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The Geognosy and Mineralogy of Scotland.

By Professor Heddle.

SUTHERLAND.—Part VI. (*Conclusion.*)

The Marbles of Assynt.

Having, since the date when the few observations chronicled in a previous number were made, ascertained some more definite facts with regard to these marbles, I now note these.

The localities in which I had previously observed the marble were all (through faulting and intrusions) so obscure as regards its relationships, that any conclusion as to its horizon was not warranted.

The discovery of a singular structure imbedded in the marble, led to my again taking up the inquiry, with the result that I found new localities where it existed, and am now able to speak definitely as to its position, at least as regards the chief mass.

The difficulty in arriving at any conclusion with regard to the marble at most of the localities where it is seen, is due to three circumstances :—

first, to its being so highly altered that bedding and lamination have, as a rule, alike disappeared, or are only, at one or two spots, imperfectly indicated by the occurrence of layers of agglutinated masses of serpentine or of malacolite; second, to its being, where exposed, so corroded into tortuous and fantastic forms through rain-action on its more soluble laminæ, that the eye is at fault in endeavouring to satisfy itself as to the former relative connections of the several masses; and third, to subterranean waters having so sapped out the more calcareous and purer beds, that no inconsiderable portion of what is beneath the surface is in a carious condition, and the surface in the neighbourhood of the marble and even of the dolomite, having given way in all directions to fill up the ever-recurring voids, presents little else than a maze of grassy undulations, sudden pitfalls, and shattered rock. The visible rock is, from this last cause, tossed about in all directions, with a total obliteration of all readily decipherable relationships.

Any one who examines the dolomite throughout its myriad layers, and at its numerous exposures, will note two facts;—the first, the occurrence in it of beds markedly more crystalline than others, and especially of one bed, generally of a cream colour, which is more lustrous on its fractured surface and harder than is the main bulk of the rock;—the second, that whatever its precise relationship to the dolomite may be, the marble evidently bears *some* relationship to it; for, if they be not found in contact, they occur not far distant from one another.

Again, it is found that the marble always has the quartzite as its associate, though that association is frequently physically separated by a fault.

When we inquire what other immediate associates of the marble are seen, we find a peculiar igneous rock in an affluent which flows from Creag-a-Chroisk into the Ledbeg river,—and the Logan Rock, which towers above it where it occurs at the foot of Ben Bhrachaid. To these I have now to add two other rocks,—the so-called quartz-porphyry of Cnoc-na-Strome, under which the marble either plunges, or which has been thrust against or perchance poured over it; and, secondly, the lowest great bed of the diorite of the dolomite, which, in two localities, I find distinctly to underlie the marble, though not immediately.

The above facts taken together constitute, as I have before written, strong grounds "for holding the marble to be merely the altered dolomite."

As it was most desirable to have more to rely upon than merely *strong grounds*, I devoted some time lately to an endeavour to trace the highly crystalline bed of the dolomite into actual contact with the marble, with

the result that I lit upon localities which left no question in my mind as to what the marble represents.

Marble is laid down in my map of Sutherland at some spots in the neighbourhood of Lynn, on the Ledbeg river. These localities, being in close proximity to the rock of Cnoc-na-Strome (up to the present maintained to be igneous), were examined anew.

Immediately south of the river, and opposite to Lynn, there is a knoll of quartzite which when seen from the road appears to dip under Cnoc-na-Strome. But this is an optical delusion, induced by the steepness of the slopes of the hill; for a little dell separates all the visible rocks.

This dell contains marble, with some loose masses of a very singular pale grey rock, the chief, indeed the apparently sole component of which has a strong resemblance to a massive labradorite.

North-eastward of this, the marble appears near the stream; and here its true position is immediately apparent, as the locality is the site of a very extensive quarry in which a second channel has been cut for the stream. This channel leads to the foot of an artificial cliff or quarry-face, which exposes the main mass of the marble. This marble has a pure white colour banded with blue.

Some eighty yards higher up the stream than the cliff, the whole section is laid bare, partly by the stream and partly by quarrying. From east to west it reads :—Quartzite,—argillaceous beds, here very thin,—dolomite,—diorite,—dolomite,— marble, of a fine puce cclour,—dark grey dolomite,—white marble with narrow blue striping, and lastly grass cover. The rock to the west and at a higher altitude is quartzite. The dip is W.S.W. at about 18°. Both the puce and the white marble were worked, and the workings show clearly the relations of the rocks.

Up to the grass cover all is clear. The superiority of the quartzite to the rocks mentioned doubtless will be objected to by those who maintain that there is no upper quartzite; and some who are unable to lay theories aside when observing facts, might exclaim "a fault!"

The writer inclines to the opinion that the circumstances *with difficulty admit* of the explanation that a lateral thrust from Cnoc-na-Strome (if igneous) might have brought up a roll of the lower quartzite, in an anticline between the marble of the cliff in the stream, and the marble of the little dell. Such a roll would be similar, in its relationship to the dolomite, to the anticline of Braebag. However, as no truncated beds of the lower dolomite, nor of the very persistent bed of diorite are seen, and as the quartzite first appears *as an escarpment* which faces N.E. and not as a roll, and as moreover neither dolomite nor diorite is to be seen on either

of the flanks of the quartzite, the simplest reading certainly is that there *is* an upper quartzite. This is, however, by no means a locality which will strongly fortify any one in maintaining the existence thereof; still less is it one which entitles any one to assert that there is either fault or smash. *The fact of the marble being a bed in the dolomite series, this locality, however, makes perfectly clear.*

Crossing the Ledbeg river at this quarry, and passing a short distance northward, a small stream will be found descending from the south slopes of Beinn-an-Fhuarain. In its channel the "diorite" will be found in force, causing a small cascade, then a short space of flat grass cover succeeds, and next the marble. This may be traced in a linear succession of corroded outcrops for about one and a half miles round the hill, and along its east side; while the "diorite" will be also found coursing round along with it, always dipping under it, and being underlaid in turn by the quartzite of the foot of Braebag. This band of *marble*, as it courses north, gradually loses its saccharine character; it ultimately disappears in a line of water-filled sinks, out of the northern continuation of which the *dolomite* of the N.E. shoulder of Beinn-an-Fhuarain as gradually makes its appearance. On the south and east flanks of this hill, therefore, the marble occupies the place of the dolomite, into which it apparently gradually shades off. Both dip on every side into and under the hill; and both are overlaid on every side by quartzite, which quartzite in turn is overlaid by a red grit.

Such are the grounds upon which I hold that the marble is a metamorphosed bed of the dolomite.

In considering what may have been the agent of the metamorphosis, it has to be noted that the change ceased as the bed passed northward.

Glancing at the map it will be observed that all the localities where the marble occurs lie round, and nowhere at much greater distance than a mile from the quartz porphyry of Cnoc-na-Strome,—or from the spurs of this hill.

Beyond the fact that immediate proximity vouches for the marble of Ledbeg being the same mass as that seen in the little dell above described, little can be said of the relationships of that particular mass. In the stream channel it is seen faulted against quartzite; while at the more northerly of the spots where it protrudes from the overhanging hill-slope it is again in contact with quartzite, here thrust up in a quâquâversal dome.

The mode of occurrence of the singular structure found in the marble has now to be noticed.

The localities are the central and the more northern of the three masses which lie on the hill-slope above Ledbeg.

At the first of these localities only one portion of it is seen. It presents itself as a dark band stretching nearly horizontally from W. to E. in the marble. This band has a length of 16½ feet, a thickness of 4 to 5 inches, and it extends into the rock for a depth of at least 3½ feet. It lies in the rock in gently undulating folds. At one spot it throws off an arm or process at an angle of about 15°. This branch or arm was about 2 feet in length and about 3 inches thick. At another spot it threw off a short process at right angles.

Its exposed surface was much corroded by the weather, and its structure was thereby unfolded. That boldly displayed structure consists of gently plicated but very rough layers of a substance which evidently was less soluble in rain-water than had been that whose removal left the layers protruding. The appearance of this exposed surface is precisely that of the representation of eozoon given by Carpenter, in the last edition of his work on the microscope; and the colour is very much that of printer's ink. When broken into the rippled structure stands out to the eye in bold relief of blue-black upon a nearly white ground; this is mottled with granules of yellowish-grey.

Occasional patches of greenish-yellow granular precious serpentine occur; there sometimes are nodules of this the size of the fist, and it occasionally is milk-white. It must be noted that the aspect of this dark band as a whole is in no respect that of a siliceous band in a primary limestone; but, in its isolation, and in the abruptness of its margins, is altogether that of an imbedded structure.†

At the second mass of marble the same structure is seen, appearing here as an erect vein in the marble, the bedding of the latter being almost horizontal. This vein is 8 or 9 inches in thickness. This also goes to show that the structure as seen at the first locality is not a mere band of highly metamorphosed material.

The structure of this fabric, when seen under the microscope, appeared

† In a late discussion at a meeting of the Geological Society (of Edinburgh?—Ed.) upon this marble (called Dalbeg), it was observed by one of the speakers that it occasionally "*became* eozoic." As this phraseology indicates transition, or gradual passage, it is necessary to remark that it is altogether misleading, so far as I know of it. Whether the structure be the outcome of the action of the marble upon one included fragment of gneiss or not, it has to be noted that there is no gradual passing of the one into the other,—no *becoming*. A line of demarcation, sudden and sharp, is present all round the periphery. Black at once succeeds to white. The thing is, as I stated to the Royal Society of Edinburgh, very like one of the boas worn by our grandmothers, and still liker to one of the dried whale cutlets seen in Farös.

to me to be so similar to eozoon that I placed it in Dr. Carpenter's hands for examination.

Dr. Carpenter writes of it:—"The general conformity of your specimens and of some of the Canadian is so close as to leave no kind of doubt of their being the same thing."

The matrix, material of, and the minerals associated with this structure, have now to be noticed.

At Dr. Carpenter's request I analysed the matrix of the structure, that is, the rock in which it and the minerals found with it are *immediately in contact.*

Dissolved in moderately strong acid with the aid of gentle heat, it yielded—

Carbonate of Lime	46·307
Carbonate of Magnesia	37·632
Carbonate of Iron	1·022
Carbonate of Manganese	·368
Soluble Silica	·700
Insoluble residue	14·408
	100·437*

The insoluble matter, examined with the microscope, was found to consist of rounded crystals of malacolite, with small quantities of serpentine, quartz, margarodite, and magnetite. As this analysis differed much from that published by Dr. Anderson, I thought it necessary to examine a portion of the rock at some distance from those imbedded or included masses.

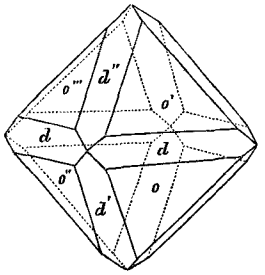
As pure and typical a portion as possible was, therefore, during a recent visit, broken out some distance away from them, and an average sample of its mass analysed, that is, not the purest white part thereof picked out, but chips from the whole when crushed up were taken.

There was got:

Carbonate of Lime	55·562
Carbonate of Magnesia	39·942
Carbonate of Iron	·358
Carbonate of Manganese	Tr.
Alumina	·306
Soluble Silica	1·481
Insoluble residue	4·238
	101·851

* The carbonic acid was not determined. Doubtless some of the lime and magnesia had been in combination with the soluble silica.

The carbonic acid was not determined. About 2 per cent of the lime and magnesia must be in combination with the soluble silica. The insoluble matter consisted totally of crystalline granules of malacolite.

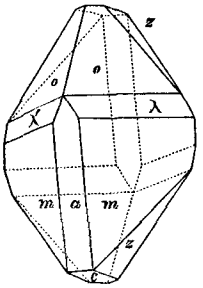


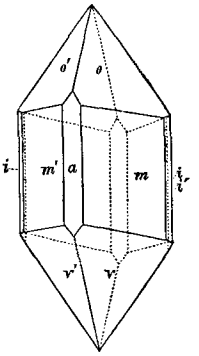
The greater part of the structure itself is formed of dark serpentine with some *magnetite*. The latter is occasionally in octahedral crystals, and more rarely in that form with dodecahedral truncations. The crystals are highly lustrous, and are energetically polar.

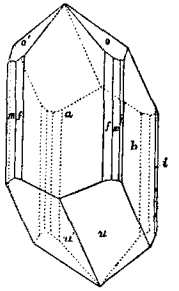
Margarodite is mixed with the magnetite.

Pale ochre-yellow *malacolite* is present in large quantity, in granules. These are generally rounded on the angles, as is so frequently the case with minerals imbedded in a calcareous bed which has been subjected to the extreme energy of metamorphism.

The malacolite is, however, occasionally well crystallised in the three types figured—*m*, *a*, *c*, *o*, *d*, *z*, generally without *d*;—*m*, *a*, *o*, *v*, *i*, and







without *i*;—*m*, *a*, *o*, *u*, *f*, *i*, and without *i*. There are also, more frequently, simpler forms. The crystals are very minute and are associated with small rock crystals.

Colourless,—opaque white,—sulphur green,—and black serpentine also occur.

The surface of much of the white marble is rough as a rasp. This is due to the protrusion, above the general surface, of crystals which have evidently proved less soluble in rain-water than has the general mass of

the rock. The lens can without difficulty make out that these protuberant crystals are saddle-shaped. They are found to be soluble in strong but not in weak acid; and a mass of the rock placed in weak acid leaves undissolved a vesicular structure composed of these, with smaller quantities of malacolite.

An attempt to conduct separate analyses of the crystals, and of the portion of the rock dissolved out by weak acid, failed, on account of the acid attacking the more insoluble crystals to a certain extent, during the solution of the general mass. All that could thus be ascertained was that the readily-soluble portion contained very little magnesia; while the more insoluble seemed to contain the whole of the iron, and nearly all the magnesia.

This fact of the separate crystallisation of the magnesian portion of highly metamorphosed dolomites is interesting, and significant of a great amount of mobility of particles. In virtue of this condition of crystalline intermixture, doubtless different portions of the rock will vary in composition.

The marble thus is a metamorphosed ferruginous dolomite. Dr. Anderson's analysis, previously quoted, may be explained by supposing that an unusually calcareous portion had been put into his hands; or even perhaps a portion of a calcitic vein of the rock.

In announcing at the Royal Society of Edinburgh the discovery of the singular structure seen in this marble, I indicated that its microscopic appearance seemed to me to show structure *not mineral*. Lately, however, the examination of numerous slices made me doubtful as to the correctness of that view, and induced me to enter upon an exhaustive examination of it. The result has been that, as regards the inferences to be drawn from the appearances which I first noticed, I have entirely altered my views.

I have endeavoured to represent in the plates (Plates VII. and VIII.) the various structures present in a slice of the dark belt, as seen with low powers. I shall indicate these as the *lenticular*, the *subfibrous*, the *ovoidal*, and the *serpentinic*.

Of these the first consists frequently of rudely lenticular sections of crystals the size of a pea, of a carbonate which is soluble only in acid of medium strength. When lenticular, the crystals are somewhat curved at both extremities in opposite directions. They are intersected by two sets of parallel markings which cross with a major angle of about 85°. One set of these markings polarises with brilliant colours with the lower Nicol alone; the bands of colour being of variegated tints, and not of any one uniform colour from end to end. As another portion of the rock is soluble in much weaker acid than are these crystals, and as in fact these

crystals when examined separately are found to be highly magnesian, they are to be set down as the dolomitic portion of the marble.

The question now is, are these bands of colour due merely to the polarised light being analysed by a thin film of air in the cleavage rents on the crystal,—or are they due to twin plates of extreme tenuity,—laminæ lying in the crystal parallel to the face $-\frac{1}{2}$ R, such as in certain specimens of Iceland spar were shown by Brewster to be the cause of the variegated plates of colour therein seen? As a thin film of air would, at its portions of greatest tenuity, exhibit a series of rainbow bands, and as the second set of markings, drawn in in black, may be seen to be cleavage rents, which do not analyse the light, there can be little doubt that the coloured striping here seen is due to thin plates; and though dolomite, there is perfect identity here with the lamellation seen in Carrara, and other marbles.

The portions which I have termed the subfibrous are the most transparent, and apparently the hardest portions of the slice. They are devoid of regular form, and are about the size of mustard seed. Even without the analyser they faintly show a fibrous structure. This the analyser shows to be intermediate between divergent and plumose in arrangement. The delicate hair-like crystals shoot generally from only a single spot in the surface of each little nodule, passing through its substance in gentle curves, as if they had grown into a cavity. The appearance differs only from that of filamentous augitic-serpentine in not being straight-acicular and radiating. Acted upon by weak acid, the fibres are left protuberant, and then appear white, and of silky to brilliant lustre. They fall to powder, and are ultimately almost totally soluble in strong acid.

As the most highly soluble and truly calcareous portions of the rock surround these fibrous nodules, they may, after the brief action of very weak acid, be picked out.

Operating upon a very minute quantity, I found them slowly decomposed by weak acid with slight effervescence; and readily disintegrated and almost totally soluble in strong acid. In the solution I could only find silica and lime.

The fibres thus seem to be *Wollastonite*. This is not uncommon in the marbles of Scotland. It is stellate-fibrous in rents of the limestone of Allt Ghoiridh in Skye; and in rents of diorite in Barra Hill, Aberdeenshire. It is radiating fibrous at Delnabo in Glen Gairn and Crathey quarries. Matted and interlacing at Corntullock, on the Dee.

The plumose appearance here is different.

From the shooting of the fibres from only one or two isolated points,

they certainly have more the appearance of having grown into a cavity than of being a substitution product of change; but the *shape* of the little masses is not that of casts of a cavity; they are too angular. And, if cavities were once present, the evidence is all against their having been *tubular* cavities, for, however cut, they show much the same form.

The ovoidal masses were those which at first sight seemed to me to depart furthest in appearance from mineral structure; after due examination their structure is the most evident of all.

At the first glance they resemble sections of tubes, the centres of which have been filled up; looked at with more care they resemble rings of oil. Processes are next seen to connect the opposite sides of the ring, which processes pass through the substance of the central material. There is more or less of parallelism or rectiliniarity in these transverse processes, and where they are frequent, there is more or less of a prevailing angle in the intersections of the different sets which traverse the central material.

These connecting processes leave no doubt as to the ovoidal masses being either olivine or augite in a condition of change.

In fact they present an admirable, though a miniature illustration of the special appearance of the transmutation of the less ferruginous *augites* into serpentine, as contradistinguished from that of *olivine* into serpentine.

That which here caused the recognition to be tardy, is the extreme roundness of the grains of *malacolite*.

These grains from their occasional yellow colour were at first considered by me to be *chondrodite;* but while figuring the crystals, I perceived how frequently they were rounded, and, picking a sufficiency from the residue of the solution of the marble, I found that they contained no fluorine, and were grains of malacolite, which were greasy on their surfaces from partial conversion into serpentine.

The dark green to black blotched and marbled serpentinic structure,—which has here and there, when examined macroscopically, a wonderful resemblance to the delineations of eozoon, and also it must be said to a rippled gneissic structure,—more resembles in appearance the lozenge angularity of serpentine formed from olivine. It is thus possible that olivine may have been here present, though olivine is unknown in Scottish dolomites. A structure very similar is, however, seen in other rocks, as in gneiss from Unapol, dolerite from Loch Assynt and Schiller spar.

Professor Lapworth, after an examination of some of my slides, pointed out a delicate arborescent dark green structure as one which called for

special study; this is only seen by the employment of a high power, and can have little bearing upon the structure generally termed eozoic.

From the above examination, while admitting that I am unable to explain the peculiar disposition of the fibres of the Wollastonite (?), I have to say that I see in this marble no structure that is not referable to mineral arrangement, and none which, so far as my knowledge goes, is referable to animal structure.*

The plate shows at 1. the *Malacolite* and *Wollastonite* (?) portions of the rock; at 2. the *Serpentine*. The other structures shown are those of rocks which resemble this last structure. 3. is Hebridean gneiss from Liverpool; 4. dolerite from south shore of Loch Assynt; 5. Schiller spar from Belhelvie.

In the banks of a stream which descends from the east side of Creag-a-Chroisk the marble is found enveloped in a dyke of an igneous rock of very unusual appearance. It consists for the most part of a pink felspar, in which brown garnets are imbedded. In section these are red, and are cinctured by a

Marble, which the writer cannot discriminate from that above noticed, sweeps round the hill east of Loch-a-Meallain on the south side of Strath-na-Sheaskink, and comes into close proximity with the series of carbonates, considered Upper Limestone by Sir R. Murchison. These occur on the east slopes of Cnoc-a-Chaorninn.

This marble can be traced so far west on the north side of the hill, that there can be little doubt that it is related to, though it does not appear to be connected with that already noted as lying on the south of Ben Bhrachaid. It is distinctly separated from the "upper limestones" by a band of quartzite; but its close proximity will doubtless, notwithstanding this fact, be founded upon by those who maintain that the "upper limestone" is merely an inversion of the dolomite.

In controversion of such a view the writer has to state that he has entirely failed to find the yellow argillaceous beds at either of the localities where he has seen the "upper limestone." He has also failed to find, at either, a trace of any of the beds of "diorite" so characteristic of the

* It may not be out of place that I should here state, that after having unravelled the structure of this Scottish eozoon, I thought I was to a certain extent in a favourable position for entering upon an inquiry into the nature of the Canadian, to which it was said to bear so great a resemblance. I cannot say that my specimens of true eozoon are at all good examples, being merely those usually sold; but of these, such as they are, I have just to say, that in them I saw nothing which I did not see in the Scotch; that I did not in them see so much; and that nothing that I did see did I see nearly so well.

dolomite; but he finds in the "upper limestone" of Loch Ailsh an albitic porphyry, very similar to, if not identical with, that which is characteristic of the upper quartzite.

As regards the beds of these "upper limestones" themselves (of which it is much to be desired that we had analyses), neither in structure nor arrangement do they seem in any way to resemble those of the dolomite, beyond this, that one of the beds at Rhieknock is *somewhat* similar to the thin upper crystalline bed at Knockan, but similar to it only at the spot where it is there subjacent to crushed schists.

A widening out of the system may bring this "upper limestone" (itself dolomitic) into the same series as the dolomite, but that it consists of the beds of the latter *inverted*, is at present mere unsupported speculation.

In fine, whatever evidence of an inversion of the dolomite series there may be elsewhere, the writer has to say that between Glen Coul and Loch Borrolan he has not been able to note a single fact which bears out such inversion, but that every fact which he has observed in any way bearing upon it is opposed to such a view. If no inversion can be shown *here*—no matter what can be shown elsewhere—the existence of an upper limestone, as maintained by Murchison at Loch Ailsh, and found by the writer at Rhie Knock, will have to be admitted.

In maintaining, however, that the dolomite as a whole is not *inverted*, I must be understood to mean that *as a formation* it dips regularly *under the rocks which succeed it to the east;* and is not cut off from them by any such fault as claimed by Nicol, so as to form a ⊐ shaped trough, (a trough the age of which can in no way be disclosed by the rocks in its proximity).

I have already stated that, though in certain localities fractured at its eastern fringes, the dolomite forms a trough in the Maoloch Corry district; and that I believe it once swept over the double anticline of Braebag, and was succeeded to the east by the overlying Logan Rock of Ben Bhrachaid. Again, in the Beallach of Braebag Tarsun it can be seen with the underlying yellow beds curving over the east side of the Braebag ridge, at an angle which almost forms a local inversion *to the east*, but it immediately rises again, and on the N.E. side of the pass is conformably overlaid by a thin band of quartzite, which in turn is overlaid in regular sequence by Logan Rock, fine grit, coarse conglomerate, and the quartzite of the top ridge.

Further east, at what may be considered a linking spot between the beallochs of Bhrachaid and Tarsun, namely, in the slopes below Dhu

Loch More, the dolomite, overlying yellow beds and quartzite, is again seen with a very low dip, conformably overlaid by a thin band of schistose quartz, this by a fragmentary felspathic and argillaceous grit *which passes into Logan Rock through the gradual augmentation in thickness of interstitialised bands of hornblendic material.*

This Logan Rock, as will be after fully described, ascends into the precipices of Ben More, and is regularly succeeded by quartzite,—the giant grained conglomerate of Coineveall being here absent. It is indeed a feature of the upper quartzite that its several and very distinct members are disposed in lenticular masses. Whether they be grit, conglomerate, or Logan Rock, they come in suddenly, in wedge like form, and as suddenly thin off; and this they do both along the strike and dip. Now, on the west side of the Braebag ridge the quartzite is seen to be thrown into two folds, the more easterly so abrupt as to constitute a small local inversion of some of its beds; and what is a mere fold at one locality, may certainly present itself, if the returning fold be shorn off, as a great inversion at another. But what the writer maintains is, that the returning folds of one or other member of this system of rocks will, in this district at least, be found dipping under the eastern gneiss;—that the state of matters is not to be represented by the letter ⊐ lying at any angle, and *separated by a fault* from the eastern gneiss, but, that it may in certain disturbed localities be represented by the letter *S*; the drooping summit of the *S* being *regularly overlain by* the eastern rocks, although the upper part of the fold is sometimes cut off. At some localities, as at Knockan, the overlying rocks are immediately those of the eastern gneiss; and where at other localities the immediately overlying rock is quartzite, or is Logan Rock, there is nothing anomalous,—for these rocks, where present, lie *between the dolomite and the eastern gneiss.* There is certainly nothing more anomalous in the fact that these rocks should come in, in such manner, in this district, than that they should do so elsewhere. That they do so come in, will be seen by any one who will walk from Dundonnell to Kinlochewe, keeping himself rigidly to the junction the whole way.

The Red Grit of Ben-na-Creisaig and Ben Fhuarain.

Cunningham left these hills uncoloured in his map; the writer purposed doing the same in his own map, and it was only some scanty observations which induced him to allow the colour-tint assigned to quartzite to remain, after it had been too hastily assigned to them.

The superiority to quartzite and to dolomite of the red rock which forms the summit of both of the above hills is evident; and the fact that both

dolomite and an intervening band of white quartzite dip towards and apparently under the red rock from both west and east, forming a small basin, is also evident. But it must be admitted that the simple conclusion to be drawn from this fact must not hastily be jumped at, as there is some faulting at the south-east corner of Ben-na-Creisaig. (Marble and an igneous rock dip under the south side of Fhuarain, and dolomite is separated only by a thin fringe of quartzite from the rock of the north side of Creisaig, but the dip is here obscure.)

Again, the nature of the rock is so very different from the quartzite in its general appearance that the desire to see it somewhere else than in mere outliers is strengthened, the more it is examined.

The rock is a loose red grit composed of tinted quartz with some uncoloured grains, and a good deal of fragmentary felspar. So far it resembles the Torridon conglomerates; but the resemblance goes no further. It contains none of the granules and fragments of jaspers, vein-quartz, and other siliceous foreign-matters so common in the Torridon rock, and its appearance as a rock mass is altogether dissimilar. Instead of being disposed in great sheets of ever-varying structure and size of grain, which weather readily into loose and crumbling slabs, this is an even- and thin-bedded rock; vitrified in appearance, and enduring. It breaks with a clinkstone ring, its beds are not readily separable, and it splits up, not into a loose gravel as does the Torridon, but into sharp-angled fragments.

It was the finding, in the trench of the Cold Stream Burn, *masses of worm-hole quartzite firmly rivetted to the under surface of this highly metamorphosed and sometimes almost flaggy rock* which convinced me that it was a member of the upper quartzite, characterised, as patches of the upper quartzite are here and again, by special local peculiarities. The passage here was an absolutely insensible one as regards the sand grains, but there was a sharply-defined change of colour.

Some appearance of a west and east fault, with a downthrow on the south of the limestone with its cover of white quartzite and red grit, induced me to re-search the north-west face of the opposing Craig-a-Chroisk for a grit similar to that of the two hills. About the N.W. corner of this hill, in the same relationship to the limestone, a thin bed of just such a grit is found; the only distinction I have observed between them being that the last mentioned is somewhat looser in structure, and not of so deep a colour.

Now, as we course southward along the outcrop on Craig-a-Chroisk this bed of grit is about 200 feet below the shoulder of the hill, and that shoulder as we approach Cama Loch consists of Logan rock. The slope

is for the most part grass clad, but in some of the bared spots the actual contact is seen. Passing up to the summit, quartzite is found overlying the Logan rock.

The section here reads, Hebridean gneiss—quartzite, white and purple—yellow beds—dolomite—grits with pyrrhotite, others with serpulites—Logan rock—quartzite. This, with the exception of the non-occurrence of the Hebridean and of the serpulites, is also precisely the section at Dhu Loch More. I would, therefore, correlate the grit of Ben-a-Creisaig with the somewhat more felspathic grits of Dhu Loch More.

When we consider the manner in which purely local beds of varying characters, markedly circumscribed in dimensions, appear in the series of rocks which have been referred to the upper quartzite, I conclude that the facts of the case justify us in referring these two outliers to that series also.

The Logan Rock.

Though this rock has been noticed before, chiefly in the description of the map of Sutherland, its detailed consideration has been deferred, in order that the several rocks to which it has been by different writers referred, with their accessory minerals, might have been described. The question of its relationship to one or other of these being thereby necessarily in a fairer way of being answered.

I have already shown how diverse and irreconcilable are the views entertained regarding this rock. Four recognised authorities hold it to be igneous; two maintain that it is upper gneiss; one that it is Hebridean gneiss faulted up; and one that it is "an old gneiss" somewhat altered.

The views entertained as regards its position by dissentients from the last contention, are more or less accordant with one another. All place it in close association with the quartzite, with the exception of Dr. Hicks, who puts it between the quartzite and a series of rocks which he conceives to be still more recent.

There was in the original view of Mr. Hudleston more latitude and caution than in that of Professor Bonney, for he did not commit himself to the *Hebridean* gneiss but only to "an old gneiss;" and such a reading would have been far from unacceptable in comparison to some of the others, at least as regards certain districts and some problems connected with these which are somewhat involved.

Mr. Hudleston, however, has lately departed apparently entirely from such a construction of his words, for, in a late discussion of the subject,

he writes:—"Although, therefore, there are certain differences in the aspect of hand specimens, and still more perhaps in the general character and behaviour of large masses, yet the "Logan" rock appears to me to possess more resemblance to the Hebridean gneiss than to any other formation in the district. There must be differences, however; otherwise so acute an observer as Nicol would hardly have continued to call this rock "granulite," "syenite," "diorite," according to the district he was describing. In Assynt his "Logan" rock is mostly "syenite," and he appears to have regarded it as intrusive.

It is probably owing to the circumstances connected with its appearance in the position now occupied by it in the Assynt mountains, and largely also to partial injection by local extravasations and to crushing during folding, that the main points, in which the "Logan" rock differs from ordinary Hebridean gneiss, arise. And yet I hesitate whilst writing this, bearing in mind that Dr. Heddle, who knows both rocks so well, does not perceive the relation, which always struck me as subsisting between the two, though I am far from saying that they are absolutely identical."

But if not identical,—what? There is the whole question.

Mr. Hudleston says that I do not perceive the "relation;" and looking above to see *what the relation is*, we read "possesses more resemblance to the Hebridean gneiss than to any other formation in the district." Now I readily grant this. The "relation" is but a *resemblance* after all; all along I have seen a resemblance, sometimes a marked resemblance; but I see something more than this; I see also points of distinction which, when all things are considered, are still more definite than those of the resemblance.

In a chronicle of the state of our knowledge of the geognosy of a country it is well that as small an amount as possible of mere theory should be intruded; but as this rock has at present to be regarded as a most critical one, it is necessary that the chronicler should do something more than merely enumerate and describe the sections which he has visited, the rocks which he is prepared to say that he has recognised, and the minerals which he has, or has not, found. I have examined this rock in more localities and to a greater extent than any other in Sutherland and Cromarty, and have in speaking of it said that even after an "extent of walking very inadequately vouched for by one hundred and seventy-seven thousand feet of climbing, I did not feel myself in a position to pronounce upon its *precise nature*." Still, while assuming the position of being unable, from the very varying features which it assumes at different

points, to give it a definite name, I am prepared to say *what it is not*. I have made every attempt to remove my own difficulties by trying to fit in the theories of its being the Hebridean rock faulted up at this spot, folded back by an inversion at that, or thrust in like a wedge at that other,—disregarding, in the so doing, all other discrepancies.

I have in another consideration of it, with all due liberality, given every latitude to metamorphosing and altering processes, augmented in energy by squeezing, crumpling, and fracturing. As the outcome of all, I have to say that, though probably *made out of it*,—as the younger is ever made out of the older,—it is not the Hebridean gneiss, and is not even of the same age as the Hebridean gneiss. I hold, that stratigraphically is is *impossible* that it is so; geognostically it is *incredible;* lithologically it is *inconceivable;* and mineralogically it is *improbable*.

Truly, in Macculloch and Cunningham, Murchison, Ramsay, Harkness, Nicol, Geikie and Hicks, Messrs. Bonney and Hudleston are attacking a goodly phalanx; the numerical preponderance of which will be some measure of the honour which must accrue to them should their view prove the more correct.

But there are two circumstances connected with the conclusions arrived at by two of the members of that phalanx which well might have "given pause" to any one in coming to an opposite opinion. I allude first to the fact that Murchison (who may be said to have instituted the Hebridean gneiss as a formation,—insisting upon the regularity of its bedding and the dominance therein of a prevailing strike), did not or could not recognise this rock as the same; but throughout, when speaking of it at many localities, connects it with disturbance. Secondly, to the fact that Nicol, who saw such a resemblance between the western and eastern gneisses, that he maintained that they were one and the same, expressly, at every point where he noticed it—(and no one noticed and pored on it so much)—*excluded this rock from the category*, describing it as different from both, and giving it specific and distinct names, according as its features varied. In the so doing, Nicol expressly excluded it from the inversion on which he insisted.

Nicol, it should be remembered, superadded to the skill of a geologist, the knowledge of a mineralogist.

Numerous, however, as are the authorities who hold that this rock, as seen in Sutherland, differs from the Hebridean gneiss, they are not in number equal to the localities occurring out of Sutherland (localities unquoted by these authorities), which also bear witness, and far more clearly and emphatically than do any in Sutherland, to the distinctiveness

of the two rocks. These localities will be noticed in the consideration of the county in which they occur.

In speaking of this rock it is needful to state that I am far from asserting that the Hebridean rock nowhere appears in the long stretch between Loch Carron and Whitten Head ;—there are in fact two masses,—the wedge-shaped mass north of Ben Uidh, and a small one in the Corry Dubh of Braebag,—which I desire again to examine :—it must be understood that my remarks apply to the rocks which occur at the localities which are specially noted.

In considering the features of this rock, the physical and petrological may be taken first.

It may be remembered that in speaking of the Hebridean gneiss, I stated that its most marked feature was the distinctly segregatory arrangement of its component minerals, and their invariable highly crystalline condition ; that its divisional plans were so marked, with often an approach to an actual separation, that they came to be lines of weakness, into which waves and rain could make their way. The opposite of all this obtains as regards the Logan rock. It is true that at certain localities, it is in a certain sense crystalline in structure, but this is not the rule; and whether it present itself with a crystalline structure or the opposite, there is alway a marked blending and inter-fusing of its mineral constituents.* So uniform is this *mass-mixture* of ingredients, that one of the difficulties connected with this rock is that, except at junctions, it is difficult if not impossible to make out bedding, dip, or even such structure as enables us to say what the very nature of the rock is. Mr. Hudleston writes, " one of the most difficult tasks is to make out any definite system of divisional planes, which might be regarded as showing the bedding." This distinction is very characteristic.

When we stand upon a glaciated surface of high tilted Hebridean, we feel our tackets† gripping a rough gritty rock ; while parallel stripes of strongly contrasted colours pass away from the eye in gently rippling and closely adjacent lines.

A glaciated surface of the Logan rock again is dangerously smooth, looks like coagulated mud, in clotted lumps, while its coloration is in utter confusion. In some places a blotching of red, green, and white ; in others, a mass of twisting and interlacing lines.

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* Well seen in the rock of Glen Logan, where the intermixture of the red and white felspar is such that Mr. Hudleston pronounced the former to be oligoclase.

† " Tackets," anglice " boot-nails."

Nor do these highly contrasted rocks lie far apart. One of the localities claimed for an inversion is Loch Glen Coul. The two rocks—*one* according to the inversionists,—do not lie a mile apart on the south shore, and under three hundred yards on the north. The Hebridean gneiss is seen upon the south shore of the Loch, so perfectly and regularly bedded that a boat can at almost any spot run safely ashore along the jointings, and its occupants step out, as at a pier. The dip is at a low angle to the W.N.W., and the waves have found so ready an entrance into the jointings, and between the beds, that blocks fit for building purposes lie pitched about. Such blocks in fact, have, without any dressing, been employed for building the piers at the Ferry of Kyle Sku. The Logan rock again, where first seen at the head of the Loch, protrudes from the turf in rugged nobs, in which neither bedding or jointing can be seen. Half-way up the ridge which forms the ascent to the stack of Glen Coul, the Logan rock which forms that ridge, is glaciated into smooth contours, which should well disclose its structure; but no recognisable bedding is seen, and it has so uniformly coherent an arrangement of its parts, that a chip or specimen can only be procured by attacking some protruding corner. Here the lineated structure—the convoluted serpent-like folds,—point down the loch; that is at right angles to the strike of the lower rock. As regards inversion here, the lower rock dips the wrong way,—presenting fractured out-crops towards the supposed trough; while, again, any *indications* of bedding which the upper rock presents, are at right angles to the direction required for an inversion.

Nicol was censured for supposing inversion possible between Kean-na-Binn and Hope Lodge, a distance of nearly five miles; but the distance on the north shore of Glen Coul is only a few hundred yards!

As regards the segregation of its components, the feature of the rock is that it is in the main concretionary, and not linear; and where tending to linear, it is highly tortuous and involved. Its constituents are a hornblende which is not so dark in colour, or so lustrous by any means as that of the lower gneiss; not so crisp-crystalline and foliaceous, but mere short-flakey, or as Mr. Hudleston calls it, "thin banded and matted." "A hackly pinkish felspar," instead of the yellowish-brown, flakey, and pearly-lustred orthoclase of the Hebridean. Both of the above minerals are minutely sprinkled and spotted with interstitial quartz and oligoclase.

But the marked constitutional feature of the rock is the almost invariable presence of the so called "*epidosite*." This is palpably a secondary product, as it occurs invariably in veins, which ramify into rents which are

often disclosed only by its presence. This large amount of epidosite I regard as one of the characteristics of the rock.*

There are two other features—constitutional features—one of which, at least, distinguishes it still more. This is the occurrence in it of *belts*—(I cannot call them by another name, as I am unable to say that they are beds)—of varying thickness, from 1 yard to 20 or more, of a substance which differs much from the main bulk of the rock. This is a fine-grained, dark brownish-green, muddy-like rock; hardly dense enough to be called aphanitic. This is interlaced throughout and to a marvellous extent by extremely thin veins of epidosite (?). In the hill of Glasven there are numbers of these dyke-like bands, the first three, at least, of which have a strike parallel to the line of outcrop of the underlying dolomite and quartzite. These bands sometimes seem to tilt the obscure beds of the inclosing rock, while in the Coire Laich of Coineveal the same rock occurs not in clearly defined belts, but in masses nearly as large in amount as the Logan rock itself. Now this dark green rock, dense and uniform in structure as it appears to the lens to be is, when a section is made

* Mr. Hudleston writes, "I have usually been disposed to regard the abundance of epidosite as one of the features of the "Logan" rock which especially distinguish it from the Hebridean gneiss: but Dr. Heddle states that this peculiar *mélange* occurs in greater quantity, and perhaps in a purer state in the west of Ross-shire than in any locality known to him. This is in the Hebridean gneiss near Poolewe. Hence this presumed distinction vanishes."

But Mr. Hudleston here writes in misconception of my meaning. If my description of the Hebridean gneiss be turned to, it will be found that, *in speaking of the substances occurring therein*, I referred to a substance which occurred in "*some districts*;" which substance I conceived to be the same as one described by Macculloch as found in the western gneiss, and which he thought green felspar. *That substance* I said I had found in greater quantity at Poolewe than at any other spot where I had got it. My analysis of the Poolewe specimens proved a failure, but enabled me to draw certain conclusions. I knew that Dr. Macculloch considered it a felspar; I also knew that Mr. Hudleston had applied the term *epidosite* to a similar substance got in the Glen Logan rock, and I wrote, "I conclude that the thing as a whole is that *mélange* which has been termed epidosite." "I shall, therefore, with a *caveat* term it mean-while epidosite." I also stated or indicated the reasons for the caveat, namely, that both the Loch Maree and the Harris specimens showed incipient crystallisations of recognisable *epidote*.

Now this may not be distinctive between the substances occurring in the two rocks; but so far as my experience goes the substance from the Hebridean *always* shows incipient crystallisation; while in no one of the many slices which I possess of that occurring in the Logan rock, have I ever seen a trace of this. In all the slices the green matter passes into and through quartz, like the fibres of an untwisted cord, or as a cloudy stain. Be this as it may, instead of occurring as do the veins of the substance found in the lower rock, only *in some districts*. epidosite occurs everywhere throughout the Logan rock; and though I have not yet found it in perhaps quite such thick veins as those in which Macculloch's "felspar-like mineral" is found at Poolewe, yet it is present in certainly a very much larger total amount.

I therefore go quite along with Mr. Hudleston in being "disposed to regard the abundance of *his epidosite* as one of the features of the Logan rock, which especially distinguishes it from the Hebridean gneiss." Hence Mr. Hudleston's "presumed distinction" does *not* vanish, but it is fortified.

at right angles to its surfaces of contact with the inclosing rock, shown by the microscope to consist of a highly-contorted "chloritic" schist, of a very minute structure.

The second distinctive feature is the frequent occurrence in it of dykes of a dark, large-crystalline, igneous rock. This consists of augite and a grey plagioclastic felspar, probably labradorite. The crystals of these minerals are often arranged in an orbicular manner, like *Napoleonite*. The spheroids are about the size of marbles, and they are very evidently disclosed on the surface of the rock by the radiation of the crystals of the felspar, which are whitened through weathering. Neither of these rocks, I need hardly say, have I seen in the Hebridean.

Such are the ordinary lithological features of this rock. It might, however, be said, that an ordinary feature is *the extreme abruptness with which there is a change in the relative amount of its constituents*, but as this feature pertains most markedly to the *different beds in which it occurs*, the detail of such varieties is left to the description of them.

A geognostic feature, however, now claims attention. I have above admitted *resemblance* between portions of the two rocks. I shall admit further, namely, that it might be possible to select specimens—though not typical specimens—of the two which could not readily be distinguished; but still I say, with all assurance, that no one whose eye has, by traverses from Kishorn to Erribol, been educated into a recognition of the features of the landscape presented by the surface-weathering and vegetation-covering of the two, can fail to recognise at a glance appearances which are special to each—so special, indeed, that we are able at a distance of one or two miles to pronounce without hesitation as to which rock lies before us.

The features of the landscape of the Hebridean gneiss I have described:—a tumbled mass of little hills, sharp-angled in their outline, like petrified waves of the sea. Macculloch, speaking of them in detail, and of the numberless little lakes which are clustered among them, declares that there is not one of them which does not contain the fundamentals of beauty. This could hardly be so were they not more or less grass or heather clad; and this is, in fact, the feature of the surface of the Hebridean rock. Rock, dark in colour, protruding every here and there, form a covering in which grass at one spot and heath at another prevails.

Grass is almost unknown on the surface of the Logan rock. Heather, even, is but rarely seen. Bare rock—generally rounded or trenched by ice—sprinkled with boulders,—its internally deep colour blanched to a grey yellow through the weathering of its felspar, shows itself in an endless

series of undulating contours, and presents a surface of such extreme barrenness that, when compared with it, the Hebridean rock looks fertile and warm.

The contrast is well seen in descending the slope from Glasven to Kyle Skou. The Logan rock on the north shore of the Loch is nearly vertically disposed over the Hebridean, with only a double belt of quartzite intervening.

"The very face of the country is different. The underlying rocks *cannot* be the same," I heard a geologist exclaim when first looking across the water. The contrast is still more marked eastward of the head of Loch Coul, and between Ben Uidh and Rhie Knoc. Ice has here scoured off what little vegetation may have once clung to the crevasses or the hollows. In the midst of these lie gloomy lakes cut off from all sunlight, and a scene of such unrivalled desolation is presented that the locality has not inaptly been termed "the Valley of the Shadow of Death."

Such are the petrological distinctions between the two rocks. The mineralogical may be dismissed in a sentence.

Of the Logan rock the record is a blank.

I have searched this formation to a much greater extent than any other in Sutherland, and I have never found a crystal or a simple mineral in it. Nineteen species were enumerated from the Hebridean gneiss of Sutherland alone, several occurring in abundance. When we come to Ross and Inverness shires it will be found that several others have to be added, but neither in Sutherland or in any county in Scotland have I found a single mineral in this rock. It will be indeed difficult to show how the faulting up of a rock, or its inversion, could abstract from it all the substances which had once crystallised therein. It is quite rational to suppose that crushing, rending, and churning up with limestone fragments might, through evolved heat, produce *new* minerals, but that such operations should abstract pre-existent formations is altogether incredible.

Its *constituent* minerals sometimes, though rarely, approach, but no more, to a definite form. I found a mass of graphic granite, about the size of a man's head, at Liath Bhad, Glen Coul; and Mr. Hudleston picked up a weathered fragment, in which the skeleton crystals of quartz were larger in size, in Glen Coul itself. The hornblende in the little cliff which faces the west on the extremity of Ben Bhrachaid is somewhat actinolitic; it is fibrous, and of a leek-green colour. Minute specks of *pyrites* rarely occur in one of the beds at Camer Loch.

This is the only rock mass I ever examined in which I have found no minerals.

Localities of the Rock.

The most southern locality at which this rock appears in Sutherland is along the north-east shore of Cama Loch. The section from the west to the east-end of the lake, reads as follows:—

At the west-end we find the Hebridean gneiss with its usual appearances of distinct linear arrangement of constituents,—well seen in some glaciated islets in the lake. Weather action has, through partial abstraction of the felspar, exalted the appearance of parallel banding of the hornblende and quartz. To the north-west the huge cone of Suilven stands as an islet of Torridon sandstone, the basement beds of which stretch as a flat pediment for nearly a couple of miles eastward of the head of the lake. Walking along the north shore, we tread upon the upturned edges of the lamination of the gneiss. The exposure of its internal structure is excellent, but no epidosite is seen. About a mile from the head of the lake one of the basement beds of the Torridon-foot of Suilven, distant nearly a mile to the north, sweeps suddenly southward from Cnoc a Vuic, crossing our path. It dips to south-east at about 8°, and thrusts itself as a small cliff, a few yards in width, into the waters of the lake. Upon its eastern side the Hebridean again appears, and extends for some hundred yards, when it is overlain immediately by the quartzite.

Beds of this rock abundantly riddled with wormholes, are passed over until the mouth of the Allt-a-Chroisk is reached. Here there come in, conformably to the quartzite, hard and dense beds of the argillaceous rock, with "fucoids;" the dip being 11° to east-south-east. The fucoids are here less carbonaceous, but much thicker and more massive in structure than is usual. A steep-sided grass-clad knoll overlies these beds. Upon its summit alone is any rock visible; that consists of protuberant masses of a highly typical variety of the Logan rock. Only by trenching could it be determined whether these masses are or are not *in situ*. To the eye they look loose; to the hammer they do not sound so. The knoll terminates a shallow trench; it is thus possible that it may be but a heap of morainic matter. Morainic heaps are seen about the fourth of a mile to the north-east. Such are the facts which speak to this being a "dirt heap." Those which speak against it are:—

1st. The shape and surface-dressing of the knoll are entirely different from those in its vicinity; and different moreover from the usual appearance of water-dressed morainic matter.

2nd. No rock is seen in the knoll but Logan rock, although the stretch of ground which would have cradled a glacier should have yielded Torridon conglomerate, quartzite, fucoid rock, and dolomite.

3rd. The glacier-trench consists to much the greatest extent of quartzite, only a feeble fringe of Logan rock of a different variety from that seen in the knoll occurring; moreover, no masses of the variety seen in the feeble fringe of Logan are seen in the knoll.

4th. The variety which alone forms the knoll, does not occur elsewhere in the neighbourhood. It is well described by Mr. Hudleston who took specimens, he writes:

"I hold a thoroughly typical specimen of "Logan" rock obtained from the somewhat isolated exposure to the west of Ledbeg. It is striped something like a tiger, with bands of a hackly pinkish felspar, partially relieved by dull white quartz alternating with thick or thin bands of a dark-green matted hornblende. The cracks and backings are lined with abundance of pale green epidosite, which is so characteristic of the rock in the Logan valley. Altogether this is a fair specimen, though there are others far richer in quartz."

5th. This same variety occurs in the Meallan Laoigh in Ross-shire, immediately overlying the fucoid bed.

I conclude from the above that this knoll consists of loosened, but not displaced, fragments; and the disrupting agent may have been a glacier.

A close grained vitreous and much fissured quartzite succeeds. It is seen along the shore of the lake, where the eastern end of the quartzite bed forms a small cliff. The dip is about 9°.

Immediately overlying this there is a bed of about nine feet in thickness of Logan rock of a type quite different from that just described. It is close grained, the individual crystalline aggregates being about the size of peas; has a dull brick red colour passing to yellowish brown. The lustre is greasy or waxy, and it is slightly trans-

lucent. It consists chiefly of orthoclase with little quartz, very little foliated hornblende, and still less epidosite, which is present in externally thin but closely ramifying veins. Altogether this rock is very similar to the so-called quartz porphyry of Cnoc-na-Strome. Quartzite with the same dip succeeds; this bed is less vitreous in appearance, and less fissured than that which underlies the red Logan.

This quartzite is succeeded by a thick bed of Logan of ordinary appearance, that is the green, red, white, and colourless ingredients are present in about equal amount; but epidosite here dominates largely in some parts of the bed. It is of an unusually brilliant green colour, and uniform fine grained structure. It is occasionally blotched by thin scales of a brilliant red substance, in which the lens can recognise no structure. The thin plates of this red substance are disposed parallel to the sides of the veins. The veins which are in some spots half-an inch in thickness, are purer in appearance than any I have seen elsewhere.

Quartzite succeeds as far as the point of the terminal bay of the lake, when the next bed of Logan is seen. With the exception of its under and upper surfaces which contain both quartz and white felspar, this bed is composed entirely of matted crystals of dark green subfibrous hornblende, with a few lacings of epidosite. It weathers out in rounded lumps of about two cubic feet in size; and, did not its surfaces and some few veins show its nature, it might be called hornblende rock.

Quartzite, coarser in grain, again succeeds for a short distance along the shore of the little bay; this is overlain again by a bed of Logan rock in which the constituents are smaller in individual particles, and more mixed through one another than usual.

Keeping the same line, the east shore of the lake is now quitted; and just above it to the east-north-east, we come upon a little cliff of flinty quartzite overlying the Logan rock. This bed of quartzite is about 14 feet in thickness, and is overlain conformably, and still at about the same angle, by a mass of Logan rock which stretches to and across the road from Elphin to Ledmore, and along the roadside, so long at least as any rock can be seen. Again is the feature of the rock changed. By many it would here be called granitic or syenitic. It is in appearance like a harlequin's coat, so far as colour is concerned:—a spangling mass of white, red, and green, the red, which is brilliant, predominating, and it is laced throughout by epidosite.

There is a flat space of about two hundred yards between the last seen rock, and the banks of the Ledbeg river which is covered,—and if we may judge by the banks to be seen to the north, and the gravel beds of the river, the cover consists of drift. The rock next seen is immediately upon the east end of the bridge, and it is highly characteristic, though its characteristic features are possibly due to a modification of pseudomorphic alteration. In structure it resembles the westerly dull red bed of Logan, but it has a brown colour, blotched with dull greenish grey. It has a waxy lustre, is translucent, and the greater part of it cuts easily with the knife. It consists of a muddy dull red felspar, in rude crystals, imbedded in a substance which is *identical* in appearance with the pseudophite from Plaben, Budweis.

The rock as a whole is very similar to the lower bed of the Logan rock which I have afterwards to note as occurring at Liath Bhad; the size of the component crystals is here, however, somewhat larger.

As the substance which is similar to pseudophite is peculiar, and as it gives to the rock its unusual appearance, it was particularly examined.

To the eye it looks like congealed suet, sprinkled here and there with glistening scales

Under the microscope it polarises feebly, showing a structure like ground rice; and is altogether very similar to the pseudophite of Beauty Hill in Aberdeenshire.

Its specific gravity is 2·804.

On analysis by an assistant, it yielded—

Silica	44·803
Alumina	36·050
Ferric Oxide	4·804
Lime	·407
Magnesia	·675
Water	13·835
	100·574

2·9 per cent. of the water was given off at 212°; and 2·58 per cent. of the silica was insoluble in boiling solution of sodium carbonate.

This is a massive *kaolin*.

In an imperfect analysis of the lustrous flakes imbedded in the massive mineral, there was got—

Silica	44·217
Alumina	33·373
Ferric Oxide	4 388
Lime, Magnesia	lost
Water	6·917

This looks like *euphyllite*, but there were no alkalies; and I question the possibility of separating this substance sufficiently from its matrix to make the analysis reliable.

If the first noted substance be merely a product of alteration, it is very difficult to say what mineral has been changed into it. It certainly is deserving of being re-examined. All that I am able to say of the rock is that it conveys the impression that it is an intermediate between the last seen Logan rock, and the next seen,—the quartz-porphyry of Cnoc-na-Strome.

No junction can however be seen; at least I failed to find one in the bed of the Ledbeg river. The rock-banks are here so rotten and air-wasted, that actual quarrying alone would suffice to reach an unaltered portion.

Though, however, no junction can be seen, there is not, in the nature of the surface, anything which indicates a break in the succession between the rock at the Bridge and the rounded domes of Cnoc-na-Strome and the hills to the east of it.

Exception must be strongly taken to the name given to the rock of these hills.

No true porphyritic structure can be seen in it, and of its two ingredients,—felspar and quartz,—the former is decidedly that which shows traces of crystalline form. The quartz, indeed, is frequently altogether absent. The rock, in fact, is nothing else than a mass of agglutinated granules, of the size of peas, of a more or less brilliant red felspar. The information derived from microscopic examination is altogether unsatisfactory, for the felspar of even the apparently freshest masses is clouded and without character; there is an obscure meshwork in some parts, with interstitial quartz, which usually falls out during the grinding down of the slice.

It might be hoped that a mass of rock over 800 feet in thickness, and some miles in length, would show some appearances either of bedding or of flow; all that is seen is very obscure. A structure something like bedding, but more like the convoluted structure of the Logan rock, is seen on the bared summits of the hills; and this structure runs from north-north-east to south-south-west, and has an almost vertical dip, instead of the low dip seen at the junctions of the Logan rock. But, again, the jointing of the cliff faces of the northern side of the hill indicates a rude bedding conformable to the dip of the quartzite beds at their junction with the Logan rock.

This rock stretches eastward to about the centre on the hill east of Loch Borrolan, and almost up to Loch-a-Meallean. Here it throws off a well marked spur to the north-east (Rhie Cnoc), which apparently connects it with the mass of Logan rock of Ben Rhrachaid. Eastward of the little lake, the rock is in appearance intermediate between that of Cnoc-na-Strome and the Logan rock; with here and there a great resemblance to the rock seen at the Bridge of Ledbeg; at other points there is some slight resemblance to an igneous rock. The rock of the east end of the hill is again like "Logan" of a red hue, and a grey-brown labradorite-like bed is the last seen.

To the east of this hill marble is found—the bed sweeping round the hill to the north-west, with no evident dip. After crossing the road to Loch Ailsh we have the section which discloses the supposed upper limestone.

Of the above sequence it has to be remarked that at the point westward of the bridge where the ground was covered, if not at a second point, we lost all true hold of the section; and that it is very probable, seeing that there is disclosed elsewhere an evident semicircular sweep of the whole series of rocks, that we may, after the crossing of the bridge, have been walking *along the strike*.

Before leaving this eastern and obscure portion, however, it may be well to consider what the rocks there seen really are.

The earlier geologists all term Cnoc-na-Strome *quartz porphyry*, and the hill east of Loch Borrolan they called *gneiss*.

In speaking of the localities of the marbles, I noted the fact that these were all more or less adjacent to the dome of Cnoc-na-Strome or its off-sets. Giving all due weight to that fact, I have yet to say that I incline strongly to the opinion that the red rock is a mere variety of the Logan rock. I would not *now* even go so far as to regard it as a volcanic rock which had broken through the "Logan" and incorporated portions of it,—though that was my earliest contention with regard to it.

If we consider the marked variation in character in the successive beds of the "Logan,"—if we consider what is disclosed to us in other parts of the country, namely that the Logan rock comes in with extreme suddenness, forming masses or lumps which are lenticular when considered either along the strike or at right angles thereto,—if we remember the close resemblance of this "quartz porphyry" to the red bed on Cama Loch, and the apparent passage of the "porphyry" into Logan rock eastward of Loch Borrolan,—and when we come to know that Scoonan Beg and Sail an ruar come in (equally red with Cnoc-na-Strome) to form the connecting-links of the Logan rock between Scoonan More and Meall-an-Aonaich,—I conceive that we are justified in deciding that the red rock may prove to be a mere variety of the "Logan." It certainly does not depart in appearance or in simplicity of components from the ordinary variety of that rock, to a greater extent than does the hornblendic belt which is sheathed, and no more, in recognisable "Logan" on the shores of Cama Loch.

As bearing upon the section seen along the shore of Cama Loch, it has to be stated that at but a small distance northward of the shore exposure (above described) the Cnoc Ledbeg rises in a steep and craggy face, which exhibits the different beds as they sweep round the angle of the hill to be exposed on its west face continuous with Cnoc Led Vuie, in the true line of their strike. The alternation of these beds can thus be seen and proved to exist a considerable way back from their exposure on the lake shore.

The height of the Cnoc is not such that its western or its south-western cliff contains the whole of the enumerated beds, at any one spot; but, by starting from the shore line at any one bed and scaling the opposite cliff, all which lie above the selected bed are passed over, with the exception of the easternmost which sweeps round on the eastern slopes of the Cnoc.

Starting for instance from the first little quartzite shore-cliff, we pass over the red bed just above its summit, then traverse a low hill slope, coming upon quartzite at the cliff foot: over this in the cliff we find a thick bed of "Logan," overlain by a thinner bed of quartzite; and just over the rounded brow of the cliff we come to "Logan" again. All dip into the hill at a low angle. The sequences are similar wherever we scale the cliff as it droops to the eastward; we find successive thin bands of varying types of a rock, which are all structurally different from the great mass of the Hebridean rock which lies but a mile distant. These beds are interbedded with bands of quartzite, more or less vitrified in appearance, which beds show no worm holes, and there is no appearance from top to bottom of argillaceous beds or of fucoids.

When the beds of "Logan" are followed along the strike in the west face of Cnoc Ledbeg, some are seen to thin out, while others seem to assume laminated quartz, and to shade off into quartzy beds. One such bed, seen in the little bealloch between this hill and the more northern Creag-a-Croisk, is stratigraphically apparently a fissile quartzite; but when broken it is seen to contain much felspar which is sprinkled throughout it in such a manner that it has to be pronounced an intermediate. The last bed seen which can be decidedly pronounced "Logan," almost immediately overlies a highly crystalline blueish-grey dolomite, in Creag-a-Croisk. This bed has a bright red colour, and the only petrological difference between it and the Cnoc-na-Strome rock is that it contains some isolated particles of bright green hornblende, and is somewhat more coherent in structure.

Nowhere throughout the whole of the section is there the smallest appearance of slickenside or of folding or crushing. I own myself quite incapable of con-

ceiving how any system of faults at an angle of 9° could have produced such a structure as that described above; or how any folding over of the beds could have brought back the great solid mass of the "Hebridean" in flakes of ever-varying composition, and could at the same time have multiplied one thick bed of the quartzite teeming with organisms, into five or six thin flinty beds, which show no organism whatever, and this moreover without anywhere revealing a trace of the fucoid bed which is associated therewith at so small a distance as only a few hundred yards.

Northward, along with the overlying serpulite grit, of the section described, the first point where the Logan rock is seen is in Ben Bhrachaid. Meall Diamain to the west, consists of worm-hole quartzite, rolled in so gentle an anticline, that the height of the hill above the valleys on its north and south flanks is probably a near measure of its thickness. The fucoid beds are seen in the col between this hill and the craggy western front of Ben Bhrachaid. I have not seen the dolomite, but as the ground is swampy there may be a wash out. The "Logan rock" succeeds above, with its usual rough and uneven surface, and is succeeded by somewhat flaggy beds of quartzite, the total thickness of which is quite insignificant when compared to the huge masses of Braebag and Meall Diamain to the west. Of this section it has to be said that although the superiority to the "Logan rock" of these thin beds of quartzite is perfectly evident, that of the Logan rock to the fucoid beds is not altogether so. At the actual junction the ground is soft and covered, and screes of loose stones run down the sides of the hill, covering the line of junction on its south side; on the north foot of the hill, however, the quartzite, though it shows a feeble fault about the line of the col, and a still feebler one a few hundred yards eastward of this, is seen to pass under the "Logan rock" for a considerable distance to the east.

Altogether, this is not a section upon which I would found much.

As regards the *nature*, however, of the rock here seen, it must be maintained that it is very different from the Hebridean. The hornblende in the little cliff spoken of, is almost fibrous, and of a greasy lustre; and it is so riddled and cross-hatched by thin veins of epidosite as to have no small resemblance to serpentine.

The Logan rock is now seen to the north, as a band which lies between two beds of quartzite, in Meall an Aonaich, and in Carn nan Conbhairean. As the debris of the quartzite of the summits of these hills has streamed down their southern sides, the junctions are there obscured. I have not examined the north-east sides, where good exposures are to be looked for. The band of rock in both hills is seen to be continuous with the great mass in Ben More.

Passing eastward, two admirable and similar sections are exposed in the streams which issue from the Dhu Loch Beg, and Dhu Loch More. The description of the latter will suffice. Starting from the quartzite foot of Braebag Tarsuinn,—littered with water-dressed heaps of debris which has been swept from the foot of the great escarpment at the south side of Coneveall,—and crossing the head waters of the Oikel, we come upon the yellow argillaceous beds, surmounted by the dolomite, just where the ascent in the channel of the stream becomes rapid. A small cascade in the stream marks the next junction. The cliff of the cascade is the result of the endurance of a bed of cherty rock and of the scooping out of the underlying dolomite. It admirably displays the junction of the latter with its cover, and also the nature of the several rocks. The overlying bed of cherty rock is thin, fine grained, slightly muddy looking, sprinkled abundantly with minute cubes of pyrites, and pervaded with branching seams of flinty chert. As it was of importance to ascertain if this chert could in any way represent the lower quartzite inverted, I separated the flinty bands from the general mass, crushed it up and examined it with acid. There was considerable effervescence, and the solution contained both iron and alumina in considerable quantity, with some soluble silica.

The chert is immediately overlaid by what may be called lithologically a felspathic grit. This is a pinkish yellow, close-grained rock. It breaks with nearly equal ease in three directions, due apparently to the felspathic granules lying much in the same direction. The felspar seems to be orthoclase, and the quartz, present in about one fifth of its amount, is colourless to milky,—and of a vitreous to fatty lustre. Both felspar and quartz are in sharp angled particles of about the size of shot. Under the microscope the felspar is somewhat moulded round the quartz

fragments, so it must have undergone considerable metamorphism, and is not truly a grit. This rock is exposed for about 100 yards in the bed of the stream. when it is seen to become gradually banded by dark-green belts; these are disposed parallel to the strike of the underlying rocks. The bands are at first pale in colour, from the small amount of green material. This is sprinkled throughout the belts like grains of gunpowder. When the rock is broken into, the dark bands are found to pass under those of pale tint at a dip, as nearly as can be estimated, the same as that of the underlying quartzite and dolomite. The alternate more felspathic belts—still dominant in width—are, in the proximity of the quartzite, quite free from the darkening material, so that the above fact is easily seen. As we ascend in the bed of the stream, the relative dimensions of these beds is inverted; the dark predominating, and also themselves darkening in colour. As the dark bands have proved both less soluble in the water, and less easily worn by the friction of suspended gritty sand and rolling stones, they protrude above the level of the more felspathic portions of the rock, and appear as a series of ridges which mark accurately the line of strike. Wherever broken, the dark material of these bands is found to be crystalline hornblende. By the continued increase of this ingredient the rock becomes typical "Logan;" and, for some little distance above the point where it must be so termed, bands of the pink felspathic character are seen.

Towards the upper part of this series of transition bands, and where the rock would be regarded as more gneissic than gritty in structure, there exists a band slightly more protuberant than the rest. This had been mentioned, and was pointed out to me as a *dyke of basalt*, and was said to cut off abruptly the felspathic grit from the Logan rock, and to break the succession. This band I found to consist in reality of *dolomite* pervaded with augitic matter and somewhat serpentinized. Out of it I broke masses, the size of the fist, of a highly crystalline carbonate. These masses had almost a pearly lustre; and besides the carbonates of lime and magnesia, contained much iron carbonate.

From this point the rock becomes typical "Logan." It extends across the flat which holds Dhu Loch Mure, and rises north of it, as a series of buttressed precipices. It is immediately overlaid by a great belt some hundred feet in thickness of quartzite. This belt stretches unbroken for some miles, being continuous with that on the summit of Coneveall, as well as with that seen in the hills which prolong the ridge to the south-east.

I regard this section as an absolutely conclusive one; it reads, quartzite,—argillaceous beds,—dolomite,—chert,—felspathic grit passing gradually into "Logan" rock, which contained near its base a thin belt of dolomite,—quartzite.

Where can a fault be placed? There is not the smallest appearance of one, nor of anything of the nature of disturbance. The edges of the gently dipping beds are spread out like a pack of cards, and they succeed one another in rectilinear and close-fitting contact.

Above the cherty bed which is elsewhere associated with it, the dolomite is succeeded by a rock which had been once at least fragmentary, which is banded parallel to the lower rocks, and this banding unquestionably unites it in *age* with the overlying rock, whatever amount of question there may be as to the nature of that rock. How can a fault, moreover, account for the appearance in what some hold to be the Hebridean gneiss of a bed of dolomite unknown in it elsewhere?

Then as to inversion. The section at Knockan* establishes the fact that the dolomite is overlain by the eastern gneiss. We should, therefore, on the theory of an inversion, expect to find some reduplicated beds of that series of rocks in the centre of the dolomite; or, on the extreme supposition of the inversion having taken place *before* it was overlain by the eastern gneiss, we should find the supposed inverted fold of the Hebridean overlain by the newer eastern gneiss. The dark rock is, however, overlain by quartzite.

The theory of an inversion posterior to the deposition of all the rocks, demands the reappearance above the dolomite of, first, the yellow beds, distant not many yards down the stream; and, secondly, of the vast thickness of the quartzite of Braebag above these yellow beds.

* And others in Cromarty.

Such a theory absolutely fails, moreover, to account for the felspathic grit,—for the thin bed of dolomite in the dark rock,—and for the fact of the quartzite overlying the dark rock. The occurrence of such a felspathic rock would have to be pointed to in some part of the extended exposure of the undoubted Hebridean, for it is far from trifling in extent,—stretching apparently the whole way between the streams which issue from the two Dhu Lochs, as a cornice of vertical cliffs 60 to 80 or more feet in height.

In fact, this felspathic grit invalidates faulting and inversion alike; while its occurrence is perfectly in accordance with what has been said above to be one of the features of the Logan rock,—namely, that it varies markedly in appearance in different localities.

If we run a section across the rocks at the east end of the Bealloch of Coneveall, we gain further information.

In speaking of the dolomite I mentioned that a patch of that rock occurred upon the north-east slope of Braebag Tarsuinn overlying the yellow beds, which with the dolomite were thrown at a high angle by the crushed double anticline of that hill. The underlying quartzite, the yellow beds, and the dolomite give us our position definitely in considering the rest of the section. Immediately north-east of the dolomite there lies the deep trench of the Bealloch, on the north-eastern side of which, though at a lower level, another patch of dolomite is seen. As the floor of the trench is covered with detritus it is quite possible that a rent is also concealed. If such exist, it certainly does not break the succession, for the yellow beds are found underlying the dolomite of the north side, and by regarding both patches of the latter from a position which flanks them, it is seen that there is no displacement, but only a medial cutting out of the bed, the line of dip on the Tarsuinn side falling exactly as if extended upon that on Coneveall.

This outlying eastern portion is seen for only thirty-four yards along its strike, but it is regularly bedded and unbroken. This is evidenced by a bed near the bottom of the mass of about a foot in thickness—and of a fine grained structure and pale blue colour; which stretches like a broad ribbon from end to end, unbroken. Over this, the dolomite is of the coarse granulated structure which is the prevailing character of that rock wherever exposed to atmospheric waste. The bed dips at a low angle into the hill. North-east of this bed there is a grass cover for eight yards, when a well-marked and perfectly unbroken bed of quartzite is seen. This has exactly the same dip as the dolomite. The bed is about eight feet in thickness. A heathery sward succeeds for a short space, when Logan rock of the convoluted serpent-like structure comes in as a sort of rounded cliff, which *can be skirted almost continuously along the strike* to a little above the point of transition of the felspathic grit into "Logan" in the bed of the Dhu Loch More stream.

The direct rise, however, on the section from the quartzite, brings us upon a spur of Coneveall which is thrown out to the south-east. Ascending this, it is observable that the Logan rock upon the left, which forms a considerable portion of this face of Coneveall, is rudely columnar, or in huge spheroidal masses, with a slightly radiating structure. Great rhomboidal masses hang toppling, and the whole of this side of the hill has a shattered and ruinous appearance.

Those who are familiar with the great cliffs of the Hebridean will vouch for it that nothing of the kind is to be seen in them. Whatever point of the compass they may face, at whatever angle to the formation they may be cut, or whatever agency may have operated in their formation, all that remains is self-rivetted and enduring. Witness the smooth-faced frontlet of Cape Rath, or its pinnacled stacks; the grand precipice of Ceann Garbh of Foinaven; or the rock-ribbed sides of Ben Stack. Ragged they may be, but never loose or shattered; when ragged they look as if torn out of a mass of hackly but most tenacious iron. Here it is altogether different: the ruin of this rock has induced ruin in the overlying beds of quartzite; and enormous heaps of water-dressed debris, swept from the cliff-foot, are spread for some hundred yards to the south-east,—and that in an amount sufficiently great to resemble morainic heaps. Overlying the Logan rock we find, at an elevation of about 2550 feet, a bed, or rather a double bed, of felspathic grit. The two beds are under six feet in thickness. The structure of this grit is different from that which underlies the "Logan" as seen in the last section; the difference of structure

depending primarily, if not immediately, upon difference in the relative amounts of the felspar and quartz. Instead of a condition of firm agglutination, this rock is brittle and friable. The quartz grains, coarse in one bed, finer in the other, are greatly in excess ; the felspar, though of two colours—flesh and pale white—seems yet only orthoclase. It is in sharp-angled fragments, larger than those of the quartz ; and is kaolinised to a considerable depth in the rock. It certainly has the appearance of having been much less metamorphosed than had the lower grit ; but this is doubtless due to the felspar granules being so far apart that they could not agglutinate with one another.

These beds have a pale fawn colour. Though so limited in thickness, they are very persistent. They can be seen stretching away to the right ; drooping first as they cross the corry between Coneveall and Ben More, and then rising to come to the surface at about the centre of the connecting ridge. To the left they rise, to come to the surface on the north-west slope of Coneveall, but seen to thin off in so doing, as they cannot be found on its western slope. This drooping sweep is nearly along the strike ; and the beds are dipping into the hill also, at right angles thereto, at an angle of about 23°.

According to those who maintain that the Logan rock is the Hebridean gneiss, that rock is not held to be (as usual) inverted at this spot, but merely *faulted up* ; and these grit beds are regarded as the basement beds of the lower quartzite. This contention goes hand in hand with the view maintained by certain of the opponents of the sequence laid down by Murchison and Geikie,—namely, that it is irrational to maintain that a rock so feebly metamorphosed as is the quartzite could underlie strata which have been altered into mica schists, gneisses and syenites.

Among the many contentions of those presently engaged in a controversy as to the age of these rocks, no one has been more persistently urged, and enunciated with more unhesitating assurance, than *that the quartzite and the associated dolomite are slightly if at all metamorphosed.*

The writer has often been desirous of ascertaining from those who wield the wand of " metamorphism " so jauntily, and are so familiar with its potency, if they could conceive of any circumstances in which it might be inoperative, or were acquainted with any substances which it was impotent to change.

Certainly of late years we have, in this country, been more familiarised with a glib use of the expression *metamorphism* than enlightened as to its mode of acting. We have not, indeed, ever been favoured with facts bearing upon it such as might prove of use to those who so condescend as to make use of facts.

Where have we been presented by those who speak and found on the absence of metamorphism in the quartzite and in the dolomite, with any facts which go to prove their contention ?

Where is our enlightenment,—drawn from their knowledge of the composition of the rock,—the presence or absence of cement in its sand grains,—the nature of that cement,—the influence upon that cement of

heat, pressure, moisture,—the modifications of that influence effected by the varying nature of the overlying rocks? Where are we to look for such a series of investigations, analyses, and reasonings, as those undertaken by Bischoff, Delesse, Damour, before *they* diffidently propounded their contentions with regard to questions infinitely less wide and perplexing than *metamorphism* must long continue to be?

How comes it that when so many scientific men are honestly striving after the truth, it should be so terribly difficult to confess that they have not yet attained to it?

How metamorphism acts, we may not know,—but, *upon what* it can operate, and what it sometimes *can effect*, we do know. Acting chemico-physically, it can change *substances which are capable of change;* and acting physico-chemically, it can bring about the union of *substances capable of uniting*,—if they be present, and be also in contact. But it cannot change the *unchangeable*, and it cannot effect combinations, if one material alone be present.

Silica *alone* is chemically inert; and sand, however much agglutinated, is a chemical residue. In the carbonates of lime and magnesia, again, all the combination-changes which can take place have been effected; if beds of these materials be buried deep in the earth's crust, so that the escape of carbonic acid is prevented, they may be crystallised into marble; but no other physical change of structure has, in these rock masses, been recognised; and, chemically, only the alkaline metals could transmute them. Even granular-silica, however, if it have been buried deep in the earth's crust, has been found to become crystalline, or actually crystallised;—sometimes veins in the latter condition, intersect granular belts: while carbonates which have been buried deep—but such only—are found to have effected a surface-union with the elements of their enclosing rocks; and so, under the guidance and restrictions of chemical laws, have formed definite mineral species.

So universally recognised is the qualification of *deep burial*, that the field mineralogist, when in search for lime-silicates, never turns aside to examine recent rocks;—experience has told him that his time would be thrown away.*

While the writer, not having any particular theory to substantiate, has made no special study of these western rocks as regards the amount of change which they have undergone, still certain facts connected with

* Sir Robert Christison found *apophyllite* in a Coal-measure limestone quarry, at Chapel in Fifeshire; but it was in a cavity, and evidently had been formed through water infiltration.

them presented themselves to him, which entitle him to say that the statements that the quartzite and dolomite have not been metamorphosed, or have suffered a trifling amount of change, *is a bare assertion*,—the outcome either of insufficient observation, or of scientific ignorance.

Of these rocks it has, in fact, to be said, that while they might have been more transmuted, transmutation has in them gone a long way.

The dolomite, at all points where it is in force and well exposed, shows a crystalline bed;—where impurities have been present in the bed, these now appear as crystals of augite, as at Coire Chaorachain, &c.;—and where the altered bed has been thick, as near Ledbeg, it is a perfect marble; and there *malacolite*, *Wollastonite*, and *magnetite* appear in the mass of the rock; with *serpentine*, *pyrrhotite*, and *lime-felspar*, at the lines of contact.

As regards the quartzite,—along the whole south face of Ben Harran and the slopes of Coneveall, it is so markedly crystalline, that the sand-grains have become crude crystals of quartz; and all around the tarn which lies south-west of the summit of Na Tuadhain, there is every here and there a passage into masses which are collections of small doubly-terminated prisms of rock crystal. These are sometimes nearly a fourth of an inch in length. Here also, brecciated portions of the rock are cemented by hard, dense, massive *psilomelane*. But the evidence of the metamorphism of the quartzite is much clearer in the two beds of grit found near the summit of Coneveall, than at any other point known to the writer. A section of the apparently loose grit (mentioned as there occurring in two beds), shows the "sand-grains" not *agglutinated* to one another, but *interlocked by mutually interpenetrating, sharp-angled "processes,"* which vouch for a certain amount of softening and recrystallisation; and the line of contact of the "sand-grains" has at some parts disappeared, and at all has become faint.

The fluid cavities are arranged in two ways. A number of semi-angular particles of orthoclase (?) are sprinkled through the stone; lines of fluid cavities start from the rounded angles of these, and radiate therefrom through the "sand-grains." Other lines of fluid cavities stretch from side to side of the stone, passing through the sides of the sand-grains at all angles.

Numerous minute doubly-terminated crystals of transparent pale brown *zircon* occur. The size of these bears a certain ratio to the size of each grain of quartz. Though not absolutely central in position in each grain, they are never found at the sides. No large crystal occurs; no chip of a large crystal is seen, and the small crystals are never broken.

The inference is unmistakeable. The fluid cavities were not pre-

existent to the fracture of the grains of silica; they were formed at a date posterior to the agglutination of the grains. The zircons crystallised out of the silica *after* it had been fractured into grains; and at the time of their formation, the substance of the silica had been so yielding that the crystallising force was able to draw the molecules of zircon through it to the common centre of the crystallising effort. The arrangement of the fluid-cavities in lines, shows that this plasticity was posterior to the re-agglutination. The amount of metamorphism to which the quartz had been subjected, after it was reunited as a number of "sand-grains," would appear to have been even greater than it had ever been subjected to before the processes of fracturing had torn it from the parent crystal.

Thus is it seen that the view that the dolomite and the quartzite have not been metamorphosed is altogether untenable.

Overlying this highly instructive fragmental grit, there are beds of coarse and of fine grained conglomerate. In that which is coarse, the included nodules are rarely sub-angular,—generally much rounded and smoothed. Frequently they are themselves brecciated, the fragments being re-cemented.

They are all siliceous, and of more or less brilliant tints, in which purple prevails. They vary in size from that of marbles to that of turnips. Some are apparently vein quartz. The cement is green, of varying tint, and it is pearly in lustre; it is disposed in a general parallelism to the floor of the bed, being plicated where it folds over to envelope the nodules. This cementing material is so similar in all respects to that of a bed, shortly to be noticed, which underlies and passes into the Logan rock, that the writer could not undertake to discriminate between them. At those parts, moreover, where it contains felspar, it is hardly to be distinguished by the eye from Logan rock; and it cannot be distinguished by the microscope from certain varieties thereof. This rock, as a whole, has a dark green colour, spotted with purple and white.

The fine grained bands are more of the nature of a grit. There is in these little or no foliated cement. The granules are the size of seeds, and frequently show false bedding. Here and there they contain flakes of the green mineral along with blotches of felspar, with some hornblende; where this is seen it is difficult to discriminate between these bands and the Logan rock.

The representative of the fragmental bed appears, I believe, elsewhere; but I know no other locality in Sutherland where this conglomerate is seen; it is merely a local basin,—vouching for deposition on a very uneven bottom.

A band of very even-bedded quartzite of several hundred feet in thickness, overlaps the grit and conglomerate both to east and west,—rising to the summit of Coneveall, and stretching over the hill tops for several miles.

The questions having reference to unbroken sequence in this section are, first,—is there a fault between the dolomite and the next band of quartzite? and, secondly,—is there one between that quartzite and the Logan rock to the north of it? I do not hesitate a moment in saying that there is no fault at the first of these points. In so pronouncing, I endeavour not to be influenced by the evidence of the last section, because neither can the dolomite nor the quartzite be traced into connection with the masses there seen;—I judge merely from the appearances of the ground.

The dip of the two rocks is the same—about 20°; the cliff-faces of the two are parallel; the sward lies perfectly smooth between; and there are no appearances of faulting along the strike, in either direction. As to the second point,—as the distance is much greater, and the surface heather-clad and rough, there is no evidence either way,—there is certainly no evidence of a fault; but, seeing that, on the other hand, the Logan rock can be walked along continuously to where it overlies limestone in the last section, this is assuredly admissible evidence against the existence of a fault.

While, however, this section does not perhaps offer any more direct evidence against the existence of a fault (that is of the Logan rock being merely the Hebridean) than did the last, yet it negatives still more decisively the theory of an inversion. For,—even supposing that the non-appearance in inverted order of the beds of dolomite and also of the yellow beds be disregarded; and that the one band of argillaceous and cherty quartzite be allowed to represent the hundreds of feet of that rock which lie a gunshot distant to the south-west,—what mode of inversion of the fundamental gneiss could fold the quartzite over the dolomite, so as to be beneath a mass of that gneiss itself, and at the same time carry that quartzite upon its own upper surface in such a manner that the said quartzite formed an overlap to a local basin of conglomerate,—a basin of a nature which has never been found in, or connected with, the *lower* quartzite at any locality whatever?

The section near to the western opening of the Bealloch of Braebag—Tharsuin falls next to be noticed. Standing at the bottom of the pass, and looking north-eastward, the long rugged sweep of the craggy face of Coneveall stretches before us from west-north-west to east-south-east. We are looking at the strike-joints of the rocks. Immediately in front, there is a pinkish flinty quartzite, dipping into the hill face; this is overlaid by very thin argillaceous beds, and then by a scanty fringe of wasted dolomite; these are conformable. Surmounting these, we find a narrow terrace formed of comminuted fragments swept by torrents from the cliffs. Lying upon this terrace there are isolated blocks of quartzite, with adherent albitic—porphyry, Logan rock, a green schistose rock which is sometimes adherent to the Logan rock, and great masses of the conglomerate. This terrace of *débris* of course prevents all confident assertion that the rock next seen overlies the lime, seeing that the *débris* may conceal a fault.

The foot of the cliff is quartzite of ordinary appearance,—this is disposed in thick beds up to about half of the height of the slope. Here there is a junction, at an angle apparently of 35° or 40,° *along the strike*. Were this appearance considered *per se*, the question might be put, is this a diagonal fault with an overslide;—is it the line of an overlap;—or does it represent the marginal edges of a lenticular mass of rock?

Though it is a matter of no difficulty to scale the face of the hill at several points, it is difficult, from the looseness of the rocks and the frequent shooting of stones, to keep a course along the junction; and at the most critical point this cannot be done.

Looking from below, it will be seen that each bed of quartzite suddenly thins as it approaches the junction, and has an appearance of passing as a mere filament under the Logan rock. Looking at the Logan rock, at no spot visible from below can it be seen to touch the quartzite. A verdigris-green fissile bed, which is apparently thicker towards the bottom, intervenes. It is also evident that the Logan rock itself thickens eastwards in a bedded manner, if not in actual beds.

Examination at the junction shows that the foliated green bed is very different from any yet described; it is composed largely of a lustrous flat-bedded but slightly wrinkled material, which has more the appearance of a green mica than of chlorite. No attempt was made to analyse it, as it was manifestly very impure; containing imbedded sharp-angled granules of quartz and of felspar, so as sometimes to have an appearance approaching to a micaceous *grauwacke*.

This bed is one of great importance. When the rock *in situ* is broken into, it is seen that the verdigris tint is external. Internally it is indistinguishable both in colour and structure from the fissile bed seen beneath the Logan rock, both at Glen Logan and Glen Coul.

Now it has to be asked,—what are we to make of this bed, on the theory of an inversion of the Hebridean?

If the Logan rock is to be regarded as a member of an ascending series this is a clearly individualised member of such series. What is it if the Logan rock be but the Hebridean inverted? For such a bed occurs nowhere in the Hebridean where it is *admittedly* beneath the Torridon conglomerates.

At the junction, any draw or drag which can be spoken to is downwards; *i.e* south-eastwards. This negatives the idea of an overslide. The whole appearance is that of a falling shift to the south-east.

The chief interest in this section lies in the question whether the upper bed of quartzite (which as a line of cliffs forms a cornice to the hill), overlies the Logan rock of the east, and the quartzite of the west of the escarpment, *without break*. For if it be contended that the terrace of débris conceals an east and west fault, and that the west end of the hill is lower quartzite, then must the two quartzites —the lower and the upper—*come together* in the western slope of the hill, unless dolomite or Logan rock intervene.

The only direct evidence which the writer is able to submit, bearing on this is, that at no point which he could reach or see was there any appearance of yellow beds or of dolomite; that the green schistose rock and the "Logan" seemed to disappear by thinning off at about a central point in the cliff face; that the upper grit extended somewhat further west than that point, but also thinned off; and that he could nowhere see the conglomerate in the west end of the cliffs.

As bearing, perhaps, upon this question, it falls to be noted, that upon the western slope of Coneveall, and not far to the west of the point where the Logan rock with the fissile green bed and the conglomerate would, if continued westward, crop out (if not overlapped by the upper quartzite), there are found two beds of a much-rotted foliated rock of a green colour, with a medial bed of a pale felspathic grit; and below this there is a similar bed so weathered as to show only a foliated green mineral, impacted in minute crystals in a soft kaolinic material.

The grit is similar to that under the conglomerate, while the altitude is about the same. The rotten rock is in structure similar to the "Logan," where seen near the Whitten Head intercolated with quartzite. Possibly these beds may represent the fringes of the fissile bed of the "Logan," and of the conglomerate; while some may consider that greater probability attaches to the view that they represent what Nicol terms "wayboards," or belts of decomposed igneous rock. These "wayboards" will be considered in the sequel. I have found the same slimy fissile rock in a similar state of decay, and weathering into a plastic clay, at spots on the ridge leading to Ben More proper; and also some distance over its north-eastern slope. I have never seen it in the lower quartzite.

My reading of this section is, that though there probably is fracturing in the Bealloch of Coneveall from the swinging of the whole system of rocks round the basin of Loch Maoloch Corry, there is no faulted upheaval north of the dolomite; that the great cliffs of the west of the hill are upper quartzite, and that we are here at the marginal fringe of a great incoming lenticular mass of Logan rock. To this conclusion I am guided by the incoming on the opposite slope of Ben Harran (apparently continuous with those of Coneveall) of many beds of the albitic porphyry, which is known only in the upper quartzite. I regard this, however, as a most perplexing locality; it is one, moreover, upon which the theories of fault and of inversion can only be brought to bear, at the cost of "making confusion worse confounded."

We now pass to three sections which are seen in the Glen-Coul district.

The more southerly of these starts from the road to Unapol, at the foot of Cnoc Coir a Bhaic. Quartzite here lies nearly conformably upon what will afterwards be shown to be the *lower beds* of the Cambrian conglomerate. This quartzite, dipping gently to east-south-east, forms the whole height of the Cnoc, and extends a short space eastward of the shore of the tarn of the same name. Quartzite-shivers and heather prevent our determining whether any dolomite here occurs, the first incoming rock being the "Logan," which ascends into the rough-surfaced Cnoc na Craige. From this it sweeps eastward across Coire Ghuirm till it is seen to be either overlain or to abut upon sheets of quartzite which sweep down from the north side of Ben Uidh. The junction at this spot I have not visited; the appearance from the summit of the Cnoc, and all along to the summit of Glasven, is that of an overlie.

Northward, the Logan rock sweeps by the Leitir-Dhubh, across the trench of Loch Beag, in under the quartzite foot of the upper gneiss in the Stack of Glen Coul. Southward, it forms the whole ground from the east shores of Loch na Gainmhich, to within a few hundred feet of the summit of Glasven. Logan rock is again met with about two hundred feet below the summit on its south side, whence it extends southward to the burn of Chalda.

As the connections of the Logan rock with the quartzite are for the most part

obscure along this line, the chief interest relates to bands of a dark muddy-green dense aphanitic rock which repeatedly intersect it.

Two bands of this are seen in it, but a short distance from its junction with the quartzite at Loch Coir a Bhaic; these bands cross it with very much the appearance of dykes, but exactly in the line of the outcrop of the rock; and there appears to be a rude bedding of the Logan rock conformable to these bands.

In the north spur of Glasven, which lies between Lochan a Choire Dheirg and Lochan a Choire Ghuirin, other three veins or beds of the same rock appear,—the first of great thickness. The junction of the Logan rock with the quartzite which succeeds, is concealed by splinters of a vitrified-looking red quartzite. What is seen leaves some impression of a fault. A double syncline and anticline of quartzite succeed; the descending fold of the latter being, on the south side of the hill, regularly overlain by Logan rock, with an apparently-conformable bedding, in which bedding two other bands of the dark rock are seen, as regularly disposed bands. In descending the south spur of the hill, there is an upthrow fault which brings the quartzite into view. A small cliff of this, thirty to fifty feet in height, can be walked along for many hundred yards, the Logan rock *forming a thin overlying cake for the whole distance.* This cake extends to the burn of Chalda, in the bed of which it either abuts against, or is faulted on to the quartzite hemidome of Cnoc-an-drien. Two dykes of indubitable igneous rock are seen a little way above the Chalda burn. They consist of dark augite with magnetite and labradorite (?),* the latter being sometimes in groups of radiating crystals. The north-east fringe of this overlying cake of "Logan" is seen but a little way over that slope of the hill, where it is seen that the cake has but little thickness.

While it is almost inconceivable that so thin a band as that here seen, dipping at so low an angle—about 28°,—can represent the Hebridean gneiss, still the interest here lies in the so-called aphanitic rock, as nothing macroscopically resembling it has been seen in the lower gneiss. In addition to the characters already noted, the lens discloses nothing except that it is riddled to a great extent by excessively thin veins of epidosite (?); it shows an obscure foliation, which I also observed to accord with its bedding surface.

The microscope, however, reveals that its structure is of a highly characteristic nature, being delicately schistose, and with its foliations corrugated in a beautifully rippled manner. It consists of myriad layers of minute crystals of hornblende of a very uniform size, and a form like grains of rice; these are impacted, apparently with the axes of the crystals all pointing in one direction, in clear viscous-looking quartz. They lie in single file forming each layer of the rock, and thrown into undulations generally where they are interrupted by the venation of epidosite. The quartz is devoid of fluid-cavities, and also of inclusions.

The occurrence of repeated bands of such a rock in so large an amount, here and elsewhere in the "Logan," apparently conformable to the underlying rock, taken in connection with its non-appearance in the Hebridean rock, cannot but be received as evidence against the identity of these rocks.

Section at Liath Bhad.—This section may be taken from a little bay on the south shore of Loch Glen Coul, where the Hebridean gneiss is seen in well-marked beds dipping gently to the west-north-west. Here the quartzite, dipping about 10° in the opposite direction, immediately overlies it,—as the Torridon does not descend the hill slope many feet from the foot of Cnoc Coir-a-Bhaic. Ascending the opposing slope of Liath Bhad, we find that the quartzite is here feebly developed, as we soon come upon the argillaceous beds. These are here in force, forming an encircling line of cliffs of 60 to 80 feet in height, the beds of which dip at about 20°. Surmounting these, and ascending to the foot of a beetling cornice of rock, we arrive at one of the best disclosed sections in the district. This is laid bare by a fall of rock, so that what is seen is unmistakeably seen. The dolomite is struck at its western fringe.

A well-defined bed of calcareous chert, containing nodular masses of crystalline dolomite and passing into a bed of dolomite itself, passes immediately under a bed of a very fissile chloritic rock of about six feet in thickness. The dip is 26° to 28°. Here and there a few inches of a cherty rock, undistinguishable from that described

* The same igneous rock cuts "Logan" on the north side of Conveall.

at the Dhu Loch More section, intervene. The chloritic rock here seen is identical in appearance with that seen in a similar position in Glen Logan, and it differs from that spoken of in describing the last section only in an appearance of greater looseness of structure, apparently due to incipient decomposition. Over the schist there is a beetling mass of rock which has an unctuous feeling. This cuts with a knife, somewhat resembles agalmatolite, and is identical with that seen at the bridge over the Loin river.

To this last, ordinary "Logan" succeeds; but, as the cliff face cannot here be scaled, I cannot say if the "aphanitic" rock occurs in this part of Cnoc-na-Creige.

Where the cliffs of the Liath Bhad descend into the water, opposite Eilean-an-Tuim, the section, which is beautifully disclosed, reads,—white worm-hole quartzite; red ditto, thick; fucoid bed; yellow beds, thick; blue belt; gritty bed; yellow bed; dolomite; cherty bed, thin; green schistose bed; massive "Logan;" red "Logan," like Cnoc-na-Strome rock.

Stack of Glen Coul Section.—On account of the presence of the Loch, the west end of this section must be taken along its north shore,—the Aird-da-Loch.

Of this the west end, for about a mile and to a height of about 550 feet, consists of Hebridean gneiss. There is no Torridon rock—a cliff of pinkish flinty quartzite immediately overlying the first rock. A second much wasted white band of the same rock succeeds; and upon this, at an elevation of about 680 feet, there is a small outlier of the Logan rock, standing a considerable distance from the main eastern mass of that rock.

There are here neither yellow beds nor dolomite. The quartzite dips at such an angle as to come down to the water edge, about one and a quarter mile further up the loch; and above this spot the yellow beds first come in, and then the dolomite a quarter mile still further east. There is thus a distinct overlap. A stone thrown by a powerful arm from the outlier, might alight upon the Hebridean rock on the shore of the lake. Faulting, with an overslide of a mile and a quarter at so low an angle, is hardly credible; and as there is no re-duplication of either quartzite, yellow beds, or dolomite, inversion is untenable in even a greater degree.

That there may be some crushing along the strike, is however very probable, as the yellow beds are seen to be tilted to an angle of about 82° in the islets at the narrows. The junction of the Logan rock with the dolomite at this point has been altogether obscured by cultivation. The former rock rises in the buttress-like foot of the Stack to a height of about 430 feet, when overlying quartzite is reached. This is, however, only a small outlier for the ground falls to the east, and the connecting ridge is again "Logan." The beds of the quartzite outlier have a gentle dip to the east-south-east, and are perched on the very centre of the Logan ridge. Looking eastward to the continuation of the ridge, however, there is seen to be a certain amount of unconformity between the "Logan" and the overlying quartzite *along the strike.*

The core of the ridge, and its northern slopes are "Logan;" and it is overlain at its summit by many beds of quartzite, which are nearly horizontal along the strike; but a great part of the south side of the ridge is composed of beds of quartzite which are inferior to those which pass over the summit of the ridge, and which thus abut (at an angle of about 50°) against the sloping side of the Logan ridge.

The impression conveyed is that there had been great denudation of the "Logan" before the deposition of the quartzite. There is no fault,—as the upper beds of the quartzite pass unbroken over inferior quartzite, and "Logan rock alike." There is a lenticular thickening of the quartzite along the strike.

The junction here is a most instructive one, as there is a well-marked passage bed, of about four feet in thickness, between the "Logan" and the quartzite. This bed, much the same colour as that of the "Logan" itself, is formed of its substance in a more or less finely comminuted state, mixed with quartz grains, and distinctly laminated conformably to the overlying beds of quartzite.

This quartzite itself is altogether different from the quartzite seen below the yellow beds at the hill foot. It is finer in grain, with more cement, entirely free from worm-holes, and at distances in its thickness which vary from four inches to a foot, it displays bands which have suffered atmospheric disintegration. These bands are little over an inch in thickness, and they are frequently, through rotting, de-

pressed to an equal distance below the general surface of the rock. They show a laminated structure which is partly due to enduring mica. When the rock is broken, however, they are visible only near its surface, and that through a comparative looseness of structure and the presence of an ochrey powder. Mr. Hudleston was of opinion that these constitute the "way boards" of Nicol. I have never seen this appearance in *admitted* lower quartzite. It is just when the brow of the ridge is surmounted, and the true foot of the Stack is reached, that the junction of this quartzite with the upper gneiss is seen.

Writing of this spot, Mr. Hudleston remarks—"There really seems to be a sort of lithological passage between the regular quartzite and the fine quartzose flags which gradually conduct to the more micaceous beds."

It was shown below that the quartzite had changed in appearance so as to be far from "regular quartzite;" but as if to give force to this linking transition, the quartzite again becomes "regular quartzite," just after the cliff is surmounted; for its beds are here white, distinctly granular, and full of worm-holes.

The mode of the transition into the quartzose flags varies at different points. A little south of the nose of the Stack I found a worm-hole bed overlain by a very fissile somewhat green bed, then a second worm-hole bed, and then fissile horny flags, splendent from innumerable layers of greenish mica.

Directly south of the Stack there are worm-hole beds overlain by open-grained fissile beds, of which mica is at one and the same time the agglutinant and the laminating material. These beds contain worm-holes, which are generally somewhat flattened in the direction of the lamination of the mica. Take away the worm-holes, these would be called upper flags. With the worm-holes, what are they? It will be interesting to study the chemical side of the theory which is to show how either faulting or inversion can make mica!

The micaceous beds to which the flags "conduct" are seen, unmistakeable in character, on the summit and neck of the Stack. The mica is so green and the structure so plicated that it might be set down as chlorite slate, were it not for the splendent lustre, and the durability of the loosened scales. These sparkle in every pool, or rustle as they are swept by every puff of wind.

The localities and sections above cited are probably sufficient to enable an opinion to be formed as to the nature and age of the Logan rock; but here I must say with Mr. Hudleston, "it may well happen that in the long range from Whitten Head to the Sound of Sleat, more than one class of rock has been enumerated under this head." I do not for a moment regard it as even unlikely that the Old Gneiss has been thrust up at some points; and I would much like to re-examine a great wedge which is seen north of Ben Uidh,—evidently faulted. Speaking of the rock or rocks at the described localities, those seemingly overlying the dolomite more or less immediately, and those seemingly interbedded in quartzite,—and, admitting many difficulties and occasional obscurity,—I may be allowed to say that, *while the sections seen in Ross-shire are simpler and clearer, the foregoing facts alone seem to me to indicate that the Logan rock is a grit which presents varying degrees of metamorphism up to a perfected gneissic structure;—a grit formed out of the Hebridean gneiss, occurring in great quantity where the removal of the cover of Torridon rock exposed the Hebridean to extensive denudation, and hardly seen at all in those districts where that cover had shielded and still shields it.*

Those who hold it to be the Hebridean gneiss may be directed to An Criochan,—three miles south of the Whitten Head,—where two beds of "Logan" three feet in thickness, will be seen in the middle of a quartzite cliff.

The Gold of the Drift.

At the time that the "diggings" were being carried on, and that the country was being searched in all directions by hundreds of "vagrom men," Dr. Joass was taking notes of all, and he also engaged in personal exploitation. What follows is for the most part a condensation from his elaborate observations, as communicated to the writer.

The extent of country over which gold has been ascertained to occur is about 20 miles from north to south and 30 in width. The rocks are gneissose schists and igneous rocks, whose courses conform to the strike of the sedimentary rocks.

The igneous rocks are (*a*) a large-grained porphyritic granite, which stretches along the south-east of the district, and (*b*) a red small-grained granite, which conforms to the strike of the gneissose rocks, and which sends out across the strata, as if into transverse fissures, short dykes from which small veins insert themselves between the more micaceous beds. In the most richly auriferous localities granitoid rocks (*c*), chiefly felspathic, are so intimately connected by interlamination with the flaggy quartzose strata that they almost appear to be the result of metamorphosed action upon true sedimentary rocks. They may, however, be contemporaneous effusions of plutonic rock.

"I venture to think that the coarse-grained porphyritic granite of the Ord and the south-east of the district should be regarded as truly plutonic and associated with upheaval. Throughout the auriferous district the red granite appears to be an intrusive rock, conforming in its course to the strike of previously elevated strata.

"The binary compound of quartz and felspar termed granitoid suggests a metamorphosed gneissic rock whose particles, yielding to such agents as heat and electricity, were melted and mineralised *in situ*. It does not appear inconsistent with this opinion that the rock in question, which is as thinly bedded as the flaggy sedimentary strata with which it alternates, should occur as a short transverse dyke, as it seems to do at Suisgill.

"If we suppose that fissures caused by local upheaval were contemporaneous with metamorphic action, these fissures would be filled by a molten rock, whether its materials were supplied on the spot or intruded from beneath." (Always supposing that there be no surface orifice of escape.)

There is also a wall of whitish hard and brittle quartz rock, which forms the Scarabin Hills. This suggested to Sir R. Murchison the idea that it was "the result of intense metamorphosis of lower Silurian rocks."

Gold Localities.

Strath Brora.—The Blackwater, in small scales from the drift lying over micaceous schist with interbedded granite (*b*), but none in burns which enter it after a course over Old Red Sandstone.

The Crask.—A small quantity at the head of the Clyne-Milton burn, over flaggy quartzite. None in Kintradwell Burn—flaggy gneiss; nor in Allt Choille—Oolitic sandstone.

Glen Loth.—The Loth-beg water, over porphyritic granite (*a*) none. Culgower burn, granite; none. Kildonan burn, over Old Red rocks, none. Craggie burn, gneissose rocks; auriferous.

Strath Ullie.—Helmsdale river, flaggy micaceous and gneissose beds traversed by granite (*b*), very rich washing, in river side pockets above Crask bridge. Kildonan burn, quartzose and gneissose, with quartz veins encased in chloritic clay, felspathic rock (*c*) present in small amount, drift of local origin, generally a ferruginous gravel. Above this is yellow clay, overlain with coarse sand, containing flexed dark earthy lines in section; the whole is covered with thin peat moss.

Gold found in greatest quantity in the lowest portion of the alluvium, but occasionally from the wash dirt immediately under the turf.

Suisgill.—Flaggy gneissose rocks with an abundance of felspathic rock (*c*) interbedded with the strata. The more friable felspathic varieties of this rock are readily disintegrated, forming sometimes a white plastic clay, sometimes a gritty sand. Towards the head of the stream this and other large-grained friable granitiform rocks become abundant, forming great slopes of granular grit. Much gold in pellicles of larger size than elsewhere.

Allt an t'Fhionnaraidh, same rock, a half-inch water-rolled pellet contained gold mixed with felspar and quartz. This suggested the binary granitiform layers and grits of the upper Suisgill. Knoc Fhinn River, branch of River Fri, gneissic flags, with much large-grained intercalated granite: a little gold. Allt Ceann á Phris, red granitiform rocks with flaggy beds; a small nugget, 5 dwts., and a good deal of granular gold. Alltduible, Allt-bhreach, and Allt-torrish, gneissic rocks, but approaching the granite (*a*); not richly auriferous. Kil-Pheadar and Cairn burns over granite (*a*); no gold.

Sgerreabeim Range, quartzite; no gold.

Elsewhere I have received notes as follows:—

In two burns between Ben Smersal and Gordonbush; in Auldtown burn. In the Helmsdale water below the bridge at the village, and on the river bank behind Mackay's Inn, shotty gold with iron sand. At Kilcormkill, six miles from Brora, in a tributary of the Brora river.

Such are the localities in which gold has been found, loose lying.

Whence came it?

Sir R. Murchison says, "transported from the great central plateaux of Sutherland." Mr. John Campbell, of Islay, is more precise, as he fixes upon Klibrick, or thereabout.

Dr. Joass says, "Nearly every stream within the area here described

has been well searched by practical diggers, *and the fact that many of them, as already mentioned, have been searched in vain, suggests no wide-spread deposit, the result of extensive glaciation, but several independent centres connected with the local rocks.*"

This last conclusion must be held to be the correct one. Any agent of transport which conveyed particles of a material specifically so much heavier than the ordinary drift as is gold, must have left the greatest amount of these in the nearer cross-courses, and could not have carried them to the more distant, to deposit them in these also in an anomalously selective manner.

Gold has not, moreover, been found in the westerly cross-course pockets and ravine traps; and it could not fail to be difficult to explain how it was swept over these to be lodged most abundantly in the beds of streams, the channels of which, though each of the nature of a *cul de sac*, yet lay open to the easterly sweep of the drift.

But the records of Dr. Joass's chronicle give information more definite than this. Not in the streams which drain from the quartzite, or sweep over the granite, or cut trenches in the Old Red grits, but *only in those of the gneissose rocks.*

Dr. Joass writes, "Several specimens of water-rolled stone, rich in gold, have been found in Suisgill and Kildonan burns; in every instance the components of these stones are felspar and quartz, with one exception, in which there is quartz only. Arguing from the comparative poverty of the drift, where this rock or its detritus is scarce, and connecting its prevalence in Suisgill and Kildonan with the rich alluvium there, we may venture to infer that the granitiform rock is the matrix of the gold."

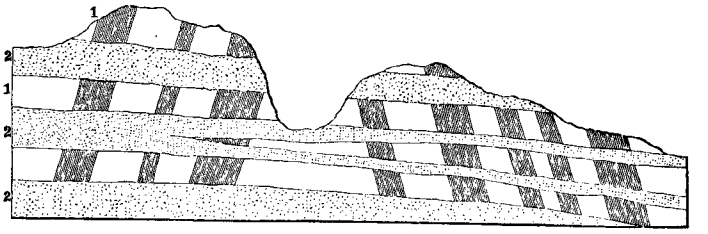
In this, however, the writer is hardly disposed to go altogether along with Dr. Joass. In speaking of the so-called syenite of Loyal and of Lairg, he had occasion to speak of the very small amount of hornblende which was present in these rocks. He had the advantage of being taken over part of the auriferous district by Dr. Joass, and, from what he saw of the "granitiform rock," he was not disposed to regard it as metamorphic, but intrusive. Still it did seem to him, at Suisgill especially, a rock very similar to that of Lairg, only deficient—that is still more deficient—in the hornblende. Coarser grained, and more of a granular and less crystalline structure, but with the same facies.

Though in many parts of Aberdeenshire he has seen what he believed to be a metamorphic granite, which had been formed by a change which had affected all the zoned bands of a convoluted or unconvoluted gneiss alike, still the change had in all cases affected *the whole mass of these alike*,

up to the line or zone where the unaltered gneiss appeared. Here, however, as Dr. Joass has shown, nearly parallel and even bifurcating bands of this rock cut horizontally across the "deposit layers" of a laminated gneiss, which has an anticlinal dip. The appearance being like the stroke which would convert an inverted V into an A, or rather a series of As of different sizes packed within each other, the intermediate spaces of the laminated rock being left quite unaltered.

As this is a most singular rock, a copy of Dr. Joass's illustration is given.

Granitiform rock in decomposed Gneiss, Suisgill.



1. Decomposed gneissose rocks dipping S.S.W. and E.S.E.
2. Granitoid rock (*c*).

All writers who have speculated upon metamorphism have called in the aid of heat; some bring it from below, some from above. The writer goes a step further, and, with Daubrée, believes that an augmentation—which may be the turning point of the changes—may come *from within*. However, so we do get it, we are glad to get it *anywhere*. But under none of these suppositions can it be understood how there should result a *zoned action*—a band of concentrated energy, with a superimposed inert layer; alternately superimposed, moreover, above each other in repeated sequence.

Certainly, if it were an *untilted* rock with alternate highly felspathic, quartzose, and micaceous layers, such a result—that is, such a banded structure—must follow upon metamorphism. The felspar would yield the zones at once. Nay more, the rock as a whole might settle down into a granitic paste. But what is called for here is very different.

It certainly is a striking fact that there is no trace of dislocation in any part of the traversed layers of the schistose rock. This is almost demanded upon the supposition of intrusion from any direction, of a rock whose layers lie at such varying angles; while, on the other hand, it is as imperatively demanded (upon a supposition of metamorphic change) that the layers adjacent to the metamorphosed bands should have been loosened in

structure—opened out, deflected in some part, where they were softening into the granular magma.

Most interesting as it is in relation to metamorphism, the bearing of this rock on the present question is whether or not an igneous rock, or a rock which has undergone metamorphic change, can be the probable matrix of gold, while the non-metamorphosed rock either does not contain it or at least yields it in a less easily *apprehended* state. For it is quite possible that during the metamorphic process like might draw like together, so as to cohere in more palpable lumps. But with such knowledge as we have of the rock-matrices of gold elsewhere, we must hesitate to credit granite with being its matrix.

While, however, it was most convenient for Dr. Joass to assign his quartz-felspar nodules to the granular grit of his granitiform rock, I have to say that in all the specimens I examined, both the quartz and felspar of these nodules appeared to me to have more the appearance of being those of an exfiltration vein. While disposed, however, to believe that the occurrence of such veins in the rock is sufficient to account for such specimens, I am inclined, from what I saw of one quartz vein, though of only that single one in Kildonan, to believe that the larger quantity of the "scale gold" came from such purely quartzose veins.

The evidence yielded at the time by the vein referred to was not very direct. The writer broke off a large and, as he thought, a clean mass from the vein, carried it some eighteen feet above the stream, and broke it carefully up, using a cleaned rock as an anvil. In his search among the gradually removed fragments he found no speck, but he had hardly left the spot when he was recalled by Dr. Joass, who pointed to a speck of gold lying among the powdered quartz. This speck the writer does not think could have come out of the quartz, *unless it was from an open cavity*. It had none of the hackley structure of attached and imbedded gold, nor had it its superficially dull colour. It was smooth and brilliant, *rubbed* in fact, and so must have been merely either lodged in a chink or attached to some mud upon the rough sides of the quartz.

Notwithstanding this failure as regards the only "likely vein" which the writer saw, he considered it to be so likely a one that he has little doubt of its being more or less auriferous. He also does not hesitate in joining issue with Dr. Joass in regarding the Sutherland gold as being of *home growth*, and *not far carried*.

The quantity of hepatic pyrites found in the washings seems to have been very small, as also of "*keely*" or "*keels*."

Black magnetic iron sand also was in so small quantity that no sample

could be had for analysis, though it was of considerable moment to determine whether it was magnetite, or iserine, or crushed ilmenite.

Black *rutiles*, of about the size of peas, were occasionally found. The figure of a complex twin which I saw in Mr. Heathfield's hands is given. Minute dodecahedral *garnets*, scales of *mica*, and *specular iron* are also found.

The larger pieces of gold which I have seen quite bear out the view that they have not been carried far; they are mostly in the form of thin scales with remarkably rough sides. The colour is pale, with a slight tinge of green.

The following are analyses. That made by myself was executed upon scales, of the size of the nail of the little finger, purchased from Mr. Wilson, of Inverness.

	S. G.	Gold.	Silver.	Iron.	Silica.
1. Suisgill	15·799	81·11	18·45	—	0·14= 99·7
2. Do.	—	81·27	18·47	—	0·26=100·0
3. Kildonan	15·612	80·34	19·86	0·12	tr=100·32
4. "Sutherland"		79·22	20·78	—	=100·0

1. David Forbes, *Phil. Mag.*, Vol. XXXVII. 2. Ditto. 3. Heddle. 4. Makins.

The figure is that of the largest nugget found: it was from Suisgill. This is now in the possession of His Grace the Duke of Sutherland: it weighs 2 oz. 17 grains.

Since the above was written I have been instructed by His Grace the Duke of Sutherland to analyse a quartz vein which occurs in the Suisgill Burn. This vein was examined in consequence of statements having been made by interested parties that the rocks of the district contain large amounts of both silver and gold. The crushed quartz was examined by the most perfect amalgamation processes, and yielded a button in the proportion of 39·2 grains per ton. This button, upon analysis, was found to contain—

Gold	... 28·57
Silver	... 71·43

being in the proportions of a very poor *electrum*.

This quartz vein yielded small quantities of *ilmenite* and *magnetite*, and it also yielded so considerable a quantity of magnetic iron, which precipitated copper, and was bruised by the friction of a pestle, that I communicated with Messrs. Johnson and Matthey (who had crushed the quartz) as to the possibility of its having been abraded from the stamps. The following reply was received:—

"Nov. 16, 1880.

"DEAR SIR,—In answer to your letter of yesterday, we beg to say that the sample of mineral sent to you was crushed on a cast iron roller mill. We do not, however, think that any particles of iron became mixed with the ore during the process of crushing.

"Yours faithfully,

"JOHNSON, MATTHEY & Co."

I accordingly examined the iron, so far as the quantitative determination of silica and carbon. Of the former there was 12·1 p. c.; of the latter ·79. This being a proportion of carbon very much smaller than any cast iron contains, it at least becomes a question if some *native iron* be not present in the rock, sheathed, like that of Unst, in magnetite.

Old Red Sandstone.

The first westerly appearance of this formation is where it reposes upon rounded bosses of gneiss in the neighbourhood of Tongue.

Here it forms a north and south line of disconnected outliers of a conglomerate, very different in appearance from the conglomerates of the west.

Hugh Miller cannot have noted these differences, as, in his whimsical comparison of Sutherland to a gneissic picture set in a sandstone frame, he made use of some part of these northern outliers to form the top rail of his frame.

Nicol also seems to have correlated them with the western conglomerates, for he says that if they belonged to the Old Red formation, we should find some fragments of limestone. These, in fact, do occur in such abundance in a small outlier—which exists at sea level south of the Harbour of Scullamie—that calcareous sinter incrusts the face of the rock.

The character of the conglomerate of the Tongue outliers is altogether different from that of the Torridon rock.

It is formed of masses which are of much larger average dimensions, while they are much more brecciated and less generally rounded. Upon closer inspection it will be observed that the component masses themselves, in general, belong to much less crystalline rocks, while the rock itself looks of far less age, probably from a greater looseness of structure, which appears to be due to a deficiency of cement.

In the hills round Tongue the bedding of the rock is not well marked, and there are but few beds of a fine grain. Further north, however, as in the cliffs of Craig Vercan and Roan Island, the bedding is well marked

and even in the latter free; while in the hollow which lies immediately east of Ben Breck a purplish red sandstone hardly distinguishable from the rock on the summit of Teallich is found.

The lower beds of the outliers called the Griams are formed of a rough, angular, and occasionally granitic conglomerate, which passes into upper beds with more highly attrited components.

It is upon the authority of Mr. Crawford, of Tongue House, that I have placed conglomerate upon the summit of the Craig Mohr of Ben Armine. It certainly hangs on to the north skirts of Stomino, and caps some of its elevations; and Mr. Crawford holds that the Ben Armine outlier connects this with the masses in the neighbourhood of Loch Brora.

I have neither seen nor heard of any mineral body in this conglomerate beyond the occurrence of patches of reddle in the sandstone east of Tongue; an occurrence which is one point of distinction between this and the western conglomerates; no fissile schist which could weather into reddle occurring in the Hebridean rock. Other parts of this Tongue rock more resemble the purple flags near Braemore.

Reference has before been made* to the three varieties of conglomerate at Portskerry, Red Point, and Isauld Burn mouth, and the opinion of Sedgwick and Murchison that these could not be correlated with one another has been considered.

There are certainly marked differences between these three varieties of the rock: the first containing sharp-angled and pale tinted greenish fragments, imbedded in much granular, felspathic, and sandy paste; the second has little paste,—this is granitic in character, while the imbedded masses are rough surfaced, nodular, and highly felspathic; while the last consists of much rounded and smoothed balls of syenite which are impacted loosely in a firm cement of the same description.

There can be no question, however, that these are mere local shore lines, and that the varying features are due to the varying characters of the parent rock from which the fragments were torn.

Admirable lessons are—especially at the two last localities—taught as to the formation of conglomerates. Precisely as in wandering round the shores of a sandy bay, we at the present time find a rolled and rounded shingle overlying a bed of sand at one spot, and mantled by it gradually at another, while on the opposite shore splintered and angular slabs which have slipped from some overhanging cliff are covered up here or washed bare there of the gravel swept seawards by a stream, so do we

* See pp. 241, 242.

read in these rocks the arrest of these processes of chance arrangement, and have evidence of the fluctuating circumstances which are ever associated with the zone where wind and water meet.

There is probably no locality in the country where this is better illustrated than at the Red Point. Here an old shore line drawn in zones of granitic shingle and enveloping silt, and elevated some 50 feet above the present water level, has been so air wasted and wave-washed that the rougher masses of the shingle protrude through the blue flags precisely as do boulders and coarse shingle above the sand or slime of a recent beach.

Speculations as to the cause of the fracturing seen here, and which has been adverted to both by Sedgwick and Murchison and by Geikie, can hardly be entered upon without leading to a consideration of the circumstances under which the formation as a whole was laid down. For it is certainly a circumstance worthy of note that while mile-long stretches of the shore exposure of the formation show vast sheets of rock continuous without break or even flexure, those points where a local base presents itself, or where we are approaching to the true base of the formation as a whole, should evidence dislocation, smashing, and repeated elevation or downthrow.

It is not to be wondered at that in such circumstances local effects should be referred to local causes, and that where a granitic rock was present it should unhesitatingly be regarded as the source of the disturbance. Those, moreover, who adopt such a contention must at least be allowed to claim that, before their views are discarded, some indication of a more feasible cause should be at least indicated.

If we can as yet do little more than this, we can at least show how, under more consistently developed views of the circumstances under which formations circumscribed in extent were formed, there is good hope for the belief that the explanation desired is almost, if not altogether, within our reach.

For the old view, that the successive deposition of sedimentary strata on a limited space of the earth's surface was *an effect* of continuous depression of the sustaining surface, is giving place to that which regards it as *the cause;* while the belief that a *general depression* of the district had taken place at the time, and was all that had to be considered, must to an equal extent give place to the view that the depression and formation of the trough by the accumulating weight of the sediments could only go on *pari passu* with an equivalent elevation of those tracts of country

which (lightened of their superficial beds, which as *debris* had been transported), were being thrust aloft to restore the equilibrium.

Old and new theory alike require at least a plastic substratum upon which the crust which is being flexured is to rest; but while the older view provided no receptacle or retiring ground for the displaced material of that substratum, this may be said to be not only amply provided for in the billow-like upheaval, but to be the immediate agent of the upthrust.

It is all too soon for us to attempt to estimate our indebtedness to those who first perceived that which now appears so evident,* or to those† who, following out the sequence of necessary results, showed how the counterpoising elevation, thrust aloft until its mantle of congealed vapour, by shielding the rocks from the more rapid agents of degradation, first stopped the supplies which were forming belt after belt below, thus bringing the first stage of the process to a close,—and then, itself overburdened by the ever-increasing weight of snow and ice, was borne down to elevate that which had been depressed, but which was in turn destined again to rise, when its subsidence to a more temperate altitude dismantled it of the coat of congelation which was normal only to the greater elevation.

So does Dr. Rickets argue out the cause of the glacial period; but geologists have evidence enough to show that old formations had their glacial periods before recent rocks were laid down. If the sequence in the reasoning is sound at all, the sequence of events must have taken place not once, but often. Nature must have repeated herself in this as in other things.

But there is a circumstance connected, perhaps specially, with this formation, though not with this formation alone, which has not, so far as the writer is aware, been alluded to in connection with this hypothesis of equivalence in depression and elevation; and this circumstance appears to the writer to have not only a very direct bearing upon the contention of Dr. Rickets, but to fortify its probability. I allude to the fact of a great fault running along the edge of the formation at or near its shore line. Such a fault is seen close to the junction of the formation on the east side of Shetland; and a similar fault crosses Scotland from Stonehaven to its western shores. More imperfectly and less continuously are faults seen along or close to junction lines, from Whitten Head to Loch Kishorn.

Had there been merely general depression of the crust in a district where a cinctured lake-formation was being laid down, followed by general

* Dr. Charles Rickets, Mr. Starkie Gardner, and the Rev. Osmond Fisher.

† Mr. T. F. Jameson and Dr. Rickets.

restoration of level, it is very difficult to see how the rent should occur, not where there was the greatest accumulation of weight and the greatest bending, but where the fringe was thin and the pressure altogether trifling. But, if on one side of a line of junction there be bending downwards, while on the opposite side there be flexure upwards, *there* must be the greatest amount of strain, and *there* or thereabouts there must be a certain amount of thrust and a great amount of twist, at the time when, after the slowly effected alteration of circumstances, the weight of the upward-borne land inverts the flexure. Should the rent pass downward so as to reach the yielding substratum, and should it be fluid, some portion will pass upward to plug the opening;—as is the case along the great fault south of the Grampians. Should the rent, on the other hand, be within the fringe of that which is the land, the displaced wave of plastic or fluent matter may be poured out in a line of volcanic throats,—as along the seaboard of the Americas, and other seaboards. Here, as a consequence of the plastic wave having found exit, there can be no elevation of land behind. Or, if the rent takes place within the margin of the basin itself, during the period of its subsidence, we may have a similar line of *subaqueous* throats throwing out flows which are to become interbedded sheets; as along the east shore of the liassic formation of the Western Islands. Here again, and for a similar cause, there may be no elevation of the adjacent land.

To altogether different causes are we to assign the rents and hitches, simulating the effects of local protrusion of igneous matter which are to be seen at such localities as the Red Point. The disturbance at these frequently appears to be due to more causes than one. Murchison says that the strata cannot be traced into junction with the granite on the east, though he goes on to say that the strata there seems not much disturbed. But this is not so. The strata can be traced right up to and touching the granite, and they are not disturbed to the smallest extent. Bed after bed of the flags rise, layer after layer, up the vertical face of what seems to have been a sea precipice of the older rock. For a short distance within the margin of the flags there is a slight downward drag, and that is all the "confusion;" the great slabs of the formation lie like a wide pavement altogether unaffected below. But round at the Point itself the two formations are brought here and there, as Geikie says, "together along a vertical junction line, by a few small faults." Sometimes washed out "geos" show portions of the older rock hanging over the beds of the newer, which occasionally appear to prop an isolated pillar.

This had been a promontory of the shore of the old lake. Had its waves, which cut the promontory into a straight faced cliff, cut also deep

"geos" and left isolated stacks to be buried in the accumulating shingle, even as they are doing all round the coast at the present day?

Some portion of the appearances in no respect differ from these. Still there are others. While Sedgwick's imbedded block is not now to be found, still there are appearances of after-motion and bending of the flags, seen at or near these local bases, and there alone. These promontories with their outstanding stacks, around and between which the conglomerates have mantled, are the rivets by which the one formation keeps a firm hold of the other.

This is admirably seen at Port Skerra, where aiguilles and spikes of the old rock penetrate the beds of the new like the fangs of a dog; bearing, however, a still greater resemblance to the manner in which the rocky spikes of a Highland hill pierce the under surface of a great sheet of snow, and keep it hanging on to a slope, despite its tendency to slide into the valley.

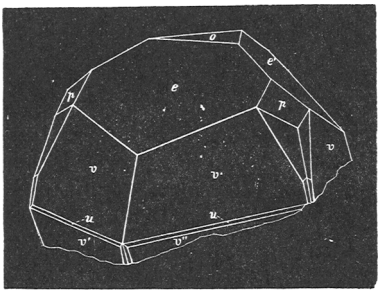
Some such drag there must have been here, when re-elevation pulled the still moist basin of the Old Red up to a level which was to become dry land. The dip is all away north-westward; and just as some portions of the conglomerate are at Eilan Roan even now slipping back into the waters, might there have been a tendency to slide here. But the roughness of the underlying rock prevented separation; the great stretch of the formation in front nearly altogether prevented crumpling; and at the promontories, as at Port Skerra, the old rock had got so firm a grip with its fangs, that although there may have been some small amount of tearing, the grasp was so sure that even yet the spikes and aiguilles hold on to some fragments which the sea has not been able entirely to carry away.

Of the upper members of this formation, as seen at the border-land near Reay, Geikie, in his classical essay on the Old Red Sandstone of Western Europe, has told all or nearly all that there is to tell. To the accuracy of his general description of the strata from Holborn Head to Strathy the writer can vouch. He has some doubts as to the correctness of his view, that the beds in the neighbourhood of Bighouse overlie those nearer the Red Point, nor can he admit that the grounds of his inference—for it is nothing more—are either sufficient or at all conclusive. Mr. Tait also, who is very familiar with all the stratified rocks of the district, and who accompanied the writer along the shore-line, regarded the rocks at Bighouse as a repetition of the beds exposed further to the east; even actually predicting to the writer the sequence before the rocks were reached. So perfect an identity at *two parts* of an ascending series is highly improbable.

Only at two points in this extensive exposure did the writer observe minerals worthy of note.

The jointings in a freestone escarpment a short distance east of the Isauld Burn are lined with pseudomorphs of *limonite* after pyrite.

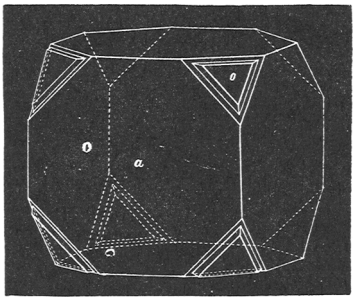
At Gie-uisg Geo, west of the Forss River there occur veins of calcite; these have a direction which bears directly on the veins of Hoy and the Stromness shore, and they may be a prolongation thereof.



The calcite of the veins is tinted brown from bitumen, and is confusedly crystalline. It carries the following minerals:—

Clear pellucid imbedded crystals of *calcite*, in the form drawn.

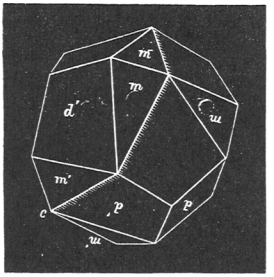
Bitumen in brilliantly black, hard, and brittle lumps.

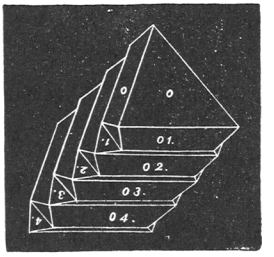


Galena always in crystals of cubo-octahedron, as figured.

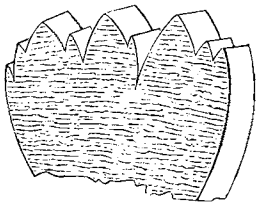
Pyrite in pale-coloured crystalline coatings, and on blende.

Brown *blende* in twins of *d m* arranged as a coating, and in linear aggregations of twin octohedra—the latter rare.





Marcasite, very rarely, as in figure.



All these are imbedded in calcite, there are no cavities. The lead is not in sufficient quantity to pay.

The following partial analyses of the flagstones from Castle Hill quarry have been published by Dr. Hoffmann:—

	Bottom Flag.	Middle Flag.	Top Flag.
Silica and Silicates insol. in HCl ...	61.39	69·45	68·40
Alumina and Ferric Oxide ...	4·87	11·50	10·21
Carbonate of Lime	21·91	10·66	10·93
Salts of Magnesia, the Alkalies, &c.	8·23	2·20	6·16
Organic matter	3·40	5.79	3·88
Loss at 100°	·20	·40	·42

But little information can be derived from the above; it can hardly be admitted that they "confirm the view that the great tenacity of these flags is in all probability due to the fine admixture of silica and alumina." It may be said to be well for the rocks, as also well for those who utilise rocks, that their components are united by a force of somewhat greater energy than mere *fine admixture*.

On account of the much larger proportion of carbonate of lime in the bottom flags, these should be set apart for special uses. The calcareous beds of this formation are low down in the series, and we have the same thing in these flag quarries also.

Associated with these flagstones and in many other parts of Caithness there are dark bituminoid flags very similar to those already described as found in Walls or Orkney.

Dr. Hofmann has given the following analysis of one such:—

Silica and insoluble Silicates	69·96
Alumina and Ferric Oxide	8·15
Carbonate of Lime	7·72
Salts of Magnesia, the Alkalies, &c. ...	2·91
Organic matter	10·73
Loss at 200°	·53
	100·00

A much more highly bituminoid shale from near Barrogill Castle was also analysed by Dr. Hofmann. This yielded :—

Fixed matter, consisting of silicate of alumina, ferric-oxide, and sulphate of lime, with some phosphoric acid ...	69·79
Organic matter	30·21
	100·00

One ton of the material furnishes 2690 cubic feet of a highly luminous gas nearly entirely free from sulphur. The residue in the retort contained 8·5 p.c. of carbon.

Trias, Lias, and Oolite.

The narrow belts of these rocks lie in the east of the country. But few minerals are to be looked for in such recent strata. Dr. Joass has them under his immediate eye, and Professor Judd took them into his immediate keeping.*

Dr. Joass sent me cherty nodules from the trassic strip which occurs at the mouth of Dunrobin Burn ; he desired an opinion as to their being correlated with the so-called cherty rock of Stotfield on the opposite coast. I could not do more than recognise a general similitude. The Dunrobin specimens are true cherty, coagulated, *colloidal* silica ; the Stotfield is, for the most part, *crystalloidal*, sheathing smaller quantities of the *colloidal*.

Doubtless there are many analyses of the Brora Coal. I give the following :—

Its colour was black, lustrous and brittle like "cherry." Specific gravity 1·373.

It yielded :—

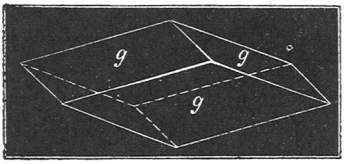
Water	11·494
Gas	35·077
Carbon	45·183
Ash	8·246
	100 (H.)

A fissile shale which forms a band about one a and half inches in thickness in the middle of the coal, and which had a brown colour and a specific gravity of 1.825, yielded :—

* I have qualitatively and to a certain extent quantitatively, examined specimens from each of the above rocks with a view of seeing if they can by analysis be distinguished from the dolomites of the west. I found them to be all more or less dolomitic, and they can be readily distinguished by the presence of alumina and of phosphates. Taken as a whole they are not nearly so pure as is the rock at Assynt.

Water	6·247
Gas	20·338
Carbon	19·72
Ash	53·895
	100 (H.)

From boulders of the upper oolite lying near Culgower, Dr. Joass sent



me septarian veins which carried *calcite* in three forms. The ordinary "nail head" (*g*) as figured, *c g*, and the "dog-tooth," which latter invariably lay upon their sides. This is an unusual position for that form.

Dr. Gunn here found, in similar but more siliceous specimens, round drops or globules of *asphalt* imbedded in thin veins of calcite: these drops were jet black, rich brown in thin splinters, perfectly spherical, and of high lustre. *Galena* is associated with the mineral. Unfortunately there was not a sufficiency of the asphalt for analysis, but I found it to be perfectly soluble in benzole, and to burn, when heated, with a brilliant smoky flame.

No radiating structure could be seen in the globules when broken, but a concentric one was sometimes visible; and the round drops sometimes had a perfectly spherical central hollow, with a brilliantly lustrous inner surface. Fractured chips with sharp angles also lay among brecciated portions of the calcite. The latter when dissolved in acid leave a thin film of volatile oil. Doubtless this asphalt is of fissile origin, and the mode or method of segregation of these spheres is very difficult of explanation. Can it have been that it was soluble in or combined with the calcite up to the time of the latter crystallising? Tarry masses of it occur in micaceous rock in Fife, and in dolerite in Skye, in similar association, and at these places the calcite also contains it in considerable amount; indeed calcite contains it sometimes as a colouring matter when no separate bitumen is visible, as at Kinghorn in Fife.