The Geognosy and Mineralogy of Scotland.

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SUTHERLAND.—PART IV.

The Igneous Rocks.

A VERY few dykes of the "greenstone type" are to be seen in the lower gneiss.

There are some localities at which the gneiss seems itself to have furnished the material of the dyke, if not to pass into it by insensible gradation.

One is a dyke seen in the vicinity of Badnaternag, on the north shore of Loch Assynt. Here the dyke runs along the strike of the rock.

A second locality is about half a mile south of Unapol. The dyke itself has here disappeared; but the gneiss in contact with it presents very singular features. Macroscopically it is massive and devoid of bedding; dark green in colour, sprinkled with a pale green, and almost aphanitic in deneseness.

Under the microscope it shows its crystals of hornblende to be broken up in their centres by a minute sprinkling apparently of quartz and apatite. Only the fringes of these crystals are dichroic. There is little quartz in the rock. The felspar is striated, and contains much apatite. A black mineral is present in tortuous forms; it may be *iserine*. The rock appears to be undergoing a transmutation into an "igneous" one.

A true dyke occurs on the shore at Loch Inver. This Loch Inver rock is a *mélange* of equal sized crystals of augite, olivine, and a striated felspar. The augite is fine foliated, in ill-defined crystals, and, if iserine be excepted, free from endomorphs. The olivine is in comparatively small amount, and unaltered. The felspar is either in well-defined broadly striated or twinned forms, which are also minutely lineated; or it fills up the interstices of the olivine crystals as a hyaline glass. This is pervaded with needle hexagons, probably apatite. The opaque black substance, set down as *iserine*, is either embedded in the augite, or surrounds the felspar. The augite and iserine are rarely fringed with a highly dichroic substance, probably Biotite. The lineation communicates an appearance of oily softness to the crystals of the felspar, which renders the rock characteristic.

Another dyke cuts the lower gneiss on the south-east shore of Loch Assynt. This is much serpentinised, though to appearance unaltered. The olivine is in much the largest amount; little of it being, however, unchanged. The augite is much altered, granular, and plugged by rounded crystals of altered olivine. The felspar is minutely granular, and pervaded with apatite (?) Much opacite is sprinkled everywhere. The manner in which the augite is riddled with olivine is the characteristic feature of this rock.

A third, more massive dyke, which the writer could not reach, is seen to cut the south-east bank of the same lake, near the point where it suddenly narrows at its western bend.

Apart from the granitic veins already noticed, the above, or similar dykes, are all the igneous rocks which I could find in this formation.

Apart altogether of their lithological nature, a very special interest attaches to the existence and modes of occurence of igneous rocks in a formation so deep-seated.

Professor A. Geikie has lately shown that one of the most recent outbursts of volcanic matter consisted of that extended system of dykes which cut, in parallel course, the rocks of the Western side of Scotland. Only a single outburst, indeed, has to be assigned to still more recent times;—namely, the lava stream which, now forming the pitchstone ridge of the Scuir of Eigg, had flowed into a river canôn, the exposed portions of whose bed disclose the truncated ends of several dykes belonging to the above system.

As the strike of this great system of dykes is but little removed from that which prevails in the high-tilted beds or banding of the Hebridian gneiss, and as the jointing between these beds is unusually free, it might have been expected that it would have been here developed in great force. Yet, if the map of Professor Geikie be examined, it will be found that, though the rest of the western shore-line is scored with red lines, those portions which represent the Hebridian gneiss and the conglomerates, are in this respect *a perfect blank.*

Perceiving the bearing which this fact might come to have in determining the relative age of certain of the formations of the north-west, the writer made some extended traverses, in order to ascertain whether this blank in Professor Geikie's, and in all the earlier maps, was to be assigned to the fact that these formations had not been examined, or to the fact that such dykes did not occur therein.

Among these traverses were the following :—On the Mainland, the shore line was followed from near the Ferry on Loch Erribol, round by Cape

Wrath, to Rhiconich. From Loch Inver to Loch Polly. From Ullapool to Sand. In the Islands, the Hebridian rock was crossed from Stornoway to Tarbert, in Harris; and from Stornoway to Loch na Muilne. The coast line was examined, for the greater part, from Loch Carloway, on the West of Lewis, to Rodal in Harris. The island of Rum was walked round.

The result was that, while granitic dykes of quite different habit were found here and again in force, no igneous dykes other than those already recorded were found.*

As a fact, this must be considered significant; but significant of what? It will be answered,—the area subjected to the rending and eruptive forces did not extend so far North;—not further than Sleat in Skye, the limit of the red lines in that direction in Geikie's map.

Unfortunately for such a contention, the dykes are found in numbers cutting the Old Red in Orkney, and doing so with the strike normal to them elsewhere. In Shetland, dykes also cut the same formation, with the same strike; and in these Islands, a second significant fact is noted, namely, that not a single dyke cuts the formations which there occur and which are more ancient than the Old Red.

It is thus not by any limitation in *northerly* extension, that the absence of dykes in the old rocks of Sutherland and Ross is to be explained.

They are not limited in easterly extension; for, if they have not been traced from sea to sea, dykes certainly of this age have been traced into the Eastern sea.

Those of the west of the mainland enter the Western sea, and reappear in certain of the Islands, but in certain of them only.

They are very numerous in such as are composed of sheets of volcanic matter; but it must not be supposed that they only plugged rents formed by the shrinkage of a great cake of cooling lava, for they occur with a very similar frequency in that "upper-gneiss" which Murchison and Geikie have correlated with the Silurian.

Professor Geikie's map shows the *more northerly* portion of Sleat to be lined by them, and, in coasting along the *southern* stretch to the point of Sleat itself, I found that the number which there occur is very much greater than that of the more northern. Again, in examining rocks of the same formation from Corran Ferry to the Sound of Mull, on the east shore of Morvern, I found that they were so numerous as at some points almost to dominate in bulk over the rock which they invaded.

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* There are two dense hornblendic belts which somewhat simulate dykes in the cliffs of the west shore of Loch Carloway

Dr. Macculloch has given a delineation of the manner in which the red sandstone of Strathaird in Skye is cut by the probable continuation of the dykes of Sleat; but no trace of these is found in westerly continuation to cut the Hibridian of North Uist or of Harris.

The dykes of Eigg point to Rum; there, one dyke is seen to cut the augite rock, but I could not find that a single one cuts the green flags of the so-called Cambrian rock.

It thus appears that these dykes in the north cut comparatively recent rocks, but do not cut the gneisses of Shetland. They cut the so-called Silurian or "upper-gneiss," and all more recent rocks lying away to the east; they do not cut the Hebridian gneiss by any extension to the west; nor is that rock cut at any medial point at which it appears.

Is it not thus rational to conclude that this system of dykes was *limited in depth*;—that the zone of the operation of the forces which gave birth to the material which forms the dykes, was superior to the Hebridian rock, and superior to the gneisses of Shetland?

I have never seen any igneous rock in the Torridon conglomerates.

The igneous rocks of the quartzite must be regarded as of unusual interest, as they may aid in settling the question as to the existence, in one part of the country, of an *upper* as well as a *lower* series of beds of that rock.

As the existence of a series of beds eastward and vertically superior in position to that which immediately overlies the conglomerate, is admitted,—and as that more easterly series has not yet been in any way *identified* with the more westerly, I shall meanwhile speak of them as the *lower* and the *upper*.

Igneous rocks of the Lower Quartzite.

The lowest of these in the series has already been noticed and described, as it is seen at the most westerly point of its occurrence, namely, near the summit of Canisp. It appears to be there not more than 100 feet above the Conglomerate. The large size, and the characteristic appearance of its crystals, as there found, have been noticed.

It is seen in much larger bulk, though of much less striking features, above the outcrop at An Cuileum, and on the slopes of Beinn Garabh, opposite to the inn of Inch-na-damff. Here it has been exposed, through denudation of the overlying beds of quartzite, over a great extent of the hill slope. It, and the quartzite, dip persistently to the E.S.E. Its characteristic features, both as regards size and definition of its crystals, —*orthoclase*, *albite*, and *pinite*,—are not here well pronounced; and there is a marked deficiency in the relative amount of orthoclase.*

The same red porphyry, with still smaller crystals of albite, and an almost total absence of crystallised orthoclase, is seen in the bed of one of the branches of the Allt an Uamh which flows due west from Braebag. It has here a dip to the W.N.W., and this is one of many evidences of the district forming a trough between Canisp and the Braebag ridge.

The second of the igneous rocks of the series is seen conformably bedded, a few hundred yards eastward of, that is above the bridge over the same stream, (the Cold Spring Burn). The bed of rock is only a few feet in thickness, and varies somewhat at different parts. It is dark green in colour, and markedly hornblendic throughout. There is presemt, indeed, sometimes little else than an interlacing of crystals of an actinolitic hornblende with a red felspar; the latter presents itself generally as paste; Pyrite, and a flaky substance, possibly pinite, are however also present.

Higher up the stream, a dyke—or possibly a *neck* of the same rock, cuts its bed, striking nearly at right-angles to its course; and, still higher up, there is, in a series of blocks which cross the stream, some evidence of a third occurrence of the same rock.

All of these lie palpably below the dolomite. To the east of it, and east also of Beinn-nam-Cueamhseag, a dome-shaped roll of the same rock is seen. It is exposed over a considerable space, rising from under quartzite to the west, and dipping below it to the east. On the west side of the south-west spur of Braebag, a distinctly interbedded band of the same rock appears at the low level of about 1,000 feet; while on the south spur itself, at about 1,600 feet, three beds are seen, which, with the intervening quartz beds, disclose admirably the double anticline into which the quartzite series is folded along the whole Braebag ridge. Of these eastern exposures it has to be said that they probably represent the beds seen in the Cold Stream Burn, brought up by the anticlinal roll; and it has to be noted of those on the south side of Braebag, that, in the paler colour and more foliated structure of the hornblende, they present a slight resemblance to some varieties of the "Logan rock." It is doubtless some of the same beds which, cutting through the hill, are to be seen on the north side of Miall Diamain; and in the fault at the Corry Dhu of Braebag a dyke of a somewhat similar rock is seen.

* A specimen was this year (1882) given me by Dr. Callaway, from near the shore of Loch Assynt, which has much *actinolitic hornblende;* and thus shows a transition into the igneous rock which occurs next in the series.

Igneous Rocks of the Dolomite.

The next bed seen in rising on the series, occurs in the dolomite, among its lowest members. It occurs nearly immediately between two dark somewhat fetid and anthraconitic layers of the rock. It is admirably seen for nearly a mile along the stretch of the Strouchrubie Cliff. It is difficult to find the upper surfaces of any of these beds sufficiently exposed to enable conclusions to be drawn as to whether they are lava-flows, or intrusive; but a rude columnar structure, with rents of equal magnitude at the upper and under surfaces, which is seen in this bed, along with the uniformity of its structure and absence of all slaggy appearance, countenances the latter view.

This bed is very persistent. It is seen *all round* the Stronchrubie dolomite basin, wherever there is any extent of outcrop exposure; and, with its associated dark beds, it defines the limits of that basin better than do any of the beds of the dolomite itself,—characteristic as some of these are.

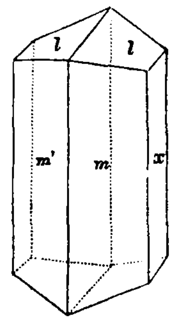
I have found it dipping W.S.W. in the Ledbeg River, about a mile above the bridge; N.E. on the South-west slopes of Ben-an-Fuarain; N. in the bed of a stream which flowed from the south side of that hill: N.W. on its South-east foot; W. on its East slope; W.N.W. on the North-east of Loch Maolloch Corry,—here twice seen through faulting. Mr. Hudleston found it in the stream above the Old Woman's Cave. It is again seen along a considerable line, North-west of the Cave of Dreadful Sounds, dipping S.S.W. to S.W.; on Cuil Dubh; and near the upper fork of the main stream of the Traligill River in Glen Dubh.

This bed, where last seen to the south of Inchnadamff, sinks beneath the turf,—the whole series being thrown into a downward flexure as it curves round to reappear on the slopes of the lower third of Cnoc-an-drien. A bed of the same rock rises out of till, which forms the stream-bank immediately to the north of the bridge over the Traligill river; but that this is the continuation of the beforementioned extensive bed can hardly be asserted, seeing that the outcrops to the north show in their ample exposure *a series* of igneous beds.

Crossing the Cnoc-an-drien section from the lake, a little north of the school-house, two are met, a short distance from the road, at a low level; and a third occurs at 550 feet, with only one thick bed of limestone intervening between it and the so-called upper quartzite. This here overlies the dolomite perfectly conformably, and without the smallest appearance of a fault.

The lowest of the beds near the road differs from that already described to a marked extent. It is of a blue colour; contains much *Biotite* with *ferrite* (?), and some hornblende; it also carries so much carbonate that it effervesces with acids.

That next in the series is seen as a neck. It forms a boss of considerable extent, which on the south distinctly cuts off a bed of granular quartzite. North of this, it throws out a narrow process between two dolomite beds, and here its constituents are best developed. The hornblende is so freely and distinctly crystallised in the form drawn, that the rock is a very beautiful one. Here the bed is not above a couple of feet in thickness; but it rapidly thickens, until where it is seen a little to the north it overhangs the road as a small cliff. Much granular pyrite, impacted in an almost granular hornblendic matrix, is now present; and the rock, especially to the south of the road, has become excessively tough.



The third bed near the quartzite is much of the same nature as that in the Stronchrùbie Cliff.*

If the same series of rocks be traversed to the north, at the Chalda Burn, two beds in addition to those enumerated are seen. These lie between the second and third of the former series, and are undistinguishable from these in appearance.† Again, near the Traligill, the series shows two others, which lie below the second; so that some of the beds either die out, or thin off so as not to be readily found.

Amidst the turmoil and confusion which exists where this series of rocks is crossed by the Polandrien Burn, two dark and nearly vertical igneous beds are seen. They are of dense hornblendic material; and may be either dykes, or certain of the forementioned beds, altered by the crushing which is here evident.

There is a merely local dyke of red porphyry, similar to that of the upper quartzite, which cuts the dolomite very nearly on the line of its dip, on the flat east of Knockancliff.

* It is, in no respect, of the nature of felsite, as stated by a late observer.

† The immediate, and what might be almost called *adhesive*, superposition of quartzite to dolomite at this locality, at an angle of 4° to 5°, must surely negative the view that a fault occurs here; while the absolute absence of any reappearance in inverted order of the argillaceous beds, within so short a distance as half a mile, is equally demolishing to the theory of an inversion of the whole series. The locality speaks plainly to the existence of an upper quartzite; there is neither need for fault, nor room for inversion.

Igneous Rocks of the Upper Quartzite.

I have before mentioned how the lower quartzite of the ridge of Meall Diamain is, in the Col between it and Ben Bhrachaid, overlaid by slabs of the yellow argillaceous rock which underlies the dolomite; which slabby beds are in turn overlaid by what the writer believes to be the same rock as occurs in Glen Logan, near Loch Maree, in Ross-shire. It here forms the mass of Ben Brachaid—the rough, nodular, or "speckled" hill; and it has been described how, at the eastern end of this hill, the outcrops of three distinct beds of quartzite, somewhat slabby in feature as compared with the more granular rock of Meall Diamain, were to be seen.

This is certainly one of the localities which must be quoted as favourable to the existence of an *upper* quartzite, by those who hold such a view; and I therefore commence with it, in reviewing the igneous rocks which are to be seen in this series.

In passing up the section, though down the hill slope eastward to Loch Ailsh, there is to be seen an interesting series of beds; but as the section is best read in an opposite direction, *i.e.* from east to west, we will take it in that direction.

The west shore of Loch Ailsh is concealed by bog and cover, until we come, on the S.E. spur of Ben Brachaid, to the following sequence, in descending order:—

1. "Hornstone" porphyry, bedded. The "paste" is fine granular, glistening, and brownish-purple; the imbedded crystals are sharp-angled, isolated, "cuboidal," translucent, and like bits of hot suet. Very rarely they are pale green. The bed is about two and a half feet in thickness; its dip and strike accord with that of the system. Loose fragments of this rock weather so that the paste becomes cream coloured, and the crystals opaque white.

2. A second bed of the same, of about four feet. In this there are several layers of granular quartz. These layers are from half an inch to four inches thick; the grains are sharp-angled (? fragmentary) and of sparkling lustre,—it might almost be said vitrified appearance.

3. A bed of about one and a half feet of yellow fine-grained granular quartz. The grains are much smaller than those of the above, not so markedly fragmentary in appearance, and there is some appearance of rounding.

4. A bed, some inches only in thickness, of a rock similar to 6.

5. A bed of quartzite, two feet; like 3, but of a lively light-green tint. 3 and 5 have occasional specks of a soft ochre, but no pyrrhotite was detected.

6. A bed, four to five feet, of a rock *banded* and *blotched* with the material of 1, throughout a matrix of a bright-green colour; which matrix consists chiefly of a coarsely-fibrous or crystalline green mineral, apparently hornblendic; with some crystalline felspar, and granular quartz.

7. Worm-hole quartzite. The beds are here thin, but they sweep up the hill-slope, and thicken into the beds on the east top of the hill.

8. Green (Logan) rock of Ben Brachaid.

The interest here centres in Nos. 1 and 6; 1 was accordingly analysed,—both the imbedded crystals, and the paste; these seemed alike pure. As the crystals were about half the size of peas, they could be cut quite free of the paste.

They yielded—

Silica	66·615	
Alumina	17·556	
Ferric Oxide	1·867	
Lime...	·732	
Magnesia	·384	
Potash	1·830	
Soda	10·086	
Water	·729	
	99·799	(H.)

The paste yielded—

Silica...	66·846	
Alumina	20·11	
Ferric Oxide	1·428	
Lime..	1·033	
Magnesia	·307	
Potash	·441	
Soda	9·697	
Water	·333	
	100·195	(H.)

Both are therefore *albite*; and with such a similarity of composition, it is difficult to see how the paste should not have crystallised also. The rock has no claim to the name "hornstone." Those who hold this to be an igneous bed might argue that the formation of definite imbedded crystals in rocks, and the dimensions of these, are alike dependent upon a retardation of cooling. Standing on the spot, however, and having regard to the appearances seen in beds 2 and 5, the writer could come to no conclusion, judging from their relationships alone, than that both would be generally regarded as metamorphic.

At and near the summit of Cnoc-an-drien,—(another locality which would have to be quoted in evidence of the existence of an upper quartzite)—there is, however, a rock, certainly not in hand-specimens to be distinguished from the above, which cuts at several spots right through (without in general disturbing) the beds of the upper quartzite. It is here in true dykes, two to four feet in thickness, and also forms knolls, which are apparently isolated from each other, among the lakelets on the top flat of the hill. No rock could be more clearly igneous. This *may* be different from that analysed. No analysis has been made, but, except in colour, the writer could perceive no distinction. The colour is a reddish chocolate, often padded or blotched with a pale olive skin; the crystals are here white.

The quartzite beds are cut almost vertically, and a vitrified crust of quartzite, bleached white, is *firmly adherent* to the porphyry. This crust is about eight inches in thickness, and is separated from the quartzite of the bed by a rent, sometimes gaping, which rent is nearly at right angles to the bedding of the rock. The writer never saw a finer illustration of rending, singeing, and cementing.

The appearances at the two localities are thus most perplexing, as a material seemingly one and the same appears to be *metamorphic* at one spot and *igneous* at another!

Again, among the shattered outcrops which protrude from the craggy south face of Coniveall, and indeed among fallen blocks at its foot, there are to be seen square cleft masses, one side of which consists of this porphyry, while the other is quartzite; and the lens can find no line of demarcation. The paste gets in among the quartz grains on one side, while an albite crystal may be found altogether away from the felspathic paste, lodged among siliceous granules. There is no sharp welding of side to side; if there is not a *transfusion*, it must be said that there is apparently a gradual passage from a loose-grained fragmentary rock to a vitreous paste. It must prove a perplexing inquiry to determine what was the nature of the genesis of such a rock.

It may be fairly expected that the observer should give some expression of his opinion, even if it should be an uncertain sound; but he considers that he has not yet data sufficient to enable him to form any such opinion as would be satisfactory even to himself.

Reverting to the bedded rock on the S.E. foot of Ben Bhrachaid, it has to be noted that it is by no means clear what these beds represent. They may represent a repetition—a lithologically modified repetition of the green, or "Logan Rock." Only *one* great bed of is overlies the quartzite of Meall Diamain, forming the hill of Ben Brac. id: but at least *four* beds of the same rock, some of which differ much from the others in character, are known in the upper quartzite; so this may be one of these. I have not analysed the white striated felspar of the "Logan rock;" but the microscopic evidence points to its being *oligoclase*, and not albite. Or, again, the beds might be held to represent the incoming of the upper gneiss below the so-called upper limestone, as green flaggy beds of this gneiss are to be seen below the limestone at Rhie Knock.

The bog to the eastward of Ben Brachaid makes everything obscure.

Again, the precise inference to be drawn from the existence of the "upper limestone" here, cannot be spoken to; for, though it *appears* dolomitic, it has not been yet analysed; neither do we know if albitic felspar is the substance which, under the name of hornstone, has been enumerated as one of its members, or if that felspar is an ingredient of the upper gneiss of the neighbourhood. Until we have information on these points the question is altogether too speculative.

In the upper quartzite there are to be found, on the south slopes of Cnoc-an-drien, a series of igneous beds, certainly three, brought to surface by several folds, which have been heavily cut in upon by denudation.

These consist of a rock generally similar to what occurs in the lower quartzite, and in the dolomite; still they differ from each other to an extent sufficiently marked to enable us to identify and determine the position of the several beds of the quartzite which separate them.

The first of these beds is found at an altitude of 690 feet,—not many feet above the dolomite,—the last igneous bed of which it much resembles. The second is seen after a swamp is crossed; it is at an altitude of 700 feet. This bed differs from any in the lower quartzite, or in the dolomite, in containing fatty quartz, and in having a milk-white felspar, the crystals of which have a reddish fringe. It is a much paler coloured rock than the others. The third bed is dark green from excess of hornblende, and it seems also to have a hornblendic and not a felspathic paste.

The above three beds are, through repeated folding of the quartzite, brought to the surface more than once on the hill-slope. Their relative position is, moreover, not interfered with by two dykes of a very singular rock, or by several dykes of the albitic porphyry.

Of the igneous rocks of the upper quartzite, as seen elsewhere, I would note especially what is seen in the ascent of the stream which flows from the Col between Ben Harran and Coniveall. Between 400 and 450 feet of the central portion of the slope consists of alternate beds of the red albitic porphyry and of quartz. A bed of grey porphyry underlies the highest red porphyry bed; above this there is quartzite and two beds of an igneous rock which has some of the features of the "Logan rock." Quartzite again succeeds, and the highest beds of the series—seen on the N.W. slope of Coniveall,—consist of a soft green fissile schist, an igneous bed, and lastly, a second bed of the schist. The igneous bed here is so much altered by weathering that its present features should not be taken as evidence of much value, except as proving a difference from the beds at the bottom of the series, which protrude through the turf, through *resisting* decay.

This rock at present consists of a soft grey paste enclosing a pale green foliaceous diallagic mineral. The same rock is to be seen on the N.E. slopes of Ben More, on the same horizon.

It thus appears that there is a very characteristic igneous rock, *the Canisp porphyry*, in the *lower* quartzite;—and an equally characteristic rock, *the albitic porphyry*, in the *upper* quartzite. The first occurs in a single bed, but in such enormous quantity that Nicol speaks of a square mile. The second, though at no single spot equal in bulk, is more generally distributed, occurring in many beds,—in many dykes,—and is apparently eruptive.

Not a particle of the characteristic rock of the *lower* beds has been found in the *upper;* neither has any of that of the upper beds been found in the lower, though in some localities the one set is nearly vertically disposed over the other.

It remains for those who maintain that there is only *one* quartzite, and that it has been folded over by an inversion, to explain the above facts, so as to confirm, and not militate against, their view.

There is still a rock, up to the present held to be igneous, which falls to be noticed here. This is the so-called "quartz porphyry" of Cnoc-na-Strome, of Scoonan Beg, and of Sail-an-Roar. That of Cnoc-na-Strome being Murchison's "red porphyry of Loch Borrolan."

This rock usually has no quartz. When present it is not in imbedded crystals, but as a paste. The felspar is orthoclase;—it is muddy, structureless, and unsatisfactory under the microscope. Cunninghame mentions having observed in it well crystallised rhombic-dodecahedrons of *magnetite*.

The writer has great difficulty in accepting this as an igneous rock. The chief argument for such a view lies in the aid which it would afford in explanation of the turmoil which exists among the neighbouring rocks.

Possibly also such a view might be held to account for the presence of the adjacent marble.

The ground between Cnoc-na-Strome and Cnoc Ledbeg is obscured by detritus, but the writer has entirely failed in finding any line of demarcation, or faulting, either there, or between this red rock and the green igneous (?) rock of the hill east of Ault-na-ghalgach, at the spot where the junction occurs. Nor can one be found between Scoonan More, which is "Logan rock," and the overlying Scoonan Beg, which is the "quartz porphyry". At both localities the one rock, if it does not pass into the other, at least succeeds to it without break. All along the summit of Cnoc-na-Strome there is a rude bedding which is quite consonant with such bedding as is to be seen in the "Logan rock" of Cnoc Ledbeg, which it overlies; and bedding, or a structure as closely resembling bedding as any which is to be seen in the "Logan rock," is admirably seen in Scoonan Beg with the same strike, but having an almost vertical dip. Moreover, one of the more westerly beds of the "Logan rock," which is intercalated with the quartzite on the north shore of Cama Loch, is only to be distinguished from this "porphyry" by the very sparing presence of hornblendic matter. This bed, of brownish-red colour, contains little or none of the so-called *epidosite*,—the distinctive ingredient of the "Logan rock."

If it be urged that such a mass of highly crystalline felspar is something altogether new in a metamorphic rock, it has to be replied—firstly—that it has never yet been settled that the "Logan rock" is metamorphic in the usual sense of the word; and, secondly, that portions of the green rock of Liath Bhad on Loch Glen Coul, consist of much purer and broader, flaked masses of orthoclase than any in Cnoc-na-Strome, in which orthoclase the quartz is arranged in a graphic form—vouching for a still more perfect plasticity.*

Again I have to note that at the bridge over the Ledbeg river, near Ledmore, the rock, which certainly appears to be that of the hill foot of Cnoc-na-Strome, is largely changed into an agalmatolite mass—quite indistinguishable from the appearance and condition of the "Logan rock" where it overlies the dolomite at Liath Bhad. If the Cnoc-na-Strome rock be igneous, I believe it has caught up and transfused itself into masses of the "Logan rock."

The study of this district will prepare those who enter upon it with unprejudiced minds for new and wider views as to metamorphism;

* Mr. Hudleston picked up in Glen Coul, from the surface of "Logan rock," a loose fragment, in which the graphic lettering was surpassed in largeness of character by that of only three localities in Scotland.

and such views may be still more amply developed by including in the study the singular porphyry which occurs in the S.E. foot of Ben Bhrachaid.

Igneous Rocks of the Upper Gneiss.

All the larger masses of this are of the fine grained white or grey syenitic type. They occur at Ben Loyal, Ben Stomino, and in the low district lying east of Lairg.

The rock is very fine grained, the hornblende is small in amount, and nearly an equal quantity of black mica is frequently present. *Sphenes* are far from frequent, and I did not see on Ben Loyal any clearly defined crystals. They are there very small, light hair brown in colour, and of the simpler forms. I could find no *Allanite.*

The rock of Loyal is disposed in great tabular sheets, with but few joints at right-angles. As this is one of the most gracefully contoured hills in Scotland, it may not be well to more than hint at the wealth of building material, finer than Aberdeen granite, which lies here. An opening in the corries south-west of Ribigill would, however, appear no larger than the scalp of a mountain torrent.

Cunninghame mentions *psilomelane* as occurring loose on the surface, between the summit of the north cliff and The Castles,—the top of the hill.

Upon the eastern slope of Ben Bhreck—a hill formed of Old Red Conglomerate, which lies south-east of Tongue—two large syenite boulders, probably from the crags of Loyal, are imbedded in till.

These were partly cut up for lintels, and fragments of what was designated "a pretty green stone," which came out of one of them, found their way into Dr. Joass' hands. This at once led to an examination, and ultimately to the larger part of the boulder being broken up by the writer in the interests of science.

I regard this as mineralogically the most wonderful and interesting stone in Scotland.

It was not only in itself a perfect mineral casket, containing in its small bulk as many minerals as do some counties, but it contained these in numerous crystalline forms, and also in crystals of large dimensions. It contained minerals found no where else in Scotland, and one which is altogether new to science. It offered ample scope for the speculations of the theoretical crystallographer, supplied abundance of material for the labours of the analyst, and, as it can hardly be ever proved to demonstration whence it came, it may always be turned to as an admirable bone of contention for those who prefer an evening's wordy war to a day's hammer-work upon a hill-side.

The boulder weighed originally about 100 tons; it is of the same rock as Ben Loyal. An exfiltrative granitic vein of about two feet in width passed through it; in or close to this, the minerals were found. These, arranged in the order of their occurrence from the substance of the stone to the centre of the vein, were:—

Babingtonite.	Ilmenite.
Fluor.	Amazonstone.
Sphene.	Oligoclase?
Allanite.	Quartz.
Orangite and Thorite.	Specular Iron.
Magnetite.	Strontianite.
Lepidomelane.	Bhreckite.
Radiated Cleavelandite.	

And a substance of a somewhat doubtful nature.

It has been said that it is an exfiltrative vein; the crystals grow from both sides; the structure of the rock merges into that of the vein by a gradual incrementation of its parts; and the minerals appear in particles of increased size as they approach to, or incorporate themselves in, the vein structure.

The *Babingtonite* first appears in specks in the syenite itself; it seems to replace the hornblende. Near to, and at the junction of the fine grained rock with the coarse crystalline vein, it assumed the form of rough crystals, which were an inch or two in length, and increased much in width at their inner extremities.

The outer portions of the crystals were for the most part rough, somewhat incoherent, and penetrated by minute crystals of *lepidomelane*, *sphene* and *fluorite*.

The interiors of the crystalline masses were generally much flawed, but quite fresh. They had a vitreous lustre; a dark green colour; and they were both hard and tough.

No definite crystals were formed, but the summits always pointed to the centre of the vein. The specific gravity was 3·3.

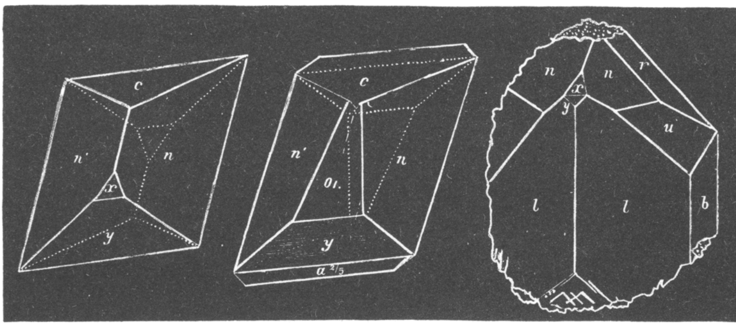
The substance yielded—

Silica	50·845
Alumina	1·402
Ferric Oxide	9·56
Carried Forward	61·807

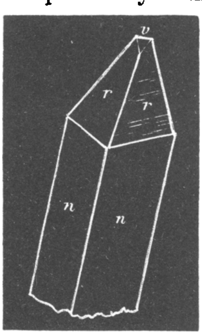
Brought Forward	61·807
Ferrous Oxide	8·307
Manganous Oxide...	1·153
Lime	17·661
Magnesia	5·538
Potash	1·072
Soda	2·914
Water	1·485
	99·937 (H.)

Before analysis, it was taken to be *pinite.*

The *fluorite* is rare ; it is of a pale purple colour, is in small fissured masses with a rude attempt at an octohedral form.



The *sphenes* are of a dark brown colour. The first three crystals figured were imbedded in brown orthoclase ; the fourth projected into an open cavity of the same.



It was sometimes also imbedded in *Cleavelandite* and *Babingtonite.*

It yielded—

Silica*	35·5
Titanic Acid	30·4
Alumina	2·586
Ferric Oxide	4·914
Manganous Oxide	·4
Lime	26·423
	100·232 (H.)

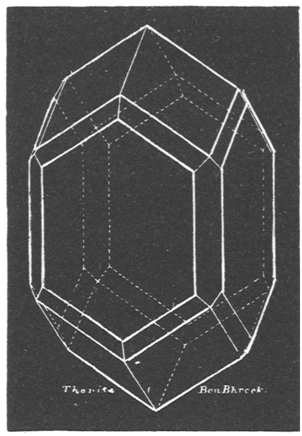
The *Allanite* was also imbedded in brown orthoclase. No regular

* Since the silica of this sphene, as obtained from the bisulphate fusion, was not quite white when heated, it was re-fused ; but it yielded no more titanic acid.

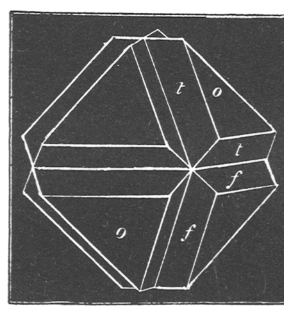
forms were seen, only single faces. It was in crystals about the size of the "lead" of a pencil; the usual yellow stain in the rock, and the jetty black lustre, were unmistakeable.

The *thorite* occurs in numerous round lustrous particles of the size of large shot. Pieces larger than a bean, however, occur; these are of a rich brown colour and very high lustre, except towards the outside of the particles, where they are sometimes dull and lighter in colour.

The centres of the larger pieces are sometimes light yellow *orangite*; there being a gradual passage into this colour through a rich brownish red. Some pieces, however, consist of *orangite* throughout.



Two small perfect crystals were obtained of the form figured. These are set down as *thorite* from their want of lustre, their opacity, their light brown colour, and want of hardness. Groups of larger attached crystals were also found. These were without the truncations of the edges. When broken they showed conchoidal fracture, a rich brown colour, and a brilliant vitreous lustre.



The *magnetite* occurs about the same zone, imbedded in felspar, in nodules of the size of peas and beans. It rarely shows octohedral faces; one twin tetrakis-octohedron was obtained.*

This magnetite is of a blue-black colour, and a high lustre. The powder is reddish-brown, and is strongly magnetic.

* In the figure the faces marked *f* should be *t*.

It yielded—

Ferric Oxide	83·482
Ferrous Oxide	12·682
Manganous Oxide	1·200
Silica...	1·200
Alumina	·288
Lime...	·896
Magnesia	·500
	100·148 (H.)

From the centre of the crystals of this magnetite there were obtained some minute laminable specks of a magnetic substance which dissolves without residue in chlorhydric acid; and which precipitates an acidified solution of copper sulphate. Hence these must be *metallic iron.*

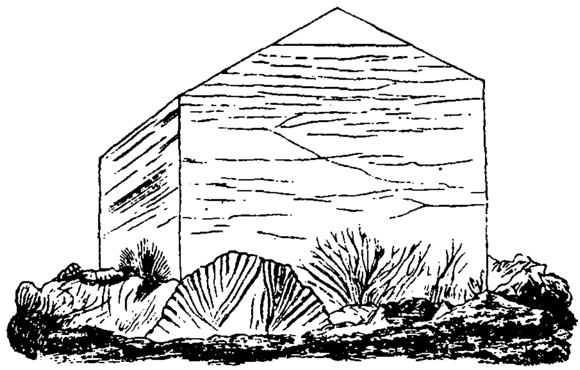
The *lepidomelane* occurs in plates, one or two inches in size, of a deep rich brown colour. These are imbedded in crystals of amazonstone, and they also separate crystals of the latter from flesh-coloured felspar. They are easily cleavable, but are, even in thin plates, nearly opaque. The mineral is not so tough as the Haughtonite of granites. It is slightly biaxial, and transmits light of a brown colour. Its specific gravity is 2·965.

It yielded—

Silica	40·076
Alumina	12·408
Ferric Oxide	13·474
Ferrous Oxide	2·668
Manganous Oxide	·615
Lime...	1·076
Magnesia	14·661
Potash	7·570
Soda	2·153
Water	5·293
	99·994 (H.)

This and the specimens from Achadhaphriz, are the only dark micas which I have, by analysis, proved to be lepidomelane in Scotland.

The radiated *Cleavelandite* occurs in considerable quantity. It marks the zone of the appearance of the *green* orthoclase; there being much *flesh-coloured* orthoclase outside of it. It forms a curving belt of over half an inch to an inch in thickness; this belt being formed of lamellar



crystals which diverge as they become imbedded in the crystals of Amazon-stone. On the surface of the crystals, or in section, the Cleavelandite resembles a radiated zeolite, with a sheafy structure, the sheaves being occasionally isolated. The plates are white or colourless, and lustrous,—the lustre being pearly on the flat faces, vitreous on the edges: they are not much thicker than paper. Occasionally they radiate into quartz. The specific gravity is 2·622.

It yielded—

Silica	67·789	
Alumina	18·764	
Ferric Oxide	1·428	
Manganous Oxide	·076	
Lime	·516	
Potash	·757	
Soda	10·492	
Water	·159	
	99·981	(H.)

The *ilmenite* occurred in very small quantity, in thin blue-black plates, which lay between crystals of orthoclase, and also among the plates of the Cleavelandite. It was very much more readily powdered than is usual with this mineral.

The powder was reddish or brownish, and not blue-black as is usual.

It yielded—

Titanic Acid	50·646
Ferric Oxide	9·873
Ferrous Oxide	17·784
Manganous Oxide	5·172
Lime...	3·187
Magnesia	11·687
Silica	1·724
	99·973 (H.)

Of many ilmenites which I have analysed from various parts of Scotland this is very much the richest in titanic acid.

Orthoclase has been stated to be the matrix of several of the minerals which occur towards the outer portions of the vein. That orthoclase has the somewhat muddy flesh-colour which is so usual in the mineral. As it passes towards the centre of the vein it becomes clearer in colour, being somewhat like that of veal; and there are seen, in association with the magnetite, some crystals of a fine amazon tint. In this situation they are of about half an inch in size, and of simple forms.

It is a noticeable fact that of the orthoclase in this mass it is only the *amazonstone* variety which occurs in regular crystals; the flesh-coloured portions are crystalline, but not in definite forms.

These small crystals of amazon-stone first noticed occur imbedded in crystalline flesh-coloured orthoclase; and as we pass towards the centre of the vein, where the larger crystals commence to grow inward to its medial line, it is found that the roots of these crystals have the usual flesh-colour, while their summits or terminal portions have the amazon-stone tint, there being a gradual shading off of the one colour into the other.

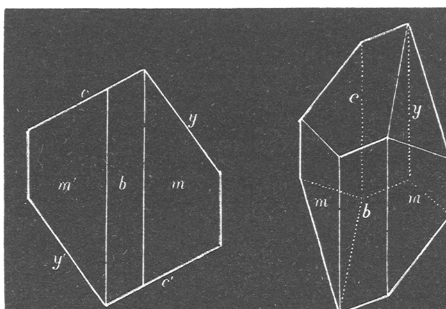
It has also to be noted that while there is no indefinite, *i.e.* porphyritic arrangement in the *position* of the crystals, yet (as in the case of the albite of the Ben Brachaid porphyry) the *whole* of the orthoclase is not in defined crystals. Some, indeed a considerable portion of it, forms only a confusedly crystalline padding to the amazonic portion. That portion had become possessed of more and more intense power of polar arrangement as it increased in purity;—and this increase of purity took place as it approached the centre of the vein. Even here there are but few free summits or even faces; the vein has been almost totally plugged, and the amazonstone crystals are enveloped, even as regards their centrally-directed terminations, in quartz or in flesh-coloured felspar.

The *amazonstone* occurs in so many forms that the various crystallizations of the mineral might, to a great extent, be studied in this one stone.

Two distinct types present themselves,—the *ordinary type*, or that in which there is no dominant growth along any axis; and the *clinodiagonal type*, with dominant growth along that axis.

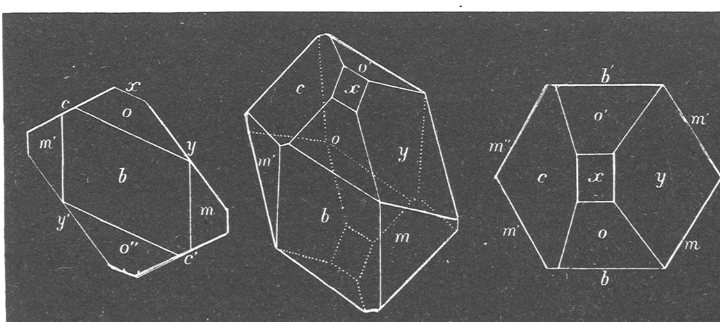
The first type *only* occurs in the small crystals which are found imbedded at some distance from the centre of the vein. The second type is markedly the dominant one among the large crystals lying in the vein centre.

Among the small *exterior* crystals some have so few faces, while others have certain faces *so largely developed*, that the forms are difficultly recognisable; figure 1 is an instance of the first.



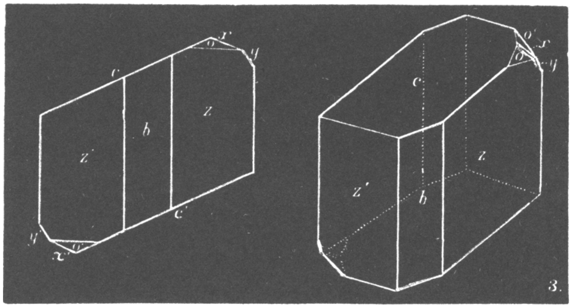
1.

In figure 2 the dominance of faces y, b, and c is marked;

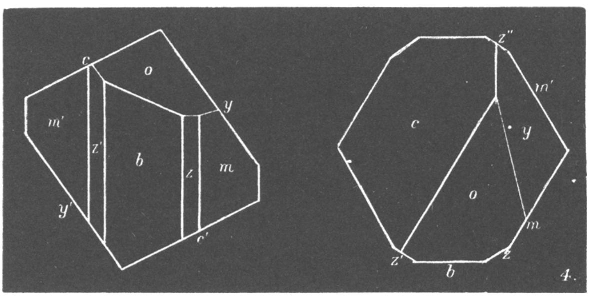


2.

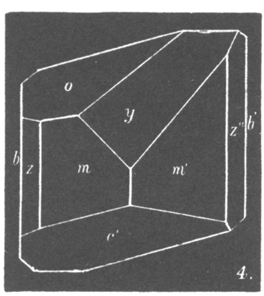
while in figure 3 the dominance of *c* and *z* is equally remarkable.



In figure 4 the hemihedrism of the face *o*, though not producing marked



distortion when looked at in plan (as in its first presentation), does so when the crystal is regarded either when the summit is looked at, or in the line of the clino-diagonal.



The analysis of the mineral was made upon fragments sent to me by Prof. Nicol and Dr. Joass, shortly after the discovery of the stone in 1875. Its specific gravity is 2·569; its cleavage angle, 89° 43′.

It yielded—

Silica	64·204
Alumina	18·895
Ferric Oxide	·455
Protoxide of Manganese	·152
Lime...	·725
Magnesia	·076
Potash	12·752
Soda	2·952
Water	·512
	100·228 (H.)

Copper, chromium, and nickel were specially sought for, but no trace found, nor was there a trace of ferrous oxide.

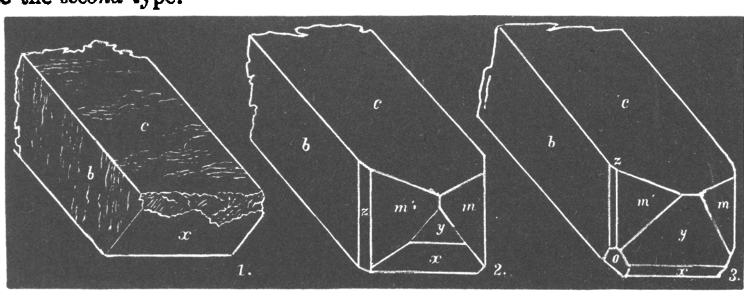
Many of the crystals are of so fine a colour that, when first seen, the effect, merely as a coloured stone sticking out of the side of a hill, was quite startling. From the centre of this mass, specimens of unparalleled magnificence were obtained.

Plate V. gives portraits of some of the crystals,—by no means the finest. Those figured varied from 8 to 18 lbs. in weight. Two crystals, which were un-terminated prisms, and which were unavoidably broken in the extraction, had the following very unusual dimensions :—

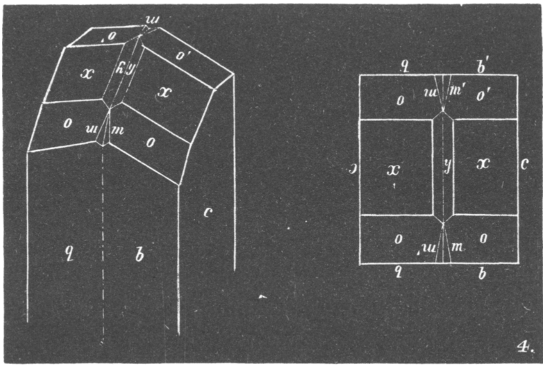
	Length along *b* and *c*.	Breadth over *b*.	Breadth over *c*.
1st	15½ inches	10 inches	8 inches
2nd...	12½ ,,	8 ,,	6 ,,

A magnificent museum specimen, now in the possession of His Grace the Duke of Sutherland, shows, on a surface of some three square feet, eight perfect and several imperfect crystals, of the size of the fist.

The crystals from the vein itself belong, as I have said, almost entirely to the *second* type.



The first of these crystals might have had more faces than *b c x* alone, as the fracture may have carried off *z m* or *y*.



Simple crystals are however here rare; hemitrope forms prevailing, the axis of revolution being normal to *c*.

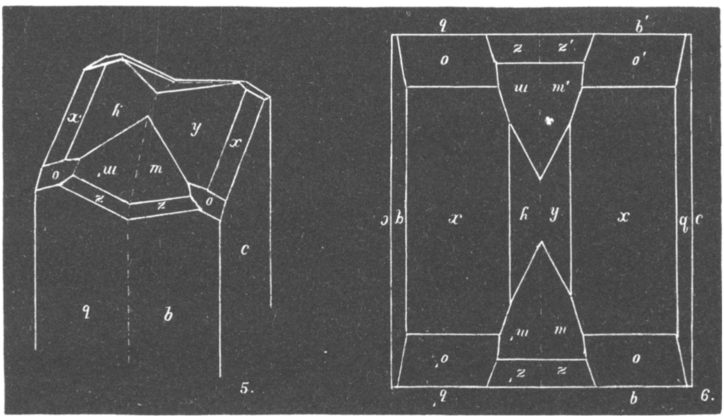
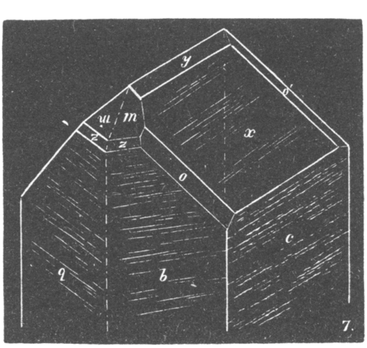


Figure 6 is the plan of the termination of a magnificent crystal, quite as perfect as drawn; this lies upon the surface of the large specimen which is in Dunrobin Castle.

These hemitropes are most frequently either hemimorphic or hemihedral. Figure 7 is hemimorphic, as regards the faces *o* and *y*.



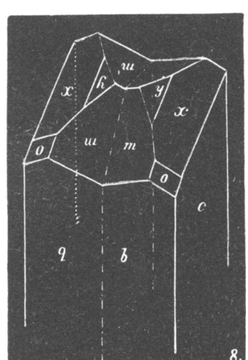
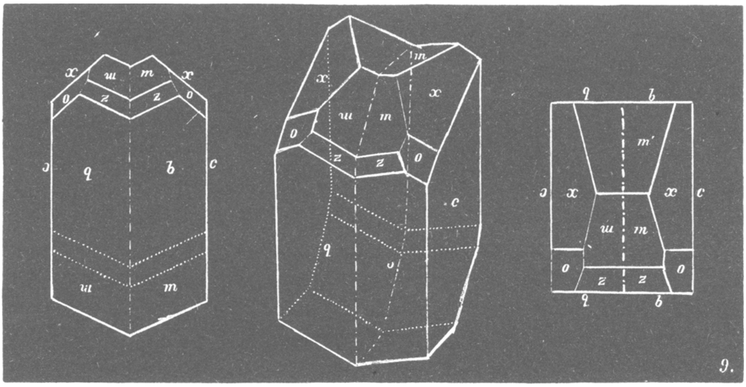


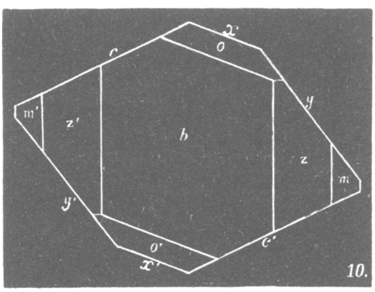
Figure 8 is *alternately* hemihedral, as regards the face *o*.

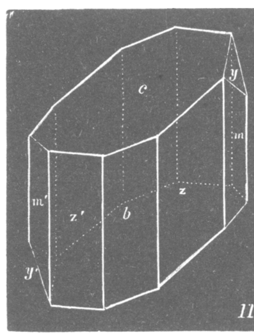
While figure 9 is so also as regards the faces z and o.



Of the forms belonging to the *first type* which occur here, figure 10 shows great dominance of faces b, c, y.

Figure 11 a still greater dominance of face c.

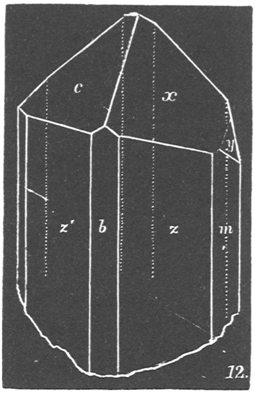




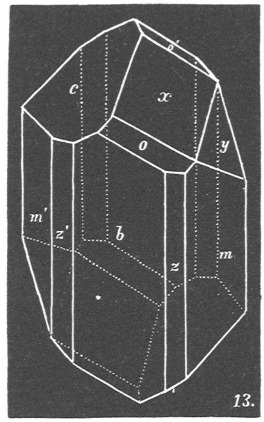
12 is a very unusual development.

13 represents the only specimen found here of this most common of all the forms of orthoclase.

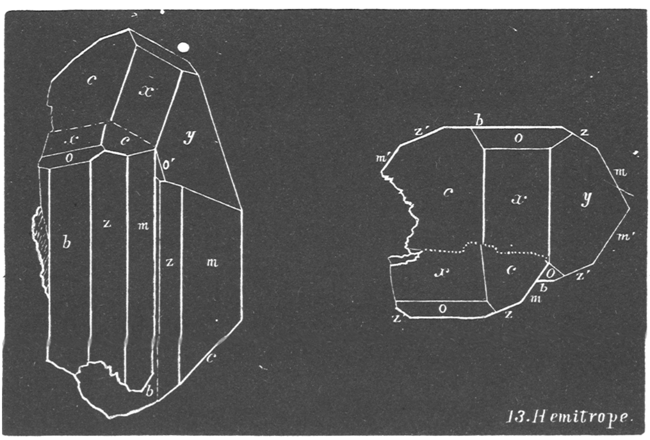
I found one hemitrope of this last figure with the axis of revolution vertical, and with planes x and c nearly coinciding. A nacreous flash, which is reflected from x, but is absent from c, also shows that the revolution is a vertical one. The one portion of the hemitrope is much smaller than the other, and there is a peculiar dovetailing of the halves which will be noted below.



12.



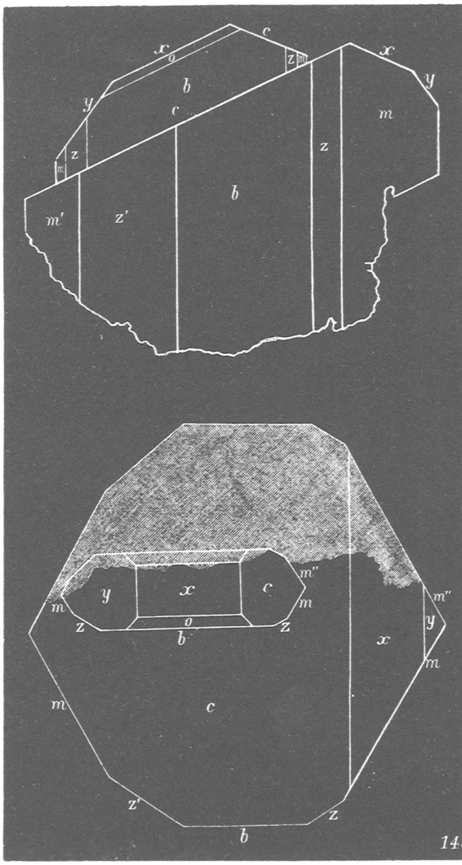
13.



13. Hemitrope.

The next figure, 14, is a hemitrope of the same form, arranged in accordance with the same law; but here the revolved portion is not only much smaller, but is *inserted* into the bulkier portion, which latter is somewhat distorted, from unequal development of its faces *z*.

All the hemitropes of the second type are readily separated along the face of composition. When they have been separated, it is found that the two portions had been held together, first, by a mutual interpenetration or dovetailing, which is well seen in figure 6 of the plate (this figure was drawn by my lamented friend, Professor Nicol); and secondly, through a structure which becomes at once evident to the eye, upon the surfaces of both halves of the crystal.



This peculiar structure I had observed many years ago in the *orthoclase* of Rubislaw quarry, near Aberdeen; I had noted afterwards that it was very generally if not always to be seen in the felspar of veins or dykes, especially of exfiltrative veins. It sometimes occurs in large, sometimes in small development; but never having seen it so strikingly displayed as in the amazonstone of Tongue, I very specially examined it in this, and made the following observations thereon:—

When viewed only on the surface of an opaque crystal, the structure resembles, in its somewhat interrupted markings, a graphic delineation of the distant waves of the sea; or the light reflected upon a polished piece of fine-grained ivory, cut parallel to the length of the tusk. When viewed in a transparent crystal through a lens, it resembles the fibres, great and small, of a partially untwisted cord, spread loosely and more or less uniformly across the crystal—the direction being invariably parallel to the face *a* of Brooke and Miller (*ii.* of Dana).

Professor Nicol of Aberdeen, who quite independently observed the same thing in these crystals, writes me (12th Nov. 1875) as follows:—

"The most curious felspar I have seen is one from a boulder. It is a macle like those in p. iii. of my 'Elements,' but broken at the ends; it is about 8 inches long by 2 broad.* It consists of red and green layers running across the cleavage face, and down the side of *m*, approximately parallel to its edge, and at right angles to the plane of cleavage, almost like fibres of wood or muscle. The brown and green are not in twins, but mixed in irregular plates—the cleavage runs right across both. The layers look like fat and flesh fibres in a piece of well-mixed beef. These fibres are not quite continuous, but more or less interrupted or broken. They are thicker near the outside.

"You call it amazon-stone, but I think it is rather orthoclase, *mixed* with the green mineral. This is more gem-like and less altered than the red. I am inclined to think also harder."

Up to the time of receiving Professor Nicol's letter I was uncertain whether these markings were to be regarded as due to a peculiarity of structure, or to an actual difference in material; though I inclined to the latter belief from having observed the fact, noted above by Professor Nicol, that the fibrous-like substance invariably weathered faster than the general mass of the crystal. The opinion of so acute an observer as Professor Nicol strengthened me in this belief; but it was not until I had analysed many such felspars, and more minutely examined the structure, that I definitely came to the conclusion that Nicol's view as to their being *actually two chemically different substances conjoined in one crystal* was the correct one.

The observations I have made, so far as yet carried out, are the following:—

1. *The Structural Appearances.*

These fibres and fibrillæ invariably differ in colour, lustre, and transparency from the general substance of the crystal through which they are spread. When viewed perpendicularly to the face *c*,—that of most perfect cleavage,—they frequently appear opaque, white, or brownish-red, always lighter in colour than the general mass of the crystal; but this opacity is,

* This crystal had been sent to him by Dr. Joass.

except in the case of weathered crystals, the result of the manner in which the light is reflected from them.

Placing the crystal as usual, with the macro-diagonal transverse to the observer, and reflecting light from the general surface of the face *c*, the striæ pass as dull or opaque white interrupted lines from the observer, the face itself frequently exhibiting a faint lineation between the fibres, parallel to the macro-diagonal; but on revolving the crystal upon the diagonal about 4° either to, or from, the observer, the corded structure starts out with a nacreous glimmer, somewhat similar to that in *sonnenstein;* the edge between the two reflecting faces lies parallel to the macro-diagonal of the large crystal, and the light appears under the lens to be reflected from innumerable interrupted cleavages.

When the somewhat imperfect *a* cleavage is obtained, a less interrupted and somewhat more brilliant flash is thrown from spots upon its surface;—careful observation being required before the impression is done away with, that the light is reflected from thin plates of talc.

In the more brilliantly green-tinted and transparent amazon-stones, the colour of these so-called fibres is usually of an opaque white; in some duller crystals they have precisely the tint of dead muscle. It has also to be noted that they are quite as largely developed in those portions of the crystals which are flesh coloured, as in the green; though from the contrast of colour not being so marked, they are not there so readily observable.

2. *Is the Material of the duller Portions different from that of the general Mass?*

In no specimen that I have seen is it within the bounds of possibility to separate the one from the other, so as to determine this by actual analysis;* but it may reasonably be concluded that they are different, on account of (1st) the higher lustre of the filamentous portions when unweathered; (2nd) the greater rapidity with which these portions do weather; (3rd) their greater opacity when weathered; (4th) their inferior hardness,—for a soft knife drawn across both does not scratch the general mass, but only the fibrous portions.

3. *What proportion of the Crystal does this intruded or extruded material bear to the ordinary Orthoclastic Substance?*

The habit of taking the specific gravity of all minerals analysed, led to my being able to form a fairly approximate estimate of this.

* Quite recently, I have been able to knock off so much of the white skin (which appears to ramify as this structure in the crystals) as enables me to say that it is a soda-lime felspar. Feb. 1883.

Many determinations of specific gravities of orthoclase from diverse localities give an average of 2·555.

A crystal of the variety called Murchisonite, obtained at Loch Ransa, on Arran, gave the exceptionally low specific gravity of 2·3;—the weight if the crystal was 163·3 grains in air; 92·3 in water:

$$163{\cdot}3 - 92{\cdot}3 = 71;\ \tfrac{163{\cdot}3}{71} = 2{\cdot}3.$$

It was boiled, when it gave out much air from lines transverse to the face *c*; it was now cooled under water, dried with blotting paper, and reweighed in air and in water. It now weighed in air 169·5 grains, and in water 98·3 grains,—the buoyant effect of the air previously in the pores being done away with.

$$163{\cdot}3 - 98{\cdot}3 = 65:\ \tfrac{163{\cdot}3}{65} = 2{\cdot}512,$$

which is, therefore, the true specific gravity of the solid matter of this crystal.

But the weight of the crystal in air with its pores filled with air was 163·3 grains; and with its pores filled with water, was 169·5 grains; the weight of a bulk of water equal to its pores is therefore 6·2 grains; and as the substance has a specific gravity of 2·512, the bulk of its pores in its own material would weigh $6{\cdot}2 \times 2{\cdot}512 = 15{\cdot}57$ grains. This, added to its original weight, so as to get the weight which the crystal would have been if solid, gives $163{\cdot}3 + 15{\cdot}57 = 178{\cdot}87$ grains; the weight of the bulk of the pores was 15·57,—and $178{\cdot}87 \div 15{\cdot}57 = 11{\cdot}487$.

So that these pores are about one-eleventh and a half, $\tfrac{1}{11{\cdot}5}$, of the total bulk of the solid.

The relation between these pores in Murchisonite and the subject under consideration is now to be shown.

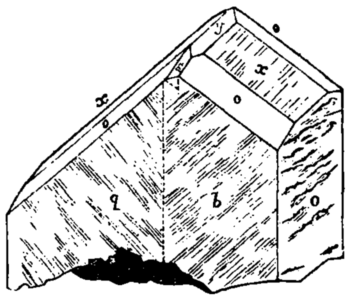
Murchisonite is chemically an orthoclase, but it is characterised by an extra cleavage—(not seen, so far as I know, in Scotch specimens), and by a peculiar pearly glimmer when viewed in certain positions. An examination into the cause of this optical peculiarity seemed to show that it was due to a structure identical with that above described as occurring in the amazon-stone,—only that vacuities took the place of the material constituting the fibrous net-work.

The crystal I was examining, however, being a complex twin of eight individuals, was ill adapted for the display of internal structure; and I was fortunate in having in my hands a simple and well-developed crystal which Mr. Dudgeon had sent me to figure.

I was not, of course, able to get a section of it, but an examination by the lens at once and unmistakeably showed that the characteristic lustre was due to internal reflection from a multitude of flattened microscopic pores, arranged accordant with the axis of the crystal, parallel to the face *a*.

So far as the power of the lens went, the pores seemed similar to those of *hypersthene* (Paulite).

The structure, therefore, is identical with that under consideration, only that in Murchisonite it is porous, or empty.



Hemitrope of orthoclase from the Hill of Fare.

A crystal lent me by Professor Nicol actually showed this identity. This crystal was a hemitrope of the form depicted; it was got in a quarry at Upper Craigton, Hill of Fare, Aberdeenshire. The general colour of this hemitrope is a reddish brown; the faces *b* which are smooth and somewhat transparent, show the fibrous structure, shining up from the depths of the crystal on account of the relative lightness of its colour. The face *c*, again, shows a lineation through deficiency of substance; consisting of a transverse series of pitted markings, which are the openings of the pores.

A point of considerable interest in this crystal is that the portion covered by the face *m* is either of a purer or of a different nature from that of the general mass. It forms a small wedge of nearly colourless and transparent material *let in* to the general substance.

The weight of this crystal in air was 48·28 grains; in water, 27·12.

$$48{\cdot}28 - 27{\cdot}12 = 21{\cdot}16,$$
$$48{\cdot}28 \div 21{\cdot}16 = 2{\cdot}282,$$

which is the specific gravity with pores *air-filled*.

Boiled in water, air escaped from the pitted markings; after cooling in water and drying it weighed 50·13 grains in air, and 29·13 in water.

$$48{\cdot}28 - 29{\cdot}13 = 19{\cdot}15,$$
$$48{\cdot}28 \div 19{\cdot}15 = 2{\cdot}521,$$

which is thus the true specific gravity.

But the water weight of the pores is equal to the difference between 48·28 (its weight with these pores air-filled), and 50·13 (its weight with pores water-filled),$=1·85$.

And $1·85 \times 2·521 = 4·66$,—the weight of the bulk of the pores if they were solid.

This 4·66 added to the original weight of the crystal, 48·28, gives 52·94 as what would have been the weight of the crystal if it had been solid; and $52·94 \div 4·66$ gives 11·36.

So that in this crystal the amount of the foreign matter now represented by pores is about one-eleventh and a third, $\frac{1}{11}.\frac{1}{3}$, of the whole crystal. A remarkable coincidence with the proportions in the Arran crystal.

I find that many crystals of orthoclase exhibit these vacuities in their substance, exactly corresponding in position to that of the structure which has been described. Crystals of adularia from St. Gothard are frequently hatched, and cross-hatched in twins, through the lineation produced by this deficiency of substance. I possess a crystal which is little better than a skeleton from this cause.

4. *What is the Material of which this Knitted Structure is composed?*

It would not, as before mentioned, be practicable to separate the material from the orthoclastic mass: by a consideration, however, of the composition of those felspars which exhibit the structure, a conclusion, which it would not be unreasonable to consider as closely approximate to the truth, may be drawn.

The analyses of such felspars show so slight a departure from the average analyses of orthoclase, that the substance evidently cannot be very far removed from orthoclase in composition. The only decidedly noticeable differences are an excess of soda over that normal to orthoclase, and the introduction of some lime.

The first point here to be noted is that as the amount of silica is quite normal, and as the substance of the lineation is the softer part of the structure of the crystal, it cannot consist of quartz. Had this been the case its occurrence in the position occupied would not have been altogether inexplicable, for then it would have consisted of the excess of silica over and above that necessary to saturate the bases in the formation of felspar; which excess, indeed, the quartz in granite veins must probably all be regarded as representing. Such an excess of silica, *and so separating*, forms in the graphic felspar of Ben Capval and Stromay, in Harris, a structure wondrously similar to that under consideration.

The *sonnenstein* appearance of the layers gives rise at once to a suspicion of their being composed of some species of felspar; but how a felspathic material should, in thus being extruded from another of similar nature, form so strange a structure, instead of regular crystals, is the roblem to be solved.

Now, seeing that other felspars are paragenetic with orthoclase in veins, that they are softer, and, with the exception of albite, more readily decomposed, it is very probable that the material consists of one or other of these.

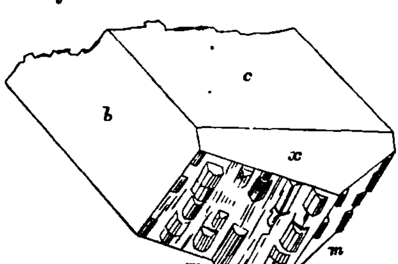
There are, however, judging from geognostic relationships afterwards to be pointed out, only two that it can well be,—albite and oligoclase,—and the evidence appears to be rather in favour of its being the latter.

An admixture of oligoclase with the orthoclase would introduce both soda and lime,—albite would only bring in the former, and that only at the cost of simultaneously increasing the quantity of the silica, which oligoclase would not do.

As regards association, oligoclase very frequently accompanies orthoclase in granite, especially in veins. Again, albite is exceedingly rare in Scotland in granite. I only know it at Stirling Hill, and Murdoch's Cairn quarries, near Peterhead, and in smaller quantity in the quarry of Craigton, Hill of Fare; moreover at these localities it does not occur in veins, but in druses in the granitic mass.

Albite, moreover, it is well known, weathers less rapidly than orthoclase (except perhaps in the rare case of its occurring in trappean rocks); but the material of these laminæ, or whatever they be termed, weathers decidedly more rapidly.

And lastly, albite is not paragenetic in time with orthoclase,—the latter is always proterogenetic to crystallised albite, the crystals of which are generally disposed on the top of the former. Indeed, in Murdoch's Cairn the albite is evidently a product of a change in the orthoclase, being always disposed on apparently corroded *m* faces of the latter, the axes of the



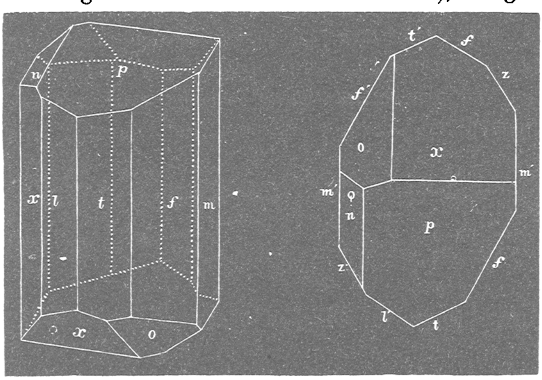
Albite on orthoclase, Murdoch's Cairn.

crystals of both being accordant in direction. (See figure.) Oligoclase, on the other hand, is in all respects paragenetic with orthoclase,—at Lairg they are imbedded side by side in quartz; at Sclatty, Rubislaw, Craigie-Buckler, &c. they are mutually assertive, and mutually interpenetrating.

In the Tongue boulder, though ordinary albite does not occur, yet the sheafy Cleavelandite variety is somewhat rarely found; but this is here markedly proterogenetic to the amazon-stone. It thus forms a "basement mineral" to the crystals of the latter; and though a few crystals of what *may be* albite are disposed on the surfaces of crystals of orthoclase, its occurrence in two zones is most unusual.

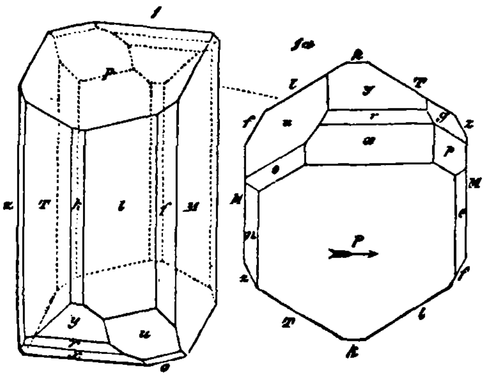
It has to be stated, moreover,—whether it be an argument for or against the above view I know not,—that at several of its localities oligoclase does not occur *otherwise* than thus imbedded—that is, does not occur in separate crystals—indeed this is the case in those localities where this structure is best seen. The same thing, however, applies to albite, which does not occur in determinate crystals or masses at any of the localities where the structure has been observed, with the single exception of that of Stromay.

The evidence in favour of the material of the structure being *albite* is extremely weak. It consists merely in the fact of some minute crystals (which occur coating some of those of amazon-stone), being in the form

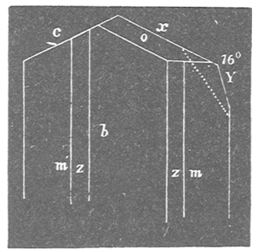


drawn. This form may be referred to *albite*; but, without angular measurements, they could not be set down definitely as albite, as the form is quite referable to *oligoclase*. Indeed, the black line figure is the form lately given by Naumann as *characteristic* of oligoclase; and this, it will be observed, is but a more complex form of the Sutherland crystal.

It has been stated that these minute crystals occur on, or coat the amazonstone. It will also be observed that in Professor Nicol's figure (see Plate V., fig. 1), he makes the quantity of the interstitial matter increase near the surfaces of the crystal. This is very often the case; sometimes the interstitial substance may be even seen to run in from an outer-coating



of white material. This white layer only occurs on certain faces. A most interesting illustration is the figure in the margin, where a crystal of the ordinary form has a quantity of the white matter *set on* to it, upon the face *y*. This small portion is rivetted to the general mass of the crystal by throwing processes into its bulk, and it is the ramification of these processes which produces the structure in question. The little tip of white material has on it a face more acute than *y* (Y), which forms with *x* an angle of about 76°.



It is here to be noted that there is in *Perthite* a somewhat parallel banding of *orthoclase* and *albite*. The two were in that mineral probably paragenetic in time; but the microscopic structure of *Perthite*,—the only variety of felspar in which there has been a chemical determination of the nature of the layers,—is so different from *this*, as to form the very strongest argument against the view that the intruded mineral is *here* albite.

A piece of special pleading in favour of admitting this structure to be formed of *albite* is, that by so doing the amazon-stone would be included under *microcline*. As the angular inclinations of all the crystals depart from a right angle, they *are* microclines whatever be the nature of the distorting substance.

This *departure from a right angle* has now to be considered.

5. *Has this intruded Foreign Matter any effect, and, if any, what, upon the inclosing Crystals?*

The cleavage angle of every one of the felspars showing this structure departed more or less from 90°; *and the departure from a right angle is greatest in the felspars which show the structure in its strongest development.*

Lairg, 89° 39′; Rubislaw, 89° 58′; Stromay and Ben Capval, 89° 50′; Tongue, 89° 45′; Cowhythe Head, 89° 40′; Blirydrine, 89° 40′; Eslie, 89° 40′; Anguston, 89° 49′; Yestnaby, 89° 56′, are a few quotations; these being, out of measurements of several fragments, those which were the most common. Though measurements nearer to 90° were occasionally obtained in such felspars as show this structure, none were absolutely at the right angle.

If we suppose that the foreign substance is oligoclase, and that the polar axes lie accordant with one another,—which it will be shown that they do,—the obliquity of the cleavage angle in that substance should more or less distort the orthoclastic cleavage.

The angle of oligoclase differs 230′ from that of orthoclase; the amount of oligoclase present seems about $\frac{1}{11}$; the eleventh part of 230′ is 21′.

The case of those crystals which, like the Murchisonite, are systematically porous, here calls for consideration. The crystal from Arran, being a complex twin, was unfitted for the determination of the angle.

If the open structure and the filled-up structure be in reality the same, and if the crystals now vacuous be also more or less triclinic, we must conclude that the oligoclastic material segregated out of the orthoclastic, when both were solidifying nearly contemporaneously; and that in the hollow crystals the more decomposable mineral had been weathered or dissolved out. All Murchisonites I have seen were either loose stream-rolled crystals, or they were weathered; but it was not so with the Hill of Fare specimen; it was taken from a freshly-opened cavity.

It cannot be supposed that the crystalline molecules of the orthoclase arranged themselves preconcertedly, so as to distort the crystal; and also so as to leave vacuities for the reception of *a pre-selected* substance. The action of the crystallipolar force, in its wondrous production of hemitrope, twin, hemihedral, and hemimorphic crystals, must be said to be *determinative*, but we cannot assign to it the function of being *deliberative*. And though it is quite conceivable that pre-existent vacuities might be plugged up by the accretion of a subsequently solidifying felspathic material, or, in its absence, of the siliceous paste, still it is inconceivable that vacuities—the *absence* of material—could distort the angle of a crystal. "Nothing can come of nothing." An insufficiency of accreting molecules sometimes produces modifications—new faces on a crystal, —but is powerless to alter its angles; and we are thus forced to conclude, as above, that the contemporaneous, or nearly contemporaneous solidification of the triclinic substance within the orthoclastic, distorted it laterally; and that the open structure in all felspars in which the angle departs from 90° is, in a double sense, an *outcome*,—due to the removal of a material soluble in a solvent which is incapable of attacking the orthoclase.

I have somewhat particularly described this structure, as I have known it to be mistaken for that striation which is insisted on by some geologists as a reliable criterion in the discrimination between orthoclase and the plagioclastic felspars;—the following distinctions may, however, be pointed out:—

The structure differs from the striation of twinning in that its markings are not rectilinearly parallel, but occur in undulating lines,—more undulating in *c* than in *b*; they *cross* the face *c*, being at right angles to the macro-diagonal, while the lineation of repeated twinning is parallel to the macro-diagonal; they are not alternately lustrous with the other parts of the crystal, on revolution upon an axis parallel to their own strike; they are coalescent; and they are lighter in colour than the rest of the crystal.

I might add that, as these markings are as frequently seen in these vein orthoclases as striation is in the plagioclastic felspars, they are as good a mode of discrimination between the two as is the latter; and, as they have never been seen in a plagioclastic felspar, while striation may occasionally be seen in *every* plagioclastic felspar, they give, where seen, some absolutely *specific* information, which striation can never do.

As the hemitropism of the crystals of amazon-stone exhibits this singular structure in a modified development, it calls for notice.

This amazon-stone, as before noticed, is frequently in hemitrope crystals which are pervaded throughout with the corded structure, and that to such an extent that the white opaque filamentous matter acts as tenons to the two halves of the hemitrope, binding them together, until separated by force; then the white substance is seen with fractured edges like the separated sutures of the disconnected bones of a skull.

The faces of the separated halves of the hemitrope are found to be highly polished and lustrous; the white ruptured lines passing across them in relief or depression according to where the fracture operated,—like the rugosities of a single-struck file.

On pressing the two halves together, a certain amount of cohesion is re-established, as in the forcible reinsinuation of the sutures of the bones of the skull.

Difficult as it is to account for the arrangement of the molecules during the reversed polarity which is operating whilst a twin or hemitrope crystal is being built up, there is here something more difficult still: for, across the path of the molecules of the green matter, while moving towards their appointed positions, there must simultaneously have been moving those other white molecules, engaged in their work of building up an inosculatory net-work; a system of net-works rather, extending not like the float of the fisherman in single line, but in innumerable parallel dispositions, stretched with perfect verticality * across the crystal, as the net of the fisherman is stretched by its leads with perfect verticality in a tranquil sea. But a consideration of what must be the relative motions of the molecules which are going to form a hemitrope crystal, would necessitate our comparing their influence upon the white layers in such crystals to that of a flood-tide impelling the buoy-rope and also the lead-line of a net the one way, while a medial current of ebb swept its corded structure in the opposite. In accordance with this,—at the face of revolution of the two halves of the hemitrope, the line of direction of this multitudinous net-work abruptly bends, and in its altered course maintains, as before, a perfect parallelism to the face *a* of the revolved segment of the crystal.†

It is this lineation, parallel to the face *a*, which, in a hemitrope thus formed,—*i.e.* by revolution on an axis normal to *c*,—produces the "herring-bone structure" seen in the orthoclase of rock sections; and not, as has been stated, one which is "characteristic of macles of the Carlsbad form."

This lineation, which strikes across *c* at right angles to the edge of *b*, could produce no angular lineation in a "Carlsbad twin" formed by its *first method*, namely by revolution *round an axis normal to b*; as the severed lines would again meet with the same strike. Neither could any herring-bone structure be formed by this lineation in a hemitrope or twin of the *second method*, namely where there is revolution of one half round a *vertical* axis; for the same rectilinear apposition would again result. There would have to be (which there is not) a lineation parallel to *o*, before a "herring-bone lineation" could be produced in either case; and

* Supposing the crystal to be placed as usual with the faces *m* vertical.

† See figure 3 of Plate V., also Hill of Fare crystal.

even then it must perforce be a *hemimorphic lineation*, parallel to *two only* of the four *o* faces.

But this white substance, if oligoclase, must not be regarded as merely *extruded* from the green, in the manner that amorphous impurities would be.

As a definite chemical compound, it is itself subject to the operation of the crystallising force, in its double function as a physical separater and a symmetrical arranger. It is so arranged here, and the law of the arrangement is a singular one. It has been stated above, that the white reticulated structure is generally parallel to the face *a*, and gives a glimmering cleavage reflection when revolved about 4°, either to or from the position of ordinary reflection of the face of the crystal as a whole. This glimmering reflection is unmistakeably from repeated cleavage faces, which give between each other an angle of about 9°. Such a cleavage angle is unknown in orthoclase; but the angle is as near that of the salient angle between the faces *p* of hemitropes of oligoclase, as reflections from so small surfaces could be expected to afford. Such hemitropes, however, are formed by the revolution of one-half of the crystal round an axis at right angles to the face *m*—that is, round the brachydiagonal—which, of course, is at right angles to the axis of revolution of the main crystal.

In fine, we have here a squat crystal of orthoclase,—squat as regards the length of the vertical axis,—which crystal is a hemitrope accordant with face *c*, laced throughout by thread-like hemitropes of oligoclase (?), the main axes of the two being accordant, but the axes of the hemitropism being at right angles to each other. We have molecular repulsion co-existent with a peaceful crystalline consorting in one and the same fabric, a consorting which, perhaps, is all the more firmly interwoven, that, as regards hemitropic arrangements, the substances uniting have agreed to differ. Perhaps only those who have studied the motions of the molecules which, in a fluent menstruum, are engaged in the building up of regular solids, can in any measure appreciate the intricate evolutions of the molecules of these two substances, as they evaded one another in finding each its alloted place.

I would propose the term *corded structure* for what has been described; and I adopt to the full Nicol's view, to which I would give the following detailed expression, that *two substances of a nature differing both in composition and in molecular segregation,—differing also unquestionably in the system of crystallization to which they belong,—have here harmoniously united in one structure, in which the rectilinear rigidity of crystalline arrangement is pervaded, but not infringed, by the flowing curvatures and* *wavy lines of a structure as involved as the anastomosis of plant or animal life.*

I must, however, refrain from proposing a name for the crystals which exhibit this structure, until their optical properties disclose whether the included substance is albite, or, as I suppose, *oligoclase:* should it prove to be albite, these are all, of course, *microclines*; should it be oligoclase, the crystals have the same claim as has that mineral to a specific name.

I have here to note that in the summer of 1876 a single mass of apparently a dark green felspar was broken out of a vein in Rubislaw quarry by Professor Nicol and myself; this upon examination was found to exhibit the structure very plainly. The felspars here proved to be not only orthoclase but also a striated oligoclase ; and the included and colouring material proved upon analysis to be the new mineral to which I have given the name of *rubislite*: so that this singular structure may be impressed upon oligoclase as well as on orthoclase, and the plugging material is not necessarily a felspar.

The Structure as seen in the Microscope.

The structure which is visible to the eye, aided by the power of a lens, has, thus far, alone been considered ; but when thin slices of the amazon-stone are examined in the microscope, especially with the aid of polarised light, a still more intricate and wonderfully beautiful arrangement of the parts unfolds itself.

The lineation which has been mentioned as being faintly seen on *c* parallel to its edge but transverse to the corded structure, is now seen to be the result of the apposition of acutely wedge-shaped crystals. Two sets of these interlace with each other, like the teeth of two combs placed in apposition with forcible mutual insinuation.

With parallel Nicols, one set of these crystals—the teeth, as it were, of one of the combs—is highly coloured, the other being colourless, or polarising the complementary tint in feeble amount ; but each individual crystal—each tooth of the comb—is transversely banded by stripes of complimentary colour ; as if itself built up of myriad crystals,—a pile of numerous twins, the length of the individuals whereof diminishes gradually to the summit.

With crossed Nicols all this disappears from the lately coloured set, that which was previously colourless now assuming an identical appearance.

The twinning thus developed, being at right angles to the twin-face of the large crystal, and also at right angles to the supposed twin-face of the myriad individuals which build up the corded layers, produces therewith a structure of wonderful intricacy, and one which is altogether inexplicable by the known laws of the crystalline force.

The appearances, when examined by polarised light, of slices cut parallel to *c* and to *b*, are shown in the plate. (Plate VI.)

When the slice is examined without employing the analyser, the appearances go far to prove that two if not more felspars go to build up this comblike structure itself. This is disclosed first, by an opacity in some few of the teeth. The analyser immediately shows that these do not polarise at all, and their granular structure seems to show that they are decomposing. In marked contrast to the opacity of these, is the alternately greater pellucidity of the teeth, as thus seen.

The minute crystals which cross-bar the teeth are now seen to intersect several of them; at least they sometimes do so, tapering to both extremities. Others give a lozenge shaped section, indicating that they probably are oblique or anorthic. When the slice is in focus generally, these also seem somewhat opaque; but the throwing the slice slightly out of focus, shows them to be transparent,—the apparent opacity being due to a difference in their refractive powers.

The impression conveyed is, that these *cross-bar crystals* consist either of a third felspar, or a different mineral.

No optical phenomenon whatever is developed in slices parallel to *a*; this goes so far in negativing the supposition of there being a twinning of crystals in the inclosed oligoclase.

This *comb-like* structure, above described and figured, is altogether different in its nature and appearance from the "rectangular-reticulation" which is to be seen in Aberdeen, Dalbeattie, and many other *mass-granites*, which do not show the "corded structure."

I have, indeed, seen but rare traces of the rectangular structure in association with the corded structure (with one exception, possibly); and where these traces were visible, the difference in the two structures was clearly defined. The rectangular structure is delineated, in continuous *lines* which are of *nearly* equal length and of equal width; in the rectangular directions those parallel to *a* are, however, neither so uniform in spacing nor so marked in tone as the other set. The cross-barring of the combed structure is delineated by *bars* of diverse colours, which are not continuous, either as regards their breadth or position, with those of the adjacent wedge-like crystalline shoot.

Where the corded structure is but feebly developed, the comb-like structure is still less so; it being then confined to the centres of the spaces which lie between the opened cords; and here the only cross-barring consists of a system of very flat transparent lens-like portions, which do not polarise. These also are very different from the dark bars of equal width of the "rectangular" structure.

Having sliced many portions of the amazon-stone, I have seen but two modifications of its peculiar structure. In one the *corded structure* was cross-barred, the general mass being plain. In the other a series of broad sygmoid-like undulations of diverse colours passed diagonally but intermittently across the spaces which lay between the cords.

The single locality in which I have seen an association of the corded and of the rectangular structure (there being no traces of the comb-like) is in the orthoclase from the great dyke opposite the rock of Stromay, in the Sound of Harris. And I have to add that, so far as my observations have gone, the felspar of graphic granite does not show the corded structure, but a rectangular one in which the lines parallel to *a* consist of a series of intermittent and irregularly disposed fissures. In this there is a marked approach to the structure of *Perthite*. *Perthite* consists of alternate layers of *orthoclase* and *albite*; the orthoclastic layers being reddened by the presence of innumerable crystals of *rubin-glimmer*; the albitic layers being white. The relative position of these plates in the compound crystal or mass is identical with that of the comb-like and also of the corded structures in the Sutherland amazonstone,—that is, disposed in plates parallel to *a*. Now, both the Canadian and the Scotch specimens of *Perthite* show a system of fissure-like markings, both in the red and in the white layers. Those in the red are very fine and numerous; and such are confined absolutely to these layers. They are not at all of the nature of rents, but more resemble strains. Those of the white, on the other hand, which are parallel to *c*, though not amounting to cleavages, from a want of continuity, *are* rents; and sometimes crack across and cut several of the red layers.

I have stated above that I had found in the quarry of Rubislaw, specimens of orthoclase in which the new mineral *rubislite* occupied the position of the oligoclase in the corded structure.

Lately I have had a slice made of a specimen, and I find that it contains, on one side, corded processes of *rubislite*, on the other of *oligoclase*; while at other parts the rubislite seems to *stain* the oligoclase. More than this, what seems to be *a rent* (it passes at right angles to the line of the corded structure) is filled with rubislite. This fact, taken along with the occurrence of rubislite in *both* felspars, and the occasional irregularity of the structure itself, certainly leaves room for the question if *all this* *structure may not consist of a system of rents, which have afterwards been filled.*

In the Rubislaw specimen the corded structure shows "cross-hatching" *in its own substance;* the principal lines of the cross-hatching being at right angles to the main direction of the "corded structure" itself.

Remaining minerals of the Amazonstone Vein.

The *quartz* which is present in this vein hardly appears till the centre of the vein is reached; small quantities only being seen imbedded in the felspar.

The roots of the larger amazonstone crystals contain it occasionally, arranged in a crudely graphic manner. Larger lumps of a brown colour, with paler portions which pass like cords through their centre, are also present here. These paler portions seem to result from lines of minute fluid cavities. Lastly a few large dark-brown crystals occur mixed with or superimposed upon the amazon-stone crystals. They are somewhat muddy, and not well formed.

Specular iron in small quantity and in minute scaly crystals coats the free faces of the quartz.

There were found, on the sides of some of the cavities which occurred in the centre of the vein, three spherical masses of a cream colour. They had a radiated crystalline structure, from the surface of which free crystals protruded; but these were without lustre, and were too ill-defined for determination of their form. The centre of the spheres had a tremulous lustre, and was of a pale brownish-white colour.

Two of these spheres were of the size of tennis-balls; the third, which was used for analysis, was small.

They were disposed upon the surface of quartz and amazon-stone crystals, the free summit of the crystals projecting into the cavity, which contained a little water. Minute crystals of specular iron sometimes lay transversely to their fibres, and also did the green mineral next to be described.

The analysis of the sphere yielded—

Strontia	58·846	
Lime	8·529	
Carbonic Acid	32·305	
	99·68	(H.)

There was also a loss of ·099 per cent. in the water bath.

This is, therefore, a calcareous *strontianite.*

Dr. Thomson has given an analysis of brown strontianite from Strontian, which agrees very closely with this in the quantity of lime; but that analysis has lately (? on account of the lime) been dropped out of books of reference.

The specific gravity of this strontianite is 3·447.

The last substance which has been formed in the regular separatory sequence which has occurred in the formation of this exfiltrative vein, proved to be new; and I have attached to it the name of *Bhreckite*, from the hill upon which this most extraordinary mass of rock lay.

It occurred in such very small quantity, that nearly the whole had to be employed for the analysis.

This substance was deposited upon the surface of the crystals of brown quartz; and its immediate associates were the *specular iron* and the calcareous *strontianite.*

In appearance it resembles a very fine-grained dense *aphrosiderite;* but its colour, being a bright apple-green, was nearer to that of *celadonite.*

It was minutely granular or scaly; it was soft and friable.

The portion analysed was spread out under the microscope, when even with a high power it was to all appearance uniform and pure. It occurred in very minute lustrous scales.

The analysis, executed on ·484 grammes, yielded—

Silica	34·917	
Alumina	7·158	
Ferric Oxide	12·713	
Ferrous Oxide	2·105	
Manganous Oxide	·414	
Lime	16·082	
Magnesia	8·264	
Water	17·768	
	99·655	(H.)

Of the above water 1·033 was lost at 212°.

There were traces of alkalies, but there was not enough material to determine them upon; separate quantities having, of course, to be used for the determination of the ferrous oxide, and of the water.

The mineral was freely soluble in chlorhydric acid.

By this feature it may be distinguished from all the so-called "chlorites," with the exception of *glauconite*; it likewise serves to distinguish it from *celadonite*, which of all minerals this most resembles.

From *Delessite* and the scaly varieties of *saponite* (which *are* soluble in chlorhydric acid), it differs in virtue of its large amount of lime; a feature of its constitution which also serves to distinguish it from *glauconite*, and from the chlorites likewise.

The calculation of its atomic constitution is as follows:—

		Atoms.			
Silica	34·92	1·164		8	36·28
Alumina	7·16	·14	·3	2	7·78
Ferric Oxide	12·71	·16			12·1
Lime	16·08	·574	1·04	7	17·69
Magnesia...	8·26	·413			8·46
Water	17·77	1·974		13	17·69

Atoms.

$$\dot{R}\,7,\ \dddot{R}_2 2,\ \ddot{S}i\,8,\ H_2 13,$$

which gives the percentages of the last column.

This is the only chlorite-like mineral which contains lime in quantity; if established by occurrence elsewhere, it will stand next to *chonicrite*, and in composition it is not far removed from the *metaxoite* of Arppe.

The boulder which yielded this extraordinary association of minerals, was broken up by dynamite. It was found to be perfectly fresh and unaltered by aqueous percolation, or accession of air. At a distance of about a couple of feet from the vein there occurred small cavities, the sides of which were drusy with minute crystals of felspar and hornblende.

A pale yellow almost white incoherent powder, which was moist, and somewhat soapy to the touch, filled these cavities.

When freed as far as possible from grains of the matrix, it yielded upon solution in weak acid—

Insoluble and Silica	2·615
Strontia	54·222
Lime...	8·201
Magnesia	·846
Potash	·435
Soda	·261
Alumina	·879
Ferric Oxide	1·428
Manganous Oxide	·692
Carbonic Acid	29·948 to 30·728
	99·643

The analysis was made on two different portions, and can only be approximate.

This is a most singular result, as it shows strontianite to occur in a granular form.*

The Syenite of Lairg.

Murchison, in his "Generalised Sections," depicts the syenite of Ben Loyal as tilting up the contact rocks to east and west; and though he does not state that he actually saw such tilting at the spot, he throughout writes as if there was no question as to the syenites being eruptive.

I failed to find any spot near Ben Loyal where the contact was seen. Near Lairg, however, the circumstances for such examination are altogether favourable, as an actual contact can be seen in a small quarry half a mile from the village; and the railway-cutting, a mile or so to the south, also affords more than one point whence instruction may be gleaned.

The writer, however, had his attention more immediately directed to the question as regards the rocks *in the vicinity* of the syenite, through Dr. Joass having again guided him to a mineral locality situated among such rocks. Dr. Joass had procured some new Sutherland minerals from a pensioner; he sent them to the writer; and as the locality was one which in a former year had appeared to Mr. Dudgeon and the writer as one of marked interest, it was lately examined; and on the first occasion of such examination the writer had the advantage of Mr. Hudleston's experiences.

The district in question is that which impinges upon the great mass of syenite, upon its west margin. It showed rocks so altered and granitic in their nature that Mr. Dudgeon and I agreed to carry the line of the syenite, nearly two miles to the west of the junction as laid down by Cunninghame, by Nicol, and by Geikie. Further examination, however, satisfied me that though highly metamorphosed and syenitic in parts, it was gneissic as a

* Amazonstone was first stated to have been found in breaking up a boulder at Ribigill at the foot of the great north precipice of Ben Loyal. This was thought to be an error, but in the year 1882 I was presented by Mr. Wisdom with a portion of a crystal of amazonstone, which he broke ont of a wall about 60 yards from Ribigill; and he stated that he thought he could see a vein running up the face of the cliff. Dr. Joass, in a letter of date March 20th, 1883, writes:—"The other day a good specimen of amazonstone, containing part of a large crystal of tourmaline, was brought to me as found in the burn running out of Lochan Hacon, where the rolled specimen was got which contained small flakes of talc, and which you thought curious. If is of interest to know that the vein with the amazonstone comes to the surface somewhere on the Ben Loyal side of the Tongue strath, either in this burn or on some of the slopes overhanging it" This crystal of *tourmaline* is the first found in Sutherland. The absence of that mineral from the red granite and other veins of the Hebridian rock is a fact worthy of note.

whole,—had no connection either geognostically or in constituents with the syenite of Lairg,—and, indeed, that there was a distinct belt of less highly metamorphosed gneiss interposed between the altered districts and the true syenite. In my map, therefore, the boundary line of the syenite was again carried back to its old position.

The district is termed the Gruids; it stretches two or three miles west of Lairg, and is somewhat less in extent in a north and south direction. The rocks here fairly well exhibit transitions from gneiss into a granitic rock; but the transition is incomplete, as there is no mass of perfectly transmuted rock. This change takes place through an increasing dominance of bands of metamorphic segregation.

The general appearances associated with this change, I have described in my papers in the Transactions of the Royal Society of Edinburgh,* so that I now only glance at the local features.†

At the west end of the district towards Rhian and Druim Baltifiar, the country has been much scoured by ice, and numberless false boulders strew the surface. Observation shows that these have been only pushed about, and not transported any distance. They consist merely of portions of rock torn off the protruding, because less disintegrated, bands of the rock. Closer observation also shows that such bands had been less disintegrated, in virtue of their having been the more highly altered,—the more perfectly metamorphosed.

Here the most singular variety is one which presents itself at first sight as a dull green felspar, with imbedded semi-fibrous hornblende, and some *Biotite*. Inspection with the microscrope shows that if this variety contains hornblende at all, it is in a form difficult to recognise as such, as it polarises with a uniform structure and an oily roundness of the edges.

Passing to the Ord Hill, the appearances which are common to veins of dominant change are well seen; the abruptness of flexure, and the suddenness with which they thicken, thin, or disappear, is most marked. These bands are of a beautiful and characteristic syenite, of which the felspar is to a great extent of a lively brick-red. It is in well-pro-

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* Vol. xxix. p. 6.

† As the *modus operandi* of such changes can be most easily studied by aid of the microscope, I have adopted what I considered the simplest and most satisfactory method of wide-spread publication,—namely, placing sufficient masses of each rock in the hands of Messrs. Cole & Co , St. Domingo House, Oxford Gardens, London, W All subscribers to the highly deserving and admirably conducted enterprise of this Company will receive slices.

nounced crystals, and the foliaceous hornblende is also distinctly segregated apart.

No connection whatever can be discovered between the rock of this hill and the syenitic mass at Lairg. Indeed, as we approach the river Shin, we find much more massive veins,—less flexured, and consisting of white felspar and quartz in amorphous agglutinations.

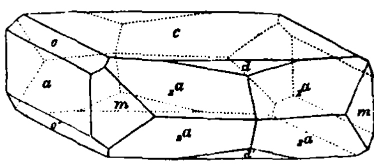
The district is one which should be studied, along with microscopic sections of its rocks, by all interested in metamorphism.

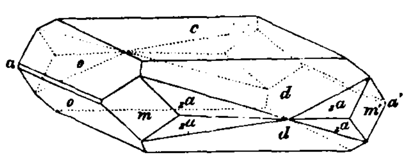
These rocks show little change, except in the syenitic belts, and they maintain unaltered the ENE dip which is normal to the district.

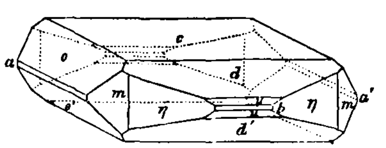
Minerals.

The minerals forwarded to me by Dr. Joass as from this district, consisted of blue *fluor* in granite; *specular iron*, of a blue-black colour and considerable thickness of crystal, adherent to syenite; crystallised *chalcopyrite*,—and finely crystallised *rock crystal.**

On my first search with Mr. Hudleston I found only a specimen which carried rock crystal,—prismatic and doubly pyramidal, along with crystals of pinkish baryte, in the three interesting forms drawn. This was broken out of a loose block.

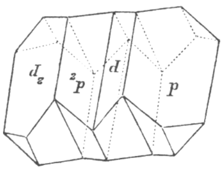


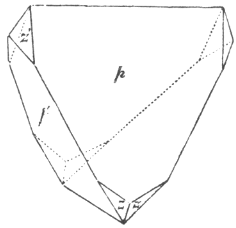


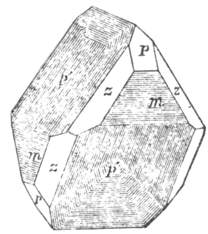


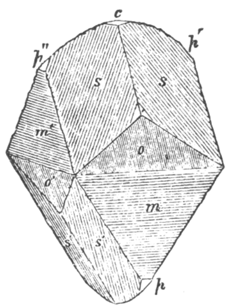
* There was also a small specimen of *cryolite* with crystalline *sederite*. This must have been "picked up" by the pensioner in some other way and place.

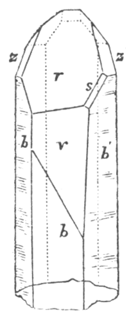
I afterwards obtained *in situ* specimens which carried *chalcopyrite* in the following four forms; one specimen also had a twin so complex and











so imbedded in the rock that I failed to make out its form. This specimen had also *rock crystal* in the form drawn; it was more pellucid, and in every way finer than I have seen elsewhere in Scotland. The rock crystal was imbedded in calcite.

A piece of chalcopyrite sent by Dr. Joass had the form of fig. 5.

I could find neither the *specular iron* nor *fluor*. The occurrence of the latter at this spot I doubt, as the matrix of the specimen is not here found.

The question as to the igneous nature of the great mass of the syenite of Lairg is one which, from the excellence of the exposure in the little quarry to the east, can be entered upon by all.

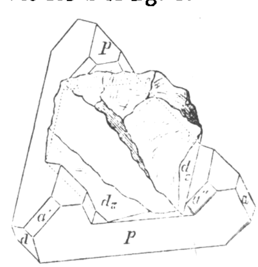


Fig. 5.

A large sharp-angled fragment of the adjoining gneiss lies impacted in, and surrounded by the syenite; this had also overlapped it, but the cover is now removed. The syenite will also be seen to have insinuated itself into rents of the gneiss, which forms one side of the quarry. The material which fills these rents is much of the same size of crystal-grain as is the general mass of the syenite. The gneiss is nearly flat-bedded in the neighbourhood, and the impacted fragment lies also in a horizontal position in the paste. The actual junction of the two rocks seems to have been fortuitously struck. The rock of the fragment appears little if at all altered. Veins from the syenite enter its rents, and these have a crystalline structure, which is more minute than that of the main mass. This must be read as pointing to a more rapid cooling of the substance which filled the rents; in other words, to the intrusion of a molten mass into a cold mould. At one spot only does any crystalline structure seem to have been induced in the fragment, and there even it is obscure or doubtful. The fragment is in no sense *resolved*, even on its edges.

That the rock is igneous it would be difficult to disprove, but there is no disturbance, and no evident alteration. The only direct evidence, thus, in favour of such a view, seems to lie in the more minute structure of the smaller of the veins thrown out from it; - an argument not of much force, seeing that the larger rents are normal in size of grain.

The syenite itself forms the greater part of the higher ground between Strath Fleet and Strath Brora, extending eastward to about Morvich.

To the eye it has a darker shade than that of Ben Loyal. An examination with the lens shows it to contain much of a striated white felspar, some orthoclase also white, and little quartz. It has more hornblende, and especially more dark coloured mica, than is present in the northern mass. Here, indeed, the mica is in excess over the hornblende; and not unfrequently has segregated apart in flat masses the size of the hand. These show a laminated arrangement of the mica, the flakes of which curve round a common centre. This mica, and indeed all the dark mica of the district, is much more strongly dichroic than is the hornblende.

The rock also contains minute *sphenes*, generally with rounded angles. They are in simple forms, hair-brown, of high lustre, and translucent.

Cunninghame states that he saw well crystallised forms in the neighbourhood of Pittentrail.

Examination with the microscope shows the striated felspar to be almost invariably twinned, down the centre of each crystal. Its striation is minute, but ill-defined.

The orthoclase also is ill-defined, both as regards want of definite form, and absence of characteristic structure. Opaque and white portions occur,—sometimes diffused, sometimes in isolated patches. No speck of titaniferous iron is visible. The quartz has fluid cavities large and small; it also contains imbedded portions of curvilinear outline of a more hyaline quartz, which portions are devoid of cavities.

Colourless hexagons, which may be *apatite*, are abundantly present. The sphenes are invariably flawed, the fissures being curvilinear, and transverse to the longer axis of the crystal.

The most characteristic feature is the presence in both of the felspars of minute crystals of an apparently colourless mineral in forms similar to the fourth figure of orthoclase drawn in the present chapter. These endomorphs comparatively rarely occur in the striated felspar.

While the crystals of apatite occur embedded in all of the components of the rock except in the sphenes, and in all lie in every position, this is the exception with the colourless crystals which occur in the felspars. In the striated felspar they are arranged almost always with their longer axes accordant with the long axis of the felspar. They are thin, almost scaly, and the scales lie at right angles to the striation. Seen in the midst of the striation they present an appearance like a number of square-ended fishing punts floating down a stream.

It is, however, in the orthoclase that these endomorphs are most abundant and most regularly positioned. That position seems to bear out in its entirety the view I submitted as to the crystal fabric of the Tongue amazonstone.*

The portions of the orthoclase which contain these endomorphs, it has to be remarked, do not show either the "corded structure," or ordinary cross-hatching; it is only the position of the endomorphs themselves in relation *to the faces of the orthoclase* which is in such portions disclosed.

In ordinary light they are easily seen, in virtue of the sharpness of their edges, and of an increased transparency of the slice at the spots where they occur.

In polarised light they are seen to have a feebler depolarising effect than has the orthoclase in which they are imbedded. Not merely can their marginal edges be seen, but their transparency permits of the edges of their medical planes appearing. The most distinct show the figure of a plagioclastic felspar. Generally, indeed almost always, they lie in only one position; this is, they are bedded on the face *m* of a plagioclastic felspar, and their terminations all point the same way. In addition to *m*

* The examination of numerous sections supplied to me by Messrs. Cole with a view to the description of the rock in their "Studies in Microscopical Science" has enabled me considerably to extend my knowledge of this rock. Slices can be obtained from Messrs. Cole & Co.

they show the faces *p t l* of albite; and that they are plagioclastic is shown by the face *p* of one summit always being seen *through* the crystal.

They polarise so feebly that a Leeson's goniometer does not suffice for measuring any of their angles, but with Ross's I got about 114°55, as the angle which the edge between *t* and *l*, and *p* and *m*, form with each other.

From the step-like, or in-and-out nature of the composition face of the twin, and from the fact of the imbedded crystals being in an inverted position on the two sides of the line of composition, I conclude that the orthoclase is present in Carlsbad twins, and that the endomorphs rest with their faces *m* parallel to the face *a* of the twin.

The chief interest connected with these minute crystals lies in their relationship to the comb-like or cross-hatched structure. It has been remarked above that the slices which show the crystals lying on their faces *m* show no cross-hatching. Again, it is found that the rock, when sliced in the direction which shows cross-hatching, presents no appearance whatever of any of these crystals *in a recognisable form;* yet, from their abundance, they must be present in the slice. In describing the amazonstone, I showed that the comb-like or cross-hatched structure (taking them as one) is seen only in slices parallel to *c* of orthoclase; and that the wedge-shaped crystals which form the comb-like structure lie parallel to *b*, and "are transversely barred or broken up, as if themselves built up of myriad crystals."

We see, both in the amazonstone of Tongue, and in the cross-hatching here, that the *bars* have a feebler depolarising effect than any other part of the structure; and we know that minute flat crystals disposed parallel to *a* would be at right angles to *c*; and hence, would cross-cut flat or wedge-shaped crystals which lie parallel to *b*. Hence, we may conclude that these endomorphs form part of the structure in cross-hatching, and that the special part is that arm of the cross which lies parallel to *a*.

So considerable a proportion do these minute crystals bear to that of both of the white felspars, that no very definite information as to their nature would be furnished by analysis; and it is, indeed, from analyses of the constituents of exfiltration veins which occur in the rock, that the striated felspar has been referred to oligoclase. Such veins occur near the summit of Cnoc Dubh, and one such (now entirely quarried away) furnished, from this quarry itself, the material analysed by me.

We are fortunate, in many ways, when such veins occur. That they have resulted from the rock throwing out, from its own mass, the material of its own substance in a state of solution, (under pressure), to fill rents which have traversed it, there can be no reasonable doubt.

While it may be maintained that such veins cannot supply us with the whole of the materials of the general mass of a rock, as the more insoluble cannot be swept from their original position, in virtue of their insolubility,—it has to be replied, that such veins *do* contain substances usually quoted as types of insolubility. Such are *baryte, ilmenite, magnetite, sphene,* and *quartz* itself.

More than this,—on account of such veins presenting us very generally with giant crystallisations of the several constituents of the rock, they exhibit these unmistakeably, even when no trace can be seen elsewhere in the rock.

These plugs of exosmotic transference have the following features, which speak to their mode of formation :—

Their structure is similar on their opposite sides; they show more or less perfectly a series of bands of successive growth; the size of the crystals which they contain increases towards the centre of the vein, even as regards undue increase in the volume of that extremity of an individual crystal which points to the centre; any vacuous spaces which may occur lie in the centre of the veins, and into these the free summits of the crystal growths protrude.

A section of such a vein thus forms a marked contrast to that uniformity of size of crystal-grain which gave its name to *granite.*

In the latter, the crystallising force latent in each constituent, seems to have been asserting itself in independence, during the time that the rock, apparently as a whole, was rapidly solidifying; and so each substance was interfering with those which touched it all round its periphery. No perfect crystals could so be formed; and a structure crystalline, but not crystallised, resulted.

In the vein, there was no such rush to solidity. There was still self-assertion,—as selective cohesion called the molecules of the several individual substances, each to consort with its fellows. There was mutual interference through *lateral* contact, but free forward extension into not a vacuous space, but into space filled with a readily displaceable fluid. So there resulted the drawn-out crystallisations,—the graphic lettering, and the capping of crystals, which are typical of such veins; the individual segregation into large and pure crystals, more or less in parallel arrangement, as if under the guidance of a common polarity,—in contradistinction to a confused congeries, in which each crystal seemed to be a law to itself alone. There ensued the large crystallisations so generally obtained from *solution*,—as distinguished from the minuter individuals got by the chilling of masses which had been liquefied or rendered plastic *by heat.*

But the crystallisations which such veins supply are exceptional, not merely as regards their size, and occasionally their regularity of form, they are very much more exceptional as regards the uniformity of their structure,—in other words, their physical and chemical purity. Therefore, in such may we much more rationally hope to descry optical properties special to each mineral, than in the contaminated individuals occurring in the *mélange* of a rock mass. During the slower process of their formation from watery solution, not only has each molecule ample time to find its way to its appointed place in the crystal fabric, but it has also time to evade, instead of sweeping before it to incorporation, any alien substance which may lie in its path.

Endomorphs, microliths, and their congeners are hence very much less frequent in the giant crystals of veins, than in those of a rock mass.

As it has in the past been the custom of the chemical mineralogist to glean from this pure source, so should it be the practice of the petrologist to learn therefrom the optical properties of the mineral constituents of rocks also. It would also be well that he should commence his investigation of rock structure upon slices cut from its veins. Above all would it be well with him if, as the preliminary of all, he called in the chemist's aid, authoritatively to tell him what it was that he was looking at. Not till he does so, is he a worker in *a fixed science*,—not till then are his steps sure. As exfiltration veins are the hope of the crystallographer and of the chemist, so should they be the sheet-anchor of the lithologist.

We have already seen the wonderful productions of one such vein in the syenite of Ben Loyal; those in the syenite of Lairg cannot compare therewith; still from these veins alone could I here get material pure enough for analysis.

The vein in the little quarry was about two feet in width; *orthoclase* and *oligoclase* formed its mass, occurring in nearly equal quantity. The crystals of each were about two inches in length and breadth.

Among these there were imbedded crystals of *Haughtonite*, of *Allanite*, of *sphene*. In cracks there also lay a minute quantity of a substance of a purple colour. This much resembled *yttrocerite*, but probably was *fluorite*: it did not, however, lose its colour when heated.

The orthoclase was of a pale pinkish tint: its cleavage angle was 89° 59′, its specific gravity 2·555.

It yielded—

Silica	62·616
Alumina	19·634
Ferric Oxide	·064
Magnesia	·636
Lime	·604
Potash	13·72
Soda	2·92
Water	·13
	100·324 (H.)

The oligoclase is frequently imbedded in, or sheathed by, what little quartz there is in the vein. It occurs in somewhat more regularly defined crystals than the orthoclase, and, being occasionally imbedded in the latter, probably solidified somewhat anteriorly to it; still the crystals of both have so interfered with each other that no definite forms were observed.

The oligoclase crystals are of a yellowish cream colour to white; opaque and dull, not visibly striated, but cleave so readily at the twin face as to appear somewhat foliated.

In breaking up a large crystal a portion was obtained from its centre which was colourless, translucent, and distinctly striated. As this seemed to indicate that incipient weathering had obliterated the reflection which discloses striation, both the opaque and the transparent portions were examined.

The specific gravity of the transparent variety was 2·618, its cleavage angle 86° 15′. The opaque variety had a cleavage angle of 86° 10′.

Respectively they yielded—

	Cream Coloured.	Colourless.
Silica	62·052	62·813
Alumina	22·444	22·919
Ferric Oxide	·352	·156
Magnesia	·14	·08
Lime	4·2	4·25
Potash	·86	·84
Soda	9·22	8·53
Water	·36	·29
	99·628	99·878 (H.)

Chemistry has not solved the riddle here. In the first place the structure is not absent from the portions which were in contact with the orthoclase *on account of any contamination with it*,—for these portions have in every respect a more oligoclastic composition than has the centre. Again, it cannot be said that there has been afforded any proof of the incipient decomposition which presented itself to the eye;—because the alkalies are, in the opaque portion, in excess of their quantity in the apparently fresher parts; and the alkalies should, in virtue of the decomposition which results from surface exposure, have been abstracted *first*.

The ready cleavage along the faces of the planes of composition, shows that the compound structure remains in those parts where it cannot now be discerned. It would be merely giving the difficulty the "go-by" to say that there must be some change in molecular structure resulting from exposure to light.

The *Haughtonite* which occurs here has, in those crystals which lay on the surface of the rock, suffered some small amount of change; for they have that dark green colour which I have found to take the place of the original dark brown of the unaltered mineral. The crystals which occur in the centre have this latter colour in marked freshness.

Here the crystals have assumed a habit which is frequent,—characteristic indeed of the mineral,—namely, running out in a single direction. They are about half an inch in width by two to three in length, and have sometimes a tortuous course. Where brown, they have a brilliant vitreous lustre; where green it is more or less greasy.

No plate large enough to determine the specific gravity, or transparent enough for determining the optical properties, could be found. The mineral yielded—

Silica...	35·555
Alumina	16·694
Ferric Oxide	1·883
Ferrous Oxide	18·037
Manganous Oxide	·694
Lime...	2·722
Magnesia	8·472
Potash	9·896
Soda	·105
Water	5·714
	99·722 (H.)

The crystals of *Allanite* occurring here show no forms; they are larger in size than any I have seen in Scotland, with scarce an exception. They are here, as elsewhere, surrounded by a brown stain, when imbedded in one or other of the felspars.

The *sphenes* also are large, but ill-defined; they were quite different in appearance from those in the syenite, being dull brown and opaque.

One crystal, which differed from the others in having much resemblance to *Keilhauite*, but which also had somewhat of a decomposed appearance, was analysed. It was in the form of the arrowhead twin, only one half of which was present, but this was about three-fourths of an inch in length by one-fourth in thickness. It was dull yellow, much flawed, softer than sphene, and slightly earthy.

It was only partially decomposed by fusion with potassium sulphate, and was consequently again fused therewith. Finally, to make certain of the purity of the silica, the latter was again fused with Fresenius flux, and treated for titanic acid; but it yielded not a trace thereof.

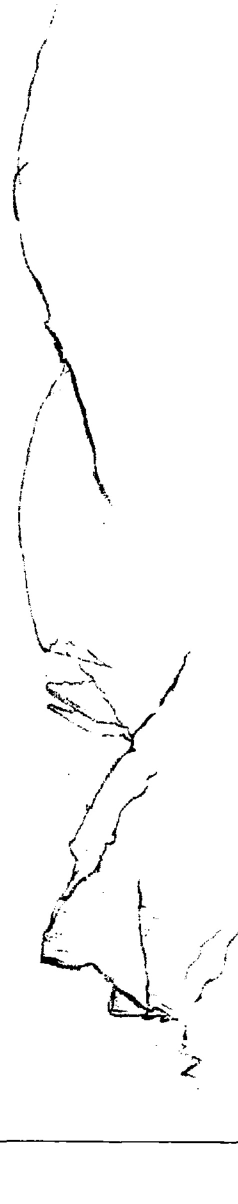
There was got—

Silica...	44·300	
Alumina	·585	
Ferric Oxide	7·165	
Manganous Oxide	·700	
Lime...	1·400	
Magnesia	45·910	
Water	·131	
	100·191	(H.)

It therefore would appear to be a pseudomorph; and the replacing substance is chemically much of the nature of *olivine!*

Granite of the Ord.

In this coarse-grained, apparently igneous granite, Dr. Joass has found *fluor* extending through a considerable stretch of the rock; but chiefly in the neighbourhood of Culgower and Loth. It occurs in thin reticulated veins, of a purple colour, with only traces of crystallisation. In some parts it seems to act as a cement to the crystalline components of the granite.



OUTPOSTS OF QUIRAING FROM THE NORTH.

M.F.H. Del