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I.—*Address on "The how and the where to collect minerals in Scotland."*

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PROFESSOR HEDDLE remarked that this title would sound strangely to southern ears; as in England and probably also in Ireland, the putting money enough in the pocket, and proceeding to the shop of a dealer, was the ordinary, and indeed the all sufficient method; though some enthusiastic collectors might go so far as to visit the openings of mines; while some adventurous ones might even explore them. In Scotland no such method of procedure could be adopted; there were absolutely no mineral dealers now in Scotland; there were almost no mines, and of these none now yielded minerals of special interest.

He would not say that it was not here quite as necessary to put money in the pocket, but the collector must in all other respects depend on his own individual exertion: he must search for and extract the specimens from the including or enclosing rock himself.

Before proceeding on such a search, at least if the search was to be original, it was all important that he should learn the geology of the district; not necessarily as taught in books, but as taught by the rocks.

The experience of some five and twenty summers devoted to such exploration, in many districts of Scotland, enabled Professor Heddle to indicate the following situations as the chief localities in which minerals might be hoped for.

1st.—*Junctions of formations and of strata—at least among metamorphic rocks.* It was to be expected that metamorphic action, by stimulating chemical affinities, would induce the formation of a greater number of minerals where two rocks of different composition came in contact, than would be found in the general mass of either.

2nd.—*At or near the point of contact of injected dykes or igneous masses*: And for reasons very similar to the above. There was here more active, though more local metamorphism; from direct heat acting in conjunction with the insinuation of a material of a nature different from that of the penetrated rock.

3rd.—*At escarpments, faults, shore cliffs, and hill-tops.* In these situations we have the advantage of searching the rock in section,—more or less through its mass as it were; just as if we were directly cutting into it by quarry or railway excavation. And such localities lead one to reflect on the vast expenditure of force, artificial or natural, which a single mineral specimen represents:—of rending force of gunpowder, or breaching force of sea wave, or elevating force of earthquake throe.

The mineralogist is placed at a great disadvantage as compared with his brethren of other departments of natural history. The botanist, the entomologist, the zoologist, find the objects of their regard on the surface, almost ready to their hand; the conchologist and marine zoologist, perhaps the most unfavourably situated among them, have merely to drag a dredge over the sea bottom; but the carrying of ponderous hammers up steep hill sides, in the mere hope of a find, is a favourable presentation of what the practical mineralogist has to do, before he begins his work.

4th.—*The amygdaloidal beds of igneous rocks of tertiary age, and chiefly the upper surfaces of these beds.*

5th.—*The junctions of limestone strata with rocks of metamorphic age.*

The last of the above localities Professor Heddle regarded as being, in Scotland, the most richly mineral-bearing of the whole; and, as he saw that the list of papers to be submitted to the meeting was a full one, Professor Heddle intended to confine himself to a consideration of the causes of the fruitfulness of the last enumerated locality.

He had frequently observed that limestone strata in the metamorphic rocks of the Highlands of Scotland seemed to function as igneous rocks, in the changes they induced or seemed to induce in the including rock ; but this special mode of functioning, at first sight very anomalous as regarded a substance and structure of unquestionable organic origin, was only to be observed in certain circumstances.

If the limestone bed was thin, whether disturbed or undisturbed, convoluted or not so, there was no change. The stratum itself was still *limestone*, a more or less impalpable paste—amorphous in its nature—structureless ; or if with recognisible structure, then it was that of an imbedded and badly developed organism. Here the including rock showed no greater amount of metamorphism in the vicinity of the lime than elsewhere ; while, in neither lime nor including rock were there to be found any minerals, other than the ordinary ingredients of their general mass. And all this also holds with equal force in the circumstances of the lime stratum being of considerable extent, so long as it be untroubled,—unconvoluted.

But it is not so if the stratum be at one and the same time large in mass, and highly contorted. Then, the calcareous mass no longer is amorphous in its substance, and organic in its structure; it presents itself as a *granular limestone*, often as a true marble; that is, it is *calcite*, and is crystalline in structure, and in all its inherent properties. Again, the including rock is, in the immediate vicinity, much more highly metamorphosed than it is throughout its general mass. While lastly, imbedded in the limestone, and to a smaller extent in the altered rock, but in both cases near their point of contact, there are found numerous minerals, *all* of which are such as can be formed by the union of the constituents of the inclosed limestone with the inclosing gneiss.

The assigning of the above local changes to the mere presence of limestone in a rock which is undergoing ordinary metamorphic change, will not suffice as an explanation of what is found in the above case. Ordinary metamorphic change is, in our almost total ignorance of the subject, usually assigned to hydrothermal action (how excited?) at great depths, *i.e.*, under enormous pressure. Such a thermal change should affect a plicated and a nonplicated included rock alike; and should certainly affect a thin bed of lime more than a thick. As the result of any change thus passing from *without inwards,* that is from the gneiss to the limestone, we should expect to find the thinner parts of the stratum of the latter wholly converted into large granular marble, and very fully pervaded with mineral species; while the thicker masses of the lime should be much less altered in both respects: but this is the opposite of what obtains; and so any explanation which requires that the agent of change should act from *without inwards* does not suffice.

The whole facts of the case seem to point to an action taking place from *within outwards.* So at least is it to be seen how there should be greater change where the stratum is thickest; the greater the mass the greater must be the amount of action, if that action proceed from within.

But what action, physical or chemical, can be conceived to take place within, or emanate from a sedimented, amorphous, organic limestone, which shall credit it with being at one and the same time the agent of its own metamorphosis into its crystalline allomorph,—of augmenting the metamorphosis of a rock in its immediate neighbourhood,—and of stimulating to the chemical union of the material of its own mass with the constituents of that rock?

Among the physical agencies which induce a change from the amorphous or colloidal to the structural or crystalloidal condition, we find *plication* and *heat.* Sir James Hall's experiments have shewn that direct heat under pressure will change limestone into marble or calcite; and *plication,* in the very act of transforming a colloid into a crystalloid, does so at the cost, so to speak, of an elimination of heat from the substance so plicated. Melt lead, pour it out on a flat stone,—in cooling it assumes the structureless amorphous form, with rounded colloidal outline; if, after cooling, it is bent in the hand, it gives out heat, becomes crystalline in structure, gradually loses its pliability, and assumes the brittleness inseparable from the crystalloidal state,—the same holds for iron and all metals capable of assuming the colloidal state; bend or beat them, they give out heat, becoming crystalline and brittle in the so doing.

The heat here eliminated is an outcome of the change from the colloidal to the crystalloidal condition; the agent of the elimination was the plication to which the substance was subjected, which plication was at the same time the immediate agent of the physical transformation.

Professor Heddle then suggested that it might come to be found that *the specific heat of substances in their colloidal state was always greater than that of their crystalloidal.* He was not aware that the attention of physicists had been directed to this point; nor was he aware that any researches had been made specially to determine it.

The following table, embodying all he had been able to find, seemed clearly to bear out such a view:—

Colloid.		Crystalloid.	
Water	1·	Ice	·72
Lamp Black	·260	Graphite	·201
		Diamond	·174
Limestone and chalk	·264	Calcite and marble	·201
Chalcedony	·195	Quartz	·179
Titanic acid (artificial)	·172	Rutile	·163
Peroxide of iron (artificial)	·176	Hematite	·166

Should it prove to be the case that the amorphous form had a specific heat always exceeding the crystalline, a step probably would be gained in the explanation of metamorphism generally: it might at least be held that the high specific heat of limestone, and the much lower heat of calcite or granular marbles, explained the local metamorphism which he was now considering; as the plication, crushing and folding of the strata, *expressed or extricated as heat of active energy* the difference in the amount of the specific heats of carbonate of lime in its two states,—the excess which was special to it in the colloidal. This expressed heat left only a residue, so to speak, sufficient for granular limestone; while it became the active agent in stimulating the chemical affinities existing between lime and the silica, alumina, and alkalies of the gneissose matrix. It thus led directly to the formation of minerals, while it is at the same time expedited or perfected a more through metamorphosis—i.e., the assumptiou of a more perfectly developed crystalline structure,—in the previously only partially metamorphosed rock.

The assumption of a definite crystalline structure,—a character or property directly attached to a definite chemical composition,—must of necessity extrude from the resultant calcite the phosphate of lime and fluoride of calcium which limestones contain, uniformly distributed throughout their mass. *Apatite* and *fluor spar* are accordingly among the crystallised minerals found imbedded in the saccharoid "primary" limestones.

Whether the extruded heat can actually fuse the residual calcite may yet be ascertained by direct experiment; but it would seem to be almost a necessary deduction, that no mineral could be formed by such an action, possessed of or requiring a specific heat greater than that of the original source of the expressed heat.

It must be borne in mind that chemical elements do not alone go to the formation of any substance;—a due amount of certain physical agencies is the special portion of each, lodging in their pores as resting places;—of the chemical ingredients one alone may suffice; of the physical—among which heat, phosphorescence and magnetism may be said to be those most germain to minerals—heat is the only one which is never absent. Chemical Affinity then can only *predispose* to the union of the constituents which go to form the substance; for something more is requisite before the formation can be accomplished—before the substance, can, so to say, assume an independent existence,—namely the supply of the heat special to it—to the perfect putting together of the whole as a mineral species.

It has, however, to be admitted that we are unable, positively, to affirm that the expressed heat may not be so concentrated in the spots where the chemical action is operating as to afford any specific heat required.

Two arguments against such a view may be, however, adduced;—the first, that the heat extricated throughout the general mass would not readily be localised or carried specially to any point in so badly conducting a substance as granular limestone or marble;—more probably would it accumulate within the limestone itself, even to the point of its fusion: and, indeed, the occurrence of porphyritically disposed crystals of quartz with rounded angles, throughout the general mass of some marbles, would seem to indicate actual fusion.

The second—that it has not yet been shown that there is the necessity for such concentration.

The high specific heat of the matrix is, in the present case at least, amply sufficient; no one of the minerals found in the above localities possessing so large an amount of heat as ·264—that of limestone.

That of the following is known:—

Fluor	·19
Apatite	·170
Tetrahedrite	·192
Actynolite	·204
Augite	·194
Diopside	·190
Pyrrhotite	·16
Molybdenite	·102

It is a somewhat significant fact that *limestone has a specific heat superior to that of any other rock mass;* we speak of mollusks and crustaceans as “cold blooded,”—though it is believed that they have a temperature somewhat higher than that of the medium in which they live;—but the calcareous matter which they have secreted from solution in that medium, for the defence of their soft parts, is deposited and arranged with an organic and noncrystalline structure, and consequently has had conferred upon it the high specific heat of the amorphous state; and so the long buried skeletons of these organisms are abiding store-houses of heat, until called upon to yield up their surplus store and thus become the active agents of future change.

A brief sketch may now be appended of the localities in Scotland where limestones of the age referred to above occur.

Although there are many localities where metamorphic rocks contain calcareous beds, yet their continuity and connections can nowhere so easily be made out as in the counties of Banff, Aberdeen, and the north of Perth. In this district the general trend of the outcrop is from N.N E. to S.S.W.; the dip, usually at a high angle, being to the E.S.E. The lowest member of the series which includes calcareous beds is an argillaceous mica-schist; this is succeeded to the east by a highly metamorphosed quartzite of a pinkish tint; the dip of which is somewhat more southerly than that normal to the series. Eastward of the quartzite the characteristic “gnarled gneiss” of Scotland supervenes, rolling over the country in repeated folds; convoluted and contorted in the extreme. This gneiss is composed of orthoclase of a somewhat bluish tint, passing occasionally to cream colour, and containing over half a per cent. of lime; a black or bronzy mica, which will probably prove to be lepidomelane, and pale blue quartz, quite subsidiary in amount. This rock, highly characteristic from the manner in which its dark micaceous layers display the marvellous plications into which it has been crumpled, dominates throughout the county of Aberdeen to a far greater extent than the granite-blotched geological maps admit: and it is a question, to be determined perhaps not so much by the labours of the officials of the Geological Survey, as by work special to this Society, whether, the granitic masses represented by these blotches, be not the completed result of the action of the same agencies which produced the intermediate stage of gnarled gneiss.

In no place, perhaps, can the gneiss be shown actually to abut upon the quartzite, for there intervenes a bed or a series of beds of limestone, associated for the most part with serpentine; and associated also throughout a district of the country, in which there would appear to be a bifurcation of the series, with a mass of rock usually assigned to the plutonic division of the igneous rocks, and the basic section of that division.

It has been stated above that the dip of the quartzite was not absolutely conformable to that of the mica slate; the relations of this quartzite have yet to be thoroughly investigated: probably it will prove to be the lowest member of the series; it is in the north somewhat talcaceous, and micaceous in its southern reaches. Such being the general relationships of the rocks, their geographical position has now to be pointed out.

The argillaceous mica schist is first seen in the north, a few miles south of Cullen in Banffshire, stretching thence to the S.W. it occupies the whole of the low ground of the Vale of Deskford, Glen Isla, Glen Rinnes, Glen Livat, the braes of Abernethy, and the upper reaches of Strath Alnack; and the lower part of these hollows is occupied by a frequently interrupted but on the whole very persistent bed of limestone. The general character of both schist and limestone being an absence of disturbance, trouble, folding, or dislocation of their beds.

Of the quartzite little need be be said: a considerable though detached mass of it appears in the neighbourhood of Cullen: the portion supposed to overlie the argillaceous schist of the western valley, commences in the Durn hill, south of Portsoy, and stretches in two parallel ranges of highly elevated land, protruding as it were through the sea of micaceous mud which lies at their feet, with but few breaks in the continuity of their course, till, converging after forming the buttressed walls of Glen Clunie, they constitute the great mass of Ben Uran and Ben y Gloë:—reappearing in small amount here and again, and being finally denuded off, after forming the terminal fifty feet of the sharp summit of Aonach Beg near Loch Ousan.

Immediately above the quartzite there comes in a series of beds of serpentine of at least three varieties, alternating with beds of limestone; the thinner beds of the latter of so trifling and inconstant a character, as to lead to the suspicion that they may not be sedimentary limestones at all; but be due to a metamorphism of the diallage rock, which, by the action of carbonated waters, was transmuted into beds of serpentine and calcite. These beds of serpentine all show themselves in the north in the neighbourhood of Portsoy in Banffshire; they hold a parallel, or perhaps a united course as far as the head of the Blackwater in the same county, where they appear to separate or trifurcate: one, which continues to hug the quartzite, according to McCulloch, is seen in the Ey Forest, and probably loses itself in the serpentinous marble of Glen Tilt: another, seen on the Kindy, the north-east shoulders of Culbleen, the Coyle, and Little Kilrannock, is lost among the cliffs of the Canlochan of Glen Isla: while the third, associated almost throughout with gabbro and true syenite, crosses the Alt Devoran, forms the hill of Tombreck or Towanrieff, re-appears at Knockespock, Chapeltown, Premnay, Barra Hill, and Belhelvie, passing five miles north of Aberdeen into the German Ocean at the Schiller-spar of the Black Dog Rock.

Throughout the whole of this extended reach the serpentine is so commonly associated with limestone, that where they do not appear in company, they may be mutually said to represent each other; all, more or less included in the gneissose rocks, share the vicissitudes of dip, strike, and plication to which the including rock has been subjected; and these limestones offer a marked contrast in almost every respect to the undisturbed and comparatively barren bed first mentioned as occurring in the argillaceous sandstone.

It is in those portions of the limestone beds which are not associated with serpentine, but which lie among the most highly plicated, disturbed, and fractured strata, that the largest number and the largest amount of mineral bodies are found. Doubtless, the fact of one stratum having an argillaceous, and the other a gneissose matrix, cannot be without influence; but the absence of minerals in the gneissose beds, when these are either small in quantity or unplicated, shows the amount of that influence to be but small.

The following contrasted columns present these differences to the eye.

Lower Limestones.
Generally in argillaceous schist, and usually unplicated.

Redhythe, Banffshire.
Matrix gneiss, stratum thin, very highly plicated.
MINERALS.
Talc, in small quantity.
Pyrrhotite, in small quantity.
Biotite, very rare.
Rutile, very rare.

Fordyce.
Matrix gneiss, stratum thick, not plicated.
Talc, rare.

Maisley.
Matrix argill. slate, stratum thick, not plicated.
Antimonite.
Fluor.

Botriphine.
Matrix argill. slate, stratum thick, not plicated.
Kyanite in quartz seams.
Margarodite in quartz seams.

Dufftown.
Matrix argill. slate, stratum thick, not plicated.
Quartz, rare.

Glen Rinnies.
Matrix argill. slate, stratum thick, not plicated.
No minerals.

Candelmore.
Matrix argill. slate, stratum thick, not plicated.
Chlorite, rare.

Alt na Corleachan.
Matrix argill. slate, stratum thick, not plicated.
No minerals.

Carn Ellick.
Matrix argill. slate, stratum thin, not plicated.
No minerals.

Upper Limestones.
In gneissose rocks, and usually highly plicated.

Royndie Bay.
Matrix gneiss, stratum thick, not plicated.
MINERALS.
Mountain leather, rare.
Mountain cork, rare.

Ardonald.
Matrix gneiss, with cover of clay slate, stratum thick, not plicated.
Margarodite, rare.
Kyanite, in quartz seams of, and
Grenatite, in the slate.

Limehillock, Grange.
Matrix gneiss, stratum thick, not plicated.
No minerals.

Glen Bucket.
Matrix gneiss, stratum thick, not plicated.
Margarodite.
Pyrite.

Green Hill of Strathdon.
Matrix mica slate, stratum thin, not plicated.
No minerals.

Glen Cairn.
Matrix gneiss, stratum thick, much plicated, dip inverted.
Cinnamon stone abundant.
Idocrase abundant.
Pyrohotite abundant.
Andesine common.
Funkite scarce.
Coccolite common.
Prehnite scarce.
Epidote common.
Wollastonite scarce.
Actynolite scarce.
Lamellar Quartz common.
Pseudo-prehnite common.
Greenovite, very rare.
Rhodonite, very rare.
Diallage, very rare.
Biotite, rare.

Gaulrig.
Matrix argill. slate, stratum thin, not plicated.
Fluor, common.
Steatite, scarce.
Sphene, rare.
Ripidolite, rare.

Boharen.
Matrix argill. slate, stratum thin, not plicated.
Fluor
Hornblende,
Kyanite, in matrix,
Staurolite, in vicinity.
Garnet,

Upper Limestone.
Muir and Midstrath.
Matrix gneiss, stratum thick, not plicated.
In the limestone.
Fluor.
Graphite.
Sphene.
Malacolite.
Quartz.
Pyrrhotite.
In the Matrix.
White Orthoclase.
Lepidomelane.
Apatite.
Apatite, scarce.
Calcite crystallised, scarce.
Lepidomelane, in matrix.
Scapolite ? ?
Pyrite, very rare.

Crathie.
Matrix gneiss, stratum thick, contorted.
Hornblende and Actynolite.
Sahlite and Coccolite.
Wollastonite.
Prehnite.
Grossular.
Garnet, abundant.
Greenovite.
Idocrase, abundant.
Pyrrhotite.
Pyrite.
Andesine.
Fatty Quartz.
Biotite.
Fluor.

Froster Hill.
Matrix gneiss, stratum thick, plicated.
Augite.
Actynolite.
Pyrrhotite.
Pyrite.
Andesine.
Biotite.
Talc.
Sphene.
Chlorite.

Shinness, Sutherland.
Matrix gneiss, stratum thick, moderately plicated.
Malacolite, abundant.
Sahlite, abundant.
Actynolite, scarce.
Biotite ?
Sphene, scarce.
Molybdenite, very rare.
Apatite, rare.
Pyrrhotite, rare.
Tremolite, rare.
Lepidomelane
Orthoclase
Lepidomelane in matrix.

At the conclusion of the meeting Mr. Dudgeon, who has been Professor Heddle's confrère in many of his wanderings, exhibited specimens of several of the more interesting minerals collected by them: these had been gathered from localities ranging from Unst in Shetland to Lackentyre in Dumfries; from Ben Capval in Harris, in the west, to the Black Dog Rock in the east. They embraced seventeen species new to Scotland, while Dr. Heddle's analytical labours gave promise of some seven new species.