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

By Professor Heddle.

THE MAINLAND.

Anyone who contemplates on a map the great size of this island in geographic extension, and its extraordinarily irregular outline, would conclude that it must be composed of various formations, and that the connections and dispositions of these must be intricate in the extreme.

The latter conclusion will, however, upon a more careful observation, be found to apply only to the western portion of the island. However deeply trenched by the sea in its lower grounds, however persistently thrusting its cliffs oceanward in its higher, the ridged and furrowed outlines of the eastern, disposed in almost rectilinear sequence, indicate but one formation,—various as the members of that formation may in mere lithological features appear.

Two depressions of nearly equal magnitude and depth,—Bigsetter and Soulam Voes,—separate this eastern section geologically and almost geographically from the second. This western division is as intricate in its geology, as it is peculiar in outlines.

Deferring minuter details to the consideration of the more interesting spots, the main features of these two natural divisions may be meanwhile glanced at.

If we except a series of strata of Old Red Sandstone age,* which, with a general south-easterly dip, lie unconformably upon the subjacent rocks, the whole of the eastern section of this island will be found to consist of

rocks of a highly metamorphic character, and, in the main, of one general type.

Underlying a conglomerate of the "Old Red,"—here loose in structure, granular, granitic, and sprinkled largely with "chloritic," or perchance glauconitic dust,—there occur thin beds of chloritic-schist, which are succeeded by much more persistent and uniformly spread strata of argillaceous-schist. These rocks have a general dip to the west, and, as they are overlaid in regular ascending series westward, they form the lowest visible member of the whole stratified rocks of Shetland.

These clay slates form the greater mass of a prolonged tongue of land which, for twenty miles, stretches southward from the main bulk of the island.

The western coast of this stretch of country is skirted, though not continuously, by thinner beds of a hornblendic schist, which carries much felspar, and which, in the southerly districts, is to a large extent replaced by quartzoze strata; the hornblendic rock is well seen in the south at St. Ronan's island, and in the north at Hawksness.

These rocks, being of a harder and more enduring nature than the clay slate, may have proved in great measure the barrier which has repelled the inroads of the western sea; though a still more westerly band of a granitic rock, which forms the line of demarkation between the two great divisions of its strata, doubtless had, for long, performed that function.

This granitic band or dyke cuts off the peculiar slates of the Fitfiel Head (already described in the chapter on Unst) from those of the Cliff Hills,—raises the ruins only of its former course above the waters in a line of islets in the bay of Scalloway,—courses up the trough between Bigsetter and Magnusetter Voes, and possibly is continued in ampler development in the mass of igneous rock which forms the coast, and the islands which break the surface of the Sound of Yell. To this rock Hibbert has assigned the name of epidotic syenite. At its southern extremity it does contain some small quantity of epidote, and grains of the same mineral may be seen in it, where it becomes porphyritic, as in the neighbourhood of Bigsetter Voe: but throughout the larger mass of the rock as seen at Yell Sound the constituents appear to be solely minute dark-green crystals of hornblende and albite. As it approaches the granite of the Roc district,

* East of Lerwick a quarry of dark-grey flagstones, which are profusely sprinkled with mica, contains a peculiar calamite-like organism of sometimes a couple of feet in length; this has a bulbous dilatation with apparently rootlets. Specimens of small fishes, apparently acanthoides, were shown the writer; these were imbedded in a brown fine-grained muddy sandstone; they were stated to occur in a quarry north of Gardie, in Bressay.

orthoclase and quartz are superadded, and though the rock retains its markedly crypto-crystalline character it can now be regarded as merely a very hornblendic granite.

Of this south-eastern or clay-slate portion of the mainland it need, in the present connection, only be said that its strata are at their northern limits deflected eastward from their usual S. by W. and W. by E. strike Here also there is a departure from the simplicity of their structure in this, that to the west of Rovie Head, and between the clay slates and the conglomerate, there is intercalated a bed of limestone which curves round to to reappear in the Greenholm, and the dangerous rocks called the Brethern; and, that on the western shore of Deals Voe two successive strata of hornblendic schist, similar to the limiting one already noticed, are to be seen. Thin beds of limestone also occur here.

The ground lying between the westerly hornblendic rock and the granite is occupied by frequent alternations of strata, usually more immediately included under the term of gneissic rocks. Of these, many varieties as regards presence, absence, and relative proportion of the felspathic or micaceous ingredient of such rocks, are to be seen; but they may be divided into four great belts both in virtue of inherent lithological differences and to a great extent by an actual partition being effected by three great bands or series of compound bands of limestone.

In fact, one great feature of the gneisses of Shetland, as a whole, is the manner in which they are pervaded with interstrata of limestone.

The most easterly of the three larger belts of limestone is, in the Island of Tronda, in actual contact with the hornblendic rock to the east; and is also to a certain extent interstratified with those portions of the same rock which occur to the west of the Cliff Hills. It is like most of the others of a pale blue colour, a fine granular structure which is somewhat obscure, and it is very frequently schistose from interlaminated margarodite.

This bed courses up the Vale of Tingwall, still in contact with the hornblende rock, and thins off towards the Head of Catfirth Voe.

According to Hibbert, the lime of Laxfirth and of Eswick are offsets which can be traced to a junction with this.

To this limestone, the first of the four divisions which go to form the central gneiss of Shetland succeeds. It may be defined as the typical gneiss of the islands,—somewhat more schistose, less frequently contorted, and paler in colour than the gneisses of the mainland of Scotland. It is very rarely diversified in appearance; hardly ever carries even garnet, occasionally hornblende in small particles, and altogether is most barren of

minerals. Its prevailing strike is that of the Cliff Hills, that also of most of the schistose rocks—from a little W. of S. to a little E. of N.

The second, a less important series of beds of lime, commences in the south at Ustaness, sinks into the head of Stromness Voe, and probably forms the beds of the lakes north thereof.

This bed is succeeded by the only gneiss which I have seen in Shetland which contains a dark mica; this, in too small particles to be recognizable, is in but small amount after all, for the beds here are unusually quartzose, little felspar even being visible. This rock may be seen from Bennyness up the greater part of the east shore of Weesdale Voe; but I do not know that it continues up the country; it should come out of the heather and bog at the head of Olnafirth; but the shore is there concealed by sand.

These quartzose beds are overlaid by the largest mass of limestone in Shetland.

This is first visible in the south in a cluster of islands in Weesdale Voe; as the sea loch gradually narrows it appears on both of its shores, being here, with interstrata of schists, probably half a mile in width. It diminishes from this width considerably as it courses northward, until it is lost in a bifurcation in the peninsula of Foraness at the mouth of Deals Voe, after a course of nearly twenty miles.

Westward of the lime there occurs a series of strata chiefly of mica-slate; these follow the limestone throughout, but contain no interbedded strata thereof. This is the longest ridge of highly elevated land in Shetland; its altitude seldom falls, and it contains the four elevations of Weesdale Hill, 842 feet; Scallafield, 916; Snuggie Hill, and The Leas of Deal, 820;—it has received the name of the Western Kame.

West of this the strata are again normally gneissic, felspar being here in excess; granitic and quartzose veins also interlace the beds, and both limestone and hornblende are seen where, at their northern extremity, they approach the granite of Olnafirth.

In crossing this extensive system of rocks from east to west it is observed that the interstrata of hornblende diminish in bulk and in frequency until the granitic rock is approached, when hornblende makes its appearance to a small extent, in a state of diffusion throughout the mass of the adjacent strata.

These strata are as a whole wonderfully continuous and rectilinear in their strike.

Subject merely to local variations in the angle, the whole system dips to the west, with a prevailing inclination of about 40°.

To the north there is less of regularity in the series; there being here noticeable a general sweeping of the outcrops towards the east. As the rectilinear course is again taken up in the Island of Yell, this is doubtless due to their being impinged upon by the granitic mass to the north west, and to the continuity of their course being partially broken in upon by eruptive rock, both at west and east, namely at Olnafirth and Lax Voe.

Nowhere else perhaps in Scotland is it made so manifest that a series of diverse rocks, varying so markedly from soft to hard, from friable to enduring, from light in colour to sombre from their blackness, form but members of one system, differing in the individuality of their composition, but agreeing in the circumstances of their formation, and as to the agencies concerned in the transmutation which they have undergone.

The uniformity of their strike and dip,—the occurrence of intercalations of limestone (indistinguishable in their characters) amongst the diverse members, and of hornblendic strata indiscriminately throughout the whole, can lead to no other inference. These features are here more noticeable than any direct merging of the several rocks into that member which may be adjacent. The individualising of the various members of a series may be called for elsewhere in Scotland, and is not altogether without its advantages even elsewhere in Shetland, but it is little more than a mere convenience here. Here, also, and elsewhere in Shetland, we are taught that however advantageous and applicable as a distinctive term such a name as hornblendic gneiss may be elsewhere, it is often a mere mineralogical variety; and while the hornblendic rock of the lower gneiss (Laurentian) has features quite distinct from those of any rock *in this district*, a rock entitled to the name of hornblendic gneiss cannot of itself be a mark of distinction between two great formations; though doubtless any great prevalence of that rock may come to be so.

The only other observations I shall make on this general series pertain to its limestones: these, of blue and yellow tints, and distinctly metamorphic, form, as a rule, the valleys, through disintegration and solution; and open up the rocks to the ingress of the sea. The north and west Voes of Dale and Weesdale, and of Laxfirth and Scalloway, with the intervening troughs, are excellent types of this. But there is a notable exception; limestone forms the enduring backbone of the lengthened ridge which separates Whitehouse from Stromness Voes.*

The larger interstrata of these limestones separate the more distinctive masses of the rocks: the smaller are mostly associated with the hornblendic belts.

* Time did not suffice for my endeavouring to attain to the cause of this anomalous endurance.

But the marked peculiarity of the limestones altogether, is the absence of simple minerals either in their mass, or at the lines of their contact with the adjacent rocks. These most fruitful situations elsewhere in Scotland, are here altogether barren, this,—their feeble metamorphism and the small amount of folding in their beds, are everywhere observable; the latter indeed forms a distinctive feature of the Shetland schists.

If in this eastern portion of the Mainland of Shetland we have simplicity and regularity, in the western we have complexity and confusion.

Two triangular wing-like appendages, attached to the portion described, form the geographical configuration of this section; but the structure of these outlying portions is very dissimilar.

In both, granitic rocks occur, producing marked disturbance.

Holding firmly to the view which regards much of the granite of Scotland as the completion of the metamorphism of gneiss, I am unable to adopt for a moment any such view as regards the granite of Shetland. The nature of the rock itself, the abutments of the stratified rocks against its flanks, and the disturbances it has produced among their adjacent layers, forbid such a view.

In both of the triangularly shaped districts, igneous rocks have found some portions of gneiss to break in upon, disrupt, separate, and mangle. And this has been so thoroughly accomplished that in the northern triangle only a few fragments are visible, no one of which retains the normal strike and dip.

In the southern triangle, granite, which is found here in much smaller quantity, has been merely driven like a wedge between the gneiss of the eastern division and a series of quartzose beds;—these are red in the west, blue in the east.

The strike of these quartzose districts is quite different from that of the gneissose rocks; having a bearing which lies nearly at right angles to those of the east.

I had only opportunities of observing them for a few miles N.W. of Veila Sound, and in one or two spots at the head of Voes on the north-west coast. Without wishing to question Hibbert's conclusion that they are entitled to the name of quartzite, I have to say that in some places I observed them to be very flaggy and micaceous, that they seemed to contain organic or at least carbonaceous matter, and that they have an appearance much more recent than that of the eastern and western rocks.

I had unfortunately no opportunity of satisfactorily examining the connections of the *red* western beds, on either side. Those near the village of Dale seem to be separated from the grey eastern beds by a great porphyry

dyke which runs up the country, but from the shelving and covered nature of the ground it is not easy to determine that it may not be an interbedded mass.

This "red quartzite" when examined in hand specimens gathered at Snarra Voe cannot be distinguished from the red Cambrian sandstones of the summit of Teallick in Ross, or from those of the north of Rum.

To the west of both of these triangular appendages, volcanic rocks of Old Red Sandstone, and perchance still more recent date, appear; these will be noticed in their places in the description of special localities.

These conveniently may succeed each other from north to south.

POINT OF FETHALAND.

The geology here is very simple.

Along the line forming the south boundary of the mass, gneiss is to be found; this, by the almost entire loss of its felspar, a marked increase in the size of its plates of mica, and the very occasional addition of crystals of garnet, assumes, on the east coast, the characters of a coarse-grained mica-slate.

The little peninsula of Fethaland is formed for the most part of gabbro. Some portion to the west is, however, composed of a rock which can with difficulty be assigned to either gabbro or gneiss; and the nature of this it would be no easy task to determine, were it not that it is seen to hold a geographical position intermediate between the two.

Towards the east the gabbro softens; its diallage becoming more flakey, and its felspar becoming either smaller in amount, or diminishing in quantity. At a point immediately above Kleber Geo it might be called diallage rock, were such a name held to express one composed of *diallage alone*. Specimens of the mineral of fine colour and high lustre may here be got (D. and H.) the finest being those which have acquired an increased lustre from exposure.

Eastward of this spot, the rock, though never actually passing into serpentine, becomes markedly serpentinous; beds of chloritic slate, steatite, "potstone," and actynolite-slate prevailing.

These are best seen, indeed in the peninsula are almost confined to the bight called Kleber Geo.

In the Edinburgh Philosophical Journal, vol. x, page 96, we read of the point on which the lighthouse of Scalpa or Glass-island stands—"this point still retains its Norwegian appellation Klibberness, *i.e.* soapstone promontory." In Shetland we find the name of Kleber Geo applied to other localities than this; "soapstone" in the islands is well known, being invariably called a kleber or klemmer stone. It is utilised in two ways. The first, as a chronicle. Any unusually flat cleavage face or "back" of the rock is selected, and upon these tablets of stone may now be read names without number—male and female bracketted in suggestive contiguity—a formal and public declaration of vows, held in Shetland to be as binding as the passing of the hands through the Orkney stone of

Odin—dates carrying one surprisingly far back, the past and the present* are there in no stinted numbers, etched on every available spot on the surface of the rock.

The other purpose to which the Shetlanders apply, or used to apply, this stone is as an unguent. When pounded it was used for cuts and wounds, in the same manner as that other "foreign substance" called lard; having been inserted more or less thoroughly between the cut surfaces, they regarded it as quite as effectual. Being "soft, and clean, and greasy," its application was just as rational, neither more or less.

The *steatite* of Kleber Geo occurs in regular beds, with the strike common to the adjacent rocks: the mineral itself is minutely granular and generally of a reddish-yellow colour. It is occasionally studded with minute crystals of *magnetite*.

To the east of the steatite and further down the slope there are thin beds of *actynolite schist*. This rare rock seldom occurs with well pronounced characters, being generally more a mass of interlacing "matted" crystals of actynolite,—more an actynolite-rock than a schist. Here, however, it is markedly schistose, splitting with ease into thin flakes; these are considerably contorted, and as the interlacing fibres which form the rock are very delicate, and the amount of quartz granules is almost imperceptible, it is of necessity very friable and tender. It is of an unusually pale green colour.

To this rock there succeed beds of "*potstone*," which pass into massive *chlorite*.

No two authorities seeming to agree as to the nature of potstone, and their descriptions thereof differing widely,† I am fain to take refuge in the definition of Nicol, "Potstone is an uncertain mixture of talc, chlorite, and other minerals. There is a safe vagueness in this,—it will easily include the rock to which I here apply the name. Its general appearance in these islands, however, goes a long way to induce me to prefer Dana's definition—"ordinary soapstone, more or less impure."

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* And those of many who it is to be suspected never were there. A fervently constitutional conservative gentleman, who was once on the spot with the writer, availed himself of this licence, by engraving the name of the reigning monarch in characters of loyally surpassing depth.

† *e.g.* In Jukes' Geology, p. 83, we read "Potstone includes the impurer, granular, dark-coloured varieties of *steatite*;" p. 143 we read "Potstone is a massive form of *chlorite schist*." In Cotta, p. 251, we read "Potstone consists of a felt-like web of chlorite; sp. gr. 2·8 (?); content of silica, 30—60 p. c. (?)" How long are geologists to be content with such a knowledge of the composition of rocks as is expressed by "30—60 p. c. (?)"? The only full and correct description of potstone which I can find is in Haidinger's translation of Mobs' mineralogy.

This fittingly describes the rock from most of the localities in Shetland, but at the two limestone localities of Lude and Froster Hill, on the mainland of Scotland, its appearance rather inclines to that of ordinary massive chlorite; while in the island of Scalpa, specimens intermediate in appearance are to be found.

Although I prepared for analysis specimens from several of its localities, these invariably were found to contain an amount of visible and non-separable impurity such as forbade their being regarded as a simple mineral—or even a substance of invariable composition;—this relegates them to the category of "rocks."

By a process of mechanical analysis, which I shall describe elsewhere, I have succeeded in separating the several components of potstone, to such an extent as to make them recognizable; and there is this test which I believe will serve to separate steatitic potstone from fine-grained massive chlorite, or the more chloritic variety,—the impression of the nail, or bruise of the hammer on the former is *white*—on the latter *green*.

Premising then that the rock or stratified material to which I shall apply the name oscillates *in appearance* between that of a dark-green massive steatite of a somewhat loose and large-grained structure, and that of a massive granular chlorite of an unusually fine-grained structure (a variety which appears to be special to it when limestone is its matrix), I shall describe the modifications occurring at the several localities in which it is found.

The first of these, which I omitted noting when writing of the mineralogy of Balta, is the Doos, Geo in that island. Here the "potstone" is the basis or "basement mineral" from which the fibres of the altered asbestus have sprung—or upon which they lie.

This is perhaps the purest potstone I know. It forms a thin bed; is of a greyish green colour, has a loose granular structure,—the granules being translucent,—is softer than the nail, gives a white streak, breaks with equal facility in all directions, has an uneven fracture, and is very uniform in appearance. When closely examined with a lens the visible impurities are seen to be minute flakes of talc, specks of pyrite, and granules of magnetite; all apparently occurring in very small amount.

The breaking out of the hard magnetite from the soft matrix invariably destroys sections prepared for the microscope.

By mechanical analysis it was found to contain about a two hundredth part of chromiferous magnetite—a twentieth of flakes of talc—which lay in *one* direction, the bulk being steatite.

The talc was in one sense a thing apart from the steatite,—the powder of the latter was almost white—that of the included talc pale-green. The specific gravity of this rock is 2·806.

The potstone of Kleber Geo differs materially from this; it has a dark-brownish green colour, a close "impalpable paste," which bears an equal resemblance to precious serpentine and to steatite, is studded here and there with minute spangles of lighter-coloured talc lying in *all* directions, and it also contains specks of pyrite, of a black substance in hardly visible crystals, and thin seams of precious serpentine (?) Its specific gravity is 2·787. It is softer than the nail, and is markedly more frangible in one direction, generally showing a subconchoidal fracture.

In this potstone we obtained a single specimen of a lustrous black metallic mineral in thin scales, probably *ilmenite* (D. and H.) If so it is the only instance in the experience of the writer of its occurrence along with steatite.*

The massive chlorite which succeeds to the potstone contains rarely inferior specimens of *magnetite* and *pyrite*. *Asbestus* and *amianthus* (Hb.) also occur. Hibbert adds "much *indurated talc*."

This name is applied with still greater laxity even than "potstone." Mohs and Jameson apply it to talc slate; Hibbert certainly does not regard it as such, as he on the same page describes his talc-schist as something quite apart. Macculloch defines potstone as "indurated talc schist," and gives it as his opinion that "indurated talc" "is of the nature of agalmatolite."

The name implies that the substance *has been altered*; I have observed a substance which appears like steatite of unusual hardness at the following localities,—the granitic belts of hornblendic gneiss in Sutherland; the great granite vein of Ben Capval Harris; in gneiss on Garlat Hill, Tarfside; near Stirling Hill, Aberdeen, in epidotic granite; and in the veins of grey granite occasionally†—this substance proved on analysis to be agalmatolite:—at Ben Capval and Stirling Hill it contained small imbedded flakes of talc. So Macculloch's conjecture as to its true nature was correct.

But that substance I have never seen in association with steatitic or chloritic rocks; and what the substance may be which Hibbert enumerates under the above name, as being associated with *talcose slate* and *steatite*, I know not.

As regards *talc-slate* itself, I have already, in speaking of the application of the name to rocks in Fetlar, shown that I believe there has been in

* I have almost invariably acted upon the principle of sacrificing even a unique specimen of an unknown mineral for analysis, should there be a sufficiency for that purpose,—there was not so here.

† A substance almost indistinguishable in appearance occurs in veins cutting a gabbro on the east side of Beauty Hill, this proved to be *pseudophite*; this was evidently formed by a change in the labradorite.

the older geological writings much of laxity in the application of the term. Indeed I question if there is at present much advance in this respect, or can be in this case and a great many others, until we have analyses and precise descriptions of typical examples.

As an illustration of the amount and character of the information we obtain from "text books" on this subject, I shall quote from two. First from a work of many excellencies, of over 500 pages,—we read:—

"*Talc slate and chlorite slate.* If the mica in mica slate were mixed with or replaced by talc or chlorite we should have (*sic.*) these rocks."

Cotta says of Talc slate,—

"Contains silica 50—57 p.c.

"The principal mass of these rocks consists of talc. It contains little quartz. As it contains less silica than the mineral talc (which has 64 per cent.) we may infer that some chlorite enters into its composition."

Truly it would be a difficult problem to mix a large quantity of a mineral containing 64 p.c. of silica, with even a little of another containing 100 p.c., so as to make a compound which had only 50 to 57! And it would be equally difficult to bring down the percentage of silica by such an admixture of chlorite as would effect the numerical change, without simultaneously converting the recognized grey colour of "talc slates" into a well-marked green.

An admixture of margarodite, (with its 46 to 48 per cent. of silica,) with quartz, would, however, yield some such resultant percentage as that required.

There can be no question, however, as to the rocks to which Hibbert applied the name, inasmuch as many of their localities, and the transitions of the rocks into ordinary mica-slate are repeatedly pointed out. I have already shown that certain of the Fetlar rocks to which he applied the name are not entitled to it, and I believe there is great room for doubt if most of the Shetland rocks,—or indeed if the rock which is generally designated by the title in Scotland is so entitled.

Jameson directs us to several localities where "talc-slate" occurs; Nicol states that it is "abundant throughout the Scottish Highlands:"—Some years ago I found my notes and my mind so pervaded with doubts as to there being *any* talc in the slates so indicated and designated, that I separated the glistening, somewhat greasy mineral from several of these slates, and found on analysis that it was *margarodite*, in every case where it was light in colour.

In the case of a brown greasy slate, got a mile east of Cowhythe Head, in Banffshire, it was *Biotite*.

Of a yellow one carrying andalusite, from Clova, Aberdeenshire, it was *pihlite*.

What would be generally considered an undoubted bed of this rock, was found by Dr. Gordon, of Birnie, on the north shore of Colafirth Voe;—another, apparently equally entitled to the name, was found by Dr. Aitken and myself in limestone above Milltown Glen Urquhart,—but here it was in so small amount as to function rather as an imbedded mineral than as a rock;—of both of these I shall give analyses, which show them to be margarodite-schists.

The only other rock I know in mass, which has any title, and that a doubtful one, to the name, is one which is composed of crystals of talc lying in all directions, with apparently a small amount of paste of the same. This occurs at the Black Dog Rock, near Aberdeen, as a line of boulders protruding through the sand, doubtless representing an outcrop. The same singular rock I have seen in a dyke a mile north of Keig Bridge, Donside,—but this should be termed talc-rock.

My attention has lately been particularly drawn to this question by a letter from Professor Dana, in which, from his experience among American rocks, he was led to doubt the applicability of the term as used by me in speaking of the schists of Banffshire.

The term was that which had been adopted by several geological writers, —indeed all who have described this district have agreed in regarding it as the most markedly talcose in Scotland.

It was several of these very slates, which I had already found to contain margarodite; but, in consequence of Professor Dana's letter, I have lately made several careful traverses of the district with the special purpose of being in a position to speak to all of them.

I find that the rock which upon hasty examination has most appearance of containing talc is that which is to be seen immediately to the east of the verdigris-green serpentine of Portsoy, and which also appears in greater quantity in the harbour of Whitemills. At Portsoy the rock is about 12 feet in thickness; being at about the level of high water, it has been acted upon in such a manner as to have a great part of its substance removed from its outer surface, a kind of glistening felt of crystals remaining. When broken into it is found to be composed in greater part of clay slate, but this is impregnated to a considerable extent with granular pyrites, and to a much smaller extent with glistening scales,—a mixture apparently of graphite and margarodite,—but some small amount of talc may be present. It stains the fingers of a dark slate blue—is very similar to the Fetlar graphitic schist—and by many would be called an altered alum-shale.

At a single point a rock was found by Mr. Peyton, which consisted of a quartzite with fibrous structure, with adherent talc; this, however, was in coherent layers, not uniformly intermixed with arenaceous quartz.

Altogether I am left in the position of doubting if there is any talc-slate whatever in this "very talcose district of Portsoy."

Minerals.

Though interesting and instructive as regards it rock masses, Kleber Geo is disappointing as a locality for collecting minerals.

Not so, however, another geo which lies on the opposite side of the little bay, directly in the line of strike of the strata. This new locality (D. and H.) contains in small compass three minerals so well marked that all were analysed.

Just under the turf of the steep bank of the inflexure of the coast which is called Pundy Geo, there are to be got specimens of *picrolite* (D. and H.) of peculiar appearance. Apparently the mineral has been formed from large pre-existent crystals of actynolite. A layer or bed of some six or eight inches or more in thickness has a regularly columnar structure; the columns, which are easily separable from one another, equal in length the depth of the bed, they are of half-an-inch in width, and have the form of crystals of actynolite. Frequently, however, the structure of these columns is markedly fibrous. The colour is dark-green; the specific gravity is 2·671.

They yielded on analysis,—

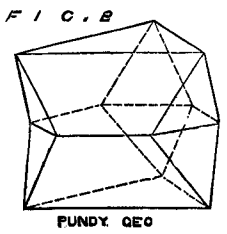
Silica	42·932
Alumina	1·847
Ferric Oxide	5·104
Manganous Oxide	·419
Lime	·8
Magnesia	36·195
Potash	·81
Soda	·366
Water	11·5
	99·973 (H.)

A change of actynolite into serpentine is here shown, and it is almost complete. The columns or pseudo-crystals of this mineral are sometimes kept apart by plates of glistening white *talc* (D. and H.)

Beds of massive *chlorite* (D. and H.) of a minutely foliaceous or confusedly crystalline structure, and a lively green colour are to be seen at the water's edge. Of the fine-grained variety probably the finest specimens in Scotland are to be got here from a tilted bed of six feet in thickness.

It yielded,—

Silica	24·3
Alumina	20·858
Ferric Oxide	3·567
Ferrous Oxide	16·718
Manganous Oxide	·55
Lime	·504
Magnesia	22·2
Water	11·547
	100·244 (H).



Imbedded in this chlorite, magnetite occurs in simple and hemitrope octahedral crystals in great abundance; (D. and H.), and, from the perfection of the crystals and the contrast of their deep colour with that of the matrix, the specimens are of much beauty—being indeed the finest which I have anywhere found in Scotland.

The hemitrope crystals lie with the octahedral face parallel to the bedding of the rock,—the position figured. The crystals are up to about three-fourths of an inch in size, they are of a blue-black colour. Their specific gravity is 5·134.

Being slightly penetrated by chlorite, their analysis showed a small amount of foreign matter.

Ferric Oxide	65·617
Ferrous Oxide	32·166
Manganous Oxide	·5
Magnesia	·684
Alumina	·393
Lime	·223
Silica	·7
	100·184 (H.)

Potstone in small quantity also occurs here.

A small vessel could lie in Fethaland Wick, except during a gale from the east: if forced to run for a harbour that of North Rooe is within five miles. This inlet has a rock right in the middle of the entrance, and somewhat within a line drawn between the two points. The channel lies to the north of the rock—a quarter of the width of the whole mouth of the inlet off from the north point. When well within the bay the craft is to be held somewhat to its southern end. The anchorage is in 3 fathoms at low water. Five miles further south is the spacious and clean bay of Colafirth.

COLAFIRTH.

In the stratified rocks in the neighbourhood of this Voe, and the two immediately to the south, there is an inversion of the dip usual in the gneissose rocks of Shetland. Convulsionists would not hesitate to assign this to the agency of the large mass of granite which lies immediately to the west, and which descends almost to the shore of Colafirth Voe.

It is true that at first sight the strata have much the appearance of a mere fragment entrapped between the granite of Roeness and the igneous rock of the Islands of Yell Sound. What is to be noted here is that the granite, doubtless an eruptive one, has not followed the weakest joints,—the lines of stratification; but both to north and south, cuts across these at various angles, while it runs nearly parallel with them in its centre; but at no spot in which the junction can be seen, is there contact tilting of the beds, fracturing, or indeed disturbance of any kind.

In speaking of the island of Yell, an upper bed of hornblendic gneiss was stated to dip to the north or north west; strata of much the same nature occur with the same strike and dip between Norby and Papa Little at the south-east shore of St. Magnus Bay; so that the strata we are now considering may, with those of Fethaland and Hillswick, be but the highly altered beds of the same upper rock thrown into the ascending fold of an extensive trough.

In the very centre of a trough so formed, and in that portion of it where it is fringed on both sides by granitic flanks, a large mass of what may be meanwhile called a fine grained greenstone appears; and it at once becomes a question whether this is anything more than the product of the aqueo-igneous, fusion of the deeper-seated portions of these hornblendic strata.

Considerable countenance is lent to such a view by the fact that the "igneous rock" consists almost wholly of minute crystals of augite and albite,* while, as will be shown, the typical rocks of the sedimentary series are composed of hornblende and albite.

Traversing from west to east, we here pass over all of the better known varieties of gneissoid rocks; these are admirably displayed along both

* Smaragdite and a, to me unknown—striated red mineral are also visible in the microscope.

the north and south shores of Colafirth, within a stretch of country little exceeding a mile in length.

Starting from the north-western inlet of the bay, we find a peculiar granite, which, from its extreme and prevailing red hue, gives the name of *Roe* to several points of the surrounding district.

This granite is remarkable from the entire absence of mica: it is also peculiar from its extreme massiveness, both on the large and small scale, being singularly devoid of jointing, and in hand specimens appearing more like a solid felspar than a rock which derives its name from its granular structure.

It contains but little quartz; this,—of a massive, white, opaque, and somewhat horny appearance,—is diffused, not in grains, but in a shred-like tortuous manner, as if it had filled up crevices in the other constituent.

The granite has very much the colour assigned to it in the map. Where it approaches the schistose rocks it is much of the nature of a felstone; containing, however, minute granules of quartz and hornblende.

The rock which succeeds to this in passing eastward, I have meanwhile simply called breccia. Still further eastward there is a belt I call aphanite, this again is succeeded by a thin belt of brecciated rock.

Some part of this triple series has been noticed by Hibbert, who also names it aphanite; I quote his description:—

"The aphanite and granite of Northmavine at their junction mutually penetrate each other by extensive processes, showing that they must have consolidated nearly at the same time, and that during this period the consistence of each was in a yielding state. This view is strengthened by the regular and gradual transition which is often shown between the two rocks, each mass receiving or losing hornblende at its junction."

"One of the most curious appearances is presented in the granite to the north of Roeness Hill, by the *invasion* or inclusion of a dike of aphanite. The line of its course may be easily seen in taking a north-east direction from a point of land on the north-west of Colafirth Voe, between the foot of Colafirth Hill and the commencement of the hills called the Biergs; the disorder that has taken place by the invasion is evinced in the irregular surface of the hill for a distance of five miles. On the west of the granitic mass, the dyke has nearly reached its termination, since it is exposed along the precipices of the coast in the form of smaller veins, branching out in numerous directions, and presenting every variety of form."

There can be no question as to this being the rock I have above referred to, and that it must, a short way north of the point where I observed it, curve round to the north-west; there can also be no doubt—if

Hibbert's description be even in the main correct—that it is, or has *assumed* at the west the structure and mode of functioning of an *intrusive* rock, as he holds it to be; and lastly, there can be little doubt that it will, in the present day of waning Wernerianism, be now generally held to be an *igneous* rock, which Hibbert tries afterwards to prove it not to be.

There are some points, however, in this description, to the accuracy of which I demur.

It must be evident that two rocks, which were in such a yielding state that they were simultaneously mutually penetrating one another, could never form a breccia; and a fragmentary breccia is certainly what does occur next to the granite, at the point noted. There is here no penetration of the granite by the aphanite, as regards processes or branching veins being thrown off from the latter into the former; nor do I believe there is the slightest penetration of the aphanite by *the* granite of the Roe Hill.

The rock which lies between the granite and the aphanite is compounded of sharp-angled fragments, cemented by granitic paste; but that the fragments are derived from the adjacent aphanite, I cannot admit; nor can I admit that the cement is an intrusion from the adjacent granite.

The fragmentary portions—from the size of a hazel nut to that of the fist—some dense in structure, and dark in color, some open in structure and comparatively light in color, are all portions of a laminated rock: they much resemble hornblendic bands in a dark-mica gneiss. The granitic cement, altogether unlike the red granite near it, is a spangled melange of two felspars, white and red, with quartz and mica; it has all the appearance of a product of exfiltration, or of positional rearrangement of the felspathic bands of gneiss;—a something not intruded from without, but extruded from within.

Some of the dark laminated fragments seem opened up by the insinuation of this granitic paste, and to be dissolving away into it.

It seems to be no intermediate between,—no melange of granite and aphanite, but a rock undergoing change. Examined in thin slices in the microscope, the structure of the dark portions is clearly that of schist. The dichroism of the dark imbedded crystals shows them to be hornblende; but there is also a jet black opaque substance, (acting as a paste,?) which I do not know. It has no metallic lustre.

Hibbert remarks—"the relationships of the syenitic greenstone (aphanite) to the granite, though curious, are in the present state of our geological knowledge, of very little importance."

I shall venture to alter this sentence to the following,—the relations of this aphanite with the contiguous breccias, to the granite and to the

adjacent serpentines are of the very highest importance—in our present efforts to ascertain the true nature of metamorphic change. So important that I doubt not that this locality,—the geognosy of which, the greater attractions which mineralogy possessed for me at the time, permit me now to describe all too imperfectly,—will come to be one often quoted in the future.

The true aphanite which succeeds is a very close and minute-grained crystalline mass of a dark-green color. Its specific gravity is 2·925. Under the microscope it appears as an ill-defined aggregate of minute crystals of hornblende, with apparently albite.

The breccia which succeeds this to the eastward, contains large sharp-angled fragments of the same aphanite: these are quite uniform in structure, and quite unlike the laminated fragments contained in the rock to the west. The paste here also is entirely different, being a pale colored porphyritic granite.

This breccia is associated with a thin band of what, in the absence of specimens for microscopic examination, I call black chert.

Eastward of this there is a stratum of considerable width of serpentine;* this, though varying now and again in its appearance, is neither so markedly divided into separate beds nor so characteristic in its colouration as it is in its extension on the south shore of the Voe.

Among the specimens collected by Dr. Gorden, there is a variety which, with the exception of minute diffused crystals of talc, is absolutely structureless, and of a uniform rich oil green colour. This might be improperly called a potstone. Most interesting specimens, showing the evident passage of actynolite into serpentine, also occur.

Others show what is extremely rare in Shetland, mottlings of a dull red, along with white or yellow veins. Dark green is however the general tone, this being sprinkled with minute specks of magnetite, but

* I am indebted to my friend Dr. Gordon, of Birnie, for enabling me to furnish a minute description of the rocks of the north shore lying eastward of the breccia; my time when walking across the section permitting only of my noting the sequence, but not of my gathering specimens of the rocks.

Dr. Gordon, who during several visits to Shetland, had been engaged in independent geological research, kindly went over from Hillswick and took specimens along this north shore, and elsewhere in the district.

Though, from the great amount of *mineral* analysis which I have yet before me, I am at present unable to analyse these rocks. I yet consider several of the specimens collected to be so typical examples of rocks of which we have no analyses confirmatory of the names which have been assigned to them, that I still hope to be able to supply this want. And if so, I take this opportunity of stating that Dr. Gorden purposes to deposit the specimens analysed in the Elgin museum.

beyond it there are not, in the specimens sent to me, any imbedded minerals.

As associates to the above, granular *labradorite* occurs, carrying plates of margarodite, which are disposed within it in gneissose arrangement; and there is also a peculiar margarodite gneiss;—one at least of these rocks can be traced some distance to the south.

Dr. Gorden has observed this serpentine some distance inland in the neighbourhood of the road leading to North Roe; so there is a probability of its connection with the rocks of a similar type which occur at Fethaland.

In close proximity to the serpentine, Dr. Gorden obtained the specimens of the rock which I have above stated would be usually set down as being without doubt true talc slate; it is here of a pale green colour, and high glistening lustre.

The ingredient resembling talc is in excess; it occurs in broad somewhat contored flakes; these the nail readily ploughs up and rolls in powder before it, recognising however an occasional rasping sensation from the imbedded granules of quartz. The substance abraded is perfectly unctuous and may be rubbbed down till the individual foliæ almost disappear.

This, being the most typical "talc-slate" I know, was analysed.

It yielded,

Silica	46·3
Alumina	27·39
Ferric Oxide	5·368
Ferrous Oxide	7·253
Manganous Oxide	·097
Lime	·951
Magnesia	2·26
Potash	4·685
Soda	2·29
Water	2·955
	99·549 (H)

Being compounded apparently of about three parts of margarodite with one of chlorite and one of granular quartz.

The rock is most characteristic in those beds which are in closest proximity to the serpentine.

Analysis has thus disclosed—and on account of the extreme unctuosity and softness of the margarodite analysis alone could have done so—that this most typical "talc-slate" is in reality a margarodite-schist. All these margarodite-schists are fusible before the blow-pipe. Talc-schist would

not be so, seeing that talc itself is infusible. I know no other mode of discrimination.

Eastward of this rock one which may be called a *chloritic* schist succeeds; the word chloritic being employed to designate the *colour*, and not with the intention of insisting upon the actual presence of chlorite.

Many chloritic schists would appear to owe their colour to minutely diffused actynolitic or hornblendic matter; and this may be the case here. The rock upon close examination with the lens shows broad flakes of margarodite, with a doubtful appearance of filaments of actynolite. Though obscured by the margarodite, there is still more of a gneissose than a schistose structure; plicated layers of quartz carry small crystals of felspar, and still smaller ones of garnet. Precision of language would require us to call this a green-mica gneiss.

As we approach the promentary of Scianess, the rocks become normally gneissic

In endeavouring to follow the small portion of these rocks which appear on the west shore of the bay, along the line of their strike, we are from the nature of the ground confined to the beach itself.

The peculiar breccia first described I did not succeed in finding, but in its place there are beds of schistose hornblendic rocks, similar in appearance to the fragments of rock imbedded in the breccia. The aphanite is seen in small amount on the north end of this line; it is followed by, and appears to pass into a rock here ill-defined, but which is afterwards seen to be the continuation of a most characteristic mass, which I have called schistose-diorite.

To the east of this, a massive characterless serpentine occupies two projections. This serpentine is of a dark slate-blue colour, a dense structure, and is profusely sprinkled with grains of *magnetite*. It cleaves more readily in one direction, and hence was probably formed from a laminated rock.

The westerly trend of the southern fork of the Voe again cuts this series, exhibiting a small amount of hornblende rock, lying between the serpentine and the diorite; but, from the low and swampy nature of the ground at this spot, the outgoings of the other rocks are unfortunately not seen at this most important point of their course.

The same cause prevents those members which lie most westerly being immediately taken up in traversing the southern shore of the Voe; here the strata as regards their mere exposure, afford one of the finest sections in Scotland; and, from the nature of the rocks, and the manner of their association, one of the most interesting and suggestive.

I have said that, at the ultimate west point of Colafirth Voe, low ground, or—to put it more correctly,—the absence of shore-cliff escarpment, prevents recognition of the rocks. Inland the covered nature of the ground did not permit me to ascertain whether the aphanite coursed along the granite, to join a large mass of the same rock which lies to the south near Soulan Voe,—and Hibbert seems to have been here equally unsuccessful.

The first rock (after some ill-defined hornblendic strata) which the shore cliffs expose, is that which Hibbert describes as "beautiful." He states that it is composed "of nothing more than striæ of quartz and hornblende;"—in this, however, he was at fault.

The highly characteristic rock strikingly resembles a page prepared for manuscript music,—that is to say, it is crossed at more or less regular distances, by systems of narrow parallel lines with broad intervening spaces, the lines being dark, but the spaces light in colour.

I agree with Hibbert as to the nature of the dark mineral; the lines are formed by numerous interlacing crystals of platey or sub-fibrous hornblende, disposed in laminated arrangement, (uralite ?)

The white mineral which, filling the intermediate narrow and broad spaces, has been taken by Hibbert for quartz, is however *albite*, in confusedly arranged, coarsely striated crystals, which have somewhat of a vitreous lustre.

Two other substances, moreover, go to form the rock,—disposed in a flat position between the hornblende and the albite, there is a spangling of small plates of *margarodite*, and, in association therewith, and there only, there are crystals of *pyrite*. In the specimens obtained, which were necessarily near to the surface of the rock, this pyrite had become *limonite*. Beautiful in itself, this rock is occasionally rendered markedly striking by diagonal shifting,—an apposition of narrow to broad layers frequently resulting.

To this schistose diorite there succeed thin beds of hornblende and serpentine, with, according to Hibbert, "beds of quartz, and a small amount of a pure white limestone." Neither of these I here saw, but, instead, a second but very inferiorly marked bed of the "beautiful rock"; and here Dr. Gordon obtained specimens which exhibited an evident, and it it may be said a *palpable* transition into serpentine. The hornblendic mineral is quite soft and falls to a greasy powder before the knife, which also when drawn over the felspar sinks into it with a smooth sliding motion. The rock-rents, moreover, are coated with a serpentinous crust.

Beds of "potstone" (Hb) occur in the series of strata of serpentine which follow; these are also separated by thin layers of hornblende-rock, and hornblendic gneiss.

The different natures, the order of arrangement, and the bulk of these beds of serpentine calls for notice.

The most westerly bed is a dark green, dense serpentine, carrying minute crystals of talc, but otherwise featureless; this may be Hibbert's potstone. To this succeeds a very pale yellowish-green bed, of a somewhat loose and granular structure, which is pervaded throughout with what may be called dendritic markings; these are of a dark blue colour. They differ from ordinary dendritic marking in this, that they present much the same appearance in two directions of fracture at right angles to one another. The color, structure, and appearance of this rock are altogether so characteristic that it is an easily recognise one.

To this there succeeds a bed of granular green serpentine, which, in some of its layers, is pervaded with *chrysotile* ("*amianthus*," Hibbert) of marked peculiarity of arrangement.

Lastly, there follows a bed which, like the first, is massive and structureless, but which has a peculiar verdigris-green colour.

Most of the interest connected with these beds lies in this, that not only in identity of structure, but also in order of occurrence, and in bulk, they correspond in a very striking manner with the series of beds of serpentine which are to be found, with the same strike and similar dip, at Portsoy in Banffshire.

Here also a dark green serpentine occurs to the westward, followed by a pale bed, the specimens of which are indistinguishable from those at Colafirth; this is succeeded by a chrysotilic bed, while a verdigris green mass terminates the series to the eastward. As for the width, Hibbert states that he found two of the masses at Colafirth to be 90 and 240 feet; the writer found the two principal masses at Portsoy to be 80 and 240 feet.*

Eastward of this series of beds of serpentine the "beautiful rock" again appears, but its features are not here by any means so well

* I should add in connection with this series that among the rocks forwarded to me by Dr. Gordon, there are two which I and my confrere Mr. Dudgeon did not observe: 1st, a *talc rock*, which was interesting and typical. It seemed to consist of plates of pale green talc, with a very little actynolite; these are twisted into one another in a singular manner. The knife also suspects the presence of granules of quartz. 2nd, a crystalline granular variety of the beautiful rock (?) containing specks of pyrite; this is very like an igneous rock in structure. I have seen large rolled masses of this rock near Hillswick.

marked. A vein of mixed crystals of albite and quartz is next seen, shortly succeeded by one of white granular marble of close texture. To the east of this, massive hornblende rock for a short space occurs, succeeded in turn by a rock which, according to Hibbert, "is composed of quartz, and of a white talc, which takes the place of mica." The white talc I believe to be margarodite. "Chloritic" and micaceous schists, similar to those of the north shore, with a very micaceous gneiss, terminate the section.

In crossing the section, as seen half a mile south, along the north shore of Quyfirth, we find a very inferior exposure, ill-defined types, and apparently intermediate varieties:—the dioritic beds seem to have thinned out, and the serpentine does not present distinctive features; it is indeed seen to be evanescent a short distance up the opposite slope.

The interest of the section is now much diminished; the gneiss is still hornblendic to the west, chloritic rocks are seen in the neighbourhood of Ollaberry, while, at the extremity of the Ness, granitic porphyry in small amount impinges upon gneiss.

Having been specially engaged in working out the mineralogy of the locality, time did not suffice for my attempting to solve the problem or problems which the sequence and position of the rocks here evidently presented.

To anyone attempting to solve these problems, in will be apparent that he must, as a necessary preliminary, enter upon the consideration of the nature of all metamorphic change, and the origin of the so-called metamorphic schists.

That question at present very much resolves itself into the general one, whether these rocks are products of change *in* pre-existent rocks,—products of a change in rocks which had been sediments *resulting from the degradation* of pre-existent rocks,—or of a change in rocks which had been *sediments from solution* in superincumbent waters.

According to the first hypothesis, there is from first to last no change in locale; according to the others there is a necessary, probably a very considerable change in locale.

A special consideration of the very various modifications of the crystalline schists, which the Scottish Highlands afford, leads me to give my adherence to the second of these views, almost without reserve: the views which natural occurrences and natural phenomena as there seen, induce me to adopt, being similar in the main to those entertained by Dr. Sterry Hunt, as expressed in the preface to the new

edition of his "chemical and geological essays," I here present that author's views contrasted with my own.

DR. STERRY HUNT.	THE AUTHOR.
"The crystalline stratified rocks are not Plutonic, but Neptunian in origin, and, except so far as they are mechanical sediments coming from the chemical and mechanical disintegration of more ancient rock masses, were originally deposited as, for the most part, chemically formed sediments or precipitates, in which the subsequent changes have been simply molecular. or at most confined to reactions in certain cases, between the mingled elements of the sediments."	The crystalline stratified rocks are not Plutonic but Neptunian in origin, the lower members being usually mechanical sediments—coming from the mechanical and chemical disintegration of more ancient rock masses,—were originally deposited by the simple process of sedimentation; the upper may have been thrown down from suspension by some process of chemical precipitation. The characteristic features of both have been conferred upon them by the agency of the crystallipolar and chemical forces operating in the presence of the joint influences of heat, pressure, and moisture.

There is a certain class of clayslates which I would exclude from the above, namely that which, occuring abundantly in Scotland in Banffshire, and the intersecting portions of Aberdeenshire, contain throughout—irregularly disposed,—such minerals as kyanite, staurolite, andalusite, and, above all, chiastolite.

Without doubting that metamorphism has ultimately altered such rocks as a whole, I do not conceive that it is at all necessary to call in the aid of any obscure combination of forces to account for the presence of those minerals throughout their mass.

Such minerals might readily result from chemical changes taking place in that mass while it was still plastic; or between the constituents of that mass and the superincumbent waters of a richly-mineral ocean.

The crystallipolar force alone would determine their separation as isolated crystals, before the solidification of the pulpy mass into solid rock.

And while admitting that metamorphism might render a water-soaked rock sufficiently plastic for mineral molecules (resulting from exalted chemical agencies) to segregate each to its fellow, it is somewhat difficult to understand how a complex structure like chiastolite could be formed in a mass in which there was not the most perfect mobility.

As regards this particular case, I find myself in disaccord with Dr. Sterry Hunt, who enumerates it as one of the minerals which may be formed in the mass of pre-existant rocks under the influence of high temperature and saturation with thermal waters. At page 306 of his

essays he writes, "In the mechanical sediments of later periods, certain crystalline minerals may be developed by a process of molecular rearrangement,—diagenesis. These are, in the felspathic and aluminous sediments, orthoclase, muscovite, garnet, staurolite, cyanite, and chiastolite."

While it is far from difficult to suppose the chemical and crystalline forces drawing together—even out of a semi-solid mass—the ingredients which, by some such interchange as indicated by Dr. Hunt below, would form the first five of these minerals, it is difficult to imagine these forces arranging, in such a mass, a structure so singular in its relationship to the mass itself as chiastolite.

Would the mighty force, whose operations drew together the white portions of these crystals, suddenly and whimsically suspend its operation; leaving a certain amount of what is usually regarded as the material of the rock mass itself, to prevent complete union?

Are we to assign to the crystallipolar force the ability to confer upon a certain portion of the black mass (which was elsewhere unable to resist its demands,) a power which actually prevented the completion of its effort to draw the white material to a common centre?

While it may be said that the same argument to a certain extent will apply even to a *fluent* menstruum, and that any argument which explains the want of central contact by an assumed repellant polarity in the four light-tinted portions of the fabric, applies thereto also, still it can only do so to a much smaller extent; and it must be admitted that a greater amount of probability must lie with the formation of complex crystallizations in situations where there is the most complete mobility of particles.

Notwithstanding which finding, it is not difficult to show that chiastolite crystals still more thoroughly definitively negative, it may said, the view maintained by Credner, that the crystalline minerals imbedded in metamorphic rocks, were produced in the ocean in which their pabulum was being deposited, and so simply sank into the mass of these rocks.

If the central four-sided wedge of chiastolite be composed of the rock mass itself,—as it is regarded to be,—how could it, an *amorphous* body, have, in a great mass of water, been concreted in virtue of the *crystalline force*, during the operations of that force upon the white truly crystalline portions of the mineral?

Crystals of chiastolite *must* have been formed in the midst of the mass which holds them,—but that mass must have had its particles in a state of loose coherence.

And so for most crystals of andalusite also; for these, in such rocks, very generally contain uniformly throughout more or less of the micaceous and siliceous matrix, caught up in the act of their assuming a regular form.

Another fact connected with andalusite and chiastolite crystals also tells against Credner's view, namely, that these crystals are imbedded in the rock *in all conceivable positions;* and in some chiastolite slates, as that of Portsoy, in no one position in greater amount than any other.

Supposing such crystals to have been formed in superincumbent waters, it is conceivable that a certain number, on settling, penetrated the sedimented mud with their terminations, and remained poised till they were silted over; but that number must have been small in proportion to that of those which either tilted from such a poise, or which originally fell to the bottom in the more probable position of alighting on their sides.

While the locality described above is one in which many of the questions connected with metamorphism can be advantageously studied, there are two questions connected therewith which more immediately force themselves upon consideration.

The first,—is the serpentine here, a product of the metamorphism of a readily transmutable variety of the rock with which it is geographically connected?—The second, has the schistose diorite actually been transmuted into the aphanite of the northern side of the bay;—does a rock which is unmistakably schistose when it occurs among schistose strata, function as an igneous rock when within the grasp of the granite? For although there are no traces of such appearances on the shores of Colafirth, Hibbert asserts, and bears out his assertion by sketches which show that "it is exposed among the precipices of the west coast, in the form of much smaller veins branching out in numerous directions."

While as regards the first of these questions, I, as the logical consequence of a train of argument submitted in the pages of the Transactions of the Royal Society of Edinburgh, stand committed to hold the affirmative view, I have to admit that I was myself unable to adduce any *direct* evidence from the rocks of this locality.

As regards the second, again, I was strongly inclined to think that the northerly disappearance of the "beautiful rock," in presence of the continuation of the serpentinous belt, might not constrainedly be explained by supposing it to be converted by an igneous mass which had enveloped it, into the aphanite which is its geographical continuation, and which must be nearly identical with it in composition.

The value of *more light* is well shown by this, that three specimens selected by Dr. Gordon merely as types of the rocks, almost prove the correctness of the view held, as regards the first of these questions, and go a long way to disprove the second.

The first of these specimens were that of the actynolite rock of the north, and that of the "beautiful rock" of the south side of the Voe, both of which were *softening into serpentine;* the other was the apparently igneous rock mentioned in the foot note of page 187, and which was stated to be identical with loose masses at Hillswick.

It has to be admitted, as regards this last specimen, that I do not know of the occurrence of this particular type of rock as occurring in the igneous mass to the east of Urie Firth, but it must occur at no great distance from the only spot where I observed the loose masses; and if it forms a portion of that great igneous mass, and sends a prolongation or dyke up among the weaknesses of the junctions of the stratified rocks, and is continued merely with darkened and finer grained features, plugging some rent in the granite, we have some definite record of the relative age of these rocks.

It has been before noticed that the large mass of igneous rock east of Urie Firth may be a continuation of the great dyke which cuts off the schists of the Fitfiel Head: if this injection cuts at the same time the sedimentary rocks at Colafirth and the granite of Rona's Hill, this "epidotic syenite" of Hibbert must be the more recent rock.

Minerals.

On the north west shore of the Voe, a single ill-defined crystal of *tourmaline* was found imbedded in a Biotitic schist (H.)

At a spot on the west shore, marked on the map, where the serpentine touches hornblendic rock, fair specimens of *actynolite*, and radiating crystals of green *hornblende* occur (H.)

From the numerous junctions which occur on the south shore of Colafirth it might be expected that the locality would be rich in minerals.

The coast, from the first appearance of cliffs, to as far east as the pier, is the site where they occur.

The *Albite*, which formed the white layers of the schistose diorite, mistaken for quartz by Hibbert, yielded on analysis:

Silica	66·8
Alumina	17·832
Ferrous Oxide	1·128
Lime	1·504
Magnesia	·138
Potash	·919
Soda	11·517
Water	·484
	100·322 (H.)

In structure this albite somewhat resembled a granular marble, consisting of a mass of crystals lying in a every direction. Its specific gravity is 2·622.

The hornblendic strata which follow yield perhaps the most beautiful specimens of *hornblende* (Hb.) which I have seen.

These specimens consist of bundles, bunches, or plumes of coarse bristling fibres of nearly a foot in length, of a jet black colour, and a brilliant lustre. When most fibrous, plates of bronzy *Biotite* (or *Haughtonite* (D. & H.) are sparingly distributed throughout their mass.

Here also are to be found large speciments of green *actynolite* (Hb.) of unparalleled magnificence; bunches and bundles of lustrous crystals of a fine green, radiate into white albite; plates of bronzy Biotite diversifying the appearance. Hibbert adds *kyanite*, this we did not find, it doubtless occurs in the quartzose belts.

The *Chrysotilic* serpentine contains that mineral in a form which admirably illustrates one of the varieties of vein structure. (D. & H.)

As is invariably I believe the case with this mineral, its fibres run transversely to the course of the minute veins which carry it. These veins occur with an anastomosing structure, somewhat like the fibres of an untwisted cord, spread out in a flat arrangement to a width of a couple of inches. The silky fibres are of a yellowish grey colour; on account of their delicacy, their fine lustre, and the peculiarity of their structure, they form specimens of high beauty.

At this locality, *mountain-felt* occurs sparingly (D. & H.); and delicate crystals of *arragonite* lodge in the rents of the pale serpentine (D. & H.)

The vein of *Albite* (D. & H.) consists of a protruding belt of that substance four or five feet in thickness: large, lustrous, foliated, snow-white crystals* of the mineral are separated from one another

* Under the microscope albite has an appearance, by polarised light, which is quite distinctive; the optical characters of this and other felspars will be considered apart.

by hyaline massive quartz, which is sometimes graphically arranged; the exclusion of the quartz for analysis was unusually difficult. This albite is markedly the finest I have seen in Scotland. Though there are no free crystals, its cleavage faces are of large size, great purity of appearance, and brilliancy of lustre. It rarely exhibits striation to the lens. Its specific gravity is 2·61. It yielded—

Silica	66·838
Alumina	16·733
Ferrous Oxide	2·42
Lime	·942
Magnesia	·372
Potash	·733
Soda	10·76
Water	·894
	99·692 (H.)

On the hill slope, south of Quyfirth Voe the serpentine was opened up for *chromite*, traces only were found; the serpentine here, however, has much of the appearance of that variety which is the ordinary matrix of chromite, possessing what might be conceived to be the mixed characters of the several beds which here coalesce.

At a point indicated as a mineral locality in the map, intermediate between the serpentine and the hamlet of Ollaberry, a massive granular white felspathic mineral occurs.—(D. & H.) It contained specks of pyrite, and was hardly pure enough for analysis. It would be ordinarily called "*Saussurite*," a name generally adopted for every unknown massive felspar: this doubtless is in the line of the continuation of the labradoric rock found by Dr. Gordon on the north side of Colafirth.

In close proximity with this a singular specimen was found (D. & H.) This consisted of a mass of rough crystals in parallel disposition, implanted upon massive quartz. They were of high lustre, yellow colour, and appeared to consist of talc pseudo after kyanite or actynolite.

Gold was said to have been found in quartzose veins at a place called Back, in the north east corner of the Ness, near Ollaberry.

Having inspected the single specimen said to have been there found, I have to say that it consisted of a rubbed specimen of rich yellow gold, imbedded in a greasy white quartz; that both gold and quartz are identical in appearance with those of Australia; and that veins

carrying this variety of quartz were nowhere seen to occur in the locality named as the site from which the specimen was brought.

Dr. Gordon sent for my inspection three specimens from the Loch of Burroland, the site of an old Broch; this is on the south side of the road from Ollaberry to Hillswick, and east of Punds-water loch.

Two of these specimens were junction rocks, consisting of a mixture of pale grey hyaline *labradorite*, with crystals of *margarodite*, and a general admixture of calcite.

This probably gives us the strike of the labradorite which appears on the north shore of Colafirth.

The third specimen was a massive granular grey limestone.

"Certain archæologists hold that one of the reasons for the Brochs being dry stone biggings, is that there was no limestone to be had,—otherwise the builders would have used mortar." This Broch, however, has been built on or beside the only bit of limestone in the district.

Were archæologists to become more or less of geologists, they might be aided now and again in suiting their theories somewhat better to the facts of the case.

FROM HAMNA VOE TO TANGWICK.

The whole south-west of Northmavine, from Roeness Voe to the Bay of St. Magnus, is composed of igneous rocks of Old Red Sandstone age. Only at two spots—the Falling Stack at Roeness Voe, and the Rock of Door-holm, is the sandstone to be seen. A comparison with the rock of Papa Stour, and that of the Mainland near Melby shows their identity.

The igneous rocks may, in some localities in this district, be seen to have flowed out in sheets, for the most part they are ashy or amygdaloidal. Beds and dykes of porphyry occasionally are to be seen, and the ordinary "claystone" rock is often porphyritic in structure; containing soft and readily disintegrating crystals of yellow or light-coloured felspar.

The chief interest connected with the geognosy of this district relates to the striking manner in which it has suffered from the inroads of the sea; there being probably no other spot in Britain which affords such evidences of its power.

This has been assigned to the coast being here exposed to the "uncontrolled fury of the western ocean." It certainly may be the case that the height of the cliffs and the depth of water adjacent thereto may be such as to be peculiarly favourable for the direct application of the force of an Atlantic billow, but this coast is no more specially exposed to the uncontrolled fury of the waves than any other stretch of shore which is unprotected by breakwater-skerries or islets.

The unrivalled illustrations of the devastating and disrupting power of the roll of mighty surges, which this shore affords, is altogether due to the nature and the local circumstances of its rocks.

The interest of the district, both in the above respect and in its mineralogy, lies between Hamna Voe and the Door-holm.

The rocks which encircle the coast, vary from a minimum height of 60, to a maximum of 147 feet; being, from their nature, of loose structure and easy disintegration, they everywhere have suffered much from the assaults of the waves, which have hewn their mural faces, and cut out their deep and burrowing caves.

The first noticeable special illustration of the power of the ocean, however, is a most unexpected one.

From the brink of the cliffs the land falls into a slight hollow or parallel valley, to rise again, somewhat steeply, some quarter of a mile landward, on the swellings of a hill. This valley is swathed in a turf of truly wondrous richness. Hibbert thus describes it :—"I pursued my way along a high gradually ascending ridge that impeads the ocean, which is covered with the finest and softest sward that ever refreshed the tired feet of the traveller, being frequently resorted to by the inhabitants of Northmavine, on a fine Sunday evening, as a sort of promenade. The verdure that embroiders this proud bank, on which numerous sheep continually feed, pleasingly harmonizes, on a calm day, with the glassy surface of the wide Atlantic; nor is the pleasure less perfect when the smooth coating of so luxuriant a turf is contrasted with the naked red crags which form the precipice below, whitened with the spray of the breakers which continually dash against them with angry roaring. The rich surface of pasture which thus gradually shelves from the elevated ridge of the coast, bears the name of the Villians of Ure; and well might we apply to this favoured spot of Thule, the compliment that has been often paid to some rich vale in England, "Fairies joy in its soil." After a distance of three miles this gladdening prospect of fertility is suddenly closed with the harsher features that Hialtland usually wears."

Now, in Shetland, the verdure of this "proud bank" is held to be the offspring of the fleecy foam and saline rain which so frequently deluges it,—of the surge which so often sweeps its slopes.

The harsher features which Hialtland so frequently wears might more fittingly be assigned to such a cause; a sweeping surge is not generally pregnant with such sweet influences; many spots may be seen on the western coast of Orkney, they are doubtless not unfrequent in Hialtland also, where the turf-crowned brows of cliffs, two or three times the altitude of these, are rutted, and riven, and scalped by the back-tow of the sweeping surge.

The true cause of the fertility is not far to seek; loose-lying on the sward, dotting it everywhere as they chance-thrown fell, are fragments, large and small, down to the pulverised shingle of the rich alkali-charged rock. The more massive fragments have, with no little toil, been rolled aside to form dykes; the smaller lie air-rotting, till the sward creeps over them The devastator has here become the enricher; the surge seizes upon the foundation strata of the cliff, first pounds them against its frontlet, then bearing them aloft in its grasp, sweeps them over the crest, and flings them, with loose-fingered sprinkle, far over the land.

The illustrations of the power of the surge, as here seen, are mainly in the transporting of huge blocks, and in the cutting out of deep caverns.

The sky-line of the Holm of Eshaness, which is about 135 feet high, is roughened all along by immense loose blocks, which appear at a distance little less protuberant than the hamlets of the inhabitants.

Of measured movements of such masses, Hibbert mentions the following:—

8	feet	2	inches	x 7	feet	x 5	feet	1	inch, carried 90 feet.
17½	,,			,, 7	,,	2	,,	8	,, carried 30 ,,
9	,,	2	,,	,, 6½	,,	4	,,		carried 150 ,,
9	,,			,, 9	,,	9	,,		thrown up.

A group figured by Hibbert, and consisting of blocks about 8 feet cube, has been broken to fragments by being thrown against one another; this demolition took place while they lay some distance from the edge of a cliff 86 feet in height. Jameson mentions a mass 12 tons in weight which was torn out of its bed 90 feet above the ocean, and thrown two fathoms inland.

A mass somewhat less than one cubic yard was seen by Mr. Dudgeon and the writer lying toppling upon the edge of the cliff, where it was 135 feet in height; this *must* have been thrown up, for it consisted of hard porphyry, and a bed of this lay at the very base of the cliff at the water level, the whole of the superincumbent mass and all the rocks around being amygdaloidal.

At the spot called the Grind of the Navir, a mass, thirteen by twelve, by five feet, was thrown laterally a distance of thirty feet, and twenty-five vertically; it has since been several times rolled over; the original bed of this mass was seventy feet above the sea.

It is at this spot that this work of destruction is most apparent, and it is here also that it can be clearly shown that such illustrations of the prodigious power of moving water, occur where the peculiar circumstances of the case have operated in aid of their production.

A small promontory projects westward from the ordinary north and south trend of the coast or cliff line; this promontory, instead of consisting of the ordinary amygdaloidal trap, is formed by a bed of hard porphyry which dips to the south—*i.e.* at right angles to the line of the cliff, at an angle of about 10°; this bed projects sea-ward for about one hundred yards; at its highest point, where there is a level platform, it is about seventy feet above the sea. To the north, it falls over in rough and broken cliffs; landward, the amygdaloid overlaps it

in a bed, which at its highest point is twenty-feet in thickness, at its lowest, where the porphyry dips beneath the water, this amygdaloid bed is about ninety feet in height.

Seaward, this porphyritic platform and terrace is cut off by a dyke of porphyry, which rises some thirty feet above the platform, and so presents a vertical wall to the western ocean of about a hundred feet in height.

Opposite the very centre of the level platform, the sea has forced an entrance through the upstanding dyke, cutting it square down, even below the level of the platform itself; and strewing the latter with the ruins of the breach, which now presents itself as a mighty portal, flanked by stupendous walls.

The ruins of that portal would delight the heart of a quarryman.

Sapping with gentler plash into the jointings of the porphyry, the waters have loosened the cuboidal blocks, so that the winter's billows lifted them out of their beds, and now tosses them into heaps which lie disposed according to the set of the waves. Smooth-surfaced and sharp-angled, no chisel-work would improve them. Masses from six to eight feet in length, and of proportionate width and depth—a wealth of building material—lie pitched in every position, tier over tier.

These heaps of stones are generally disposed as two great mounds, which stretch landward from the shelter of the pillars of the portal; but when the surf rolls up from north or south, they are scattered over the platform, only to be swept back again behind the rampart by the first storm from the west.

The process and the progress of all this ruin is very apparent; southerly and northerly gales swept from off the terraced platform the cap of amygdaloid which once buttressed the great porphyry dyke: doubtless its massiveness enabled it long to resist all direct assaults in front; but a flank attack prevailed. An inner dyke of less enduring material penetrated it from the north; this was sapped out, and now appears as a narrow geo, up which the water dashes. The great dyke, thus reduced to two of less than half the width, had collapsed, and the ruins of the outer portion doubtless aided in the battering down of the inner.

To the weakness incident upon a jointed structure, has also to be assigned the singular recesses which the waves have scooped out, at what are called the Holes of Scraada, and the Cannon.

At these points, dykes of porphyry, which had penetrated the cliffs at right angles to their escarpment, have been sapped out; but here

the waters, being confined in their action, have removed only the lower portions, leaving the upper as the keystones of the arched roof.

At the Holes of Scraada that roof has, in two places some hundred feet inland, fallen in ; the debris has been swept away, the shafted openings greatly enlarged and deepened, so that now two seething chaldrons of foaming waters may in storms be seen, cliff encircled, and apparently unconnected with the outside waves. Into the inner of these chasms the waters of a stream are precipitated in a cataract,—they had doubtless done some amount of the tunnelling.*

Minerals.

The traps of Old Red Sandstone age are as a rule far from generous in their supply of "simple minerals;"—this is markedly the case here.

The "porphyritic claystone" yields, some fifty yards south of the Cannon, in small flat druses, an olive-green to fawn-yellow "steatitic" looking substance, soft and of a soapy feeling—doubtless *saponite* (D. and H.) Here also *rock-crystals* and *amethyst* occur in pyramidal crystals (D. and H.)—both being traversed by spicular crystals of *limonite* of a rutilic colour,—"fleches d' amour" (D. and H.)

A little bight immediately south of the point which is opposed to the rock of Door-holm, has cliffs of a rotting porphyry, which yields *agates*, and *chalcedony* sheathing fibrous zeolite (? natrolite) D. and H.

Hibbert states that the rock of this district, "in some places," contains cavities lined with chalcedony coated with *calcite* and rock-crystals —also occasionally with "green earth,"—doubtless *saponite*.

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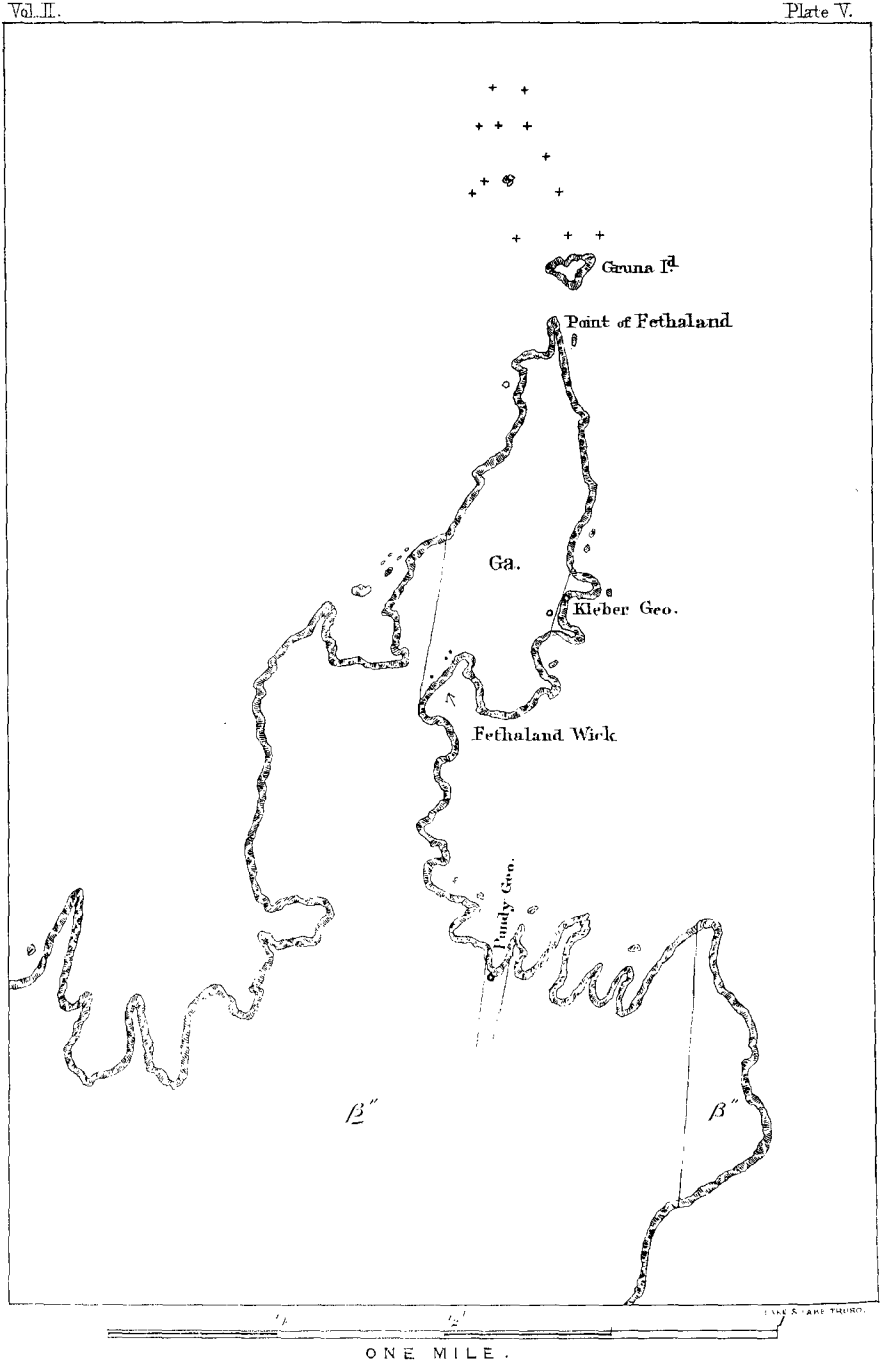
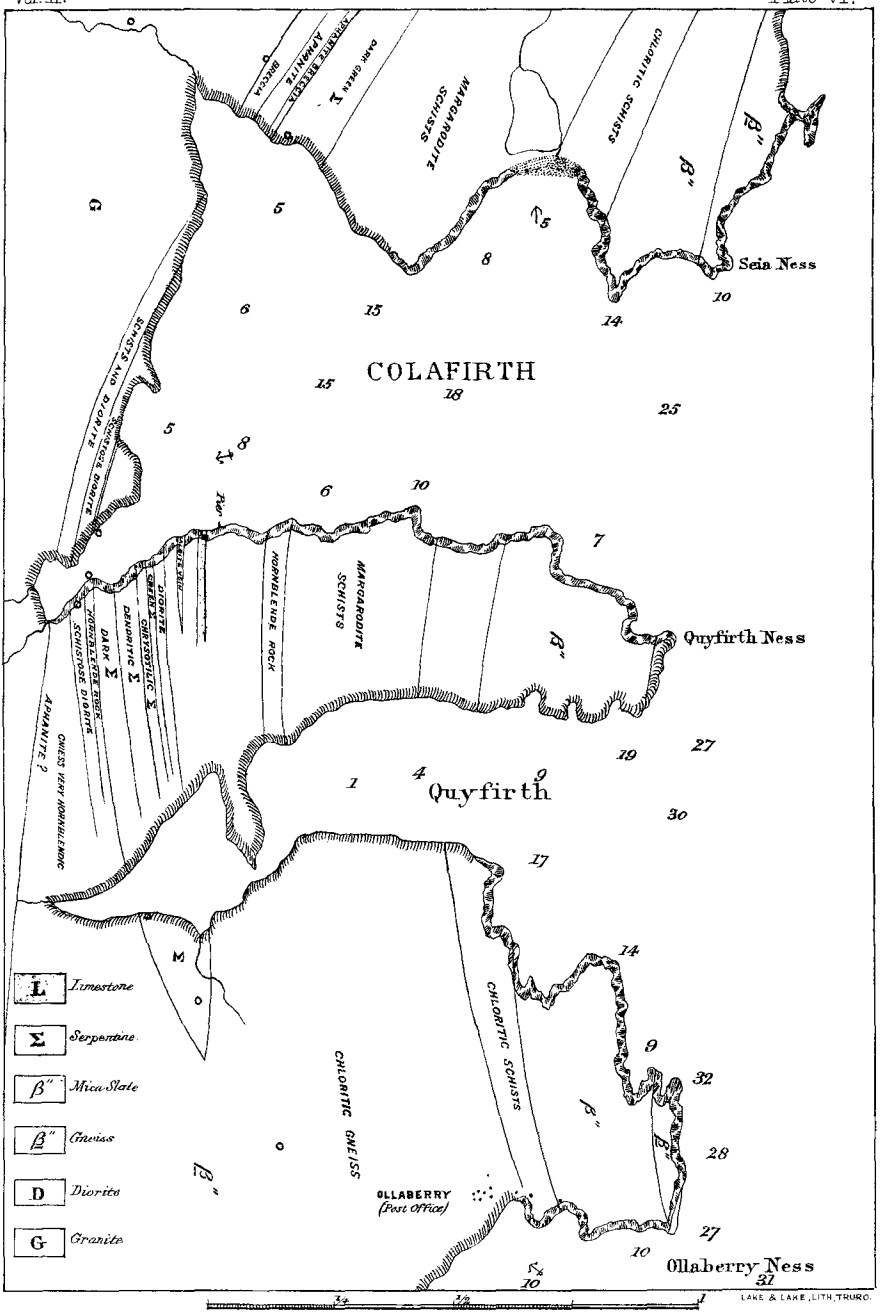
* The vacuity left by the washed out dyke at the Cannon, has two openings—one which is constantly beneath the waters, and is unseen; another circular, and about a yard in width, is a little above water level. The inner chamber is of such profundity and form, that at certain states of the tide, the included air pent up by an inrolling surge, asserts its elasticity upon the compressing liquid in its back sweep, in such a way as to catch some of its upper waters and discharge them, dissipated into steam This is accomplished with terrific force, and a noise which, to a near observer, resembles the imagined snort of a leviathan; while when heard from a passing vessel the reverberation seems like the sound of a cannon. The misty spray is discharged from the throat of the recess with astounding force to a distance of forty yards.



[*Copied from original colour plate.*



ONE MILE.

[*Copied from original colour plate.*