols to consist almost entirely of the fish-roe grains, previously described, drawn out into lines in the direction of the flow. Possibly this structure may depend on strain.

A pseudo fluxion structure is doubtless to be seen in many gneissic rocks, but that above described can alone be attributed, I think, to the action of traction in a rock in motion reduced to a plastic condition by heat.

Another piece of evidence in favour of the conclusion that the fluxion structure observable in the slice under consideration is due to traction, is to be found in the crumpled appearance of some of biotites. I have sketched one in this slice at fig. 4, plate II; a single crystal, one-half of which has been folded over and bent back flat upon the other half. This biotite must, I apprehend, have been crumpled up and folded over on itself after crystallization, but whilst the folia were still in a somewhat pliable condition. I cannot conceive of a contortion of the basal cleavage lines, to the extent represented in the sketch, being produced in any other way. A moderate curvature of the basal cleavage lines is not an uncommon feature in the mica of some rocks, and I can readily understand how this may have been produced, even in the case of mica formed in clastic rocks by an epigenital process; for such mica, formed *in situ* in the spaces between the fragments of clastic origin, might often be cramped at the time of formation, and its symmetry interfered with, from want of space for its perfect development; but I do not think a mica could, from this cause, be completely doubled up in the manner represented in the illustration.

The basal cleavage lines of the mica enclosed in the long ropy strings of crypto-crystalline mica are usually at a slight angle to the direction of the flow, as represented at fig. 5, plate II, the direction of the flow being east and west. The outer edge of these biotites is usually covered with dark fluffy matter.

The foliation of the slaty portion of No. 15 is parallel to the line of fluxion in the granite.

Rocks next the gneissose granite.

Considering how important a thorough knowledge of the Dalhousie rocks is in determining questions of local geology, I propose to give a brief separate description of each of the remaining slices.

No. 16.—Junction of an intrusive vein, 3 or 4 yards wide, and the slate into which it is intruded, close to the main mass of the gneissose granite on the road to Mamul, Dalhousie. The actual junction of the two rocks is seen both in the hand specimen and in the slice.

M.—This slice shows the junction of the two rocks perfectly. The granitic rock possesses the characteristics of some of those already described, being distinctly gneissoid, whilst foliation has been set up in the slate. The structure of the slate corresponds closely to No. 19, described further on.

The slate contains numerous crystals of schorl which do not extend into the granitic rock; whilst the latter contains many small garnets, a mineral not visible in the slate.

There are several points of difference to be noticed between the silvery mica of the granitic rock and that of the slate. The silvery mica of the granite is pure looking; is in large leaflets; its basal cleavage is very perfect; and the cleavage lines are close together; whilst twinning is not uncommon. The silvery mica in the slate, on the other hand, contains numerous inclusions indicating an imperfect separation between the several constituents of the slate; it is in small leaflets; its basal cleavage is imperfect; and the cleavage lines are sparse; whilst there are no indications of twinning.

The granitic rock gives several indications of fluxion structure. The cryptocrystalline mica forms long curving streams in the ground mass, meandering about as an Indian river in its sandy bed during the dry months. In some places these streams approach each other and join; at others they make wide sweeps and diverge considerably. The curves are sometimes gentle, but at others they are rather sharp and have a wide radius. Sometimes the streams are broad; at others they are split up into innumerable narrow meandering rivulets. The dark mica also forms ropy-looking masses drawn out in the line of flow.

An attempt to represent the general appearance of a portion of this slice has been made at fig. 1, plate II; whilst at fig. 2, plate I (*a*), an illustration is given of the crumpling of the silvery mica as seen in this slice.

In some cases the twinning planes of the plagioclase are bent out of the perpendicular. I have occasionally seen instances of this in lavas, though it is of rather rare occurrence; and it seems to indicate conditions of strain subsequent to the crystallization of the felspar before the mineral had become perfectly rigid on cooling.

Zirkel, at p. 28 of his work already quoted, mentions the presence of fluid cavities in the quartz enclosed in garnets; but the garnets themselves, in this slice, contain numerous fluid cavities with movable bubbles. The quartz of the granite itself contains fluid cavities about the same size as those in the garnets.

No. 17.—Argillaceous schist in actual contact with a thick vein of granitic rock within 3 or 4 yards of the main mass of the gneissose granite. Same locality as the last. It is an indurated rock with minute flecks of mica visible here and there.

M.—In transmitted light the ground mass appears to be homogeneous and colourless, but thin and minute flakes of a green mica are thickly disseminated through it. Patches of opaque ferriferous material are dappled about over the field; whilst the slice is here and there stained with ferruginous material, and dots of yellow and red ferrite are occasionally to be seen. Flakes of colourless mica are sparsely scattered about, and there are numerous small fragments of a bluish-brown tourmaline. Between crossed nicols the slice presents a dark base relieved by numerous patches of semi-luminous material presenting highly irregular outlines, and bright flecks of mica.

The slice contains some air bubbles, but no liquid cavities. Some of the schorl shows that this mineral has been subjected to heat, and that the air or liquid enclosures which they contained expanded and forced a way to the surface of the mineral before its complete consolidation. An illustration of this, taken from this slice, is given at fig. 7, plate II.

No. 18.—Argillaceous schist in actual contact with the main body of the gneissose granite. From the same locality.

M.—This slice closely resembles the last. There is comparatively little schorl, and it is in very minute prisms. The slice contains numerous dots of magnetite.

No. 19.—An argillaceous schist in contact with a granitic vein, 3 or 4 yards wide, close to the main body of the gneissose granite. From the same locality. This is a more distinctly foliated rock than the preceding two specimens.

M.—The ground-mass consists of quartz in minute grains. Inter-laminated with this are strings of a fibrous dark-green mica and strings of the crypto-crystalline mica which I have shown to be a characteristic of the gneissose granite. Muscovite is also very abundant in the slice, whilst crystals of schorl, many of them being very minute, are present in great numbers. It is of the type and colour of that found in the gneissose granite, and for the most part it lies in a zone corresponding to the plane of foliation, the crystals lying more or less at right angles to that plane. The schorl contains numerous enclosures and some empty cavities, the contents of which have apparently forced their way through the mineral to the surface in the manner already described. The slice contains grains of magnetite, opacite, and ferrite, and some minute crystals of garnet; also one crystal of triclinic felspar. There are no liquid cavities.

No. 20.—Slate from the quarry near the gneissose granite on the Mamul Road, Dalhousie

M.—Under the microscope this is seen to be distinctly foliated; quartz, in minute granules, alternating with a fibrous green mica that is but feebly dichroic. Some very minute and imperfectly formed prisms of tourmaline are scattered through the slice.

Light flocculent clouds of nebulous matter, opaque in transmitted, and yellowish-white in reflected light, are also abundant. A sketch of a portion of this slice is given at fig. 3, plate I.

No. 21.—A spotted schist within a few yards of the gneissose granite, Potrain Hill, Dalhousie. Viewed macroscopically this has a distinctly foliated aspect, and specks of muscovite are visible here and there.

M.—The ground mass consists of quartz in small granules of very varied and irregular shapes, interspersed with crypto-crystalline mica that meanders about in all directions.

In this ground-mass are embedded numerous crystals of muscovite, and of a dark well-laminated mica, brown in transmitted light. Some of the latter contain grains of quartz and of magnetite. Magnetite and rounded grains of opacite are rather abundant in this slice, which also contains numerous prisms and fragmentary pieces of schorl, of the same type as that in the gneissose granite. There are also numerous micro-crystals of garnet. There are no liquid cavities.

At fig. 3, plate II, I have given a representation of a portion of this slice, showing the way in which the crypto-crystalline mica and the hyaline quartz are intermixed. The dark portions, in the illustration are intended to represent the former, and the uncoloured portions the quartz.

No. 22.—A similar rock a little further away from the gneissose granite, on the same road. It is of more spotted appearance and granular texture than the last, having lost, in the hand specimen, all traces of foliation.

M.—This slice closely resembles the last and requires no separate description. The crypto-crystalline mica is very abundant. Some of the grains of magnetite are of good size.

No. 23.—A fine-grained silicious schist in contact with the gneissose granite on the cart-road, between the Mall and the Bull's Head Hotel, Sananotala.

M.—This is a distinctly foliated rock, and the description given of slice No. 19 exactly applies to this one. No liquid cavities are present.

No. 24.—A crystalline granular rock a few yards below No. 23, on the same road.

M.—This exactly resembles No. 22, and is evidently the same rock. The quartz contains no liquid cavities. Small rounded fragments of the crypto-crystalline mica are included in the quartz; whilst grains of quartz are included in all the other minerals.

In many cases small colourless microliths are attached to rounded grains of opacite in a way to suggest, at first sight, that the opacite had on cooling given off a gas that had intruded into the adjoining matrix. Illustrations of these combinations are given at fig. 6, plate II (see upper and left-hand figures). A careful study of these groups, however, showed that they are simply due to the accidental conjunction of two different minerals. Such forms as that depicted on the right hand of this figure seem to show this conclusively. The occurrence of these conjunctions, however, is so common that it seems to indicate that the rock was reduced to a sufficiently viscid and plastic condition, to allow of microliths moving by molecular attraction some little distance, at any rate, towards each other. The whole appearance of the slice, and the small rounded dots of crypto-crystalline mica included in the quartz, all point in the same direction, and indicate a viscid condition. The slice, I may add, contains numerous small rounded cavities that are probably due to shrinkage on cooling.

No. 23.—Another fine-grained silicious schist a few yards further down on the same road.

M.—This presents much the same features as the last slice. The schorl is not so abundant, and for the most part is in small prisms. The dark mica is arranged more in strings, and the crypto-crystalline mica is relatively more abundant than the quartz. In this slice it is micro-crystalline rather than crypto-crystalline.

Nos. 26 & 27.—Other speckled varieties of the crystalline granular rock a few yards further down on the same road. They contain ma grains of iron-pyrites. Sp. G. 2, 74.

M.—The description given of Nos. 22 and 24 applies equally to these specimens. Schorl is abundant.

The peculiarity of these slices is that they contain a considerable amount of zircon, in irregularly shaped granules, intimately intermixed with grains of quartz. Much of the zircon is distinctly dichroic, changing from a white, or faint bluish-white, to a delicate tint of light red. It does not exhibit colours in polarised light owing to its strong double refraction.

This is the first time that I have met with zircon *in situ* in Himalayan rocks, but a sample of the gold-bearing sands of the Sutlej river, sent me by a friend, is full of well-formed crystals of this mineral.

The quartz contains what appear to be stone cavities with fixed bubbles, whilst others have either caught up and enclosed opacite when in a plastic condition or have deposited it on cooling.

Rocks between the gneissose granite and the first outcrop of gneiss.

The cart-road, from near its junction with the Mall, between Thera and Potrain, to near the Bull's Head Hotel, Sanánotála, runs a little below the junction of the gneissose granite and the schistose rocks. Near the Bull's Head Hotel, on the neck of the Sanánotála spur, the gneissose granite re-appears, having been brought down, apparently, by the flexion of the strata. The schistose rocks between the gneissose granite on the Mall and the outcrop on the cart-road, near the Bull's Head Hotel, have been described in the preceding pages. The rocks, now to be described, are a descending series which crop out on the cart-road between the gneissose granite, near the Bull's Head Hotel, and the mica schists at Banikhet.

No. 28.—A silicious schistose rock in contact with a vein of granitic rock cutting through the schists. Viewed macroscopically two sets of lines may be made out with a pocket lens on the cut and wetted face of the hand specimen, and in the thin slice; the lines cutting each other at an angle of about 40°.

M.—Viewed under the microscope one set of lines is seen to be due to partial foliation; that is to say, to be due to the development of a tendency on the part of the dark mica to segregate in more or less parallel lines. It is noticeable, however, that the laminæ of the mica are arranged parallel to the *second set of lines*, and not to the lines of dark mica. The mica has segregated into lines, but each flake of mica in the line is arranged with its longest axis at an angle of about 40° to its own line.

The second set of lines alluded to are due to the occurrence of lenticular masses of crypto-crystalline mica, the lines of which, though discontinuous, preserve a pretty constant course in one direction. Another point noticed is that these lines of crypto-crystalline mica contain rather numerous microliths of tourmaline, the prisms of which point, as the microliths in rhyolite and similar rocks, in the direction of the flow.

These facts appear to me to indicate that the rock was subjected to two different processes of contact metamorphism; one process—due to heat—resulting in foliation; whilst the second process was probably the injection of matter from the granitic rock, possibly in a gaseous or liquid condition, along lines that followed the original direction of lamination or of cleavage.

This observation, which was very unexpected, seems to have an important bearing on the point at issue. If the crypto-crystalline mica in the schistose rocks adjoining the gneissose granite is not a product of the original constituents of those rocks but has been derived from the granite, the existence of the crypto-crystalline mica in the gneissose granite affords no evidence of the metamorphic origin of the latter or of its affinity with the schists.

The general appearance of this slice is closely similar to those of the slates in contact with the gneissose granite already described. The ground-mass consists of granular quartz. A dark green fibrous mica is very abundant, but muscovite is comparatively sparse. Schorl, as usual, is present. There are no liquid cavities. Ferrite is abundant.

No. 29.—A silicious schist adjoining the gneissose granite.

M.—This is only a variety of the spotted schists already described, as for instance Nos. 21 and 22. The crypto-crystalline mica is rather abundant and swells out into large lake-like expansions. I have observed a few stone cavities in this slice, one with a fixed bubble, and two with deposits in them.

Nos. 30, 31, and 32.—Very fine-grained schists, in descending order.

M.—These may be described together. Under the microscope they approximately resemble the slaty rock, No. 17. The ground mass consists of micro-granular quartz, in which a yellowish-green scaly mica is so abundantly disseminated as to nearly pervade the whole mass. In No. 31 it has segregated into spotty masses in which it varies in colour, in transmitted light, from a green to a rich greenish-orange colour. Some of the mica is fibrous, and is, I think, paragonite. The slices contain grains of magnetite and ferrite, and slice No. 31 contains, apparently, a little hæmatite. All contain the opaque whitish mineral described under No. 20 and micro-prisms of tourmaline. The magnetite is most abundant.

Nos. 33 and 34.—Earthy looking schistose rocks. No. 34 has a strong earthy smell, even without breathing on it.

M.—These exactly resemble 30—32 and need no separate description. No. 33 contains two minute garnets. In 34 magnetite in micro-grains is abundant. In both micro-prisms of tourmaline are plentiful.

Section below No. 4 Barrack, Ballun.

No. 35.—A fine-grained schistose rock approaching the slaty type. With a pocket lens it is seen to have a fine micaceous glaze on the splitting surface.

M.—Under the microscope the rock is seen to be made up of a mesh-work of fine fibres, or microliths, of mica, in a quartz base. Larger crystals of mica are dotted about in it here and there, and stringy agglomerations of the fibrous mica. The mica is decidedly dichroic, and each of the microliths polarises rather brilliantly. I think the species is probably paragonite.

The slice contains grains of ferrite, and I think very minute grains of magnetite; also the flocculent opaque matter previously described. In this slice its colour varies from yellowish to reddish. It is, I think, a product of the alteration of magnetite.

No. 36.—A very fine-grained, pale bluish-grey, micaceous schist. The micaceous element is much more prominent in this hand specimen than in the last.

M.—This rock is so similar to the last that a further description is unnecessary.

No. 37.—A very fine-grained silicious rock approaching the slate type.

M.—This rock is of the same type as the last two, and consists of a fibrous mica, probably paragonite, disseminated through a quartz base. It contains a long irregular-shaped, lake-like space filled with hyaline quartz that has evidently been formed *in situ*, the prisms of mica projecting into it along its outer edges. It contains some gas enclosures and a few, very few, liquid enclosures with bubbles.

No. 38.—A buff coloured, very fine-grained, friable schistose rock.

M.—The structure and material are seen to be the same as the last. The mica is of yellowish-green in transmitted light, and it evinces a tendency to segregation, forming spots of darker colour than the ground-mass. There are some good-sized bits of ferrite.

No. 39.—A pale greenish-grey argillaceous schist.

M.—In both 37 and 39 the lines of original lamination can be distinctly traced on the cut surface with a pocket lens. In this rock (No. 39) they have suffered some contortion. The lines of incipient foliation are at a high angle to the lines of lamination in all three specimens. The microscope shows that No. 39 is composed of the same constituents as the last few described. The slice contains some micro-prisms of tourmaline.

No. 40.—A very fine-grained micaceous schistose rock.

M.—This consists of a quartz base in which a yellowish-green scaly mica is profusely disseminated. It is doubtless of the same species as the preceding. The slice is dotted over with countless cubes and octahedrons of magnetite.

No. 41.—Blue micaceous slate above Surkhi-galli.

M.—This consists of an intimate admixture of quartz in micro-grains and a green mica in minute scales. An immense profusion of magnetite grains are dotted over the field, mostly in elongated irregular forms, the longer axes of which are turned in the same direction. There are numerous micro-prisms of tourmaline and very minute crystals of sphene, which require high powers to detect. In many cases the sphene and magnetite have adhered together.

No. 42.—A pale blue slate similar to the last.

M.—This is apparently a very similar rock to No. 41; but the micaceous element is more fibrous and colourless.

No. 43.—A pale french-grey coloured argillaceous schist from the same locality.

M.—An exactly similar rock to No. 41 except that the magnetite is absent and a little ferrite has taken its place. The micro-prisms of tourmaline and sphene are abundant. I observed a liquid cavity in the mica.

No. 44.—A fine-grained friable whitish mica schist.

M.—This consists principally of minute scales of a yellowish-green mica and some minutely granular quartz. There are numerous air bubbles. I have not detected any tourmaline. Minute crystals of sphene are abundant. Magnetite and ferrite are also present.

No. 45.—A white wafery schist with a silky gloss on the cleavage surfaces.

M.—A very similar rock to the last, only the scaly mica is very colourless. The grains of magnetite and ferrite are very sparse. Micro-crystals of tourmaline and sphene as in the last. There are a few minute garnets.

No. 46. A light-grey, fine-grained silicious schist.

M.—The appearance of this rock under the microscope is very different from those described from No. 30 downwards. Its affinities are with the spotted schists Nos. 19 and 23, the latter of which it much resembles. It may be described as a micro-gneiss, and it consists of lenticular grains (eyes) of quartz and triclinic felspar set in crypto-crystalline mica which flows in ropy masses round them. The quartz very largely predominates over the felspar; indeed, the latter is sparse. Large flakes of muscovite are present, but no biotite. There are some good-sized pieces of schorl of the type present in the granitic rocks-also a few rounded grains of what appears to be sphene. I have not been able to detect any liquid cavities even with the use of very high powers.

No. 47.—Paragonite slate (?)—An extremely fine-grained, french-grey coloured mica schist of slaty appearance.

M.—This has, unfortunately, been sliced so thickly that little can be made out, but it does not appear to differ in any essential particular from No. 41. Pounded fragments examined under the microscope confirm this impression and show that the rock is principally composed of an almost colourless mica in scales and fibres, and countless elongated granules of magnetite. The mica appears to be paragonite. There are as usual microscopic prisms of tourmaline.

No. 48.—The pearly mica schist of Banikhet.

M.—This is closely similar to No. 44. It is principally composed of a scaly mica, varying in colour from white to pale green, with ferruginous yellow stains in spots here and there. There is an admixture of quartz in a finely granular condition. The beautiful pearly opalescence of the thin slice, seen in reflected light without the aid of a lens, appears to be due to the presence of myriads of air or gas bubbles with which this rock is crowded. There are countless elongated grains of magnetite; the usual micro-prisms of tourmaline are also present; also micro-crystals of sphene.

Conclusion.

The general conclusions at which I have arrived from the detailed study of the Dalhousie rocks are as follows:—Fifteen specimens of the gneissose granite from various parts of the Dalhousie ridge, exhibiting some typical varieties of structure when examined macroscopically, are seen, when examined with the aid of the microscope, to be mere varieties of the same rock. No essential difference of any kind can be detected between them. All of them contain orthoclase microcline, plagioclase, quartz, muscovite, magnetite, garnets, and liquid cavities containing movable bubbles. Six of the specimens contain schorl in some abundance, and all but three of the thin slices contain biotite. In all the quartz exhibits a polysynthetic structure very prominently, whilst all contain crypto-crystalline mica.

Some of the slices give unmistakable indications of having been reduced by hydro-thermal agencies to a plastic condition, and exhibit true fluxion structure. It is also important to note that the specimens which exhibit these characteristics most prominently are those which show, when viewed macroscopically, a pseudo-foliation, and have consequently a gneissose aspect.

The rocks are not true granites, but it does not follow from this fact that they are necessarily of metamorphic origin. Between the deep-seated roots of volcanos and the lavas that have actually flowed out at the surface of the earth's crust, there must of course be many gradations. The presence of the crypto-crystalline mica in the Dalhousie gneissose granite, that is to say, the presence of an imperfectly crystallised residuum, seems to indicate their affinity with the felspar porphyries. Indeed specimen No. 13 approximates in its macroscopical appearance very closely to a felspar porphyry.

Allport, in his paper " On the Metamorphic Rocks surrounding the Lands'-end

Mass of Granite," Q. J. G. S., XXXII, 407, shows that the mineralogical changes produced in clay slates by the intrusion of a mass of granite are chiefly the development in them of some of the minerals which constitute its own mass; that is to say, quartz, tourmaline, and three kinds of mica; occasionally tremolite, magnetite ("and andalusile ?"), and in some localities felspar. The structural changes produced in clay slates by contact metamorphism, according to Allport, are "(*a*), foliation more or less perfect, with every gradation from nearly straight parallel lines to the most complicated contortions; and (*b*), concretionary, showing a decided tendency to segregation of both quartz and mica, the result being a spotted schist."

A precisely similar influence appears to have been exercised by the gneissose granite on the slates in contact with it at Dalhousie. As to structure, we have seen that foliation has been produced and "spotted schists" have been formed; whilst schorl, garnet, dark mica, muscovite, and magnetite have been introduced or created out of the constituents of the slate.

As regards mineralogical changes, Allport noticed in the rocks described by him in the paper just quoted, that the strata near the granite were "far more highly silicated than those at a distance from it," and he expressed the opinion that "there can be no doubt that much of the quartz has been derived directly from the intruded rock."

In the case of the rocks under consideration, a study of slice No. 28 led me to the conclusion that the crypto-crystalline mica seen in the schists in contact with the granitoid rock, is due to the injection of matter from the granitic rock into the schists in a gaseous or liquid condition.

Two other points are to be noted: *first*, that though the gneissose granite is rich in felspar, only one small crystal of this mineral was found in the numerous slices of rocks in contact with the gneissose granite examined under the microscope; *secondly*, that though liquid cavities are most abundant in the quartz of the gneissose granite, they are entirely absent from the schists immediately in contact with it, and are almost entirely absent from the schistose rocks below them.

Professor A. Geikie, in a critique on a paper by Père Renard, of the Royal Museum, Brussels, on the crystalline schists of the French and Belgian Ardennes (Nature, December 7, 1882) which came to hand after I had finished my examination of the slices now described, comments on the absence of fluid cavities in the quartz of the Ardennes schists as follows:—"In subjecting to microscopic examination thin slices of some of these altered rocks, M. Renard noticed that the quartz granules, presumably of clastic origin, have lost the liquid inclusions so generally found in the quartz granules of old sedimentary strata. This fact (already observed by Sorby in the case of sandstone invaded by dolerite) seems to indicate that the sand-grains have not escaped the influence of the changes which have so profoundly affected the other constituents of the former sediment."

Dr. Sorby notices this effect of contact metamorphism in his Anniversary Address (Q. J. G. S., XXXVI, 1882):— "One point of interest is," he writes, "that although the grains of sand contain many cavities which no doubt, as usual, originally contained water, they have *all lost it, as though it had been expelled* by the heat of the igneous rock, in the same manner as it is easily expelled from unaltered quartz by a high artificial temperature."

That the absence of liquid cavities, in the schistose rocks in contact with the gneissose granite, is due to heat, is rendered highly probable by the fact noted in the foregoing papers (see notes on slices 17 and 19) that pieces of schorl retain internal evidence that the contents of enclosures in this mineral had expanded by heat and forced their way to the surface.

We have already seen that whilst the granitic rocks abound in felspar, the altered slates in contact with them have not developed that mineral. I have also given my reasons for believing that the gneissose granite was reduced by *hydro-thermal* action (evidenced by the great abundance of its liquid cavities) to a plastic condition; and that portions which present a decided gneissose aspect exhibit true fluxion structure.

We have also seen that the schists in contact with the gneissose granite exhibit the peculiarities usually developed in rocks by contact metamorphism; that is to say, minerals present in the granitic rock, schorl, biotite, muscovite, garnet, magnetite, and crypto-crystalline mica have been developed in them near their point of contact; whilst the water, which was presumably present in the quartz of the clastic rock, has been driven off by heat. These facts, it seems to me, render it improbable that the features presented by the Dalhousie rocks are the result of selective metamorphism applied to a conformable series of sedimentary rocks.

The slaty and schistose rocks between the gneissose granite and the outer band of gneiss, though very varied in macroscopic aspect, present little variation under the microscope. They consist of an admixture of quartz and mica. The quartz contains no liquid cavities. One exception to this only was noted in the case of clear quartz plugging what may have been a pre-existing cavity, and which was probably filled with foreign material from intrusive granitic masses in its vicinity.

The quartz in all the slices described has lost all trace of its original clastic origin, and the mica has certainly been formed *in situ*. The change in the shape and appearance of the quartz grains has doubtless been due to after-growth in the manner pointed out by Dr. Sorby (Ann. Address, Q. J. G. S. XXXVI, 62).

The mica is of a different species from the micas present in the gneissose granite, and much of it appears to be paragonite. Some of the lower beds, as for instance No. 47, are, I think, entitled to the name of paragonite slates.

The general character of the schists may be said to be more silicious towards the gneissose granite and more micaceous towards the first outcrop of gneiss.

As the outer band of gneiss is neared, sphene makes its appearance in micro wedges and crystals, and is rather abundant. Garnets are rare. On the other hand, zircon is present in the spotted schists next the gneissose granite, and garnets are not uncommon.

Very minute prisms of tourmaline, of bluish colour in transmitted light, are present more or less throughout the schistose beds; but schorl, of the type found in the gneissose granite, is confined to the rocks in immediate contact with it.

Schorl also re-appears in No. 46, but the whole aspect of that rock is suggestive of the near proximity and the contact action of granitic rocks.

The metamorphism of the slate series, as a whole, does not seem to require the aid of great heat to explain it, for the action of moderately heated water is sufficient to account for the formation of the hydro-micas, the minute prisms of tourmaline, and the addition of quartz to the pre-existing grains of that mineral. The gneissose granite on the other hand has undoubtedly been fused, whilst its action on the slaty series in immediate junction with it has been analogous to the contact action of eruptive granite.

In conclusion, whilst I am not able to affirm as the result of my investigations up to date, that any of the axial gneiss of the Dhuladhár range is true gneiss, I find that it presents the characteristics of an igneous rock. It has been in a fused condition; it shows fluxion structure; it invades the rocks immediately in contact with it; its structure and composition is uniform over wide areas; and it expands suddenly along the line of strike from a width of 250 feet to a width of 6½ miles. The facts, at present known, point to the conclusion that the gneissose granite is an intrusive rock and has been squeezed up through a faulted flexure along an axis of maximum strain.

In my paper on the Geology of Dalhousie (*Supra*, Vol. XV, p. 44) I wrote—"The granitoid gneiss is highly porphyritic, and is undistinguishable from, and doubtless is identical with, the 'central gneiss.'" As a result of the subsequent microscopical study of the Dalhousie rocks, I have dropped the term "granitoid gneiss" in my present paper, and have substituted gneissose granite for it; and it is for consideration whether the term "central gneiss," introduced by the lamented Dr. Stoliczka, and since used to denote the "granitoid gneiss" of the North-West Himalayas, should not be discontinued in future.

The terms "central gneiss" and "granitoid gneiss" insensibly suggest cambrian and pre-cambrian times; and their use is apt to create a prejudice in the mind of the student both as to the origin and the age of the rock, for the tendency of petrological inquiry in the present day is to predicate a great geological age for crystalline rocks in which the granitic structure is due to regional metamorphism. But if the conclusions at which I have arrived in this paper are sound, it follows that the gneissose granite of the Dhula Dhár is of eruptive origin, and instead of being an archæan, cambrian, or "converted" silurian rock, it is in reality of tertiary age, and was brought into its present position in the course of the throes that gave birth to the Himalayas.

I do not intend to draw the inference that all the granitoid, and still less that all the gneissose rocks of the North-West Himalayas are of eruptive origin,—that would be too sweeping a generalisation to make from the facts at present ascertained,—but I think the most natural conclusion to draw from the evidence before us, taken as a whole, is that the "central gneiss" and "granitoid gneiss" of Dalhousie is really an eruptive rock; that is to say, whether it has travelled a short distance, only, from its seat of extreme metamorphism, or whether it was more or less directly connected with volcanic or plutonic action, it was in actual motion in a fused or plastic condition and occupies now the position of an intruder in the silurian series. I think the balance of evidence is against the supposition that it was reduced into a fused condition *in situ*.

DESCRIPTION OF PLATES.

PLATE I.

Fig. 1. Gneissose granite, Dalhousie. This sketch, taken from slice No. 1, is intended to show the polysynthetic structure of portions of the quartz.

„ 2. A portion of slice No. 16, taken from a granite vein intruded into slate, Dalhousie; (*a*) shows the crumpling of mica due to traction. See also fig. 1, plate II.

„ 3. A portion of slice No. 20. Slate from the quarry near the gneissose granite, Dalhousie.

PLATE II.

Fig. 1. A portion of slice No. 16, taken from a granite vein intruded into slate. See also fig. 2, plate 1.

„ 2. A portion of slice No. 15; gneissose granite in contact with slate, above the slate quarries, Dalhousie. This sketch represents the mode in which the crypto-crystalline mica and biotite are drawn out into strings.

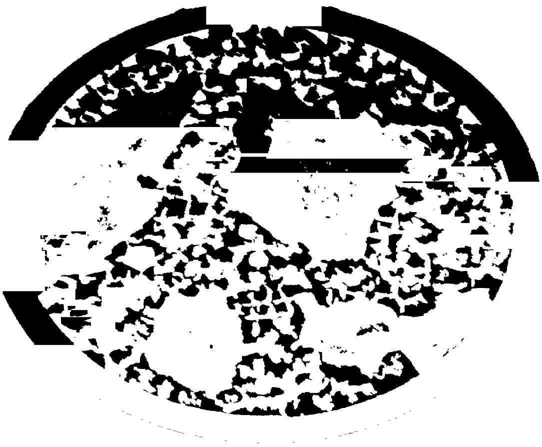
„ 3. A portion of slice No. 21; spotted schist within a few yards of the gneissose granite; Dalhousie. The sketch shows the way the crypto-crystalline mica and hyaline quartz are intermixed.

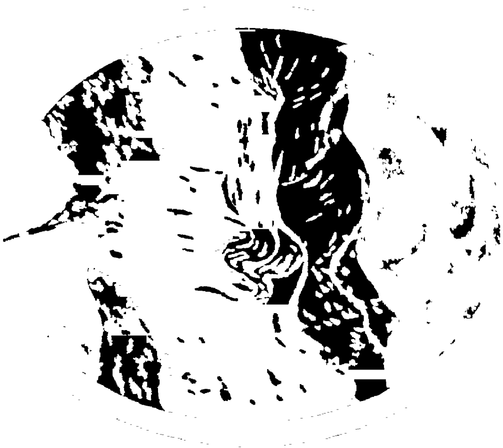
„ 4. Sketch of a biotite crumpled up by traction, taken from slice No. 15, gneissose granite in actual contact with slate.

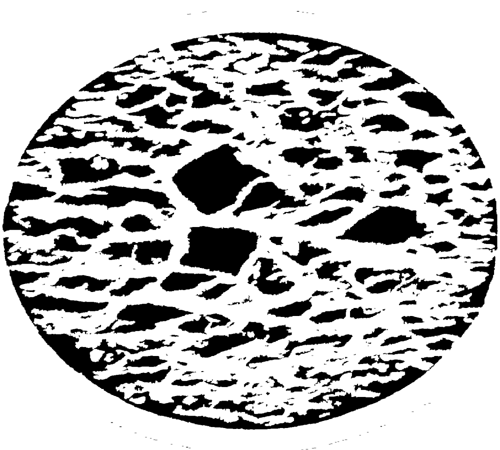
„ 5. Showing a common mode of occurrence of mica in connection with the ropy strings of crypto-crystalline mica.

„ 6. Showing the mode in which grains of opacite and microliths of an undetermined mineral adhere together.

„ 7. A crystal of schorl taken from slice 17, showing that air or liquid enclosures originally contained in it had subsequently expanded from heat and forced their way to the surface of the mineral before its final consolidation.







On the lavas *of* Aden—*By* COLONEL C. A. McMAHON, F.G.S.—(*With a plate.*)

A BRIEF account of the extinct volcano of Aden is given by Mr. F. R. Mallet, F.G.S., in his paper "On the Geological structure of the country near Aden, with reference to the practicability of sinking Artesian Wells." Vol. VII, Memoirs, Geological Survey of India.

The following description of the lavas found at Aden is taken from Mr. Mallet's paper: "The varieties of rock met with are very numerous; there are perfectly compact lavas of brown, grey, and dark-green tints, sometimes containing crystals of augite and not unfrequently those of sanidine, and there are rocks exhibiting every degree of vesicularity until we arrive at lavas resembling a coarse sponge and passing into scoriæ. The vesicles again are in some specimens globular, and in others flat and drawn out. In some places the lava is quite schistose, and might if seen *per se* be easily mistaken for a metamorphic rock. Such lava is sometimes vesicular, but by no means always so, at least not to the naked eye. Volcanic breccias are also met with, as near the main pass where fragments of dark-green lava are imbedded in a reddish matrix. Tufas are also present, but apparently to a limited extent. Some specimens of tufa shown me by Captain Mander, the Executive Engineer, were made up principally of fragments of pumice, from which it would appear that pumice must be amongst the volcanic products, though I am not aware of any locality in which it is found *in situ.* Obsidian is to be met with occasionally in thin seams."

I have not met with any detailed account of the micro-petrology of the Aden lavas, but the following passing allusions to them may be quoted here. Mr. Frank Rutley, F.G.S., in his Study of Rocks, p. 152, 2nd edition, writes as follows: "A globular condition of silica has been lately described by Michael Lévy as occurring in the euritic porphyries of Les Settons, and similar globular conditions of silica have been observed and noticed by M. Vélain in a quartz trachyte from Aden. The former author regards this condition as intermediate between the crystallized and the colloid forms of silica."

Professor A. Daubrée, in his paper on zeolitic and silicious incrustations (Q. J. G. S., XXXIV, 73), states that silicious infiltrations are found in many volcanic rocks of the "trachydoleritic class," and refers to Aden as one of his examples.

The above are the only references to the Aden rocks that I have yet met with, and the following account of some of the lavas to be found at that place may not be without interest. As I have never been able to remain at Aden for more than a few hours, my examination of the extinct crater has only been a cursory one. The specimens from the vicinity of the tanks were collected by me, but the others were collected for me by a resident Engineer through the kindness of a friend. I proceed to describe the specimens in detail.

Basalts.

No. 1.—A grey compact lava. With the aid of a pocket lens, crystals of felspar and numerous dots of a greenish-yellow amorphous mineral are visible here and there. The locality in Aden from which this specimen was obtained is unknown. Sp. G. 2·78. The rock is magnetic and under the blowpipe fuses to a black bead.

M.—The base consists of a devitrified glass in which dendritic and rod-like forms of magnetite are abundant. Magnetite is also present in regular crystallographic forms.

In this base countless prisms of felspar are starred about; whilst large porphyritic crystals of that mineral are visible here and there. The porphyritic crystals are all plagioclase with the exception of one medium-sized prism which is orthoclase. Many of the minute prisms are visibly triclinic and the others are presumably so. The porphyritic felspars contain numerous enclosures of the base.

There are several augite crystals in the slice, but they are not very fresh. Part of the magnetite has been converted into hæmatite or göthite, imparting a reddish tinge to the slice, when viewed in reflected light.

The greenish-yellow amorphous mineral, alluded to above, is probably a secondary product of the decomposition of olivine, but none of the unaltered mineral is to be detected.

This rock is evidently an ordinary basalt.

No. 2.—A very dark-grey lava from Station Flagstaff Hill. It is highly vesicular, the area of the vesicles in the thin slice being nearly equal to the substance of the lava itself, but they are too minute to be seen by the unaided eye.

The rock is decidedly magnetic and fuses readily to a black bead. It seems to be a favourite rock for building purposes, and it is said to take the chisel well.

M.—The ground-mass is perfectly opaque except at the edges of the vesicular spaces and at the ends of felspar crystals, where it is seen to be made up of microscopic globulites and grains of crystalline matter. Some of this globulitic granular matter appears to be augite.

The ground-mass contains numerous crystallites and small crystals of felspar, several of which are distinctly triclinic. They contain many enclosures of the base, and some are mere skeleton crystals. Some of the larger felspars enclose prisms of apatite.

Several augites are visible in the ground-mass.

This specimen is also, I think, a basalt.

No. 3.—A very dark-grey finely vesicular lava closely resembling the last. The rock is magnetic and it fuses under the blowpipe to a black bead. From Ras Baraldu.

M.—This so closely resembles the last that a separate description is not necessary. The vesicles are not so uniformly distributed as in the last specimen and merge into elongated confluent cavities. The thin slice in reflected light has a warm brown tint. The ground-mass is not so absolutely opaque as the last specimen. In the larger felspars the enclosures of the base are so abundant as to give them quite a skeleton appearance. A fragment of augite is present in the ground-mass.

This is said to be a good building-stone and to take the chisel well.

No. 4.—A dull red highly vesicular lava. It powerfully affects the magnet, and it fuses under the blowpipe to a very dark mass that adheres to the magnet. Locality from which obtained unknown.

M.—The ground-mass is quite opaque.

Andesites.

No. 5.—A slaggy-looking lava with crystals of felspar visible here and there. Some vesicular cavities contain a zeolite which also forms incrustations on the surface. The specimen was obtained near the Station Point Cemetery. Sp. G. 2·64. The determination of the specific gravity may be a little under the mark, as there are a few vesicular cavities. The specimen is powerfully magnetic, and it fuses at the edges.

M.—The ground-mass is nearly opaque and consists of multitudes of grains of magnetite disseminated through a base of flocculent matter, probably a product of devitrification rather than of decomposition. None of the magnetite exhibits regular crystallographic forms, and part of it has been converted into hæmatite or göthite. The latter imparts a reddish and pseudo-felspathic appearance to much of the base when viewed macroscopically.

The ground-mass contains numerous micro-prisms of felspar, whilst felspars of large size are porphyritically embedded in it. The latter are nearly all visibly triclinic, and contain very numerous enclosures of the base, and buff coloured amorphous masses, that probably represent decomposed augites. Augites are not unfrequently caught up in large felspar crystals, as is the case, also, in slice No. 1. The felspar contains gas cavities and enclosures of ferrite.

No. 6.—A dark-grey vesicular lava from the vicinity of Station Point Cemetery. The hand specimen resembles the mudstone matrix of a conglomerate from which the pebbles have been extracted, the vesicular spaces having very smooth and regular surfaces as if they had enclosed hard substances. Sp. G. 2·61. The hand specimen is strongly magnetic and fuses easily under the blowpipe to a black bead which adheres to the magnet.

M.—A striking feature in this slice is the presence of numerous crystals of a red mineral which I have not been able to satisfactorily identify. It occurs in six and four-sided prisms, and in irregular shapes, and in fragment-like pieces. Some are in long and thin prisms, others in rather massive lumps. In transmitted light it is of rich orange red colour—yellowish orange when thin—deeper red when thick. When the polariser alone is revolved it absorbs light distinctly, but does not change colour. It very frequently contains enclosures of felspar, and in one instance the latter has conformed to the shape of the prism. These enclosures seem to indicate that the mineral is an original constituent of the rock and not a secondary product. The cleavage is irregular. The angle of the prism varies very much; some being nearly right angles, others being very obtuse. The average of the measurements of 17 prisms come to 103° 52′. In a few, not included in this average, adjacent faces intersected at an angle of 135°. The variation in the angle seems due to the mineral itself and not to oblique slicing.

Extinction coincides with the length of the prism and with the diagonal of the prismatic angles seen in cross section.

Between crossed nicols the mineral changes from dark to its natural colour in this slice, but in No. 16 it changes from dark to a rich crimson colour.

The prevalence of four-sided prisms is against the mineral being rubellite, or an allied species of tourmaline; its orange colour and transparency shuts out the idea of its being hæmatite, whilst the extinction shows that it is not a monoclinic pyroxene. In some respects it would do for brookite and the angles would agree fairly well with the Arkansas variety of that mineral, but I do not feel satisfied that it is brookite.

Can it be an ortho-rhombic pyroxene? the presence of which mineral in augite-andesites has recently been determined by Cross, Rosenbusch, and Teal. Its colour is not favourable to this supposition. Altogether the mineral is rather a puzzle to me at present.

The base of the rock under consideration consists of a slightly devitrified glass, of pale yellowish colour, in which are disseminated a micro-crystalline mixture of felspar, magnetite, and granular hornblende or augite. It is not dichroic and from the angle of extinction in some pieces of prismatic form I think it is augite.

Besides the micro-prisms of felspar, scattered in great abundance through the base, felspars in larger prisms are porphyritically imbedded in the ground-mass. They are nearly all visibly triclinic, as are some of the very small ones.

Considering the low specific gravity of the last two specimens, I think they must be classed as andesites. They are evidently transitional forms between the basalts and the trachytes of the Aden volcano.

Trachytes.

No. 7.—A grey compact lava with minute crystals of sanidine visible here and there. From the vicinity of the tanks. Sp. G. 2·66. The hand specimen is magnetic, but not strongly so. Under the blowpipe it fuses to a dark bead.

M.—The ground-mass consists of an intimate mixture of minute felspar prisms and irregular-shaped pieces of felspar: countless patches or granules of hornblende, and grains of magnetite and ferrite. In this are porphyritically imbedded large crystals of felspar; plagioclase and sanidine being almost equally abundant. Two of the latter present penetration twins, the others are twinned on the Carlsbad type.

The sanidine contains numerous enclosures of the ground-mass, and also stone or glass enclosures that have deposited mineral matter on cooling. Two of these are depicted at figs. 7 and 8.

The margin of many, and occasionally the whole of the sanidines in this, and in most of the slices about to be described, have a curious dusty appearance. Under high powers these felspars are seen to be full of imperfectly defined contorted fibrous particles of a doubly refracting mineral, and the dusty appearance seems to be due to the irregular intergrowth of either quartz, or another species of felspar. These enclosures do not interfere with twinning, and the latter shows that the mineral is sanidine and not nepheline.

In a portion of the slice the hornblende and magnetite are arranged in dendritic combinations.

The hornblende exhibits dichroism very strongly. One set of cleavage lines are occasionally to be seen, and the angle of extinction is characteristic of hornblende.

The slice contains a piece of the red mineral described under No. 6.

No. 8.—A grey compact rock with numerous crystals of sanidine imbedded in it. From the vicinity of the tanks. Sp. G. 2·63. The hand specimen is distinctly magnetic; under the blowpipe it fuses at the edges and adheres to the magnet.

M.—This specimen is more felspathic than the last, and the base in transmitted light is clearer. It consists of a micro-crystalline admixture of felspar, in which very numerous patches of a yellowish-green hornblende, and grains of magnetite, are freely scattered about. There are also a good many patches of hæmatite, or göthite, most of which are directly connected with magnetite grains.

There are two sizes of felspar crystals porphyritically imbedded in the ground-mass, namely, medium-sized and very large sized. Nearly the whole of the felspar of all sizes is orthoclase, but there are a few prisms of plagioclase. The larger prisms contain numerous rod-like belonites, some of which are fractured, which are doubtless imperfectly formed apatite crystals. In some cases opacite, or granular magnetite, has formed on these belonites, and sketches of three of them are given at figs. 11, 12, and 13. These combinations are particularly worth noting, because exactly similar forms are common in the gneissose granite of the North-West Himalayas, and in both cases they seem to afford evidence of the rocks which contain them having been reduced to a fused or plastic condition.

In fig. 13 the magnetite is seen to have formed on the belonite after the consolidation of the latter, and to have completely embraced it. In fig. 12 the magnetite has partially encircled the larger mineral in its arms, whilst in fig. 11 it has consolidated along its edge. In fig. 11 a cavity, running with the length of the belonite, is seen depicted at (*a*). It is probably due to shrinkage on cooling.

It is interesting to find bodies, such as those described, common to acid lavas and the gneissose granite of the Himalayas.

The felspars contain thousands of air or gas cavities.

An isotropic mineral is to be seen here and there; one of the crystals presents a six-sided outline—the sides being equal—whilst the others are in more rounded forms. It is doubtless garnet.

No. 9.—A grey compact rock, somewhat mottled in appearance, with minute prisms of felspar visible here and there. The specimen was obtained near the tanks. Sp. G. 2·60. The rock attracts the magnet, and it fuses under the blowpipe to a dark bead.

M.—The ground-mass is dark owing to the abundance of magnetite; in other respects it does not differ from that of the slices of trachyte previously described. Amongst the large porphyritic crystals plagioclase preponderates over the sanidine, but the smaller crystals all belong to the latter species. Some of the triclinic felspar is in the form of long thin prisms.

The larger felspars contain numerous enclosures of the ground-mass. In some they are so abundant as to give the prisms a somewhat skeleton appearance.

Microliths and stone enclosures are abundant, whilst a zonal growth is visible in some of the sanidines.

There is one good-sized, rounded crystal and an irregular-shaped piece of augite, whilst numerous patches of hornblende are scattered throughout the ground-mass. The rounded augite encloses a minute crystal of hornblende. The latter mineral presents irregular shapes, but in one case the cross cleavage lines are fairly well developed.

The slice contains a garnet. Much of the magnetite has passed into hæmatite, or göthite, whilst an apparently hydrated species of iron oxide often stains the matrix round the magnetite grains.

The trachyte in this specimen appears to be approaching the andesites, and is on the border line between the two.

A sketch of a portion of this slice is given at fig. 2; a group of felspar crystals, round which much magnetite has collected, occupies the centre of the illustration. The felspars are seen to have caught up numerous fragments of the ground mass which are alligned in general correspondence with the cleavage planes of the enclosing felspars.

No. 10.—A compact light grey coloured rock with minute crystals of sanidine visible here and there. This was obtained near the tanks. Sp. G. 2·48. The hand specimen contains, caught up in the compact rock, several fragments of pumicious lava in which vesicular cavities are numerous. This seems sufficient to account for the abnormally low specific gravity, as the air caught up in the vesicular cavities of the pumicious fragments would be sufficient to vitiate the result. The hand specimen is magnetic, but it is almost infusible under the blowpipe.

M.—This seems to be quite a typical trachyte. The ground-mass appears to be made up of an aggregation of felspar microliths. In this are imbedded medium and large sized felspar crystals. Amongst the two latter sanidine is abundant and is in very typical forms. The slice contains very little plagioclase, and the felspar micro-prisms of the base are either undifferentiated or are orthoclase.

Hornblende occurs in patches throughout the ground mass, though it is not so abundant as in some of the slices previously described. There are one or two fragmentary looking pieces of augite. In transmitted light it is of a greenish-brown, or brownish-green, but of so pale a tint as to be almost colourless. It is not dichroic, and in extinction and other characteristics it agrees with augite. The outer edge is a good deal corroded, but internally it is perfectly fresh. Some of the hornblende is much corroded and altered. It is of yellowish-green colour, and most of it is decidedly dichroic.

The ground-mass contains numerous grains of magnetite. Hæmatite or göthite is present here and there, and has penetrated cracks in the sanidine; it also occurs in patches in the latter. Some apatite is also present.

A long cavity in the slice is stopped with calcite, which is here and there crystallized in characteristic forms. The calcite encloses some minute prisms of epidote. A zeolite appears to be also present.

Quartz trachytes.

No. 11.—A grey compact rock with minute crystals of sanidine visible here and there. Part of it is of dark grey, and part a very light grey colour; and when examined with the aid of a pocket lens, it has the appearance of two magmas imperfectly mixed together. The specimen was obtained near the tanks. Sp. G. 2·60. The rock is strongly magnetic. The dark portions fuse, under the blowpipe, to a dark magnetic bead, but the light portions fuse at the edges only to a transparent colourless glass.

M.—This is a very beautiful specimen in the field of the microscope. The ground-mass in transmitted light is, in parts, very clear and transparent, and in other parts, representing the dark portions previously alluded to, the magnetite and hornblende are crowded together, so as to almost cover an area equal to that occupied by the felspar. In the clearer portions of the ground-mass the magnetite and hornblende are in larger and in more perfectly crystallized grains. In the dark portions much of the hornblende is in an embryonic condition, being shapeless aggregations of minute granules, the optical characters of which are indistinct.

From the microscopic examination of this slice, I am disposed to think that the mottled character of the rock is due to segregation.

There are numerous large crystals of sanidine scattered through the ground-mass besides others of medium size. Plagioclase is sparse. The large felspar crystals contain numerous enclosures of hornblende and a profusion of stone enclosures. The curious dusty appearance seen along the border of sanidines, described under No. 7, is very prominent in those of this slice.

Patches of hæmatite or göthite are visible here and there, and some of it is distinctly traceable to the alteration of magnetite; whilst large grains of the latter have also stained the matrix for some distance round them with a yellowish doubly refractive substance.

The slice contains a garnet and a little apatite. Here and there patches of hornblende very much resemble leaflets of mica, but I do not think any of them are really that mineral, as they are of exactly the same tint as the undoubted hornblende contained in the slice, and no trace of cleavage is visible in any of the flakes alluded to. The slice, however, contains a thin string of crypto-crystalline mica meandering about in it, similar to that described in my paper on the gneissose granite of Dalhousie. This additional link connecting acid volcanic rocks with the gneissose granites of the North-West Himalayas is most interesting.

Free quartz is to be seen here and there in the ground-mass. It is evidently a residuum, and, like the quartz of granite, it is moulded on to the other minerals.

The slice also contains another specimen of the red mineral described under No. 6.

No. 12.—A pale grey compact rock with crystals of sanidine porphyritic in it, from the vicinity of the tanks. Sp. G. 2·57. The hand specimen is magnetic. Under the blowpipe portions fuse to a magnetic bead, whilst other portions are but slightly acted on.

M.—This specimen so closely resembles the last described that only a few additional remarks are needed. Plagioclase is subordinate to the orthoclase. Magnetite is plentiful and is in well-shaped grains. Hæmatite is also abundant and for the most part assumes dendritic forms, and is but feebly translucent.

Hornblende is very abundant, being present in both the ground-mass and in the felspar crystals; and some of the crystals present well-shaped six-sided prismatic sections.

Apatite is extremely abundant in the ground-mass, and the rock, when examined chemically, gives the phosphoric acid re-action with molybdate of ammonia very decidedly.

The slice contains two shapeless garnets.

Glass and stone cavities are very abundant in the felspar crystals, and are, for the most part, of types similar to figs. 4 and 5. Figs. 9, 10, and 16 are taken from this slice.

As in the last specimen, free quartz is present in the ground mass.

No. 13.—A mottled grey compact lava with felspar facets visible here and there. It was obtained near the tanks. Sp. G. 2·56. It is magnetic, and its behaviour under the blowpipe is as in Nos. 11 and 12.

M.—This specimen is so similar to the last that a detailed description is unnecessary. The ground-mass is not as clear as the two last slices; but the felspar crystals, on the other hand, do not contain hornblende, and they are much more free from enclosures generally.

Apatite is very sparse, and there are no garnets. Hæmatite is not so abundant, and it is not in dendritic forms.

The slice contains an augite with a deep dark border.

Numerous glass or stone enclosures are to be observed in the sanidine, illustrations of which are given at figs. 4 and 5. In some the matter deposited on cooling appears to be partly mineral and partly gaseous, as in figs. 6, 9, and 16; that is to say, a gas appears to have first separated from the glass, on the consolidation of the latter, and then on cooling to have deposited mineral matter previously held in suspension.

Numerous gas or air bubbles are present in the ground-mass.

Free quartz is present as in the last two specimens.

Fluxion structure is observable in a portion of the ground-mass, where the microliths of felspar are seen to flow round a large crystal.

A sketch of a portion of this slice is given at fig 1. It is not possible on the scale at which it is drawn to attempt to depict the microliths of the ground-mass.

No. 14.—A light grey compact rock with sharply defined patches of a dark lava visible here and there imparting a brecciated appearance to the hand specimen. This lava occurs near the tanks. Sp. G. 2·48. The rock attracts the magnet, but fragments of it are infusible before the blowpipe. Facets of felspar are visible in the dark and light portions alike.

M.—The ground-mass is clear owing to the comparative sparseness of magnetite. There are only two or three small pieces of hornblende present in the slice.

There is no plagioclase, but sanidine is very abundant, and, as usual, is present in very large, in medium, and in minute crystals.

Quartz is abundant and is a much more prominent feature in the ground-mass than in any of the specimens previously described. Over about half the total area of the slice, the quartz is intimately intermixed with the felspar of the ground-mass, and in polarised light the combination of the two present a curious sieve-like appearance, the quartz constituting the meshes. Here and there free quartz forms larger masses having an irregular ramifying external outline. Minute crystals of sanidine are frequently imbedded in the free quartz.

There are a few small garnets, whilst magnetite, ferrite, and hæmatite or göthite are present as usual.

No. 15.—A greenish-grey vesicular lava from behind the post office. The greater part of Steamer Point Church is said to be built of this rock. From a builder's point of view, it is said to weather badly. The hand specimen is feebly magnetic; and under the blowpipe it becomes glassy on the surface, but does not fuse to a bead.

M.—I have examined four slices of this interesting lava. The ground-mass is micro-aphanitic, and is composed of minute prisms of felspar radiating in all directions. Grains of quartz are visible here and there in the ground-mass, but they are most abundant along the margins of the vesicular cavities when they exhibit rounded and hexagonal outlines. It is I think, tridymite.

The quartz contains numerous liquid cavities with enclosed bubbles, a fair proportion of which are movable. The size of the bubbles, relative to that of the cavities containing them, varies so much that no reliable calculation can be based on the proportion between the two. One of the quartz grains contains glass enclosures that have deposited mineral matter on cooling, and one of them has several fixed bubbles. The ground-mass contains many air or gas bubbles.

There are no porphyritic crystals of felspar.

Hornblende is very abundant; most of it is in acicular prisms of irregular outline, and rather pale green colour, resembling the hornblende of the Wolf rock (phonolite) of Cornwall; but there are larger stumpy prisms, here and there, of bluish to dark green colour in transmitted light, that have sharp outlines, give good six-sided sections and occasionally exhibit cross prismatic cleavage lines. It is decidedly dichroic changing from brown to bluish-brown; but under crossed nicols the absorption is so powerful that the colours exhibited are very feeble.

No. 16.—A light grey vesicular lava from Flag Staff Hill. Sanidine and quartz are to be observed here and there. It is slightly magnetic and fuses at the edges. Numerous round silicious granules with rough surfaces are visible in the vesicular cavities; they are dull and somewhat opalescent-looking, and have none of the liquid lustre of vitreous quartz. Most of them are globular, but some are flattened and present hexagonal outlines and are seen to have a yellowish nucleus. They are infusible under the blowpipe, and hydrochloric acid takes no notice of them.

M.—Under the microscope these spherulitic bodies are seen not to be exclusively *confined to the edges of the vesicular cavities, but to occur occasionally* in the ground-mass itself. Their central portions are, in transmitted light, of buff colour, and are feebly translucent, but the outer portions are transparent. Most of the globular bodies have rounded outlines, but others are flattened at the poles and present a hexagonal prism in section. Those which occur along the edges of vesicular cavities are segments of circles, the yellow nucleus being truncated and abutting directly on the edge of the ground-mass. Under crossed nicols the transparent portion is seen to have a distinctly radiated structure, and in some a dark cross is visible. They polarise in simple black and white and never exhibit colours. In some, the rough exterior surface, alluded to in my remarks on the macroscopic aspect of the rock, appears to result from minute prisms, or minute plates of tridymite projecting from the outer surface. In both cases the angles of adjoining faces are approximately 120°.

These globular bodies seen in section resemble the spherulites of rhyolites, dacites, and acid vitreous rocks, and were those found in the ground mass, seen by themselves they would undoubtedly be taken for ordinary spherulites; but the way they stand out from the surface of the vesicular cavities, their occasional hexagonal outline, and the fact that the yellow globular nuclei of those which line the vesicular cavities ar usually bisected by the bounding surface of the ground-mass, and are not continued into it, shows that they differ from ordinary spherulites. They have evidently been formed, in the great majority of cases, either by the exudition of silica from the base into the vesicular cavities, or have been deposited in these cavities through the agency of steam or water; and are not, like ordinary spherulites, the product of the devitrification of the glassy base.

I presume that these globules are identical with those noticed by M. Vélain (see *ante*). Their behaviour under crossed nicols is not, however, similar to M. Michael Lévy's description of the globular silica occurring in the euritic porphyries of Les Settons.

It is not quite clear what Michael Lévy means by a "condition *intermediate* between the crystallized and the colloid forms of silica." It seems to me that the globular silica of the Aden lavas is only a variety of hyalite, and that its peculiarities are principally due to an intergrowth, or rather to a successive formation of hyalite and tridymite. The nuclei are probably formed of common opal.

The ground-mass of the rock under consideration is micro-aphanitic, and consists, as in many of the previous specimens, of light clear portions and dark portions, as though two magmas had imperfectly mixed together.

Some large porphyritic crystals of felspar are triclinic. Some of the felspars contain large enclosures of the ground mass which have not entirely separated from the main mass; whilst the dusty appearance described in the previous pages is very prominent in the felspars of this slice. In some cases it makes them resemble nepheline, but the angle of extinction and the twinning of the sanidine and plagioclase (for the dusty appearance is seen in both classes of felspars) usually prevent any mistake in their identification.

The ground-mass contains granules of greenish hornblende, whilst minute *four and six-sided well-shaped prisms of a brownish hornblende project from* the ground-mass into the vesicular cavities The prism of one measured exactly 124°, 30 .[1]

Apatite is present, also magnetite and hæmatite or göthite. There are also several large and small crystals of the orange red mineral, previously described. Between crossed nicols it changes from a rich crimson colour to dark.

Several of the vesicular cavities are stopped with calcite.

No. 17.—A greenish-grey fine-grained but highly vesicular lava, from the vicinity of the Station Point Cemetery. It is distinctly magnetic and fuses at the edges under the blowpipe. The siliceous globules are abundant.

M.—This is more uniformly vesicular than the last specimen, and the vesicular spaces occupy a considerable area relative to the ground-mass; consequently very large crytals of felspar are wanting and medium-sized ones are comparatively rare. In other respects this specimen closely resembles the last.

There are siliceous globules, as in the last, but tridymite is also abundant and occurs on the edges of the vesicular cavities. An overlapping of the plates is an almost constant feature in the tridymite of this and other slices. The vesicular cavities are occasionally plugged with a fibrous zeolite.

The red mineral is absent and the brown hornblende, of the last specimen, is extremely sparse. Green hornblende in acicular prisms is very abundant.

Trachytic Pitchstones.

No. 18.—A compact brick-red lava with facets of felspar visible here and there. From the vicinity of the Station Point Cemetery. Sp. G. 2·40. The rock is magnetic and fuses, but not very readily, to a white blebby mass full of air bubbles.

M.—The ground-mass is of such microscopic fineness that it requires powers of over 100 diameters to make it out. It consists of a matted mass of felspar microliths and fine granular matter. In this are scattered felspar crystals of various sizes, some hornblende and large magnetite grains. None of the felspars give evidence of being triclinic. The large felspar crystals contain numerous enclosures of the base. The slice contains countless crystallites of felspar that closely resemble those described in my paper on the basalts of Bombay,[2] having either frayed ends, or being mere skeletons enclosing the granular matter of the ground-mass.

Hyalites are to be seen in a few vesicular cavities; their outlines are semicircular.

This vitreous lava may, I think, be described as a *devitrified trachytic pitchstone*. A sketch of a portion of this slice is given at fig 3.

No. 19.—A reddish compact rock from the vicinity of the Station Point Cemetery. Sp. G. 2·38. This looks more like a rotten schist than a lava. Though not visibly porous or vesicular, yet when plunged into water it gives off a stream of minute air bubbles that lasts for some hours. It is not magnetic. Under the blowpipe it fuses with difficulty and becomes frothy.

M.—The ground-mass consists of micro-crystals of felspar interspersed with,

[1] Rutley's Study of Rocks, p. 152, 2nd Ed. [2] Records, Vol. XVI., p. 42.

micro-grains of quartz, and an amorphous opaque red ferrite. It is of much larger grain than the last specimen.

All the porphyritic crystals of felspar are sanidine. They contain stone and glass enclosures. One of the latter is depicted at fig. 14, and is seen to contain three fixed bubbles and three crystals. Fig. 15 represents a cavity within a glass enclosure; the outer glass enclosure containing a large fixed bubble and a small crystal. The inner cavity appears to contain a minute bubble. Enclosures that have deposited dusty matter on cooling; and glass enclosures, each of which contains a large fixed bubble, are not uncommon. The slice contains no hornblende.

This lava seems to be intermediate between a quartz-trachyte and a pitchstone, but must, I think, be classed as a devitrified trachytic pitchstone.

Pumice.

No. 20.—A light grey pumice obtained in the vicinity of the Station Point Church.

M.—The vesicular cavities are filled with calcite, a zeolite, and I think some aragonite.

The pumicious part consists of a glass containing millions of air bubbles; some of these are round, whilst others are elongated, and are drawn out in the direction of the flow.

Conclusion.

Though I cannot suppose that my collection of the lavas of Aden afford complete examples of all the varieties to be obtained in the neighbourhood of that extinct volcano, still it is sufficient to show that the now silent craters, in the days of their activity, poured out basic, intermediate, and acid lavas. We have presented to us inside the main crater of Aden an unbroken succession of lavas, from acid pitchstones, on the one hand, to basaltic rocks on the other. Pitchstones shade into quartz-trachytes; quartz-trachytes into trachytes; whilst the latter pass into andesites, and through them, into basalts. On the whole, the acid rocks seem to have predominated.

Many of the lavas described in these pages have a mottled, and even a brecciated appearance, and it is difficult to say positively whether this is due to segregation, or to an imperfect blending of basic and acid magmas.

It would be interesting to know the order of succession in which the basic, intermediate, and acid lavas appeared; but on this point I have no information.

The specific gravity of each class of lava is low. I did not attempt to determine the specific gravity of the vesicular specimens, and though it is possible that hidden vesicles may, to some extent, have vitiated the determination of the specific gravity of some of those examined, yet, on the whole, I am disposed to attribute the low averages to the predominance of the acid element in the Aden lavas.

The following averages were obtained :—

Basalt	Sp. G.	2·78
Andesite	"	2·62
Trachyte	"	2·58
Quartz-Trachyte	"	2·55
Pitchstone	"	2·39

The pitchstones yield a somewhat abnormally high specific gravity, indicating their connection with the quartz-trachytes; but all the others, noted above, though within the minimum limits, are below the normal *average* specific gravity usually given for each class of rock in our text books.

The ground-mass of the intermediate and acid lavas, described in these pages, is micro-aphanitic; in no instance is it micro-felsitic. There are, except in the extremely vesicular specimens, and in the pitchstones, always three generations of felspar; micro-crystals in the ground mass, and medium and large-sized porphyritic crystals.

In the basalts and andesites the felspar is, almost without exception, plagioclase. Amongst the trachytes, those on the border line of the andesites, as No. 9, contain more porphyritic crystals of plagioclase than of sanidine; whilst those that approach the quartz-trachytes contain scarcely any plagioclase.

In intermediate varieties, as Nos. 8 and 10, the porphyritic crystals of triclinic and monoclinic felspar are pretty equal in number. In the quartz-trachytes, themselves, plagioclase is either wanting or is subordinate to the sanidine; whilst in the pitchstones plagioclase is wholly absent.

Augite is prominent in the basaltic lavas, but only stray crystals of it are present in the other lavas, namely, in Nos. 6, 9, 10, and 13.

Hornblende is abundant in the trachytes and in most of the quartz-trachytes; whilst it is sparse or wanting in the pitchstones.

Magnetite is present in all except No. 20, and every specimen, except Nos. 19 (pitchstone) and 20 (pumice), distinctly attracts the magnetic needle; some of them acting powerfully on it.

Hematite or göthite is found in all the specimens except the pumice; whilst apatite is commonly present, sparsely in some, but abundantly in others.

An isotropic mineral which I doubt not is garnet is to be seen in several slices, namely, in Nos. 8, 9, 12, and 14.

There is nothing in the appearance of the mineral to lead me to suppose that it is hauyne, a mineral frequently mentioned in connection with trachytes. Zirkel, in his Microscopic Petrology of the Fortieth Parallel, notes the occurrence of garnet in rhyolites and trachytes; and seeing that this mineral so commonly occurs in granite and syenite, its presence in the lava form of those rocks is hardly surprising.

Mica is conspicuous by its absence; but there is, however, a notable exception in slice No. 11 (quartz-trachyte), in which a thin string of crypto-crystalline mica, similar to that which takes so prominent a place in the gneissose granites of the North-West Himalayas,[1] is seen meandering through the slice. This link between acid volcanic and acid plutonic rocks seems to afford an indirect confirmation of the correctness of the conclusion regarding the affinities of the gneissose granite arrived at on other grounds.

Stone and glass enclosures are common in the felspars; also cases of magnetite forming upon and embracing microliths in a way that indicates a viscid, or

[1] Records, Volume XVI, p. 129.

fused, condition, and consequent freedom of molecular action,—facts which also form interesting points of contact with the gneissose granite of the Himalayas.

The general absence of fluid cavities is generally considered characteristic of the quartz of lavas, as compared with that of granite; but exceptions to this rule do not appear to be altogether uncommon. Dr. Sorby notes one in his Ann. Address, Q. J. G. S XIV. p. 84; another instance will be given in my forthcoming paper on the Traps of Dalhousie; whilst yet another will be found in this paper in my description of slice No. 15.

EXPLANATION OF THE ILLUSTRATIONS.

Fig. 1.—A quartz-trachyte, slice No. 13. The central felspar is imperfectly formed, and contains enclosures of the ground-mass.

Fig. 2.—A trachyte, slice No. 9; with a group of felspar crystals, in the centre of the field, round which magnetite and ferrite have collected. The felspars enclose portions of the ground-mass alligned in general correspondence with the direction of cleavage.

Fig. 3.—A devitrified trachytic pitchstone, slice No. 18.

Figs. 4 & 5.—Stone enclosures, slice No. 13.

Fig. 6.—Enclosures in felspar of slice No. 13. The matter deposited is partly mineral and partly gaseous.

Figs. 7 & 8.—Stone and glass enclosures that have deposited mineral matter on cooling.

Fig. 9.—A glass cavity taken from slice No. 12 which contains an enclosure of gas.

Fig. 10.—A stone enclosure, slice No. 12.

Figs. 11, 12, & 13.—Magnetite and opacite forming on belonites.

Fig. 14.—Glass enclosure, slice No. 19, containing crystals and fixed bubbles.

Fig. 15.—A glass cavity containing an inner enclosure, slice No. 19.

Fig. 16.—An enclosure taken from No. 12, which has deposited mineral matter and also contains gas.

Note on the Probable Occurrence *of* Siwalik Strata *in* China *and* Japan. *By* R. LYDEKKER, B.A., F.G.S., F.Z.S.

I have lately received from Herr L. v. Loczy, of the Royal Geological Survey of Hungary, a letter in which I am informed that during a recent expedition to China he observed extensive tertiary formations on the Upper Hwangho (Hoang-ho) river, in which he collected fresh-water shells and numerous bones of Proboscidia and Rodentia[1] (*sic*). In Western Kansu[2] he acquired from a native dispensary other large fossil bones, and the lower molar of an elephant which he considered very similar to the teeth of the Siwalik *Stegodon clifti*; this molar

[1] ? Ruminantia.

[2] A province on the Upper Hwangho, due north of Burma.

CORRIGENDA *and* ADDENDA *to* "SYNOPSIS *of the* FOSSIL VERTEBRATA *of* INDIA." *Supra, pp. 61—94.*

N. B.—It is to be regretted that Mr. Lydekker could not correct the proof sheets of his paper. Most of these corrections are such as only the author could make.—H. B. M.

Page 62, 86. The *Cochliodontidæ* (*Poecilodus* and *Psephodus*) should be referred to the *Ganoidei*.

„ 63, line 8 from top, for *Oxychina* read *Oxyrhina:* the genus *Sphærodus* should be referred to the *Ganoidei*.

„ 65 „ 21 „ bottom, for *barioccipital* read *basioccipital.*

„ 66 „ 4 „ top, „ *centre* read *centra.*

„ 69 „ 14 „ bottom, before *British Museum*, add *Royal College of Surgeons and.*

„ 70 „ 3 „ „ for *two* read *three:* in the following line *dele* '*and a mandible.*'

„ 71 „ 1 „ top, „ *Enhydras* read *Enhydris.*

„ 72, note, for *irvaticus* read *iravaticus.*

„ 74, line 19 from top, for *H. hyopotamoides* read *A. hyopotamoides.*

„ 76 „ 11 „ „ „ *acuticornis* read *porrecticornis.*

„ 77 „ 10 „ „ „ *Nilgherries* read *Himalaya.*

„ 80 „ 2 „ bottom, *dele* '*south.*'

„ 81 „ 3 „ top, for *when* read *whose.*

„ 85 „ 1 „ bottom, for *Eg.* read *Münst:* also on p. 87, line 12 from bottom.

„ 86 „ 4 „ top, before *Sphyrænodus* add *Teleostei.*

„ „ „ 5 „ „ below *Pycnodus*, add *Sphœrodus rugulosus*, Eg. · this should also be inserted in the alphabetical list.

„ 88 „ 20 „ „ for *dhonkoka* read *dhongoka.*

„ 92 „ 17 „ bottom, for *Typholodon* read *Typhlodon.*

„ „ „ 8 „ top, „ *predicus* read *indicus.*

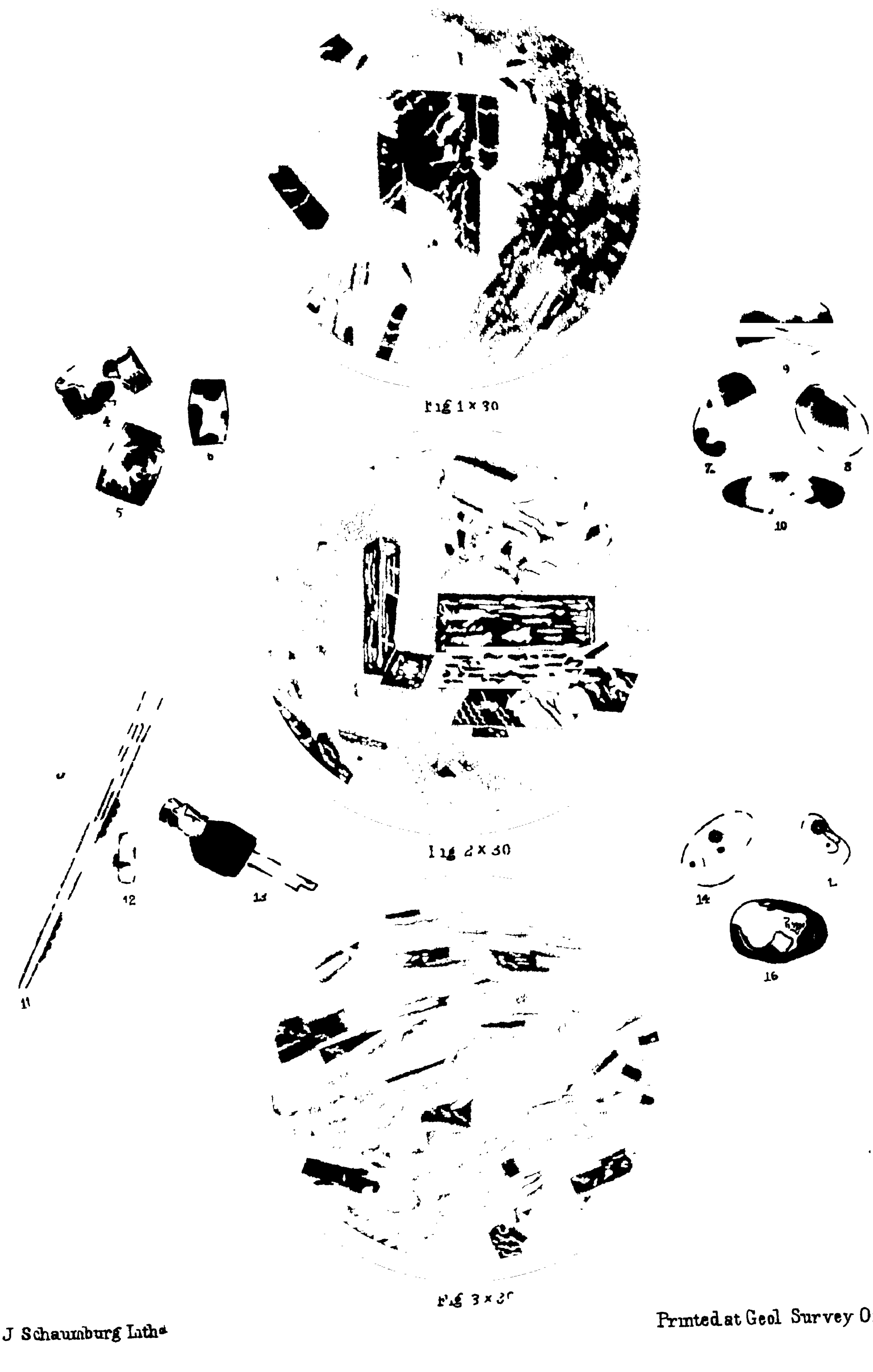


Fig 1 × 30
4
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Fig 2 × 30
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14
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Fig 3 × 30

is described as being brown and highly mineralized, and apparently in very similar condition to the Siwalik fossils.

I am promised an opportunity of examining a cast of the molar, but the description given leaves little doubt that the strata whence the fossil was obtained correspond to the Siwaliks. It will be remembered that Professor Owen has described [1] the milk-molar of a *Stegodon*, said to have been obtained from "marly beds near Shanghai," which he referred to a new species under the name of *S. sinensis*, but which I have seen [2] no reason to separate from the Siwalik *S. clifti*. The mineralization of this specimen (now in the British Museum) is precisely similar to that of the Siwalik fossils, and leads me to conclude that the beds from which it was obtained, together with the Hwangho beds, almost certainly correspond, at least in part, to the Siwaliks. The geographical position of the Hwangho beds, due north of Burma, lends a strong support to this conclusion, as it is well known that the Siwaliks of that country, whence Crawfurd's original specimens were brought, extend far up the valley of the Irawadi, and thus are only separated by Yunan and Sechuen from the Kansu district.

In the same paper Professor Owen also described various other Chinese fossil mammals, belonging to the genera *Chalicotherium*, *Rhinoceros*, *Tapirus*, *Stegodon*, and *Hyæna*, and said to have been obtained from a cave in the province of Sechuen (Sze-chuen), or between Kansu and Yunan and Burma. The mineralization of these specimens is much less complete than that of the Shanghai and Siwalik fossils, but the difference in the manner of the entombment of the specimens is probably quite sufficient to account for this. The genera are all characteristic of the Siwaliks, and although Professor Owen has assigned all the specimens to distinct species, yet it has appeared to me [3] to be highly probable that the *Stegodon* is the same as one of the Siwalik forms; while work on which I am now engaged leads to the conclusion that the Sechuen hyæna is identical with, or very closely allied to, one of the Siwalik hyænas. Whether or no the species be the same, it appears to be most probable that the Sechuen mammals belong to the same period as those of the Siwaliks, and connect those of Burma with those of Kansu.

Turning to Japan, it may be observed that in 1881 Dr. Edmund Naumann figured and described [4] various remains of fossil elephants from that country, which he referred to the following species, *viz.*, *Stegodon clifti*, *S. insignis*, *Elephas namadicus*, and *E. primigenius*; the two first being Siwalik species, the second (or the allied *S. ganesa*) also ranging up into the Narbada beds, and the third being characteristic of the latter. These fossils indicate pretty conclusively that representatives of the mammaliferous beds of India, which probably correspond both to the Siwaliks and the Narbadas, exist in Japan, and are probably the continuation of the Chinese deposits.

[1] "Quar. Jour. Geol. Soc," Vol. XXVI, p 417.

[2] "Palæontologia Indica." Ser. X, Vol. I, "Siwalik and Narbada Proboscidia."

[3] *Ibid.*

[4] "Ueber japanische Elephanten der Vorzeit." 'Paläontographica,' Vol. XXVIII, pt. 1, pls. I—II.

Since the publication of Dr. Naumann's memoir, another paper on the same subject has appeared by Herr D. Brauns,[1] which is certainly a very remarkable paper indeed. In that paper it is first of all attempted to prove that the Siwaliks are entirely of miocene, and the Narbadas of pliocene age, while the Japanese (and presumably the Chinese) mammaliferous deposits are all referred to the pleistocene. Now it is not my intention on the present occasion to go again into the question of the age of the Siwaliks and Narbadas, but there are two points in relation to Herr Brauns' treatment of this question, to which it is almost impossible to omit referring. It happens to be inconvenient to his line of argument that any of the Siwalik species should occur in the overlying Narbadas, and therefore, when such is stated to take place he adopts the very easy, but scarcely scientific, method of doubting the evidence. Thus in the case of the occurrence of *Stegodon insignis* (or the allied *S. ganesa*) in the Narbadas, it is stated[2] that the two specimens of broken teeth figured in the "Fauna Antiqua Sivalensis[3]" from those deposits are not sufficiently perfect for determination, and therefore that *S. insignis* does not exist in the Narbadas. Even if those specimens are insufficient evidence, if the author had but taken the trouble to refer to page 117 of the first volume of the "Palæontological Memoirs," he would have seen a very perfect specimen of the lower jaw of *S. insignis* (No. 1) from the Narbada described by Dr. Falconer; this specimen, which is now in the Indian Museum, where there are others from the same beds, leaves not the slightest doubt that *Stegodon insignis* (or *S. ganesa*, which, as far as teeth are concerned, is the same) occurs in the Narbadas. From this may be gathered the value of the following dogmatic statement of Herr Brauns, *viz.*,—

Elephas namadicus	solely pliocene,
Stegodon insignis	" miocene.
" clifti	" "

In the case of the occurrence of the Narbada *Bubalus palæindicus* in the topmost Siwaliks, it is argued that the specimens are not properly determined. It happens, however, that they are unquestionably the same as the Narbada species. I have not figured them because there are so many other specimens of more importance. Similarly doubt is thrown upon the authenticity of the stone implements from the Narbadas. If this sort of reasoning be allowed, of course anything can be proved.

Leaving now the Narbadas and Siwaliks which Herr Brauns has proved to his own satisfaction are respectively pliocene and miocene and contain no species in common, attention may be re-directed to the Japanese fossils. Considering, as Herr Brauns does, that the beds from which these fossils were obtained are entirely pleistocene, and therefore altogether newer than the Siwaliks and the Narbadas, it would never do that any of the fossils from them should

[1] "Ueber japanische diluviale Säugethiere," Zeits. d. Deutsch. Geol. Gesell., 1883, pp. 1—83.
[2] *Ibid*, p. 9.
[3] Pl. 56, figs. 10, 11.

be the same as those of either of the latter. Accordingly the fossils described and figured by Dr. Naumann are re-named as follows, *viz.*—

Elephas meridionalis, Nesti, = *Stegodon insignis*, Naumann, pls. 3-5.
Elephas antiquus, Falc. = *Elephas namadicus*, Naumann, pls. 6-7.
Stegodon sinensis, Owen = *Stegodon clifti*, Naumann pls. 1-2.

Now there is not the slightest shadow of a doubt that the specimens figured by Dr. Naumann under the name of *S. insignis* are true Stegodons, and belong either to the Siwalik *Stegodon insignis* or *S. bombifrons;* they have nothing whatever to do with a *Loxodon* like *E. meridionalis*. The molars of *E. antiquus*[1] and *E. namadicus* are so alike that it is difficult or impossible to distinguish them, and there is therefore at least a probability that Dr. Naumann's determination may be correct. The specimen figured by Dr. Naumann as *Stegodon clifti* is a typical specimen of the last lower molar of that species, like many in the Indian Museum. I can see not the slightest reason why this tooth should be associated with the Shanghai milk-molar of the so-called *Stegodon sinensis* and so separated specifically from *S. clifti* of the Siwaliks.

There accordingly seems not the slightest doubt but that Dr. Naumann is perfectly correct in referring two of the fossil Japanese elephants to Indian Siwalik species; while it is not impossible that a third is a Narbada form; a fourth species is, however, referred to the European and North American *Elephas primigenius*, and to this Herr Brauns adds the European *Bison priscus*, Bojanus.

These determinations lead to the conclusion that the mammaliferous beds of Japan in all probability correspond both with the Siwaliks and Narbadas of India (which may there be in normal sequence), with the former of which they are connected by the Shanghai, Kansu, Sechuen, and Burmese deposits; and that they also contain an admixture of European palæarctic forms, which have probably reached Japan through northern America. In place of the fauna of the Japanese beds being distinct from that of the mammaliferous beds of India and affording any argument for the latter being pliocene and miocene in place of pleistocene and pliocene, all the evidence points very strongly to the equivalency of the two, and to the confirmation of the latter view of their age.

The Lodge, Harpenden, Herts.

Note on the Occurrence of Mastodon angustidens *in* India. *By* R. LYDEKKER, B.A. *&c., &c.*

Several specimens of the "intermediate molars" of a trilophodont mastodon collected by Mr. W. T. Blanford in the lower Manchhars (Siwaliks) of the Dera Bhugti country (Eastern Baluchistan), are absolutely indistinguishable from the corresponding teeth in the British Museum of *Mastodon angustidens*, Cuvier, of the upper miocene of Europe.

The occurrence of a European species of mastodon on the extreme western

[1] I am indebted to Herr Brauns for pointing out that in "Siwalik and Narbada Proboscidia" I have inadvertently given the age of *Elephas antiquus* as pliocene instead of pleistocene.

limits of India is a fact of great importance, indicating that we may look for a commingling of the faunas of the Siwaliks, and of the European upper miocene and lower pliocene in Persia and Asia Minor.

These important and interesting specimens will be figured in the "Palæontologia Indica" at no very distant date.

Notes on a Traverse between Almora *and* Mussooree *made in October 1882 by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

The following notes were made on a rapid tour between Almora and Mussooree during the month of October last; they cannot of course pretend to be a detailed description, but are of some interest in view of the question of the continuity of the Himalayan rocks in the Almora and Simla regions.

At Almora the rocks are gneiss and schists of various descriptions, lying nearly horizontal on the east of the Kosi, but on the ascent to Bainskhet the dip increases to 45°, the direction being N. 10° E., a dip which continues steady in direction, though varying in amount, till the Gagas is reached. Here the road runs over alluvium for a couple of miles, but rock again shows up on the hill called Buridunga; it is a porphyritic gneiss, similar in structure to the central gneiss. As the road runs near the northern boundary of this exposure cutting across it in several places, it is seen to be fairly straight and presumably a fault, the schists in contact with the gneiss dipping south-south-east; at Dwarahat, where the road cuts across the exposure here not a mile broad, the dip of the foliation of the gneiss has bent round to south-west and, though I was not able to trace the gneiss further to the north-west, I have no doubt that it does extend along the ridge since in the streams flowing down to the Khurrogadh blocks of it are not of infrequent occurrence.

Along the road between Dwarahat and Ganain the only exposure of slates seen was below Naugaon on the south-west side of the valley where they dipped W. 30° S., while near Ganain the dip was south-west.

On the eastern side of this valley, the ridge is capped by limestone (krol), which, apparently forming the peak of Dunagiri, descends further north, at the village of Damtola, almost to the bottom of the valley, and is seen to extend northwards from Ganain as far as the eye can reach, being confined to the eastern side of the valley with the exception of two patches capping the spurs above Bushbira and Naugaon respectively. As is generally the case, no dip was accurately determinable in the limestones, but they evidently dip somewhere about north-west.

Beyond Ganain, where the road leaves the alluvium, slates come in with a dip to W. 10° N. and on the ascent become more and more schistose; the dip at the same time becoming flatter, till near Jaurasi the porphyritic gneiss again comes in with almost horizontal foliation; this is not improbably a continuation of the Dwarahat exposure.

The gneiss continues to near Bongdhar, the only interruption being below the Makroli hill, where a narrow strip of black crush rock is let down by faulting. Near Bongdhar the slates come in again, at first with a N. 50° E dip at 45°, but this soon bends round to the normal N. 10° E. dip, the schistose slates continuing beyond this with a dip varying between N. 10° E. and N. 30° E.; at the bridge over the Nyar a thin band of porphyritic gneiss, probably here merely a more metamorphosed band among the schists, is exposed; opposite Gwalkura quartzites overlie the slates and continue to the bridge between Chifalghat and Pauri. On the crest of the ridge crossed on the road to Pauri quartzose rocks come in again, while beyond this the slates are much disturbed, but keep a pretty steady E. 10° N. and W. 11° S. strike.

Beyond Srinagar there is not much of interest to note; the quartzites show up on the ridge below Maniknath which is itself capped by limestone, but for the most part the rocks are of a recognisable infra-krol type.

Beyond Tiri, where the road runs along the Mussooree ridge infra-krols, quartzites, limestone (krol) and in one place the Blaini are seen, but the structure, as is the case everywhere on the outer ridge, is far too complicated to be unravelled by a simple traverse along the strike of the rocks.

I have reserved for separate notice the alluvial deposits, of which I shall now mention the more important.

Between Bainskhet and Dwarahat near the village of Kapalna the road runs along the surface of an old lake deposit, of which a narrow strip has been left uneroded, the streams on either side having cut deep into the deposits; in both the other valleys crossed before reaching the Gagas traces of extensive deposits are seen but forming a mere skin on the rocks below, having been almost entirely removed by the streams. At Kapalna the gradual raising of the deposits has given the drainage an easier escape over a saddle in the watershed into the next valley to the west; hence the lower part of the deposit has been exposed to the erosion of its own drainage only, while in the other valleys the streams flowing down from the hills to the north have almost entirely washed away the alluvium.

In the Gagas valley there is another alluvial deposit, which, having come mostly from the hills to the west, has by its slope forced the river to the eastern margin of the plain, where it has now cut for itself a new channel in the solid rock of about 60 feet in depth.

This deposit extends up the Pokhy valley, and some of the drainage of its western extremity flows into the Chundas. Here again there has evidently been a diversion of the drainage, due to the gradual raising of the surface of the alluvium to the level of one of the saddles in the original watershed.

Near Dwarahat there is another broad expanse of lacustrine deposits situated at the head of the Baiaru river. These deposits which, be they lacustrine or no, are at any rate formed in true rock basins situated at the very heads of the drainage areas, and rising almost to the level of the watershed have never, so far as I am aware, been adequately explained. They are by no means of merely occasional occurrence, but are scattered throughout these hills; one very good example being at the head of the Blaini river near Solan on the Simla road.

The three rivers which meet at Ganain have all broad alluvial bottoms, part being close down to the present level of the streams, the rest forming a terrace raised some 30 to 60 feet, but the low level ground seems to be merely due to the erosion of the stream, and not to a more recent deposition.

Near Ganain is a very interesting lake known as the Turag Tal; it is situated at the head of one of the streams flowing down to Gunain. In the valley of this stream an alluvial flat extends right up to the foot of the barrier, which is most clearly a landslip, for not only is the gap in the hill from which it has descended most evident, but the only other possible explanation, *viz.*, a moraine, is at once barred by the absence of any other rock but limestone in the barrier which is composed entirely of fragments and not of rock *in situ*. Above the barrier is a broad alluvial surface, the lower end of which is covered by water probably not of any very great depth. The level of this alluvium is about 200 feet above that in the valley below the barrier which itself rises 50 feet above the upper alluvium; the total depth of the landslip is therefore 250 feet, and the time that has elapsed since its fall has been that required for the formation of alluvium 200 feet in thickness.

Near the head of the Binan river there is a small deposit of alluvium as also at Chopryon and Kandura near Powri.

At Srinuggar and Tiri there are extensive terraces covered with a thin coating of river gravel, but in the main merely carved out of the solid rock.

The above-mentioned alluvial deposits are all in true rock basins, but only the three first mentioned, *viz.*, those near Kapalna, in the Gagas, and at Dwarahat, seem, from their uniformity and fineness of texture, to be of lacustrine origin.

Though there was never much doubt as to the propriety of correlating the rocks on the Almora section with those of the Simla region, such shadow of it as there was may be held to be now dispelled, for in the region crossed between Almora and Mussooree the rocks are seen to become gradually less metamorphic, and the distinctions of the sub-divisions but obscurely seen near Almora become more and more marked till the rocks assume the normal character which they are found to maintain from Mussooree to the north-west.

Note on the Cretaceous coal-measures *at* Borsora *in the* Khasia Hills, *near* Laour *in* Sylhet, *by* TOM D. LA TOUCHE, B.A., *Geological Survey of India.*

I have visited and examined a section of the coal-bearing rocks situated at the foot of the Khasia Hills to the north of the district of Laour.

Position of the section.

The section examined occurs in a ravine, at the mouth of which stands the Garo village of Borsora, about 5 miles west of the point where the Panatibh or Jadukhata river leaves the hills. At the edge of the plains on either side of this village nummulitic limestone is exposed dipping to south-south-east or towards the plains at an angle of 38°.* On proceeding up the ravine along a path on the west side of the stream no sections of rock *in situ* are seen, but the path is covered with blocks of

* From this a large amount of stone has been quarried by Messrs. Inglis & Co.

a coarseish yellow and brown sandstone. The path rises for about half a mile until the mouth of a small steep ravine on the west is reached, in the sides of which the coal seams are exposed.

Description of the section.

At the junction of the two ravines carbonaceous shale is seen in the bed of the stream dipping to south-south-east at an angle of 12°. Upon this rests a seam of good coal 3 feet 10 inches thick extending for about 20 yards along the side of the ravine. This is overlaid by 5 feet of shaly sandstone, upon which rests a second seam of coal 3 feet 4 inches thick. This seam has been disturbed by several small faults or slips, and parts of it have been denuded to some extent before the deposition of the overlying sandstone, so that its thickness is not so constant as that of the lower seam. Proceeding up the ravine about 60 feet of fine yellow sandstones are passed over, and a third seam of coal is met with, cropping out on both sides of the ravine. The thickness of this seam could not be determined exactly, as a small landslip has occurred in the rocks above, and has partly covered it, but it is at least 4 feet thick, though not quite free from shaly partings. Above this the ground is covered for 50 or 60 feet with the debris from the slip above mentioned, consisting of fine yellow sandstones and shales with many fragments of coal, and above this again, at the top of the section, is a fourth seam, of shaly coal, 2 feet thick. In the whole section therefore of about 150 feet there are about 12 feet of good coal, distributed in three seams as shown below, in descending order:—

		Ft.	*Ins.*
Shaly coal	about	2	0
Fine yellow sandstone and shale	„	60	0
Coal seam, No. 3	„	4	0
Fine yellow sandstone	„	60	0
Coal seam, No. 2	„	3	4
Shaly sandstone	„	5	0
Coal seam, No. 1	„	3	10
Carbonaceous shale, thickness unknown.			
TOTAL .	„	138	2

Quality of the coal.

The coal of seams Nos. 1 and 3 is much disintegrated by exposure, so that it is difficult to get good specimens for analysis, but it appears to be a very good coal, with a bright fracture and black colour, containing numerous specks and nests of a kind of fossil resin. This resinous substance, which is characteristic of the coals of this region occurring in cretaceous rocks, together with the position of the seams below the nummulitic limestone, shows that the coal is of the same age as that of the Garo hills and the small basin at Maobelarkar, and is therefore distinct from the coal of Cherra Poonjee, which occurs above the limestones. The coal of seam No. 2 is more compact and browner in colour, and is traversed in all directions by small joints.

It also contains specks of the fossil resin. Samples assayed in the Survey laboratory by Sub-Assistant Hira Lal gave the following satisfactory results:—

	Seam.	
	No. 1.	*No. 2.*
Moisture	5·84	3·02
Other volatile matter	35·16	39·58
Fixed carbon	50·40	50·80
Ash	8·60	6·60
	100·00	100·00

No. 1 does not cake; ash pale red.
No. 2 cakes; ash red.

Probable extent of the field.

The section examined is very similar in some respects to one described by Captain H. H. Godwin-Austen (Jour. As. Soc. Bengal, Vol. XXXVIII, Pt. II, No. 1, 1869) as occurring on a small tributary of the Umblay near the village of Nongkerasi, about 10 miles to the north-west of Borsora; but to determine whether the coal-measures are continuous between these points would require a more detailed examination of the district than I was able to make. The only means of getting sections in such a country is to follow up the hill streams in which fragments of coal are found to the outcrop of the seam, and at this season (June) these streams are liable to sudden floods and become quite impassable. If it should be found that the coal does extend between these points, its amount must be very large.

Position of the seams as regards extraction of the coal.

The outcrop near Borsora is very favourably situated for being worked. It is not more than half a mile within the hills and at a low elevation above the plain. The coal rises from the outcrops so that mines or quarries could be easily drained. The foot of the hills is only 1 mile from the Patlai river, a branch of the Jadukhata, and during the rains boats can come up to within a few hundred yards of the hills.

Even now great numbers go close to the spot during the rains to carry away limestone from the numerous quarries between Borsora and Lakma.

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