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XV.—*The Geognosy and Mineralogy of Scotland.*

By Professor Heddle.

SUTHERLAND.—Continued.

Rock Sculpture.

NOTWITHSTANDING the very considerable extent of shore-line which the deepest-seated rock exposes to the ocean, it exhibits extremely few illustrations of either cliff, or rocky shore.

The rocks which do occur are found to be of an altitude which is altogether trifling,—very much more so than even the great durability of the material of which they are composed would warrant us in expecting. Indeed, from the fact of the shore-line being at right-angles to the strike of the strata, and from these strata being at so high an angle of tilt, we should expect to meet with an almost continuous line of cliff. Instead of this, we find long points of land, of hummocky or undulating contour, running far out into the sea,—a profuse sprinkling of cliffless islets, which resemble in every particular the hummocks of the land,—and long sinuous stretches of water thrusting themselves up into what resemble land-valleys, very much more than sea-bays.

The foremost conclusion certainly is, that the present could not have been the oldest coast line, or, indeed, a coast line for any length of time;—that had the old Hebridian land stood, through the long ages

of its waste, at the same sea-level as now, that sea must have, in many places, cut cliffs of an altitude very much greater than those which we now find upon its shores. The fact that the glaciated contours of the land (though which of several possible glaciations, it is not easy to make out), thrust themselves everywhere beneath the waters, and sweep over the very summit of the island-rocks, may possibly be held as sufficient to account for the absence of cliffs; as the mantling ice would sheathe and shield the land from marine action. But, *that the land has sunk*, is a far more probable explanation.

The sinking of the land would submerge and conceal all marine precipices; but there is no need to conclude that soundings would disclose any such in the Minch, as the trench in which its waters now lie, might, in its middle-reaches at least, have for long been a somewhat elevated mountain-valley.

That the land *has* sunk, and sunk at two different periods in comparatively recent times, may be maintained,—*first*, from the fact that the cliffs both of the Torridon rock and of the Upper-gneiss are continued or continuous below the water-level, to a very considerable depth. As water cannot breach the land many feet beneath its low-water level, it is evident that these cliffs were cut when the land stood at a higher altitude.

That there has been so little cliff-cutting of the oldest formation in more recent times, may, in many places, be explained by its having been till recently swaddled up in the Conglomerates; and by supposing that the breaching by the sea had only gone along with glacial scour on the land, in clearing off that cover. At what may be called the Island of Sandwood, this would seem to have been very specially the case.

Again, as regards very recent subsidence, it has more than once been recorded, that in several places in bays of the Long Island, the oar of a boat may be thrust its full length into peat, which forms the upper coating of islets which never appear above the surface, even at low water. Banks of peat at the water-edge, surprise everyone who visits that country; and sand-silted bays with entombed trees, are seen both there and in the Orkneys.

There is one point, however, to which the above does not apply. Cape Wrath would appear to have been cut at the same time that the still more lofty cliffs of the Conglomerate in its vicinity were formed; very probably it may have been of still older days; and very possibly its fellow, of scarce less noble form, may be buried in the heart of Scrishven.

There is something about this headland which impresses one in a way which no other in Britain can. The corruption of its name of Rath, into a word which is certainly not unbefitting to its surroundings, can do little more than attract; but when it is *seen* and considered, it is felt that this is, par-excellence, *the headland* of Britain.

In the first place it is *a Cape*,—more than a mere headland. There is but one other Cape, in Britain; and that one (Cape Cornwall) neither pronounced in its dimensions, nor prominent geographically. It is not the *end of the land*. But this is *The Cape:*—the end of the land very absolutely;—and it is so on more than one side, or indeed on two, for it protrudes in self-assertive fashion; and the eye ranges, with no spot of earth to rest upon,—sweeping from the North Cape of Europe, past the ocean-road to the Pole; past Cape Farewell and Labrador, and down upon the other side, to Newfoundland; so distant, each and all, that the direct path to reach them would be *through* the Earth, and not over its surface.

And it *was this Cape:*—and it probably dominated in this self-same fashion over the waters, even when the World was very young, and the place of Europe was not known.

Of all the land which was above the waters then, there remains but very little; it has a following in the rear, which, heavily weighted, has lost its freedom; and there is that other stretch across the Minch.

Here is what Macculloch writes of it:—"There is a moment in rounding a cape of this nature that is very impressive; when the new shore is not yet opened, and when we can truly feel that we are at the limit and verge of the land, with sea on all sides; contemplating the last promontory which, boldly advancing into the waters, braves the fury of a whole ocean. It was the north western angle also of Scotland, *the land's end* of its wildest region, and the most advanced post of its wildest seas. The interminable horizon, wide-spread around, reminded us that there was nothing before us now, for ever, but sea and sky.

Nor was the impression, that we were now, as it were, launched on the polar seas, diminished by the aspect of this cape. As if nothing else could resist the fury of a northern ocean, Nature seems to have reared a huge and rude barrier which neither storms nor waves should ever have power to move. I felt how insignificant Cape Rath would have appeared, how Nature herself would have erred, had Britain here terminated in any other manner, had any lower and tamer point of land been opposed to this raging sea. Here she was truly her own poet; nor could the most vivid imagination and the most correct taste, have conceived a more thoroughly harmonious adopion of character;

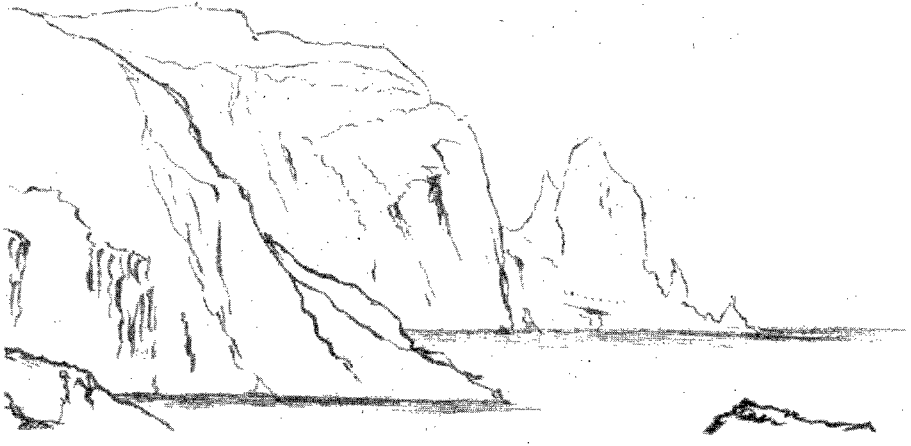
that of the wildest land to the wildest ocean, the strong-built and immoveable rocks to the furious waves;—to the majestic breaking of the lofty billows, a still more majestic pyramid, towering far above their greatest efforts; and, as the termination of the rude mountain-ranges of Scotland, a buttress worthy of all their grandeur and all their strength.

The change in the nature of the rock takes place for a short distance before arriving at this Cape, and is singularly fortunate for its picturesque character. We can feel that the effect of the sandstone cliffs, fine as they are, would have been as nothing here, compared to the noble forms of granite and gneiss which lift their broken and spiry masses against the white foam that surges against them. Here also, and nowhere else, there is a single and insulated mass of these rocks; as if Nature had especially provided them that she might guard the land from the attacks of the ocean, by a substance of unusual strength. While the cliffs are lofty, rugged, and broken into wild and angular forms, Cape Rath itself, the extreme point of the land, stands boldly out into the waves as if separated from them; a towering and noble pyramid, of three hundred feet or more in height. Nothing can exceed the elegance and majesty of its form, declining towards the sea in a second and much lower pyramidal rock; the whole forming an outline as graceful as it is unexpected, and as grand as it is appropriate." *(See Sketch of Cape Rath.)*

Still, that which most impresses is the boundless stretch of ocean to the northward. There is positively almost nothing else, round and round.

Barra, Rona, and Iceland lie to the west; the Faröes and Spitsbergen to the east; an open lane of water lies between, along which thought—skimming over the floor of Ocean and finding a way where Parry could not force his,—sweeps over what is usually regarded as the *top of the World*, glides through the opening of Behring's Straits and, but slightly vexed by the ripplings of countless Polynesian dust, sweeps still more skimmingly over Antarctic ice into the great trench of the Atlantic, and so home again after its cincture of the Globe.

The sculpturing of the rocks of this formation, so far as we can see of it, consists of the shearing off, in rugged and sometimes step-like fashion, of those smoothed and gently-moulded swellings of the land, which indicate glaciation by a ponderous sheet. *(See Sketch of Contours of Hebridian coast-line.)*



CAPE RATH.

M.F.H. Del.

Cliffs of the Conglomerate.

These are noble.

Though they do not possess the airy lightness of those of Foula, the tremendous massiveness of Hoy Head, or the savage wildness of St. Kilda, they surpass each and all of these in their diversity of form, and in their colouration. The much-praised Handa, to which the tourist is directed by the guide books (and of which the cliffs instead of being 700 feet in altitude, as therein stated, are under 400), is in reality both heavy in form, and tame in outline, in comparison with those which occur *for some miles continuously*, on either side of Cape Wrath.

There is a very marked difference in the features of the two lines of cliff which stretch at right angles to one another on either side of that Cape: to which, or to the little island of Gneiss which it terminates, these cliffs act as buttresses. The rock-surface of that islet slopes steeply down to the waters, both to the east and south; and it would be cut totally off from the rest of Sutherland if it were not that the mantling sandstones act as a cincture. The coast-line of the Sandstones commences about three miles south of the Cape, and extends as an almost continuous line of cliffs to Roan Island, at the mouth of Loch Inchard. All along this line the dip is slightly seaward—towards the trough of the formation; this may be regarded as lying in the centre of the Minch.

The cliffs therefore are formed by the faces of the strike-joints: and all more or less overhang their bases.

The coast-line at right angles to this, which stretches eastward from the Bay of Kearvaig, may be regarded as formed by fractures, accordant with the dip-jointing of the rock; and, while there is a mural precipitousness, there is here no overhang.

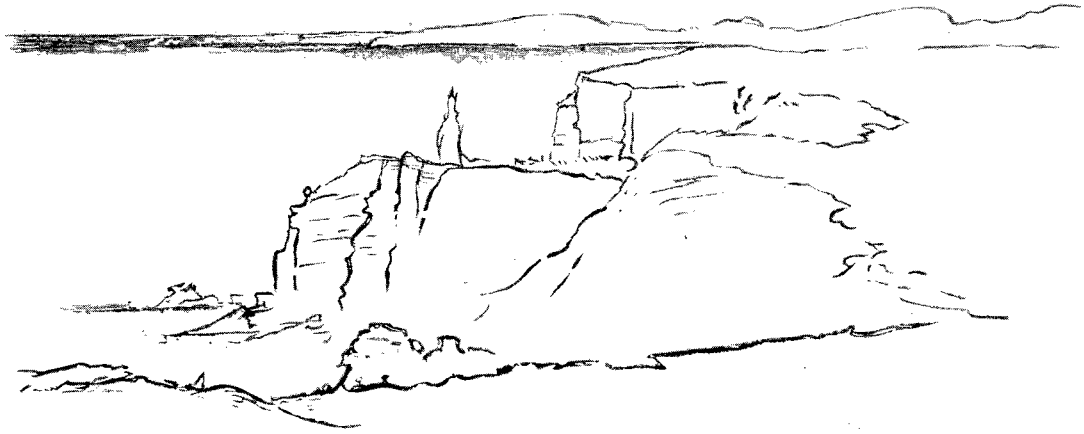
The disrupting effect of the breaching of the sea must, in the first of these circumstances, be aided by the gravitation of the rock forwards; and, in those spots where the jointing is most free and open, the cliffs give way most readily; so that along this *western* shore the line of precipice is an undulating, and very much more varied one than that which faces the *north*, where it is almost rectilinear.

The sketch given of the Rhu Vuachil, and the shore-line running north to the Cape, illustrates the undulating *western* cliffs.

Along this line the cliffs are of ever-varying height, but are perhaps never beneath 200, or over 460 feet.

GLACIATED OUTLINE OF HEBRIDIAN GNEISS - NEAR CAPE RATH.
? OLD GLACIATION.

M. F. H. Del.



RHU VUACHIL AND ROCHIL STACK. TORRIDON SANDSTONE.

M.F.H. Del.

LOAE. & RURD.

The Clo Kearvaig, which commences the *northern* line, at once starts up to an altitude of nearly 400, where it faces Kearvaig Bay. It is here sentinelled by a twin-spired stack, perhaps the most graceful in Britain. Dr. Macculloch considers it the finest in Scotland. He writes:—"Stack a Cloa, which stands here detached at a great distance from these cliffs, forms a magnificent object. Although of sandstone, and therefore displaying that mason-like structure which I formerly noticed, I know not that any other character or mode of disposition could have produced so fine an effect.

Of all the similar pinnacles in Scotland, whether on the east or west coasts, there is not one to be compared to this for elegance of form or singularity. As far as the eye could judge, it rises to the height of 200 feet or more, immediately from the sea; the basement on which it stands being extremely narrow, but rendering the effect far more pleasing than if these spires had shot off unsupported from the water. There are two associated pinnacles, in fact, of equal altitudes and similar forms; the general outline of each being gracefully pyramidal, while that of the whole is no less elegant. They remind us of the paired spires of the Gothic Cathedral; and as if Nature had meant to preserve them from accident, they appear as if bound together at two points, by transverse blocks of stone; adding as much to their effect, as to their appearance of strength and durability." (*See Sketch.*)

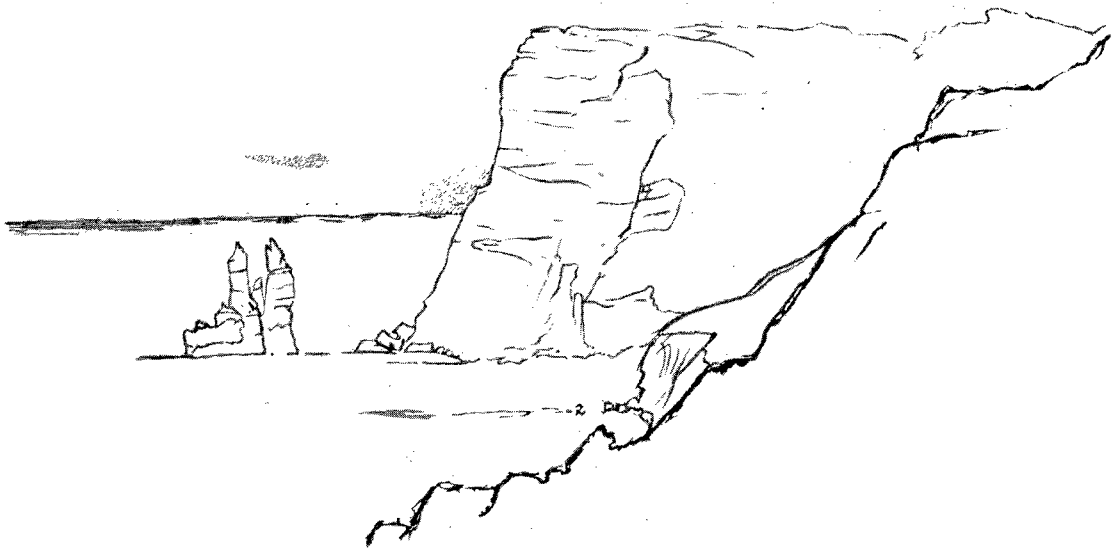
Eastward of Clo Kearvaig, the cliffs run rapidly up into the two magnificent headlands of Clomore. These are 630 feet high. Of these a sketch is given, which shows the comparative rectilinearity of the northern cliff-line. At a slightly southward curvature which terminates the hill of Scrishven, the altitude of the rock-front attains to 930 feet.

The marked straightness of this shorn-off line of coast, even beyond, that is eastward of the termination of this formation, on to the Kyle of Tongue, is of difficult explanation. Indeed the same may be said of the general rectilinearity of the north of Scotland:—by some it has been supposed to indicate the close proximity of a great line of fault.

It is no cynicism to say of geologists that *where they are at fault, they often place a fault.* But this will not do here. The line of these shores is two wavy in its straightness, and it cuts with varying features through too many formations. The variation of these features, moreover accords with what would be the normal variation of the action of the ocean-lash upon each variety of rock.

We are forced to regard it as a true ocean-cut ocean-verge.

And as we do so, the mind stands appalled in the contemplation of



RHU KERVAIG & STACK A CHLO. TORRIDON SANDSTONE.

M F H Del

the amount of waste which has taken place in what is but a fragment of the past eternity.

The creamy foam, which from the great elevation of these cliffs, is like a white fringe to a russet mantle, seems merely with gentle lavings to be washing the feet of the mighty cliffs;—laving them with with their stockings on, moreover; for mantle of seaweed, and, at a higher level, green swathe of moss intervene, and seem to protect them from the immediate friction of each sweeping surge. But, through swathe and fringe, the ocean is acting instant by instant, and its restless sap is, grain by grain, bearing to its depths the pediments of the mass.

Dr. Macculloch does not hesitate in regarding these as being true sea-cut cliffs; in referring specially to them, he writes—

"The sandstone cliffs are of a grander and more picturesque character than is usual in this rock; from the magnitude of the fracture, and the consequent breadth and boldness of the parts. But they are rendered more striking by the marks of destruction so peculiarly impressed on them; which, while they evince the violence of the wild sea that seems for ever to break along this dreary coast, are in harmony with the aspect of the now unterminated northern ocean.

But in this sandstone, we feel that, in what remains, we can trace what has vanished; the apparent wideness and breadth of the fractured faces reminding us of their recent losses, as if whole cliffs had been carried off and buried in the deep. In a few places indeed, the enormous masses remain pitched on the ledges below where they had fallen; as if the ruin had but just taken place before our eyes."

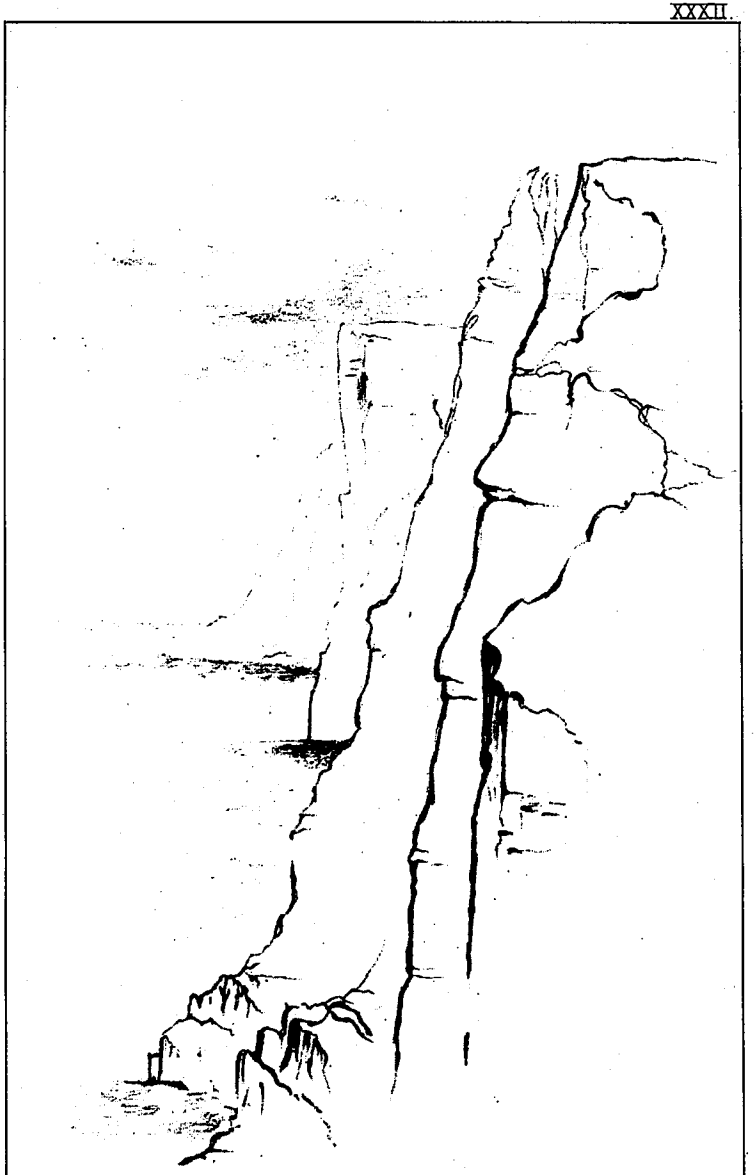
I have appended a sketch of the spot to which I imagine Dr. Maccullock here refers. It is called Poul a Vourin, and is about three miles south of Sandwood, on the west coast.

Cliffs of the Quartzite and Upper Gneiss.

There is but one Quartzite cliff,—the Whitten Head. This, with its gloomy caverns and pillar-like stacks, is unquestionably grand when contemplated from the ocean level; but from above or in front, it is certainly disappointing. (*See Sketch of Whitten Head.*)

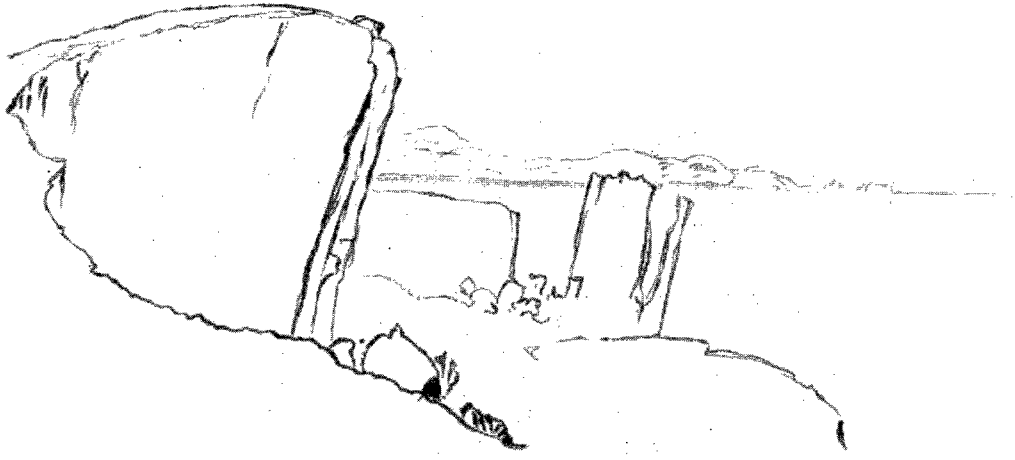
The rock is too enduring to weather into other than rounded form; and indeed there is, in the contour of its terminal summit, a suspicion of ice-action.

Due north of the Head there stand two stacks in close but not absolute juxtaposition. The justice of Macculloch's remarks on the Stack a Cloa is evident on a consideration of these. In height they are not



CLO MORE. TORRIDON SANDSTONE.

M.F.H. Del.

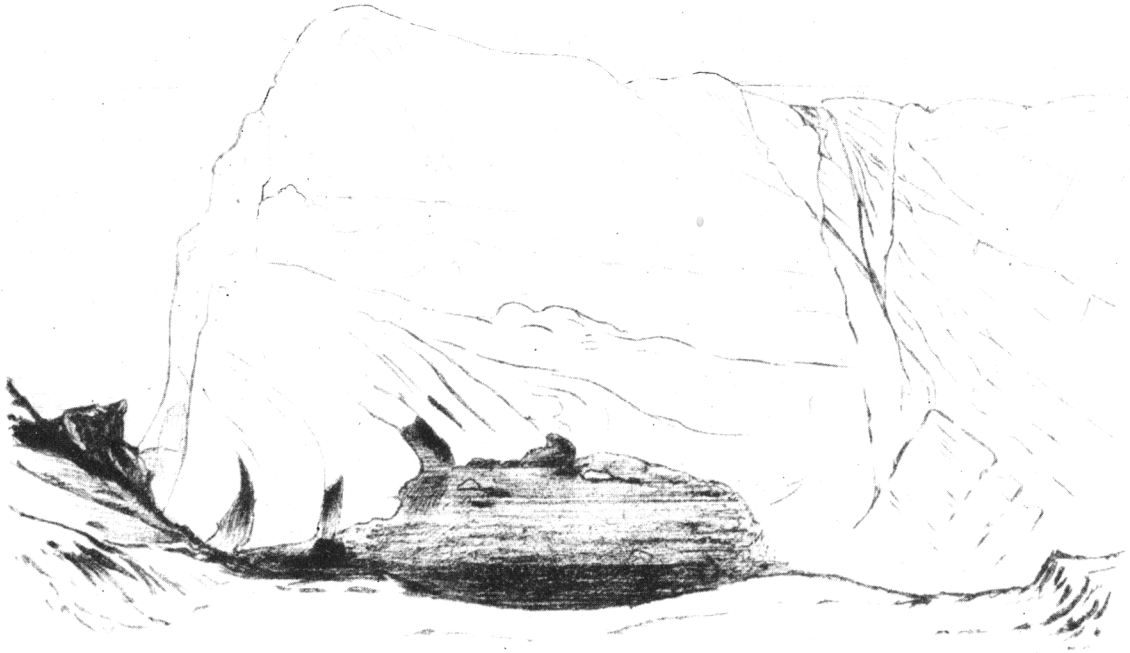


POUL A VOURIN. TORRIDON SANDSTONE.

M.F.H. Del

much surpassed by the western stack; in similitude of form, and in colour-toning, the spire-like shafts surpass it; but, having no base-ment-cincture, the resemblance to the Gothic Cathedral is altogether wanting. There is conveyed, instead, a feeling of sameness or of needless repetition; combined, to a certain extent, with that of in-security; as if they needed somehow to aid each other against the dangers of isolation.

Regarded from this headland, the sombre line of precipices, which, with strongly-contrasted blotchings of green and red, extend for miles across the frontlet of Ben Thutaig, seem to possess outlines of both dignity and grace, which must surpass those of the Whitten. They are uniformly of surpassing altitude, and attain, under Ben Thutaig, a height of 878 feet. The land undulates considerably, probably from alterations in the dip, while the cliff-line is flexured laterally to a considerable amount likewise; so that its verge has the appearance of a cord which is thrown at one and the same moment into two sets of vibrations,—vertical and horizontal. The writer was unfortunately dissuaded from visiting these cliffs, on the ground of distance; but he afterwards found that it would be nothing of a feat, starting from Heilim Inn, to skirt the whole coast-line as far as Melness,—in a long summer day.



WHITTEN HEAD. QUARTZITE CLIFF.

M F.H Del

THE HEBRIDIAN GNEISS.

From among the many names which have been suggested for this formation, I have selected the above, as "it involves no theory, and can contradict no fact."

Laurentian, fundamental, and hornblendic, are all more or less objectionable; and they are so in the order in which they stand.

Laurentian is altogether theoretical; *fundamental* is partially so, and partially assertive; while *hornblendic* is self-assertive.

While it is the case that no rock subjacent to this has yet been found in Britain, there is yet no reason why a lower may not be found. Such a term as *fundamental* should only be applied to the rock which can be proved to be that which is nearest to the earth's centre; and its application should not be confined to one country, but it ought to be reserved for that which is the lowest in any portion of the earth's accessible crust. Nicol puts it well;—"it is a term which in the history of the earth has often proved fallacious. The first has scarce been enthroned before an earlier appears, and in geology it is not the son who dethrones the father—Jupiter, Saturn—but the father who expels the son, to yield in turn to some remoter ancestor. And so it may be here."

Again, as regards the last of the three terms, while it is the case that large, indeed perhaps the largest tracts of this formation are characterised, as regards its composition, by a large content of hornblende, still it has to be noted that extensive tracts do not show that feature,—do not even contain the mineral; while very large tracts of that "upper gneiss" from which it is proposed to distinguish it by the use of the term, do contain the mineral; and, if not in an equally large amount, at least in as markedly a selective manner.

In fact the distinctive feature of the formation as a whole, consists, not in any difference from ordinary gneiss in its component parts, but in a difference in their mode of arrangement, and in their condition. That arrangement may be defined as a markedly *segregatory* one;—the condition has a highly *crystalline* one.

If the extent to which the constituent minerals of a rock-mass have segregated apart, taken along with what may be called their crisp crystalline appearance, be taken as any measure of the amount of metamorphic change which the rock has undergone,—and if the age of the rock-mass be measured by that amount,—then must the

gneiss of the west coast of Sutherland be unquestionably the oldest of that class of rocks in Scotland.

Composed in its general mass almost solely of pinkish orthoclase felspar, dark-green hornblende, small-flaked black mica, and greasy lustred quartz, it almost nowhere presents anything approaching to a uniform or close-grained mixture of these. Instead of this it shows itself in boldly banded stripes,—the dark mineral, (the hornblende or the mica,) being collected almost totally in certain of these, to the exclusion of the minerals of lighter colour, which consort in others.

Were the rock-layers arranged in anything like a gentle angle to the horizon, this peculiarity could disclose itself only where sea-cliff or ravine-scalp had, by cross-sectioning, laid them bare; but, on account of very high angle to which they have been in most places tilted, this feature of *striped segregation* is almost constantly displayed.

So marked, indeed, is it in some localities,—as along the cliffs a mile south of Cape Wrath, and at Lua Yayi on Loch Erribol,—so sharp the line of demarkation between the hornblendic and the felspathic bands, —and so frequently is there an approach to an actual separation between the layers, that familiarity with the rock alone can avail to disabuse the mind of two false ideas,—first, that these bands define actual layers of deposit,—and, when this error has been expunged, the even graver error, that the felspathic bands are injected granitic dykes.

This last, indeed, they have, by more than one observer, been taken to be.

That they are not so, may be determined by the observation of the following facts:—these felspathic bands invariably run along the strike of the hornblendic beds, never cutting them; and when the beds are flexured, they accommodate themselves to their every fold:—they never bifurcate, or contain any imbedded or floating portions of the hornblendic layers:—their structure, however confused, shews more or less of a laminated arrangement of parts, and nothing whatever of the arrangement special to an injected vein;—and lastly, their mineral composition is not that of an injected vein.

This banded structure, moreover, is possessed of a certain regularity;—the ratio of the bulk of felspathic belting, and the distance of these belts from each other is, in the localities where it is best displayed, a more or less constant one; and the felspathic belting is altogether so great in amount, as beyond measure to surpass any development of injected veins; and even, indeed, the greatest development of the vast system of trap-dykes, the individuals of which, in parallel course, intersect our western shores.

HORNBLENDIC BANDS OF OLD GNEISS, ENDURING AFTER REMOVAL OF FELSPATHIC.
SOUTH OF CAPE RATH.

M F H Del

In the south-west reaches of the county, as at Loch Inver and southward to Loch Polly, the dip of the gneiss is not so constant, and by no means at such high angles: here it is much convoluted, and the banding is neither so prevalent, nor are the layers which produce it individually of so large a size. Still, even here, in this minuter if not feebler development of this—the structural characteristic of the rock—the near approach to an actual physical separation of its constituent parts, is a most marked feature. When viewed at some distance, the unconvoluted rock resembles a page ruled for music, while at a nearer distance the convoluted and closer structure resembles a marbled page.

For the individual members of this apparently loose structure, I have elsewhere proposed the term of—*bands of metamorphic segregation.*

It has been said that there is often an approach to an actual separation of the layers of the hornblendic and felspathic bands; if it be actual, there must be lines of weakness; and the beat of waves, or the soak of rain, or the chipping action of blowing sand, may find these out. And this they do sometimes in marked manner.

At a mineral locality, (afterwards to be noted), near Cape Wrath, this rock structure is displayed in its giant development. A tongue of the almost vertically tilted rock receives the full blow of both north-west and south-west waves. These, partly by slapping into the ever-widening chinks, and partly by eating out the more soluble mineral, and doubtless finally by one tremendous finishing stroke, have abstracted many of the felspathic layers, leaving the almost black hornblendic bands to stand erect like isolated basaltic pillars, or the curved and shattered ribs of some gigantic wreck. *(See Sketch).*

At this locality the segregatory force seems to be most highly dominant in the hornblende,—that is, the hornblendic matter displays great power to exclude the silicious and felspathic. Indeed, a little further south, bands of almost pure actinolitic material occur. In general, however, the force seems to draw the two other ingredients into veins apart, though in this case not absolutely apart; for, although these veins contain little or none of the hornblende, still much felspar and quartz remains associated with it, to form the general mass of the rock. This variety of segregation is highly dominant at Lua Yayi. In the *first* locality a pale rock seems banded with black—at the *latter*, a darker-toned rock is lined with zones of a tint much lighter than that of the general mass.

But even when not appearing in this its larger or bolder development, this structure renders the rock a highly characteristic one. With its beds thrown generally at a high tilt, and ground into rounded

contour almost everywhere by ice, the persistence of the striping-forces itself upon the attention; while that striping is generally so rectilinear as to enable one to determine the strike of the rock, without reference to any face or dip.

While it is more than probable that the felspathic bands of this rock have been mistaken for veins, true veins are also, in some localities, of frequent occurrence;—exhibiting in high perfection their properties of branching, anastomosing, and interlacing.

At the locality where the hornblendic bands are so strongly developed, veins of a granite, which in substance is only remarkable for its small amount of mica, exhibit in great perfection the first two of these properties.

At the spot where, as shown in the sketch, the ribbed hornblende has been robbed of its interstitial felspathic prop, there are no views; but in a cliff directly opposite, dark and light bands are linked together by lacings of granite; and the rock is so strengthened thereby, that here a straight-faced and unbroken sheet is opposed to the lash of the ocean.

In exhibiting the interlacings of granitic-veins, probably no locality in Britain can rival that of Cape Wrath. A drawing of this, taken from the sea-level just beneath the stack west of the Cape, has been given by Dr. Macculloch in the atlas to his "Western Islands."

It has been supposed that this drawing must be an exaggeration.

After lying for a very considerable time endeavouring to unravel some of the less intricate twistings and twinings of the granite,—yea, even of the dishevelled gneissic-layers,—I would, in reference to that drawing, just make use of Dr. Macculloch's own modest words, and say, that while "it is not possible to distinguish always between the pale gneiss and the granite, the truth of the essential parts of the drawing has remained untouched."

He who would unravel the mystery of granite veins, has much to unravel here, and anyone who attempts this mystery should study long, at this spot. There is one conlusion which cannot but soon impress itself upon him in the so-doing;—namely, that the granite was infused into the rents *at no very elevated temperature*. The ramifications dwindle away to the thickness, or the thinness rather, of the edge of a knife. No molten matter could remain fluent in so narrow a crevice of a *cold* mould. In making minute castings, even in so easily liquifiable a metal as pewter, the mould is heated;—or again, as in the case of the marvellously delicate ornaments which were made when the patriotic German ladies "gave gold for iron." But it will hardly be

urged that the mould was in the present case heated up to near the melting point of granite; and in sooth it would prove far from easy to substantiate any great augmentation. Truly it is becoming necessary that geologists should tone down their temperatures.

In addition to the pale granite of the veins as usually seen in this locality, there is a second variety of a fiery-red colour, with imbedded opaque white quartz, but no mica. I have not observed these to ramify to any great extent.

Perchance of the many difficulties connected with granite veins, there is none greater than the singular manner in which the terminations of looped branchings cut the stem from which they started. This they do frequently within a very short space of their point of branching.

The cutting or self-rending, as the case may be, of a distinctly laminated rock by curvilinear rents is itself an enigma; but the fact of one portion of a vein having become so solid as to be capable of being rent, while it was still exuding the material which plugged that rent, is a very much greater enigma.

At a small quarry to which a cart-track leads, just about the summit of the rising ground behind the lighthouse, there occurs an appearance in the granitic veins which neither the writer nor, he believes, his companion Professor Geikie, had before observed.

The quarrying operations have here cut through a small outlier of the Conglomerate, and exposed a face of the gneiss, with undulating convolutions,—well marked by the dark and light bands of the stone. Branching granite veins, of from a foot to three or four inches in thickness, ramify through this, *at right angles to the zonings*. We were perplexed by observing not mere indications, but, in several of these veins, both in the main trunk and in the branches, a fairly-well pronounced development of structure within the veins themselves. This structure was *accordant with that of the banded gneiss*. That is to say,—in a precisely similar manner as the micaceous or hornblendic material of the gneiss was disposed in continuous bands, there was an arrangement in the granite vein of the dark mica which it contained. And this arrangement of the mica of the vein was disposed *in immediate continuation of the zoning of the gneiss*. It was far from as distinct, because there was not in the granite nearly as much mica as there was of the two dark minerals in the gneiss; but, so far as its mica went, it was as absolutely confined to the lines which passed more or less across the vein, *in continuation of those in the gneiss*.

A zoning or banding of granite veins *parallel* to the sides of *the vein* is not uncommon; but one *transverse to it*, and synchronous with the structure of the rock which the veins cut, is perhaps now first noticed.

The impression at first sight conveyed, was one which can hardly be for a moment entertained; it was that the zoned structure of the gneiss had been impressed upon it, *after* it had been cut by the veins, and that the linear arrangement of particles had affected both simultaneously.

This gneissic formation has a prevailing N.W. and S.E. strike; and, in Sutherland at least, it has a prevalent high dip to S.W.; but this is not without exception. At Cape Wrath it dips to the south-east, and with a much lower dip; while in the south-west of the county, the dip, though in the usual direction, is also a lower one; while there occur there, though only on a small scale, undulating folds.

It is in those parts of the county where the strike and dip departs from the ordinary, that the rock exhibits the most extensive convolutions.

A wonderfully fine illustration of contorted structure is displayed upon a rock-face immediately west of and beneath the light-house at the Cape.

The cliff-face is here formed by a strike-joint; and a smooth face of rock, nearly 90 feet wide by about 150 high, exhibits on its surface, drawn in the boldest character, both ample and minutely-crumpled foldings. These sweep from side to side in a repeated sequence of dark-green lines. It is altogether on so prodigious a scale, and so fair-fronted to the ocean, that it looks like a huge diagram displayed to passing ships.

Besides the three most usual ingredients of this gneiss, and the less frequent mica, the rock contains a substance which occurs in some districts in such quantity, that it has every claim to be itself regarded as a constituent. This substance was first noticed by Dr. Macculloch, and noted by him as occurring in Iona,—the first of the gneiss islands which he described. He thus speaks of it.

"One peculiarity attends all these rocks, namely, the great abundance of a substance hitherto considered as compact epidote, which is everywhere found in them.

"It forms either large lumps or laminæ imbedded in the gneiss; and in some situations enters into it as a constituent part. In other places

it is found mixed with hornblende in various ways, or else serving for a base in which crystals of hornblende are imbedded; *forming a rock which has been mistaken for serpentine.**

"As this substance does not seem to be very common, and seems to have in a great measure escaped attention, a description of its prominent characters will not be superfluous.

"It is generally pale-green, at times approaching to yellow. The fracture is intermediate between the conchoidal and the flat-splintery, and it is exceedingly difficult to break; the fragments are slightly translucent on the edges. It does not easily yield to the file, and scratches quartz; while in return it is scratched by that substance. Its specific gravity is the same as that of quartz, but it has not been analysed. From a comparison of the characters of numerous specimens, selected from different parts, I am inclined to consider it as a variety of compact felspar, and it will indeed be found to pass into the more common varieties of that substance. It forms a conspicuous portion of a gneiss abounding on the west coast of Rosshire."

It is the last statement of Dr. Macculloch, no less than the very close agreement in characters, that enables me to conclude that this is the substance to which I refer. The latter occurs in greater quantity, and perhaps in a purer state in the west of Rosshire, than at any other spot where I have observed it. I have broken out veins of over an inch in thickness in the neighbourhood of Poolewe.

As I did not come to the same conclusion as Dr. Macculloch, as to the nature of this substance, I have made several attempts to procure specimens pure enough for analysis,—not only on account of the desirableness of ascertaining the nature of a doubtful substance, but more especially from the fact that, as this substance occurs very frequently in certain parts of the "igneous rock," which is found in a very interesting line of country, a knowledge of its composition is absolutely called for.

Up to the present time all my attempts at obtaining an unmixed result from my picking, have failed,—not so much from an admixture of hornblende and felspar, as noted by Macculloch, but of quartz.

I have gone so far, however, as to be able to say that there are the strongest chemical, as well as mineralogical reasons, for doubting this being a felspar.

* The italics are the writer's, not Dr. Macculloch's.

Many of the Loch Maree specimens seem to show an incipient crystallisation of the green matter, which runs into opaline quartz. I conclude that the thing as a whole is that *mélange* which has been termed *epidosite*; and the occurrence in Harris of thin veins of crystallised epidote, with distinct and separate minute crystals of quartz, goes so far in negativing the conclusion that it is a felspar. I shall, therefore, with a *caveat*, term it meanwhile *epidosite*.

Garnet is mentioned by Macculloch and others as occurring in this gneiss; and my confrere Mr. Dudgeon and I found it in one locality in union with hornblende and kyanite, in such preponderating and enormous quantity, that there it was almost a garnet-rock, (eklogite) and it prepared us for meeting with it anywhere in the formation.

Where convolutions occur in the gneiss they throw the flexures of the hornblendic bands into protrusions, well seen on denuded or sea-scalped surfaces. This frequently leads to the impression that these protrusions are imbedded crystalline nodules, or kernels of the mineral, —such as would result from a concretionary structure. It requires some care to be able in all cases to undeceive oneself as to this; the more especially as isolated arrangements of crystals, or subfibrous masses of hornblende of kernel-like appearance, *are* to be found in this gneiss,—as at the Island of Ensay in the sound of Harris, and, as stated by Murchison and Nicol, at Loch Inver.

Nicol mentions such as occurring of a light-green colour, near Loch Inver, up to two feet in size.

Moreover, wherever there is any great amount of puckering, and so of local amplification of the thickness of the hornblendic layers, the crystalline force, having an unusually large amount of matter to operate upon, asserts itself with more than usual success ; and at such points, there are even to be found rudely-formed crystals or crystalline masses ;—a foliated arrangement of particles being here altogether lost.

An extraordinary, indeed an altogether unique illustration of several of the above structural developments, is to be seen among the cliffs at Rhu Craig-a-Vail,—the north-western promontory of the Bay of Scourie.

At this spot the gneiss, which is of a somewhat more thinly-banded structure, with perhaps less separation of its several ingredients than usually obtains, is thrown into highly intricate and tortuous convolutions. The domed summit of an extraordinarily plicated protrusion-fold has been denuded off, partly by marine breaching, partly it would appear

by actual quarrying,—(for the purpose, probably, of more thoroughly exposing the very peculiar manner in which the dark hornblendic layers are crumpled up.) It exhibits in section a singularly-close resemblance to a huge soup-ladle.

At the periphery of the bowl of the ladle, the darker layers of the rock are folded upon and within themselves to an extent that is not surpassed by the convolutions of the brain, or the intricate structure of the tooth of the labyrinthodon. It is a most extraordinary and extreme illustration of the pliability of solid or semi-solid matter under the exercise of enormous force.

From among the so-called hornblendic layers which are thus contorted, there is to be obtained the rare mineral *hydrous anthophyllite* —(D.) Its mode or state of occurrence is most interesting.

In chiselling off portions of the crystalline layers, the tool suddenly sank into an underlying pulpy mud or clay, of a fawn-yellow colour. This was perfectly plastic, soiling the hands and clothes; it was, even upon its first exposure, however, seen to contain spiculæ of a crystalline matter.

This damp substance rapidly hardened; it could next day be broken, though with difficulty, from its retaining somewhat of its plasticity. In the course of some months it constituted an easily crumbled stone, and ultimately hardened to the ordinary consistence of rock,—having all the appearance of a pale *hydrous-anthophyllite.*

As mineral specimens they now appear as a confused arrangement of minute acicular crystals; their colour is now pale olive-green; their lustre between pearly and greasy.

Some specimens contain small crystals of *talc* or *ripidolite,* of the same colour:

When reduced to powder, the colour rapidly changes to that of chocolate.

The specific gravity is 2·917.

The analysis is afforded—

Silica	45·508
Alumina	6·588
Ferrous Oxide	14·285
Lime	4·437
Magnesia	22·14
Alkalies	traces.
Water	6·721
	99·479 (H.)

The change of colour above noticed as occurring during the pulverisation is very peculiar. I shall have to notice this as occurring not unfrequently in the same circumstances. *It is not the result of peroxidation during the great surface-exposure which results from the process of comminution;* that this is the case, is in the above analysis shewn by the total absence of Ferric-oxide.

It probably is due to the change in the *form* of the particles being attended by some modification in their action upon light. Something of this very kind was shewn by Brewster to be the cause of the change of colour in chlorophæite. In this latter mineral it occurs upon mere exposure, and without actual interference; and is found to result from shrinkage-cracking, due to partial dehydration. I find this change is in all case *expedited* by pulverising; and I am inclined to believe that a similar though very inferior amount of the same change, which is to be seen to occur in many *saponites*, is due either to the same cause, or to their containing small quantities of *chlorophæite* in intimate intermixture.

The darker crystals which at this spot inclosed the orginally pulpy material, may be actinolite; but they more probably are themselves hydrous-anthophyllite, darkened through exposure;—they are dark-green and brittle.

While perhaps the nearest approach to independent crystallisations of hornblende are to be seen upon the slopes of Foinaven, the locality where the greatest amount of hornblendic matter segregating apart occurs, is upon the north-east foot of the hill of Kean-na-Bin, near to the branching of the shore-road to Rispond.

Here masses of *hornblende*, consisting of radiating and interlacing brushes of crystals of a somewhat actinolitic type, are to be seen, of a foot or two in bulk.

The colour is a dark but brilliant grass-green; the lustre is high; and, as the interlacing crystals are some inches in length, and the specimens can be split into thin slabs, they form one of the finest varieties of the mineral to be procured in Scotland.

Small brilliant crystals of *pyrites*, of the form *a o*, are lodged among the fibres, exalting their effect as specimens; and a small quantity of a mineral, which may be *grastite*, occurs as a thin coating, rarely.

It has been said that the ordinary constituents of this gneiss are orthoclase, quartz, and hornblende; the two former being frequently to a great extent associated apart in bands,—in these *oligoclase* is of rare occurrence. Towards the north-eastern limits of the rock, as along the western shore of Loch Erribol, at Lua Yayi, and Kean-na Bin, these ingredients seem to be undergoing alteration; the orthoclase being of

a heightened red-colour, a greasy lustre, and of markedly less than the normal hardness. Little quartz here occurs, and large lumps of massive pea-green *agalmatolite* (D. and H.) surround the crystalline masses of the felspar; this agalmatolite has probably resulted from a change of the oligoclase.

Our knowledge of *rock-alteration* being altogether scanty, both of the above substances were analysed.

The *orthoclase*, as above noted, was of an unusually-bright flesh colour; its specific gravity was 2·554; it was powdered with very unusual ease. It yielded,—

Silica	63·846
Alumina	18·489
Ferric Oxide	1·318
Manganous Oxide	·115
Lime	·43
Magnesia	·769
Potash	13·021
Soda	·919
Water	·393
	99·8 (H.)

The magnesia is here but slightly in excess of the quantity usually present.

The *agalmatolite* was first found in imbedded massive patches in granite, in a dyke near the village of Kean na Bin. It was traced to the cliffs opposite the island of Koilskeir; and, until it was analysed, it was ticketted "indurated steatite,"—with a mark of doubt.

Being in larger masses at Lua Yayi, specimens from this last locality were chosen for analysis. At both localities the mineral is fine-granular, and has a greasy lustre. It cuts like slate-pencil. Its specific gravity is 2·77. It absorbs ·7 per cent. of moisture.

Its analysis yielded—

Silica	48·723
Alumina	31·56
Ferric Oxide	2·43
Magnesia	1·809
Potash	9·485
Soda	·312
Water	5·752
	100·086 (H.)

It is many years since Dr. Macculloch threw out the conjecture that "indurated steatite" was of the nature of agalmatolite. Of several substances which might lay claim to such a name as *indurated* steatite, this is perhaps that which most deserves it; the above analysis shows the nature of the substance for the first time, and probably first proves *agalmatolite* to be British. The definite information thus obtained enables us to recognize as the same mineral, certain hitherto doubtful green masses which occur elsewhere, imbedded in granitic rocks. This substance and its probable mode of formation was also noticed by Cunninghame, who writes—"Near the village of Rispond, the gneiss makes a transition into a rock composed of large concretions of serpentine and quartz, between the two there being also every mode of gradation."

Cunninghame's "serpentine" is the agalmatolite.

While I have to admit that it is mere conjecture—(indeed, the vaguest conjecture, seeing that pieces of oligoclase equally large are rarely to be seen in these felspathic belts)—which assigns the occurrence of this mineral to a change of *oligoclase*, I have to say that I have not infrequently seen *orthoclase passing, on its exposed surfaces, into a substance not to be distinguished from this.*

I instance the orthoclase of an intrusive dyke at Geo na Shermaig, —of an exfiltration-vein at Knock Dhu near Lairg,—and of probably a similar vein in the red granite near Murdoch's Head quarry, in Aberdeenshire.

Of the ordinary constituents of this gneiss,—if they be of *this* gneiss, which is doubtful,—two other, somewhat unusual-looking varieties, were analysed. These were both found in one large mass which lay on the east shore of the Kyle of Duirness, somewhat below the Ferry.

The original locality of this mass, or of a perfectly similar rock, was found to be the north-west slopes of Ben Spinnu, at a height of about five hundred feet. (H.) Here the rock is well-displayed in cross-section, in the beds of several burns. It is a hornblendic gneiss, but the dip here is to the north-east, and at an angle of only from 20 to 32 degrees.

The rock is of a more laminated, and a less markedly banded character than is usual in the "lower gneiss"; and I much incline to believe it to be a portion of a bed of rock belonging to an altogether different age, which, like the limestone of Duirness, has been let-down by a great fault.

The felspathic layers here are less well-marked, they do not maintain any regularity in their width, and they are frequently plicated.

The *orthoclase* is saccharoid in structure, of a yellowish-pink colour, a high glancing lustre—very like a granular marble, and it is very unlike ordinary orthoclase. It contains imbedded crystals of the substance immediately to be noticed, along with rare crystals of pale-brown resinous *sphene*.

Its analysis yielded—

Silica	64·153
Alumina	19·066
Ferric Oxide	1·318
Manganous Oxide	·538
Lime	·947
Magnesia	·384
Potash	11·166
Soda	1·749
Water	·714
	100·035 (H.)

The crystals imbedded in this felspar are probably *uralite* (H.) They are of about half-an-inch in size, of a rich dark-green colour; —they show well the *c* cleavage of augite, but to the goniometer give cleavage-angles of both augite and hornblende. They are unusually hard for *either* of the last-named minerals.

The analysis yielded—

Silica	51·461
Alumina	2·968
Ferric Oxide	2·451
Ferrous Oxide	9·661
Manganous Oxide	1·076
Lime	20·073
Magnesia	10·461
Potash	·683
Soda	1·305
Water	·683
	100·827 (H.)

Thus agreeing in composition with *augite*. The structure, however, would appear to be that of *uralite;* and this combination of augite and hornblende I have never seen in any locality in which the gneiss was unmistakably the *lowest lying rock*. In *it* the mineral is invariably ordinary laminated-hornblende, seldom concreting into large crystalline masses, and then only where close-folding of the rock throws together an unusually large quantity of the mineral. The most distinctly crystalline masses of such hornblende are to be seen in the neighbourhood

of Loch Inver, and on the western slopes of Foinaven; and at neither of these localities have I seen crystals of half the dimensions of this *uralite*.

Rarely the hornblende is not of the platy variety, but *actinolitic*: broad bands of this variety, almost simulating veins, are to be seen among the western cliffs, about two miles south of Cape Wrath.

Of accessory minerals this gneiss carries but few in its general substance; and the few that I have seen occur chiefly at the locality last mentioned.

At this grandly picturesque headland, the hornblendic gneiss of the west coast differs in its features very considerably from those which elsewhere may be said to be almost unvarying. The dip here is low, and to the east or east-south-east; it is highly corrugated and folded, and it is rent, and shifted, and reagglutinated by an anastomosing and mutually-intersecting series of granitic veins. Its own granitic belts, instead of assuming, as elsewhere, much of the character of a set of parallel dykes with abrupt and sharply-marked surfaces, blend by insensible gradation into the ordinary material of the rock, which is here even somewhat of the nature of granite itself.

It is this greater consistency of the rock as a whole, this more intimate interpenetration and consequent firmer cohesion of its parts, coupled with the altogether unique manner in which its every layer is bound together by granitic cords of unusual toughness, (interlaced in such a manner as to defy unravelling,) that it has formed, and must for long form so fitting a termination to a kingdom,—so enduring a rampart against even Atlantic billows.

Such are the features of the rock for about a mile to east and south of the lighthouse; another, however, has to be noticed,—it is, within the space so included, much less characterised by the presence of particles of hornblende than is usual; being of a pinkish, instead of a green cast of colour. This local deficiency of hornblende is, however, suddenly more than compensated for, about one and a half miles south of the lighthouse; here the strata have gradually increased their dip, and assumed the line of outcrop, which is normal to the rock in the south. The beds are here almost alternatingly hornblendic and felspathic; and—as the intermediate felspathic bands have frequently yielded to the weather,—the former stand erect in repeated sequence, simulating dykes of a dark igneous rock.

Just about the same spot, also, in cove-like recesses of the older-rock, the horizontal strata of that many-coloured conglomerate which has been assigned to the Cambrian epoch, makes its appearance, in outlying portions of very circumscribed dimensions.

In the second (to the south) of these coves of the Cambrian sea,--one which is now sentinelled to the north by a grand development of the black bands of the older rock, and on the south by an equally grand illustration of intrusively anastomosing granite,—my companion Professor Geikie and I hit upon an interesting mineral locality.

It is situated on the grassy bank, only some few feet below where the conglomerate reposes in peacefully rectilinear beds upon the denuded gneiss, which here dips from the under-surface of these beds almost at right angles.

The first of these erected beds to which interest attaches, carries a *iaspery chert* with yellow *moss-agate*; in association with this *hydrous anthophyllite* (Geikie and H.) is to be seen. It has taken the form of concreted nodules consisting of bundles of radiating fibres. The mineral here is greenish-brown in colour, occasionally showing the bronzy-brown of true anthophyllite.

An ill-defined substance resembling fibrous *Wollastonite* also occurs.

The more southerly of the veins is, for the most part, a light-green fibrous-*actynolite*; but it also carries *ripidolite* and *steatite*. (G. and H.)

The *ripidolite* forms belts in the rock; these belts here consist of foliaceous masses of nearly parallel scales about the size of peas; these have a greasy lustre, and a blackish-green colour. Its specific gravity is 2·823.

It yielded,—

Silica	31·034
Alumina..	14·845
Ferric Oxide	5·73
Ferrous Oxide	17·417
Manganous Oxide..	·998
Lime	·355
Magnesia	17·422
Water	12·481
	100·292 (H.)

A year after our discovery of this mineral locality, the present writer found two others which lie in similar recesses among the rocks some little distance to the south. These contain the ripidolite in much larger quantity, but here its only associate is actinolitic hornblende.

The *steatite* forms a thin vein in the actinolite of about an inch in thickness; it is unusually dense in structure, appearing to be fine-granular. Its colour varies from slate-blue to lavender. Its specific gravity is 2·797.

Its analysis yielded—

Silica	59·108
Alumina	·463
Ferric Oxide	2·65
Ferrous Oxide	3·251
Manganous Oxide	·23
Lime	·43
Magnesia	28·67
Water	5·164
	99·966 (H.)

A thin vein of *chalcopyrite* with *chrysocolla* was found in the gneiss to the south-east of Rhiconich (D and H.); this was traced eastward up the west shoulder of Foinaven to a height of about 700 feet, but it gradually thinned off. In its neighbourhood at the latter locality are to be found specimens of *micaceous-iron*. (H.)

An isolated mass of the gneiss which lies to the north of Sandwood, contains minute grains of *iserine* (H.): this is to be seen in large quantity in the form of a black sand, which lies on the surface of a dangerous quicksand, between the lake of Sandwood and the Atlantic.

A very small quantity of this sand is magnetic, and doubtless is *magnetite*; the non-magnetic portion yielded:—

Titanic Acid	10·6
Alumina	·072
Ferric Oxide	80·876
Ferrous Oxide	5·961
Manganous Oxide	·4
Lime	·952
Silica	1·5
	100·361 (H.)

Murchison notes that in a little burn adjacent to the Ferry House on the west-side of the Kyle of Duirness, the rock is charged with *asbestus* and *actinolite*. About a fourth of a mile north of this house, a flaggy hornblende rock yields platy *hornblende*. (H.)

The not infrequent approach to an actual separation between the felspathic bands and the hornblendic laminæ of the gneiss,—amounting occasionally to a looseness of structure,—conjoined with the manner in which the high dip lays bare to the air the denuded edges of the strata, expose this rock very directly to the assaults of the various agents and forces which effect disintegration. It accordingly occasionally presents scenes of ruin and waste. On the coast line south of Cape Wrath, the more soluble felspathic portions have been sapped out so that the dark hornblendic layers frequently stand isolated like enduring dykes.

In compensation, as it were, of the weakness thus induced, its layers are very generally laced and bound together by granitic dykes,—occasionally straight in their course and independent, but much more frequently anastomosing with each other, and tortuous in the extreme.

The components of these intrusive granitic dykes, whether they be rectilinear or tortuous in their course, are very similar; but they differ from those of the felspathic bands of the gneiss, in the following particulars The ampler size of each of the several constituents,—the invariable presence of oligoclase,—and the very frequent presence of the new black mica, which the writer has called *Haughtonite*.

Nowhere perhaps are those dykes which maintain a straight course seen in ampler development, or with their several constituents exhibiting larger crystals, than in the west spur of Foinaven.

The *orthoclase*, here in crystals the size of the fist, is of a translucent pink or flesh colour. It exhibits that peculiarity of structure which I will fully describe as occurring in the amazonstone of Ben Bhreck; but here the structure is on so large a scale as to be palpable to the naked eye, even at some little distance,—instead of calling for the aid of a pocket lens. The specific gravity of this orthoclase is 2·565.

The *oligoclase*, in crystals of a magnitude nearly equalling the orthoclase, is of a snow-white colour, and is beautifully striated. Its specific gravity is 2·634. P.*

Among these specimens I found a piece or two of *Sonnenstein*, which I do not remember to have seen previously noted as British. The inclosed scales of rubin-glimmer are disposed for the most part parallel to the face *c*; and (as is also the case in perthite) they do not occur in the albitic or oligoclastic portions.

The *Haughtonite* (H.) occurs rarely. It is in crystalline foliæ of nearly an inch in size, of a velvety blackness, and of an exceedingly high lustre. Its specific gravity is 3·032.

Its composition is

Silica	36·75	
Alumina	17·858	
Ferric Oxide	2·781	
Ferrous Oxide	15·175	
Manganous Oxide	·416	
Lime	·933	
Magnesia	11·166	
Potash	9·437	
Soda	1·247	
Water	4·232	
	99·995	(H.)

* Analysis deferred (though material prepared) wherever P. attached.

The finest specimens occur at a height of about 750 feet; and here the mineral seems to be in hexagonal crystals.

Much larger plates of the same mica were found in a granitic mass, which lay upon the side of the road on the south shore of Loch Stack. (D. Jo. and H) This mass appeared to have fallen from the cliffs which skirt this side of the hill; but whether it was from an intrusion vein or not, could not be ascertained; the block had the appearance of such. The mica was in plates some inches in size. These plates had much less lustre than those from Foinaven; they were of a brownish-black colour, becoming green on being crushed.

Their composition was

Silica	35·692
Alumina	20·086
Ferric Oxide	2·233
Ferrous Oxide	14·011
Manganous Oxide	1·
Lime	1·895
Magnesia	14·769
Potash	7·381
Soda	·529
Water	2·465
	100·058 (H.)

This mineral, from the large quantity of ferrous oxide which it contains, is somewhat prone to decomposition. In some localities this is indicated by the assumption of a green, and ultimately of a pale-green colour

In Sutherland and in Harris, however, it becomes brown or reddish brown, and opaque; exfoliating much, and softening at the same time.

A good illustration of this change is to be seen in a vein which occurs in the cliffs immediately after rounding the small promontory which lies to the south of the ripidolite locality, near Cape Wrath. (G. and H.)

This vein, which consists chiefly of *oligoclase*, is much decomposed and loosened in structure,—falling to pieces readily before the pick. Quantities of crystals of *Haughtonite* occur in it.

These, on their edges, are red, opaque, and palpably decomposed.

Their *apparently unaltered* centres yielded—

Silica	34·153
Alumina	14·837
Ferric Oxide	10·961
Ferrous Oxide	13·474
Manganous Oxide	1·384
Lime	1·809
Magnesia	10·307
Potash	7·93
Soda	2·136
Water	2·8
	99·791 (H.)

The centres even of these crystals, then, though they were of some size and of a dark-brown colour, may be held to be peroxidised; and it is probable that the disintegration of the vein is due to this absorption of oxygen, and consequent expansion or exfoliation.

Even where this mineral is absent, these veins may, in exposed localities, suffer change from an alteration in the *felspars* which they contain.

In the steep overhanging bank which skirts the south-east side of the Geo na Shermaig near Cape Wrath, both the orthoclase, (here fiery red), and the oligoclase, have an appearance which indicates incipient change,—namely, a certain amount of a greasy opacity of lustre.

The *orthoclase* had a specific gravity of 2·563. P.

In the case of the *oligoclase*, it could be observed that, besides its having a fatty lustre, the usual striation was very feebly marked, and that the colour was a dirty, instead of a pure watery-white.

Its specific gravity was 2·654 and it yielded—

Silica	64·538
Alumina	24·039
Ferric Oxide	2·307
Lime	1·206
Magnesia	·769
Potash	2·586
Soda	4·133
Water	·843
	100·421 (H.)

Here there is a decided loss of alkalies, and some loss also of the lime; no marked increment—certainly no *intrusion*—of magnesia is noticeable.

Of intrusive dykes differing from the types above noticed, Sutherland does not supply many varieties.

Along the north shore of Loch Assynt the gneiss in some few spots assumes, through weathering, an appearance very similar to that of an igneous rock; and at one of these localities, some four miles from the foot of the lake, I could not assure myself that it was not of that nature. It exhibited an appearance upon decomposition, strikingly like that of onion-basalt; but unfortunately at the locality it could not be seen whether there was any junction with a gneiss of ordinary appearance.

On the north shore of a small lake, which lies between Quinaig and Unapol, there are some dykes (?) of massive *white quartz*, strikingly auriferous in appearance. A little westward of Scoorie, a pale-green much-fissured *vitreous quartz* occurs in dykes with a northerly strike. This quartz much resembles olivine; its specific gravity however proved its nature.

The most interesting dyke which occurs in this gneiss, is that which occurs in the north shore of the little harbour of Rispond.

This is composed for the most part of *graphic granite*, the felspar of which is red. From the close arrangement of the skeleton quartz crystals, and the sharpness of their angles when cut in cross-section, this is the finest graphic granite of a red hue now to be got in Scotland; (the once famous locality,—at Portsoy,—no longer yielding any specimens of value). The felspar of this pegmatite has a fine nacreous lustre; and sections of the rock form an interesting object for the polarising microscope; as the "corded-structure," previously noticed, is finely displayed, and is pleasingly diversified by the interrupting quartz.

This dyke also yields masses and crystals of *oligoclase*, over the size of the fist;—these are highly lustrous, white or colourless, and translucent; they are finely striated; their specific gravity is 2·636, and their cleavage angle 86° 14′.

Their analysis yielded :—

Silica	61·848
Alumina	21·703
Ferric Oxic	3·37
Manganous Oxide..	·196
Manganese	·09
Lime	4·129
Potash	1·63
Soda	6·952
Water	·375
	100·293 (H.)

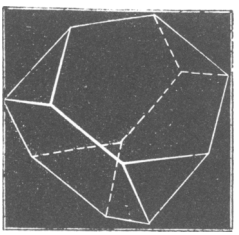
From the fine development of the striation of this oligoclase, its large character, and the purity of the specimens, this may be regarded as the best locality for the mineral in Scotland. The Rispond vein also carries *Haughtonite* of two appearances, and *magnetite*. (D. & H.) The three minerals occur in nearly equal amounts.

The usual appearance of the Haughtonite is in jet-black highly lustrous crystals, which show traces of a hexagonal form.

Having blasted the rock to some extent, in order to obtain masses of the graphic granite, sufficiently large for being formed into platters, I also, from its deeper-seated portions, procured the same mica in large plates, of a dull and somewhat greasy lustre;—the colour of these was brown. This induces the conjecture that in some cases the high lustre and greater depth of colour may be the result of exposure.

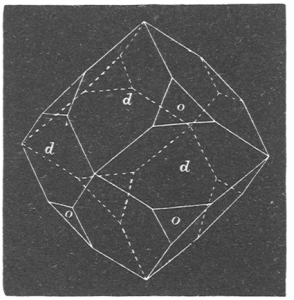
The black variety has a specific gravity of 2·99 ; it yielded :—

Silica	36·538
Alumina	22·282
Ferric Oxide	2·433
Ferrous Oxide	16·009
Manganeus Oxide	·784
Lime	1·249
Magnesia	10·
Potash	8·264
Soda	·794
Water	1·506
	99·856 (H.)



The *magnetite* occurs rarely in tetrahedral crystals with octahedral truncations; it is usually however in imbedded masses, up to half the size of the fist. These are extremely solid, appearing to be rough crystals,—fine flat cleavages always running through their whole extent. It is the finest massive magnetite of Scotland. The colour is blue-black, becoming brownish when powdered. Its specific gravity is 5·15.

Its analysis yielded,—P.



Nearer to Kean na Bin and opposite to the west end of Hoan Island, smaller granite veins of brick-red *orthoclase*, with beautifully striated crystals of *oligoclase*, also carry *magnetite*; it is here in octahedral, frequently in rhombic-dodecahedral crystals, with octahedral facets; though it is for the most part massive. Its colour is brownish-black, and it has little lustre.

Its analysis yielded :—

Ferric Oxide	89·632
Ferrous Oxide	4·241
Manganous Oxide..	·3
Lime	2·688
Magnesia	·9
Silica	1·9
Titanic Acid	·5
	100·161 (H.)

Having thus passed almost totally into *martite*.

The Conglomerates and Grits.

Overlying the well-marked and highly characteristic hornblendic rock, there rests in the most complete discordance therewith, a deposit of great thickness. This consists of beds which from bottom to top are characterised by the features which pertain to a ruin, without having any of the new or characteristic features which are essential to a new structure.

Of such a mass it may be possible to say from what, or whence it came; but, it palpably cannot bear much internal evidence as to *when* it was deposited.

External evidence may warrant its being *assigned* in age to a certain formation, if it is generally admitted that the evidence is clear, and if the inferences to be drawn therefrom be indisputable. Beyond or aside of this, all must stand as speculation.

Sir Rhoderick Murchison asserts that "these conglomerates are made up exclusively of the gneiss upon which they rest."

To this the writer must demur. While he is not in a position to deny that this many-bedded formation is in some part formed of the ruins of the underlying gneiss, yet there are two facts connected with its main bulk which are not altogether easy of explanation.

The first of these difficulties is the total, or almost total absence of hornblende in its substance, or among its rounded fragments.

The great prevalence of hornblende in the lower rock has been noted. To emphasise this. the following quotations from Murchison may suffice.

"The body of the rock is usually hornblendic. In ascending from the village of Loch Inver to Dunn Swordalan, the groves and veins of hornblende are so rife as to constitute the chief mass of the rock."

"Whether it be examined at Cape Wrath or at any point southward to Loch Inver, it has everywhere the same grey hornblendic basis."

Now, putting meanwhile out of consideration a fundamental *breccia*, the writer, who has examined the conglomerate carefully from the far north Scrishven to the flaggy beds in Rum, for the very purpose of detecting this mineral, never was able to find among its attrited portions either chip or mud of hornblende. He had also no difficulty in showing that what was in an isolated case pointed out to him as that mineral, was an earthy substance resembling granular chlorite.

Long ago Dr. Maculloch made the same observation. He writes.—"In no instance have I observed it to contain mica, nor, with the exception of red *jasper*, and that of the schist just mentioned, any substances but quartz and felspar."

As further evidence which bears upon this point, we will quote Cunninghame, who commences his description by saying "The red conglomerate is composed of variously sized and rounded fragments of massive quartz, *red jasper*, and common felspar, held together by a basis of the same. Mica occurs in minute scales, but is not abundant." Nowhere in his description does he mention the hornblende, though it is repeatedly noticed in his previous description of the gneiss.

Nicol says—"Throughout the whole of this range, the red sandstone is very uniform in aspect and mineral character. Most of it is a rather coarse grit, with fragments rarely an inch or more in diameter. The fragments are not much water-worn, and consist especially of quartz, *hornstone*, and felspar, the latter often decomposed. The grits are composed chiefly of rounded grains of grey vitreous quartz and red felspar, but apparently no mica." "The quartz is white and vitreous, or red ferruginous, or a kind of *blue hornstone*."

Professor Bonney lately writes—"I am not able to detect any indubitably fragmental mica or hornblende, and must be content to call the green mineral which is sparingly present in the matrix, and which is almost certainly a secondary product, by the vague term viridite."

In fact, neither can the lens-aided eye in the conglomerate, nor the microscope in slices of the fine-grained sandstones, find this substance.

That a finely comminuted hornblendic mud should have been held in suspension long after solid pebbles of quartz and felspar had settled to the bottom, would but be in accordance with the normal process of rock formation; but that no single crystal, chip, or unbroken pebble of the enormous quantity of hornblende which occurs in the mass of the reputed parent-rock should here appear, is marvellous indeed;—and little less marvellous is it that the alkali-charged felspar should have here proved more unalterable than the hornblende; a result demanded by the hypothesis of the formation being formed solely, or even largely from the debris of that which is at present the sole subjacent rock.

The second difficulty connected with the constitution of these gritty strata, is the very large amount of fine-grained porphyrys, and especially of colloidal silica,—as seen in jaspers, cherts, and vein-hornstones,—which goes to form its pebbles. This is vouched for in those portions of the above quotations which I have italicized. The parent-rock which yielded these jaspers and cherts must have been pervaded in no ordinary degree with veins and rents which had been plugged by colloidal exfiltration. Now the underlying gneiss is not only markedly deficient in such veins, but, so far as the writer's observations go, it is *absolutely* deficient in them,—if the one cherty vein near Cape Wrath be excepted.

How is this great and almost uniform admixture of colloidal silica to be explained, unless it be admitted that some series of rocks, of which no vestige has yet been found in the district, had yielded something towards the formation of the Conglomerate? The vast amount of this durable siliceous vein-debris, of itself vouches for the destruction of some great formation.

Dr. Hicks writes,—"These conglomerates and sandstones appear to have been shore or shallow-water deposits; and fragments of the underlying gneiss are abundant in them. Associated with these, however, are other masses which do not seem to have come from the immediate neighbourhood, or at least from any of the areas which I visited. These are chiefly bits of greenish, purplish, and reddish slates, schists, jasper, &c., similar in many respects to those found in the Cambrian conglomerates in Wales, and which were there undoubtedly derived from the underlying Pebidian beds. It is therefore quite possible that in some other areas, not far distant, representations of these Welsh pre-Cambrian rocks may be found."

These are matters which it behoved those who maintain that the so-called Cambrian Sandstones of the north are *solely* formed of the underlying gneiss, to account for, before they assigned correlative names.

There is another marked feature of the beds of this rock; it is that, though it may be said that the coarser conglomerate beds are to be found at the bottom of the series, as seen on the shores of Handa, the foot of Suilven, &c., yet the upper beds here and again, are of a coarse structure; and even when of a finer grain, occasionally contain large fragments, of angular form.

Dr. Macculloch says "It is rare indeed to find any bed which, however fine in its predominant character, does not somehow contain larger fragments. There is also no connection between the structure and the relative place of the stratum in the order of super-position; as the summits of the highest mountains, equally with the lowest beds of which they are formed, present extensive masses in the conglomerate."

The very summit of Teallich (Kea Cloch)—the highest, as it is probably the uppermost point of the whole formation,—the writer found to consist of a very coarse and loose-structured grit.

While this intercalation of coarse-grained or conglomeritic beds is a recognised feature of other formations, it is one which is exceptionally difficult of explanation when the absence of one of the ingredients of the "parent rock" is considered,—if the lower gneiss be the only possible parent rock.

It need hardly be said that no minerals occur in this formation,—veins being unknown in it; and that no fossils could be expected in it. Nicol, however, mentions having observed on the south cliff of Quinaig a few traces of *azurite*.

Its true correlation with the rocks of other localities must therefore depend, firstly, upon a perfect acquaintance with the features and the ages of those formations out of which it was formed, as well as of those between which it is intercalated. Can it be said that such acquaintance has been attained to?

The Quartzite.

Two things are indisputable as to this rock;—the first, that it overlies the conglomerates unconformably;*—the second, that the myriad worm holes which pervade it, prove it to have been once the yielding tenement of animal existences.

The metamorphism which has agglutinated its grains is complete; but these grains being of silica and almost of silica alone, metamorphism could out of it form but one mineral body.

No veins occur in it; and it it had almost to be written of it as of the conglomerate—"no minerals occur in this formation." It is not altogether so, however.

The formation, if we regard it as an independent one—which may prove not to be admissible,—has, where it is in its most perfect development, been generally divided into two great series of beds, which are separated from each other by a number of beds of "limestone." This is a reading, however, which has far from met with universal acceptance. What the writer's explorations enables him to vouch for is,—

That at the far-southern limit of the formation, an almost vertically-tilted quartzite will be found immediately opposite to Kyle Akin in Skye,—with lime neither visibly beneath it, or overlying it.

*I have been much surprised to read, in a foot-note to an excellent paper by Professor Bonney on the Petrology of the neighbourhood of Loch Maree, the following—"My friend Mr. L. Ewbank, tells me that near Dundonnel (Little Loch Broom) he traced a gradual passage from the one to the other," (*i.e.* from the conglomerates into the quartzite) * * the break therefore is probably rather local than general." My surprise was occasioned not merely by the conclusions of Murchison,—and, *as regards this point*, it may be said, of every one else,—being set aside in a foot note, and upon the evidence of of certainly a comparatively unknown man, but from the *Dundonnel district* being quoted as proving conformity. Though I have not examined the district named to nearly the same extent as I have done those to the north, I have no hesitation in saying that it exhibits a very much more highly marked *unconformity* of the formations, than is seen in the northerly districts. In referring to this point in the previous number of the Magazine, when speaking of Quinaig, I stated that the general dip of the conglomerate might be put at 5°, and of the quartzite at 7°. Now, as we proceed southward, the dip of the conglomerate increases, as does that of the quartzite, but that of the latter does so in a very much greater degree. In other words, the amount of diagonal denudation of the conglomerate is much greater in the southerly than in the northern districts. To anyone who doubts this, I would recommend a study of the manner in which the quartzite sweeps up over the denuded, and at some points, actually fretted beds of the great hill Teallich: or a consideration of the sections to the south of this, given by Geikie in the XVII vol. of the Quarterly Journal of the Geological Society.

Professor Geikie and I have, in companionship,, gone over a not inconsiderable portion of this northern district; I have seen his pencil working, and I can vouch for his accuracy. I can also vouch for his caution, for he has asked me to climb to doubtful points, and trace out flexures;—demonstrating to him while he drew beneath. As to the "break being rather local than general," I have only to say, that, while I have seen one or two points where there was an *apparent* conformity when examined *along the strike*, I have seen no spot in the whole distance between Kyle Sku and Loch Torridon where there was not a palpable unconformity, when examined *at any angle thereto*.

That at Loch Kishhorn, a high-tilted mass of limestone shows quartzite neither below it or above it;—though here an underlying quartzite may have been faulted down,—the fault forming the Loch.

That from Loch Broom to Loch Urigill there is a continous belt of quartzite conformably underlying the lime, but none above it; (unless a wedge-shaped mass to the south of Loch Urigill, which, however, seems to have been faulted there, be in that position). Throughout the whole of this stretch the lime is either immediately overlaid by the flaggy schists of the upper gneiss, apparently conformably, or a so-called "igneous rock" intervenes,—this latter being generally conformably interbedded.

That the fair reading of what is visible in the Loch Erribol district is that there is both a *lower* and an *upper* quartzite.

But he maintains that the ground in the Stronchrubie, Ben More, and Loch Ailsh district, is so concealed by vegetation, so cut up by faults, and so dislocated and fractured by igneous intrusions, that no conclusions can be drawn therefrom:—and he will even say, that those who maintain the correctness of the reading referred to, have neither shown that they have sufficiently examined this district, nor have they submitted sections thereof such as entitle them to found upon it, or which could satisfy others that this is a district which can be referred to as proving their contention. The easily accessible and the clear sections have been cited as sufficient;—but it would have evidenced more thorough work, if the doubtful and the difficult parts had been unravelled. Had this been done it would also have evidenced a greater amount of that deference to the opinion of dissentients, which courtesy demands; seeing that this district has been brought forward by these dissentients as supplying proofs and furnishing grounds for a totally different interpretation. The extreme difficulties of this district stand also as an abiding rebuke to the arrogance of those flying visitants, who conceive that it is a question which can be pronounced upon after a sojourn of a week in the country.

Much of the difficulty connected with this district would be overcome if it could be clearly shown whether a fault exists between the Maolack-Corry lime and the quartzite of northern Bræbag. The writer examined the ground for half-a-day, he could see no evidence of a fault, and regarded the line of quartzite cliffs as a wasted outcrop. He therefore believes in an *upper* quartzite; but he must insist upon the obscurity of the ground even here, and upon the many difficulties which occur in the troubled neighbourhood.

In presence of what is here seen, and what is *not* seen, he is far from favourably impressed with the general style of work, or the candour of those who can write—arguing on the one hand,—"There may be a few sections difficult to read, but when time and labour are given, they are all clear;"—or of those who, unflinchingly adopting the opposite view, reiterate assertions as to there being everywhere "a clear order of superposition," and "a regular and unbroken ascending order."

If the reading of both a lower and an upper quartzite be the correct one, and the system be considered as a whole, it has to be said of it that there are localities where it is so condensed in space, that quartzites and limestones alike have shrivelled into a bulk not exceeding the thickness of the face of an average quarry; and where the individuals of the many layers are reduced almost to sheets. At other localities again, there is such an ample development of all, that they separate from each other by miles in distance, and are separated geographically by stream, and lake, and valley. In its thinnest and most condensed development it is represented by cliff-escarpments possessed of noble features; while in its most developed, the larger individuals of the series present themselves as lofty hills, and split up into beds of marked dissimilarity of feature.

If there be two great series of beds of quartzite, that held to be the lower is everywhere persistent, but it is much the thinner. This lower bed is so positioned as frequently to form the summits of lofty hills;—but from consequent greater local denudation, it there occurs as a sheathing-cap, of a thickness which is far from as great as that of the series of beds which have been held to lie above the lime.

This quartzite contains the characteristic "worm-holes" very much more sparsely than do the "upper beds." It is frequently highly-stained with ferruginous matters, which gives it a purplish-brown tint. The colouring matter of both quartzite and conglomerate has been termed "ferrite"; but as this was the name given by the late Wallace Young to a magnesian pseudomorph of olivine—its use here is inadmissible. Where the rock is deeply stained, the "worm holes" are colourless. It is also to be observed that in almost all cases the sand-grains which fill these holes are smaller than those of the general mass of the rock. It would almost appear that the slimy matter which the "worm" left as a sheath to the tube, had acted as a species of filter, in keeping back any but the finer particles of sand from passing in to plug the spaces left vacuous after their own decay.

This "lower quartzite" contains within it, in one hill, numerous beds of porphyry.

One of these beds is stated by Murchison, on the authority of Peach, to lie *beneath* the conglomerate, and between it and the gneiss.

The locality where Peach observed this, is the south-west cliffy frontlet of the Hill of Canisp, a little east of Lochanfad.

Looking from the edge of the overhanging cliff, this position did not appear to the writer to be rightly assigned to this bed of porphyry. A little beneath the summit of Canisp, he found several beds of this porphyry intercalated among the beds of the quartzite. About 300 feet below the summit, on the east side, these beds come to the surface beneath the turf, and have suffered disintegration :—the paste of the rock presents itself as a greasy clay ; and the previously-imbedded felspathic crystals, but slightly altered, lie loose, and may be gathered in handfuls.

This is one of the most striking porphyrys in Scotland.

A structureless paste of a buff or dull-brown colour is studded in single and isolated arrangement with crystals of a bright brick-red colour, commingled with others of a pale ochre-yellow tint, and with minuter ones of a dark green.

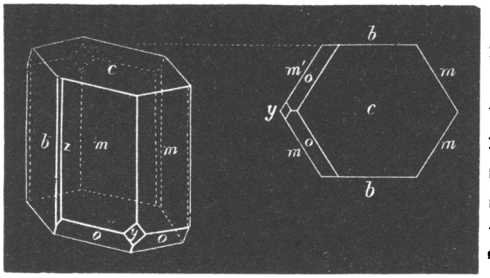
The red crystals are from half-an-inch to an inch in size ;—the white ones not half of these dimensions ; while those of dark-colour are under an eighth of an inch.

Not unfrequently the red crystals are surrounded by a sheath of the cream-coloured material, of nearly an eighth of an inch in thickness ;—and very rarely indeed, the red crystals inclose those of the pale tint. The dark crystals occur imbedded both in the paste and in the pale crystals, but not in those of red tint,—these therefore would appear to have been the first formed.

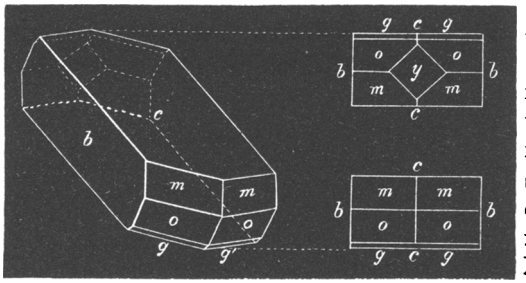
The red crystals are *orthoclase ;* even the loose crystals of which seem to have suffered no decomposition.

These yielded :—

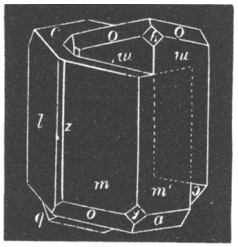
Silica	63·538
Alumina	17·363
Ferric Oxide	1·867
Manganous Oxide	·384
Lime	1·335
Potash	12·932
Soda	1·695
Water	1·123
	100·237 (H.)



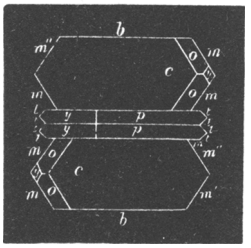
The crystals cannot be freed from the matrix so as to be figured; but those to be gathered from the surface of the spongy clay are free from adhering rock, and are of well pronounced forms. They are usually of the form in the first figure, *c m b z o y;* but the face z is seldom present.



In many, the faces *m b* are much more elongated than in the figure; and one crystal was got in which these faces were so much shortened that the crystal was as drawn in figure 2. This is hemimorphic as regards the face *y*. From the very unusual dominance of the faces *c*, this crystal much simulates one of red *stilbite*; and either of the terminations of the crystal, as seen in the drawing, might be taken for *stilbite*, were it not for the presence of the faces *g*. Indeed, as the writer has already shown that in *stilbite* a face occurs in the very position of this face *g*, and as this new face might have been hemihedal, the presence of the face *g* here, could not of itself show that this was *not* a crystal of stilbite.



Twins of *c m b z o y* occur somewhat rarely; they are interpenetrating, as in the figure.



There are also rarely to be found most interesting apposition twins of the same form; these are separated from one another by the interposition of a revolution-twin of *albite* (?) of the form *m p y l t*. This medial twin is not altogether so simple, or single in form, as drawn in the figure; consisting in parts of a number of smaller crystals,—all lying the same way however. The difference of colour of these crystals makes this a very singular arrangement.

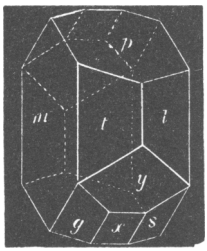
The *c* cleavage of these crystals is very eminent; and it sometimes discloses a very singular structure in the crystals. The annexed drawing exhibits this. The general mass of the crystal is traversed by a system of transverse lineations, which will be more fully described afterwards; and at either end of the crystal there is a quantity of matter of a lighter tint of colour,—possibly an intermixture of *albite*,—disposed in a plumose and a tassel-like arrangement. The surface of the cleavage-face is of brilliant lustre, but the material of these singular intruded structures, is lustreless.

The difference in the arrangement of the intruded substance, at the opposite ends of the crystals, is perhaps hardly sufficiently marked to indicate an opposite electrical polarity in these ends.

I have, in the above, called the cream-coloured crystals which are associated with the red orthoclase, *albite*. In a paper upon Scottish Felspars which was laid before the Royal Society of Edinburgh, I termed them *oligoclase*, but stated that they might prove to be *albite*. My chief reason for then considering them to be *oligoclase*, was that they manifestly decompose more rapidly than the accompanying crystals of *orthoclase* do; and we know that, as a rule, *albite* is the more durable mineral;—indeed I shall afterwards have to show that *albite* may be formed by transmutation, out of *orthoclase*.

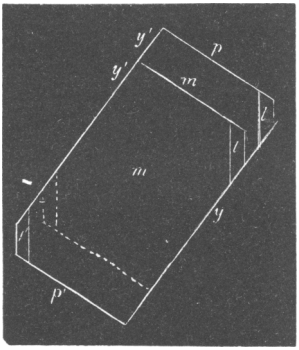
The loose and possibly slightly-weathered crystals of cream-colour yielded on analysis.

Silica	64·439
Alumina	20·436
Ferric Oxide	·877
Manganous Oxide	·384
Lime	1·333
Potash	1·135
Soda	9·962
Water	1·463
	100·029 (H.)

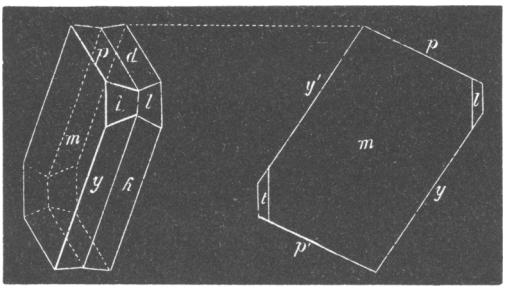


This analysis does not clearly indicate to which of these minerals—*oligoclase or albite*—the crystals belong. Certain of the crystals show striation, while others do not.

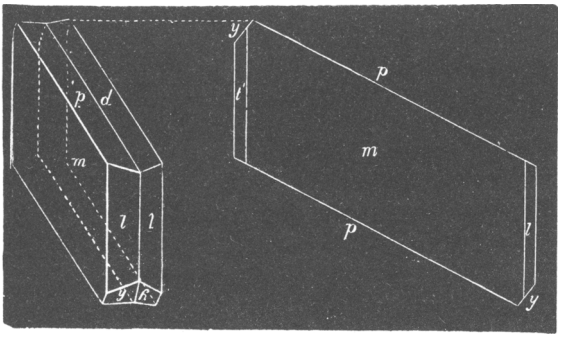
The forms in which they occur are fairly well pronounced;—but the faces of the crystals are too dull for measurement; so that no absolute determination can therefrom be obtained.

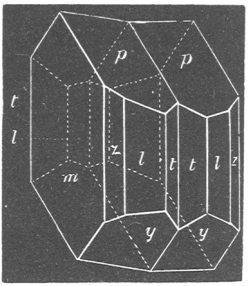


I got but a single *simple* crystal; it is in the form *p m t l g x s y*. The form *p m t l y* also occurs in *pairs* of simple crystals, attached to one another by the face *m*, but with the faces *p* not on the same level; being as drawn in the second figure.

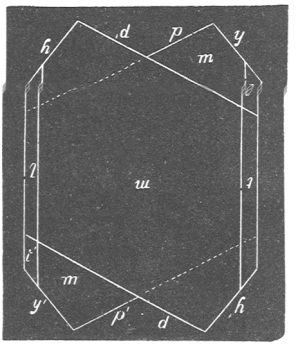


The same form also occurs in hemitrope crystals; these, from a greater or less dominance of the faces *p* and *y*, present the marked difference in form which is shown in the adjoining figures.





There are also hemitropic twins, of the form *p m y s l t*. In these twins, one half, or one individual, as the case may be, exhibits striation,—showing itself to be composite,—while the other does not do so. A single twin of revolution round a vertical axis, of the form *p m y t l*, was found ; —a plan of this is given.



All the above are forms which accord with that of albite ; but they also equally accord with the form of oligoclase.

The crystals of this felspar which lie imbedded in the rock, do not show traces of weathering; they have the colour and lustre of bleached wax. They were prepared for analysis,—P.

Sections of these crystals exhibit beautiful striation in the polarising microscope.*

The dark crystals are apparently *augite;* possibly some are *pinite.*

Murchison, speaking of the above porphyry, remarks that "no igneous rock has yet been observed to be associated with the lower quartz rock of Assynt;" and that "the large crystallised porphyry clasped round the lower part of Canisp, is interposed between gneiss and the Cambrian," and ushers in the accumulation and deposition of its coarse sediments; and that "Thus one of the earliest coarse sedimentary accumulatioms in the crust of the globe seems to have been ushered in by the eruption and spreading out of porphyry, associated with red conglomerate." He elsewhere says that this porphyry may be considered for the present to be characteristic of the Cambrian age in the North West Highlands.

Referring to the above, Nicol remarks, that "in 1859 he found that this very beautiful porphyry not only breaks through the quartzite of Canisp, but forms a mass more than a mile in diameter—in the same

* A piece of the rock was got which had a very perfect and fine twin, imbedded in it, showing beautifully the angle of *t* on *t*. The measurement of this would have settled the question as to whether these crystals were albite or oligoclase; it was therefore sent to London to be sliced, but it was broken through the carelessness of a workman.

"lower quartz rock" within a few hundred yards of the Inn of Inchnadamff.

Referring in the first place to Murchison's statement, I have to say that the only spot in which I could see it to "clasp round" in any whit the lower part of Canisp, was "in the depression between Canisp and Suilven." This was at a spot where, through absolute denudation of the "Cambrian," the quartzite lay upon the old Gneiss; and this porphyry, so far as I saw, was solely in loose masses which might have fallen from the interbedded bands above. I have indeed, *nowhere* seen any of this conglomerate in connection with the "Cambrian."

I have already borne out Nicol's statement as to its association with the quartzite; though I have never seen the point where it "breaks through the quartzite," nor have I seen the mass in the neighbourhood of Inchnadamff.

It is to be regretted that Nicol has here (as he has at other times) imitated Dr. Macculloch in a want of precision in defining his localities. A locality is a witness, which the opposite side has a right to see and examine—or its evidence cannot be taken. As it now stands, however, it must be held that this "large crystallized porphyry," if characteristic of any formation, is so of the Lower Quartzite and *not* of the Cambrian.

The "Upper Quartzite" is apparently more highly metamorphosed than the lower—the grains being almost agglutinated.

In one spot near the summit of Ben Uarran I observed secondary quartzose veins traversing it, in which there were crude *rock crystals.*

In the cliff face which overhangs the little lake which lies between Ben Uarran and Meall Naiarloch, I found *psilomelane*, which acted as a cement to a breccia of quartz.

This "upper quartzite" has, in the hill of Bræbag, a thickness of nearly 1,500 feet, and it is here very distinctly bedded. On its south-west foot, overlooking the Fiar Loch, there occurs an interbedded sheet of a dolerite, very similar to one that occurs at Stronchrubie, in the lime. *Labradorite and augite* are evident in this rock.

A bed which occurs in one of the craggy knolls which lie between Hope and Heilim ferries, exhibits where weather-polished, a structure which speaks of such an arrangement of particles as would have resulted from the motions of mollusks or annellids among its grains when these were subject to ready displacement; the feebly-defined laminæ being looped up in festoon-like gatherings.

The "Limestone."

Overlying the "lower bed," or intercalated, as has been held by some, between the two great series of beds of quartzite, there lies a deposit of limestone.

This deposit, which has frequently been described as a single bed, in reality consists of several beds. These differ considerably from one another in appearance, and they are separated into a thin lower and an upper set by a bed of silicious rock of a fawn or slightly ochrey colour. This very much resembles a bed which underlies the lime,—one which from its containing ill-defined organisms somewhat resembling fucoids, has received the name of "the fucoidal bed."

As these intercalated strata of limestone have been correlated with a set of beds which lie in uncovered exposure in the district of Durine, and as all recent speculation as to the age of the whole series of the Sutherland rocks has been based upon the occurrence of Silurian fossils in this latter deposit, it is needful to consider the geognostic features and the chemical composition of these limestones somewhat in detail.

The occurrence of two sets of beds of quartzite has been detailed above, in terms which imply little doubt as to the accuracy of the fact, in the north of the county. Near Hope Lodge, the system of beds is so amplified by the intercalation, or perchance increase in thickness of beds which are of a gneissic structure, that, *if there were no suspicion of the southerly continuance of the Whitten Head fault*, the sections there may be read as showing that here, the upper bed was separated into three distinct beds; and that the quartzite series in this district shades off into the overlying gneiss.

In like manner it has been held by some, though the statement has met with vigorous opposition, that there occurs an upper and perfectly distinct set of beds of limestone; and that these overlie the chief mass of the upper quartzite.

The writer believes that much of the difference of conclusion which has been arrived at on the first point is due to local amplifications, or local thinning away of the beds, not having been duly considered.

As regards the second, he holds the opinion that the upper limestone bed occurs among the beds of the upper gneiss as distinguished from the quartzite.

The argument that this so-called *upper bed*, the position of which is not pointed out except at one spot, has at others absolutely thinned off, is in its necessary consequences far from a satisfactory one; for while *that* argument might in itself be granted, it is stretching probability beyond all reasonable limits to require that the very characteristic rocks or series

of rocks which accompany the lime, as seen at that one locality, as well as all the beds which intervene between it and the quartzite, *should have likewise disappeared.* The so-called upper lime of the quartzite has been searched for in several of what were considered likely spots for finding it or its associates, but wholly unsuccessfully.

Were it not for the intervention of the gneissic beds, we should, however, admit that the amount of amplification or spreading out of the true limestone series is elsewhere so great, that comparatively little more would bring this upper lime within its bounds.

The system is for miles of the long stretch of road between Knockan and the Loch Broom shore so condensed that it forms but a low cliffy bank to one or other side of the road. Standing here upon the "upper gneiss," where its first beds lie upon the lime (there is here no upper quartzite), we can spring right over the low cliff, and light upon the road cut in the quartzite; or a little further south, standing upon the top of the quartzite, spring over its whole thickness of perhaps ten feet, on to the underlying conglomerate. Nay, so "condensed" are both of these rocks here, that it is quite probable that a spot might be found where the observer might stand upon the upper gneiss, and in half-a-dozen paces find himself upon the Torridon Sandstones.

An inspection of the lime and quartzite here, however, will shew that they consist not of one bed, but of many; and when we follow them along their grand expansion in Knockan and Elphin, we are guided to the Stronchrubie range of cliffs, the scalped summit of which stretches back for miles to the east:—for so many miles that *visibly* they cover more than half the ground which intervenes between their lower members and the so-called "upper bed" at Loch Ailsh.

Another cause to which the discrepancies which are found in the statements of writers is very probably due, is the manner in which the lime, quartzite, and indeed the whole district in which they occur, is cut up by intrusive rocks. In certain localities there appears merely a bed of very uniform but very inconsiderable thickness, which lies among the layers of the lime itself. But here and again an igneous rock—it may not be the same—presents itself in enormously augmented bulk; and, perhaps as a petrological consequence, it is so markedly altered in structure and appearance as not to have been always recognised as having any connection with that in the lime itself. Beds of lime, which are separated, as at Stronchrubie, by a sheet of igneous rock of half-a-dozen feet in thickness, are not unlikely to escape recognition when separated thousands of feet from each other by bossy amplifications of that igneous rock; and when they have moreover become highly metamorphosed by the greater amount of heat which that ampler bulk must of necessity have evolved.

Moreover, seeing that the igneous rock of Stronchrubie is much of the the nature of dolerite, while the larger masses of eruptive rock tend much to the character of a quartz-porphyry, a larger amount of proof that they belong to the same intrusion may be demanded, than can be disclosed in a tract of country which is swathed in the verdure which is the product of a limestone substratum. And, if the proofs of such connection be deficient, then the identity of the associated limestones or marbles must in fairness be said to be open to question.

Throughout the whole of its range from north to south, the features of this limestone do not much vary. When fresh broken it is grey in colour, and it weathers to a dull yellow tint. Some of the beds, as at Stronchrubie, and to a smaller extent at Elphin and Knockan, rarely contain thin bands of flattened nodules of pale red *chert*, arranged in close proximity, like chalks in flint. The rock is one which is not much affected by atmospheric influence,—except where here and there running waters cut "sinks" and "swallows." It nowhere exhibits pinnacles or turrets, or a crumbling structure, but rears its escarpments aloft in sheeted cliffs, massive in form and enduring in appearance. And that appearance is almost unvarying.

Calcitic veins at the Heilim quarries contain ill-developed crystals in "dog tooth," "nail-head," and other common forms. With this single exception it nowhere presents a variegated appearance.

In no part of its extended stretch has this limestone yielded fossils. White calcitic bandings somewhat resembling organisms were in a single case obtained from the banks of one of the streams which enter Loch Stack from the north east. They were found by Dr. Joass, Mr. Dudgeon, and the Author. These calcitic markings were ill-defined, and were probably chance segregations of the purer portions of the calcareous matter.

The composition of this limestone is very similar, from whatever locality it is taken. It is fortunate that an extensive series of analyses of it have been recorded, *before* the differences of opinion as to its age, and its identity with other masses in the country, had arisen.

These analyses must therefore stand as unprejudiced witnesses in determining its nature.

Dr. Thomas Anderson many years ago published, in the Transactions of the Highland Society, the following analyses.

	$\dot{Ca}\ddot{C}$	$\dot{Mg}\ddot{C}$	$\ddot{Fe}_2\ddot{Al}_2$	$\dot{Si}$	Total.
Erribol	51·04	41·36	·9	6·41	99·71
Achmore (pale bluish grey) ..	53·51	43·20	·35	2·68	99·74
Do. (darker, more crystallised)	54·88	41·85	·22	3·	99·95
Stronchrubie (white crystallised)	45·79	48·72	1·33	1·77	97·61
Do. (dark grey)	48·	42·01	·48	7·51	98·93
Knockdhu, Elphin (bluish grey)	41·58	33·47	1·92	23·07	100·04
Do. (greenish grey)	53·77	41·01	1·08	1·56	97·42
Kirktown	50·21	41·22	1·57	6·	99·
Do. (grey and earthy).. ..	51·33	41·08	·74	6·42	99·57

Throwing out of consideration the silicious and aluminous contaminations, the averages of carbonate of lime and of carbonate of magnesia are 50·01, and 41·56 respectively. These, brought up to 100 parts, give

Carbonate of Lime	54·61	54·35
Carbonate of Magnesia ..	45·39	45·65

The second percentages are those of Dolomite—so that *the rock is not limestone*, but an exceedingly typical *Dolomite* throughout.

The Marbles.

Sir Rhoderick Murchison holds that one of the members of the quartzite series is an upper limestone—that is, one which overlies the the upper quartzite. He gives to this a sweep which, passing from the south eastward of Loch Ailsh extends far behind Ben More, and even north eastward of Ghorm Loch. This in its northern portion, however, he states upon hearsay evidence alone.

As the calcareous rock of Loch Ailsh is in almost every spot a *marble*, it fails to be considered along with these.

The marbles of Sutherland were worked for some time in the neighbourhood of Loch Awe in the Inchnadamff district; but, on account of the presence of gritty particles which cut the polishers, the attempt to work them was abandoned.

This defect is much to be regretted; for, judging from specimens which were at the time polished as samples, and from such fragments as can now be picked up at the old workings, these marbles were not only characterised by pleasing tints and well disposed markings, but they were much more variegated in their characters and mode of colouration than is usually to be looked for in a single locality.

From the neighbourhood of Ledbeg, the writer obtained yellow and green serpentinous marbles, along with others of a chocolate brown, and of a lively red.

Most of these specimens, however, when placed in acid, left behind rosette clustres of doubly-terminated quartz ;—these sufficiently account for the destruction of soft polishers.

Little of the marble here is spotless or devoid of colour.

Now the question is, what is this marble? It lies very much in the strike of the great escarpment of Stronchrubie, about *four* miles distant; but it itself is a mere "bunch," which is pinned in between a trap dyke and the red quartz-porphyry of Cnoc na Strome. Have these metamorphosed it? or are we to assign the change to the large mass of the so-called "igneous rock" which forms the hill of Cnoc an Ledvui? The rock of this hill cannot be traced into actual contact with the marble, for the ground is covered; but if not from it, it is difficult to see from whence the serpentinous ingredient can have come.

From a point immediately to the south of the Ledbeg river, as it issues from Loch Borrolan, the writer has traced a pure white marble, which occurs, however, only in rounded and isolated patches, for a distance of one and a half miles to the north-east shores of Loch Urrigil; it is again to be taken up on the south-east shore of the lake, and it continues in a similarly interrupted manner as a series of deep pots, each supplying food and shelter to a birch sapling. It is lost sight of, eastward of one of the faults of a let-down wedge of quartzite, in the near neighbourhood of Elphin.

At one part of this sweep, near the north shore of Loch Urrigil, it is in close association with, though not immediately overlying a highly vitrified quartzite. Which member of the quartzite this is, is not clear, as a north and south dyke-filled fault cuts the burn of Urrigil.

In no part of this sweep is the igneous rock to be seen, and an extensive bog entirely hides everything to the eastward.

From the close approximation of crumbling *upper schists* in the banks of the Ledbeg river, nearly as far west as Ledbeg,—from evident indications of a fault in the line of sinks east of Loch Borrolan,—and the close approach of the upper schists in the hill Meoirburn, there can be little doubt that the marble of the bog between Lochs Borrolan and Urrigil is the same marble as is to be seen at Loch Ailsh, let down by an extensive east and west fault.

The Loch Ailsh marble is first to be seen immediately to the north of the mail-coach road. It is here in two distinct beds;—the lower, a pure white saccharine marble, is not to be distinguished from that of Loch Urrigil. This is separated from the upper by a band of muddy chert, which apparently contains obscure organisms, and also by a bed which has been called hornstone porphyry.

The overlying bed is not perfect in its metamorphism, and approaches in character to a granular limestone.

The course of these beds is very obscure in their northern extension, they are separated to a great extent. That which is truly marble apparently sweeps round to the south of the hill Scoonan. Marble can be seen in a large "sink" immediately to the south of the col, between that hill and the first heave of Bræbag. This col is formed by a north and south fault which cuts through the ridges.

In this col, loose slabs of a rock much resembling the fucoid beds, appear; and though neither limestone nor marble is seen in association with these yellow slabs, yet the close proximity of the marble at the foot of the hill is a strong argument in favour of its being merely the altered limestone.

Scoonan, under which these yellow beds dip—or which cuts them off—is itself the "igneous rock."

High upon the eastern extremity of its ridge, the out-crops of quartzy schists, perfectly similar to those of Loch Ailsh, are seen. These out-crops have fallen shattered, like a curled-over breaker, into a peat bog;—this not improbably conceals some washed-out beds of the lime. The appearance here is unique;—there are two or more of these ruinous out-crops, with finely jointed and squared slabs of white rock impacted in the black paste into which they have toppled over. It might thus, from its position, be affirmed by some that here the igneous rock of Scoonan "occupies the place of the limestone."

An escarpment of the yellow beds can be traced along the north bank of the Strathan Water, due south of Dhu Loch More, and lime is again met, with a north easterly dip, in the balloch or great col between Coineveall and Bræbag. If there be not a fault it would plunge under the huge quartzite cliffs of Ben More, and would sweep north westward in the precipices of Ben Harran in the direction of the outcrops which occur north of Inchnadamff on Croc an drien.

Whether it is continuous with these or not cannot be *absolutely* determined, on account of the fault which there cuts the lime and inclosing quartzite off from Ben Harran; but some thin beds first sweep up among the cliffs, and ultimately curve over and downwards to the fault. This curvature is not so much a flexure of the quartzite, as the result of a number of small faults which radiate, as it were, from a centre positioned below the centre of the hill.

The other—the upper and easterly bed of the limestone,—is to be traced to about the north end of Loch Ailsh, along or above the eastern shore.

It is immediately overlaid by highly gneissose flags; these, though having some slight resemblance to quartzite, are evidently members of the upper gneiss.

From this point Murchison says that it "sweeps round to the east and north of the mountain of Ben More, and extends up the valley of the Cashley to the side of the Stack of Glen Coul."

Immediately north, however, of the spot where the lime is lost, the igneous rock forming the Eagle Craig and the craggy hills S.E. of Ben More, comes in.

There is probably no part in the whole stretch between the Whitten Head and Loch Kishorn, in which the country is so cut up by great faults and troubled by igneous intrusions as is this. It cannot be admitted that it is a locality which it would be at all safe to adduce for the the establishment of "a regular ascending series"; and while it has to be noted that there is elsewhere,—*i. e.* in the untroubled districts,—no evidence whatever of a true upper-limestone *of the quartz series*,—that is, superior to all the beds of quartzite,—it might also be held that as far as stratagraphical position is concerned, the limestone of the col, and the marble of Scoonan, may be but members of the series which occur elsewhere condensed, and are here separated widely from the other members, either by local amplification of the thickness of the quartzose beds, or by the interstitial intrusion of the masses of igneous rock. These are here very much greater in bulk than anywhere else along the whole line of their occurrence.

If it be held that the lime which occurs in the col between Bræbag and Coineveall is an upper-limestone, *because* it manifestly overlies the quartzite of Bræbag, and *because* the quartzite of Bræbag overlies the Maolackcorry lime, then it must be held that there is also a still higher quartzite; for the whole of the quartzite of Ben More, probably 1600 feet in thickness, overlies *it*. This is a rendering which is quite admissible, as Cunninghame long ago showed that at Drum Tungi, above Heilim, there was such an upper quartzite; and the close association of five beds at this locality would reduce all to fall within the writer's view, that any *upper* lime or *upper* quartzite is but a local opening up of what is elsewhere a condensed system.

No lime overlies the quartzite of Ben More proper. The writer found that the sharp ridge of the hill all along the "Saddle" and "Bad Step," was formed by the edge of the uppermost band of the quartzite, which was padded with a plastic clay; and this clay when dug into was found to pass into an unctuous margarodite schist.

If any lime occurs where Murchison places it,—away to the back of Ben More, it must, like the Shinness lime, be a member of the upper gneiss.

The character of the rock of the hill which lies immediately west of —that is below the Loch Ailsh lime—is very obscure. It may be described as being intermediate in appearance between the so-called "igneous rock," so frequently mentioned, and a chloritic schist; whatever it be, it evidently separates this lime from the true *quartzite series of limestones*.

It has to be mentioned that the present writer has questioned numerous individuals, and especially those who surveyed the route of a proposed road from the head of Loch Shin to Loch Coul, as to whether there was any lime in this district; he invariably received a negative reply.

An analysis of the Marble of Ledbeg is given by Dr. Anderson. He obtained

Carbonate of Lime	91·32
Carbonate of Magnesia	4·74
Alumina, Ferric Oxide, &c.	·2
Silica	4·34
	100·60

It therefore is a true marble, and differs entirely from the dolomites of the quartzite.

In the first edition of Phillips' Mineralogy, *schiefer-spar* is noted as occurring in the limestone of Sutherland;—it may have been from one or other of the marble quarries, noted during the time when they were being worked.

The Durness Limestone.

After much contention it has now been agreed* that this is a fragment let down by faults which intersect at three points. It has been let down

* It is not altogether easy to make out whether Sir R. Murchison ever was among those who so agreed; nor indeed, is it easy to arrive at any conclusion as to his views. Writing in 1858 we find that on one page he says regarding them—"the ascending order of the quartz-rocks and limestones is everywhere the same as in Assynt, *i.e.* a strong band of limestone interposed between masses of regularly stratified quartz-rock." Two pages further on he writes—"The reversal by which the Durness limestone is thus placed in a trough of quartz-rock and underlying limestone, has been manifestly occasioned by a great upheaval of the old gneiss when acted upon by eruptive forces, of which clear signs are manifested in the adjacent Bay of Sangoe. There huge bosses of black hornblendic and hypersthenic rock stand out with serpentinous coatings,—the courses of the limestone in their vicinity being singularly altered, mottled and dolomitic, —"there is no doubt that the limestone and underlying quartz-rock of Durness occupy a trough." In 1859 again he writes—"This tract has been subjected to so many dislocations, that in one line of traverse only, or that in which my former section passed, can it be viewed as unbroken,—no other section represents a trough. On the contrary, the limestone is thrown abruptly into contact with the old gneiss of Kennabin on the north-east; and constitutes a narrow wedge-shaped mass between that fault and an equally large one which truncates it against the old gneiss on the west side." But other observers, *e.g.* Harkness and Nicol, have shown that so far from being "unbroken" in the line of Murchison's first section, the lime is cut up into quite a multitude of fragments along that line. The theory of a great upheaval of the old gneiss at Keannabin by huge bosses of eruptive rocks in Sangoe bay, which simultaneously altered the limestone, I shall advert to after.

nearly horizontally; but, having fallen into a V chasm, it is considerably crumpled and rent, and it is cut up throughout by minor faults, generally with a north and south strike.

But where was it let down from? It seemed not only safe and rational to assign it to the nearest similar bed, but necessary withal; for, no *upper* lime being claimed for *this* locality, only one bed was known. And so, though the continuation of the rise from the islet of Chorrie over the slopes of Ben Spinnu must have positioned such a westerly continuation thousands of feet over its present rest, this fragment has been without hesitation attached to the Erribol bed.

It is like it, moreover;—that is, it has *at first sight* a general resemblance,—but "like is an ill mark."

And then Peach found the fossils,—and the fossils were pronounced to be Silurian;—and then there was a feast of correlation, and a flood of theory,—and the grand old "gnarled gneiss," which gives their noble outlines to the Highland hills, was declared to be the same as the solidified mud of the hideous hunches of the Lowlands.

If it be so, it has to be noted that no attempt has as yet been made to account for the many differences between the rocks at the two extremities of the country; and the following facts have to be explained before the Durness lime can be held to be *proved* to be but a fallen fragment of the great north and south Erribol-Kishorn bed.

1st.—*An absolute difference in composition.*

The "limestone" of the quartzite has been shown by Dr. Anderson to be, throughout its whole range in the county, a very typical *Dolomite.*

The same analyst gives, as the composition of the Durness rock, the following—

Carbonate of Lime	90·01
Carbonate of Magnesia	6·50
Ferric Oxide and Alumina	·28
Phosphate of Lime	·27
Silica	2·77
	99·87

Being a fairly pure *limestone.*

In analytically testing the accuracy of Professor Anderson's results, I selected specimens from Garve Island, as the organisms are there still to be seen.

I give the results of the complete analyses of the two *most highly magnesian* samples or beds which I found.

No. 1 was a massive, minutely crystalline, purplish-brown variety: it contained fossils, the substance of which was white, and of a more highly-developed crystalline structure. No. 2 was grey, rotten looking, and somewhat cellular. 3 was the substance of the fossils themselves.

	(1)	(2)	(3)
Carbonate of Lime	92·	93·8	97·12
Carbonate of Magnesia ..	5·856	5·635	2·65
Silica	2·156	1·03	·97
Carbon	·31	tr.	
Ferric Oxide and Alumina ..	·19	·2	tr.
	100·512	100·665	100·74

From other trials, I should say that the average quantity of magnesian carbonate was about 3·5 per cent of the rock. The accuracy of Anderson's result is thus confirmed; and the rock proved to be chemically quite different from the Dolomite.*

Dolomitisation is a recognised geologic change; it is one which is quite in conformity with chemical interchange; it is, indeed, in certain circumstances, a necessary result of chemical requirements:—but *de-dolomitisation* is something new,—is altogether repugnant to chemical requirements,—and it would be no easy task to point to the circumstances, and unfold the processes through the operation of which it could be effected.

No law of transformation can be accepted as an established truth in science, which is revolting to any one department of science; and before the Durness *limestone* can be recognised as a fragment of the interbedded *Dolomite*, it is requisite for those who maintain it to be such, to explain this inverted interchange,—this new process of de-dolomitisation.

It will hardly be said that the exposed fragment is the unchanged material—and the swaddled-up rock that which has been transformed.

2nd.—*Difference in structure.*

It was noted above of the *Dolomite* beds, that throughout their whole range they presented *unvarying* features; the opposite holds as regards this small patch. Within the range of the few miles of its extent, it presents four such marked varieties that, from their localities, they might be called the *Dionard*, the *Balnakill*, the *Durine*, and the *Smoo* limestone.

The Dionard lime, instead of being, like the dolomite, little affected by the weather, is so readily acted upon that it is everywhere carious,—having

* An average sample of this limestone was lately forwarded by me to Messrs. King and Hunter, the city analysts of Edinburgh,—without any information as to its source, or indication that it was in any way of special interest. My instructions were to determine merely the lime and magnesian carbonates,—but to do this with scrupulous care.

These gentlemen write:—"The total CaO present is 50·82 per cent, which calculated to Carbonate yields 90·75 per cent. of $CaCO_3$. The total MgO present is 1·60 per cent, calculated to $MgCO_3$ would yield 3·36 per cent. Of course some of the lime and magnesia may not exist as carbonate."

a surface like a rasp; and, instead of the massive and sheeted rock surfaces of the former, as seen at Loch Maoloch Corry, and above Stronchrubie, we have here the features of a crumbling ruin.

The rock at Balnakill is much more crystalline than is the dolomite at any part. It is also characterised by a very singularly mottled structure. The ordinary, what may be called the basement structure of this, is a dull white; throughout this there ramifies a tuber-like structure, of size and appearance much like the dried roots of ginger. This structure is blackish in tint; but its granules are of the same size as those of the white portion, and there is not the slightest appearance of any such sharply-defined line of demarkation between the two portions as would indicate an organic origin.

In the vicinity of the village, the lime is much veined; white and red streakings traversing it in every direction.

At the last of these localities it bears much more resemblance to the great interbedded sheet of the quartzite formation; a solid and smooth-sheeted precipice,—indubitably a line of fault,—protruding boldly from the west and east shore-line, much after the manner of the out-crop at Stronchrubie.

Cunninghame writes:—"The limestone of Duirness differs from that of the rest of Sutherland, in the circumstance of containing numerous quartzose concretions of ovoidal, globular, and elongated forms, having an arrangement more or less parallel to the lines of stratification. The varieties of quartz which enter into the composition of these masses, are chalcedony, hornstone, jasper, and flint, affording a perfect analogy to those quartzose concretions which are met with in newer limestones."

3rd. *The abundant occurrence of fossils.* Not readily to be found now however. The organisms upon whose presence the foundation-stones of the geology of the whole kingdom were perchance all too squarely and smoothly fitted in, have long since been reft from the sparsely occurring scalps and turfless crags; but the cliffs around the lakelets and the rocks of the shores yielded enough to prove this to be a deposit which had sepulchred the dead in no stinted numbers.

If it be but a portion of the interbedded sheet, how came it that the organisms of this fragment which had dropped so deep,—so much deeper indeed towards the earth's core,—had escaped the metamorphism which had obliterated all traces of structural arrangement in that larger portion of the rock which lay nearer to the surface?

As regards the bulk of the rock here, there has in sooth been no such escape—the structure of the rock itself showing that it has been much more highly metamorphosed than has the interbedded sheet;—and that it has

been, moreover, much more highly affected by the agents of *secondary* transmutation. Yet here, in the more transmuted rock, the fossils are; while in the less transmuted rock, there they are not.*

The very marked manner in which this limestone has been affected by secondary transmutation, should of itself have "given pause" in correlating it with the dolomite; aside altogether of the difference in composition.†

In place of the sparse and feeble development of cherty nodules which are seen in the dolomite, there are to be seen in this, and especially in those beds which in colour and structure most highly resemble the dolomite, continuous layers or belts of *purple hornstone*, in repeated and close proximity.

In the gorge at the mouth of the Smoo burn, nodules of *horny-chert*, of a cream colour diversified with black, are frequent; these occasionally disclose what appears to be an obscure organic structure. An oval black spot, sometimes with a white centre, is surrounded with a loose sprinkling of yellow chert. Upon sectioning, however, both centre and surrounding dust was found to consist of minute rhombs of primary calcite or dolomite. These had angles of such extreme sharpness as proved that the chert must have been perfectly plastic while they were crystallising.

Upon the cliff summit about midway between the Smoo Cave and the shore line, there occurs upon the west side of the chasm, a bed four to six feet in thickness, of milk-white translucent *chert* of great purity, and of a perfectly uniform impalpable structure, and a horny lustre.

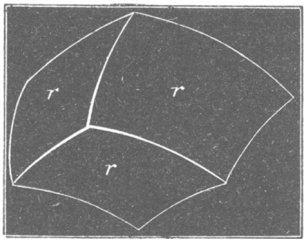
An average specimen of this upon analysis yielded:—

Silica	97·769
Ferric Oxide	1·538
Manganous Oxide	·076
Lime	·301
Magnesia	·153
Water	·207
	100·044 (H.)

The specific gravity of this is 2·641.

* An examination by the microscope of the silicious residue of this lime, when treated with acids, showed nothing clearly except silicious rods, much resembling fragments of the rootlets of the rope sponge. They were very much more minute.

† Sir R. Murchison writes,—"some of the exposed points or knobs are surrounded or partially wrapped over by a tufa-like silicious sinter, sometimes resembling a breccia, which conveys the idea of a boiling over of such matters when the rock underwent the metamorphism to which it has evidently been subjected. Even in this hard matrix my companion detected traces of fossils. The most marked of the external characters of the limestone is its coarse rugosity—the result probably of weathering upon its peculiar composition, and which gives the scarps of the rock the appearance of an elaborately wrought rustic basement of a Florentine palace." While I would not ask any chemical reader to believe in a *boiling silica* remaining inert as regards the lime *over* which it boiled, still the above is a geologic admission of extreme and evident metamorphism, and of a "composition" "peculiar" as regards the "limestones" of the district.



The cherty nodules of the Cave of Smoo are occasionally hollow, and contain *pearl spar* in curved crystals. These are of a fawn colour.

It certainly may be fairly adduced as an argument in favour of this limestone having been at least not far removed from the quartzite, that portions of the latter have been thrown down along with it; but these do not aid us in assigning to it any definite position, for they are themselves cut off from the lime by faults, and crushed up against it, so as to destroy all evidence of relative position. A great mass of the rocks which overlie the quartzite are also thrown down to the north, constituting the peninsular headland of Farrid. Though totally obscured by huge domes of blowing sand, there can be no question that this promontory is cut off from the lime by a cross fault. As it has, however, been let down apparently by the same great north and south fault, the rocks of this fragment may, if characteristic, help somewhat in disclosing the original position of the lime.

The following succession of rocks was found to occur at the Farrid Head—passing from north-west to south-east—*i.e.* from below upwards.

Schistose gneiss
Micaceous talcite
Gneiss
Chloritic Schist
Quartzitic layer
Chloritic schist
Lamellar quartzite
Gneiss
Laminated sandstone flag
Micaceous sandstone flag
Sand-covered fault, and lime.

The rock to which I have given the name of micaceous talcite is of a very singular description, and unmistakable.

In a kind of granular paste of a green colour, there lie glistening curved scales of the size of a bean, precisely like the inside of diminutive oyster shells,—they seem to be formed of minute scales of margarodite in a definite arrangement.

The lime which is seen at the north-west corner of Smoogro Bay is stated by Nicol to be separated from the succeeding rocks by an injected mass of hornblende rock and serpentine. This igneous rock I did not find, but only a fault.

Traversing the shore of Smoogro Bay again, from west to east, we fine

Micaceous rock
Serpentine
Chert
Marble
Serpentine.
Cherty flags
Serpentinous gneiss
Fault
Pebbly quartzite
Fault
Cherty mottled lime like the Balnakill
Fault

The striking beds in this series are what I have called marble and ser pentine.

The marble is undoubtedly a vein. It is formed in great part of interpenetrating large crystals of calcite, which have a capped structure throughout; this is developed by alternate layers of milk-white and ochre-yellow. If it could be procured in sufficiently large masses, it would prove a highly ornamental stone.

The so-called serpentine is distinctly foliated, and has palpably resulted from the alteration of a gneissic schist. Its mineral substance has more resemblance to a dull agalmatolite than to true serpentine. It is green, lined with red. It has no appearance of having resulted from the alteration of an igneous rock, and it is altogether small in bulk.

Nowhere could I find the "huge bosses of black hornblendic and hypersthenic rock" spoken of by Murchison as having been the clear agents of the upheaval of the old gneiss at Keannabin. Nor could I discover any altered limestone—or any limestone other than the one vein spoken of In fine, I can draw no other conclusion than that this series is a fragment of the upper gneiss let down by an east and west fault—like that of Farrid Head, and highly altered, from close proximity with the lime.

Sir Rhoderick Murchison's contention, or rendering of the rocks of this locality, here falls to be considered, as therein are conveyed the *stratigraphical arguments* for the connection (or disconnection) of this lime with that of Erribol, &c.

He writes,—"The reversal by which the Duirness limestone is thus placed in a trough has been manifestly occasioned by a great upheaval of the old gneiss, when acted upon by erruptive forces, of which clear signs are manifested in the adjacent Bay of Sangoe. There huge bosses of black hornblende and hypersthenic rock stand out with serpentinous coatings,—the courses of the limestone in their vicinity being singularly

altered, mottled, and dolomitic. Again, as we ascertained that Farrid head consisted of the old gneiss, there is now no doubt that the limestone and the underlying quartz-rock of Duirness occupies a trough."

The western or Farrid side of this trough, Murchison had afterwards to abandon; much do we fear that the eastern or cataclasmic side must be abandoned also, when the "manifest-huge bosses" which occasioned the "great upheaval" cannot be found.*

Granting, however, that they did exist,—seeing that Sangoe Bay is situated nearly in the centre of this patch of limestone, any "upheaving" forces acting there, instead of throwing it into a trough through a reversal of its eastward dip, *must have done the very opposite*,—namely, domed the limestone, and thrown it off from the flanks of the "erupting" bosses.

The nearest limestone, however, though cut up by crush-faults, and somewhat wrinkled, is nearly horizontal in its bedding; and the Sangoe rocks constitute but a disconnected fragment, cut off from the lime "manifestly" on three sides.

The actual relation of this series of rocks to the lime in the south is, however, obscured by cultivation. As the strike of the beds is at nearly right angles to their junction with the lime, there can be no question that they are cut off therefrom by a fault. Harkness seems to have noted more north and south faults than the writer was disposed to considered undoubted.

It is very evident, however, from a tongue of lime being caught in between these two fragments of the upper gneissic rocks, and from the second of these lying actually between two masses of the lime itself, that the association of these must have been somewhat intimate before the faulting took place; andas the sequence in both of the sections given is both rapidly alternating and highly characteristic, I sought for members of both among the rocks of the upper gneiss, and especially for the very characteristic "oyster-shell rock," which I had never previously seen.

This rock I (long after) found at the height of 820 feet, almost at the summit of Craig Vercan, a rocky knoll which lies directly north of Ben Hope. This position would correlate the micaceous sandstone flag of Farrid Head with the quartzitic flag of the west side of Tongue ferry; with which it indeed is identical in appearance.

Another fact of importance is the entire absence of cover to this Durin lime. Nowhere in the many square miles of its exposure is a particle of overlying rock to be seen. One marked feature of the dolomite with which it has been correlated is that it is almost everywhere *sheathed*; only

* Not upon merely petrological or chemical grounds alone, but upon geognostical also, would it be of surpassing interest if we could obtain portions of an eruptive rock which had risen *from beneath the lowest rock of the known crust of the earth.*

outcrops being visible. It might have been supposed that, sunk down between the lofty and protecting spurs of rock on each side, denuding agents would have failed to scalp this limestone of so hard a cover as an overlying quartzite must have proved. That quartzite, moreover, has endured in low positions upon the west side of the Durin ferry and to the west of Erribol ;—as it has also in the lofty escarpment of Spinnu and Carnstackie. Hence the rational inference is that the Duirness lime was never so covered.

A few large boulders lie upon the surface of the lime, but these are of granite.

Different in composition, different in structure, pregnant with fossils, more highly metamorphosed, associated with newer rocks, altogether out of place,—it will need absolutely new evidence before our theoretical geologists are warranted in declaring this *limestone* to be a chip off that old block of *Dolomite* which now stands above it.

It might not be out of place for them to bethink themselves of the two patches of a very recent rock which occur, absolutely isolated, at Loch Greinord; and to consider if a similarly isolated patch of Silurian may not have occurred somewhere here.

Be this as it may, the two "limestones" must be held to be distinct, until it is either shown that Dr. Anderson's analyses and those of the writer—supported now by that of Messrs. King and Hunter—are incorrect,—or that the magnesia so largely present in the original rock had in the faulted fragment been removed by a process which simultaneously restored organisms which had previously been metamorphosed beyond recognition, or even ocular apprehension.

And if the two "limestones" be different, then the whole fabric of Murchison's correlation of the rocks which overlie the Dolomite, falls to the ground.