CONTACT METAMORPHISM IN DEVONSHIRE.

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THERE are numerous scattered notices of the singularly interesting phenomena of Contact Metamorphism in Devonshire, to be found in various geological books and papers; but no attempt, so far as I am aware, has been made to treat them generally—beyond the references in Mr. Teall's invaluable work on *British Petrography*; and, more succinctly, in a paper contributed by him to the *Transactions of the Geological Society of Cornwall*,[1] in which he sets forth the main correspondences between the metamorphism of the Hartz and of the West of England, where similar rocks occur, which have been subjected to similar influences. This must be my excuse for presenting a summary of my own observations.

The active agents in the Contact Metamorphism of Devonshire are in the first place, and mainly, the granite of Dartmoor, with its associated felsites; in the second the dolerites intrusive in the Devonian and Carboniferous strata, now mainly diabases and epidiorites; and in the third place, and least importantly, the basalts and andesites in part contemporaneous with, and in part intrusive in, the Triassic series. The contemporaneous Devonian lavas are indeed seen occasionally to have had some influence upon the rocks over which they flowed; but such effects have been largely masked, where not wholly obliterated, by the great earth-movements to which they have been exposed, and they need not therefore enter more definitely into our consideration.

The rocks chiefly affected by Contact Metamorphism in Devon are Devonian and Carboniferous slates; and, less

[1] Vol. xi.

frequently, grit bands in the latter series. More casually hornblendic slates, and various members of the intrusive group. It is noticeable, moreover, that in many instances there has been a reactionary influence on the metamorphosing agent, to which, as a rule, very little attention has been paid.

The extent to which metamorphism has been carried is, in the main, clearly dependent upon two points—the activity of the metamorphic influence, and the nature of the rocks influenced. This may appear to be merely stating a truism; but there are variations of local metamorphism which do not seem accounted for in either way. These suggest the presence of subtler causes, and possibly the inter- or super-action of what is known as Dynamic or Regional Metamorphism, to which it is not my present purpose to refer in any detail.

The most frequent of the less pronounced forms of Contact Metamorphism is what has been aptly described by Mr. Teall as an induration of the affected rock, and a decrease in its fissility. And this is the change most commonly produced by the intrusive dolerites, basalts, and their kin. It rarely extends far from the edge of the igneous boss or band, and where most distinct gives the altered rock a massive, flinty aspect, sometimes with a splintery fracture, sometimes with a conchoidal. I have noted this effect on the margins of dolerites, basalts, proterobases, and andesites, and in connection with the interbedded Devonian lavas. Occasionally there has been a mere baking, which has had very little influence on the structural character of the rock, beyond the simple hardening. The most decided change in this respect I have noted in the county was in connection with the intrusive boss (now diabase) at Yealmpton. Here for the breadth of a few inches the Devonian slate was not only baked into a red porcelain jasper, but the laminæ actually in contact with the intrusive mass were fused and scorified.

Examples of induration are common, and occasionally the rock is both consolidated and veined, crushing having accompanied the hardening, and infiltration having subsequently produced the vein stuff. In fact, in the older instances of metamorphism later modification has not unfrequently had very important results.

In the Hartz district the change produced by the intrusive granular diabase (which is equivalent to the diabases occurring in South Devon at Rock, Yealmpton, Yarnham, and other localities with us) generally continues, to quote

the words of Mr. Teall,[2] to the production of a "compact, splintery rock, fusible at the edges of thin slips, and of a light grey or greenish colour . . . sometimes dark grey, or even a bluish-black. . . . One special feature of this rock is its mode of weathering; a thin, white crust, sharply defined from the rest of the rock, is produced. The rock is termed adinole. Other varieties of contact rock have been termed spilosite and desmoisite"—the former a spotted rock, and the latter a rock in which these spots have coalesced to form bands.

Mr. Teall adds that "adinole, spilosite, and desmoisite do not appear to have been recognised in the West of England."

They do occur, however, though not to the same extent—as in connection with the intrusive diabase.[3] Recent working on the Rock boss at Plym Bridge has clearly shown the presence of forms of spilosite and desmoisite, as well as of a modified type of adinole. But a rock which in every respect answers to Mr. Teall's description of adinole—though clearly not the typical form of the Hartz—occurs in great quantity on the edge of Dartmoor by Ugborough Beacon, and onward in either direction—compact, light grey, splintery, weathering with a white crust, and so far like the Hartz adinole that it is sprinkled with pyrites. Rock of apparently an allied type may be found in the porcellanised and banded (blue and white) altered Carboniferous shale of the Lydford district. This metamorphism is by no means according to the usual change produced by granite; but it should be noted that in each case the strata affected are probably Carboniferous, are certainly associated with hornblendic rocks, and that there is no reason to regard the granite as extending laterally far from its apparent margin.

The metamorphism caused by the Rock diabase has hitherto been undescribed. In the early stages the slate retains generally its original structural character, but instead of a constant olive or brown, the laminæ alternate in darker or greyer shades. To this a "spotted slate" succeeds, the laminæ speckled with dark greenish spots on a grey ground, suggesting at a casual glance that these spots were the unaltered portions of the original slate. In section this rock

[2] *Trans. Geo. Soc. Corn.* xi. *Op. cit.*

[3] This was written before the publication of Mr. Ussher's paper on the "Devonian Rocks of South Devon" read before the Geological Society, April 30th, 1890, in which is mentioned the identification of spilosite in Devon by Dr. Kayser.

is chiefly grey, and the spots are seen on edge at times interlacing flaser fashion. This would seem to be a form of spilosite. Then we get a distinctly banded rock in grey and green laminæ—the former weathering to a soft variety almost white. These changes, though differing in detail, are thus essentially the same as those produced in the granular diabasic metamorphism of the Hartz.

Microscopic examination carries the likeness still further. The spots in the Hartz spilosite are rich in chlorite, and we find the same fact in the spots and bands of the local examples with which we are dealing. The base of the rock is a fine-grained grey material, largely felspathic in character, much resembling an indurated slate changed by a doleritic dyke, from Ernesettle—the texture of the former, however, being somewhat more flaky (in partial retention of the original laminated structure), while the latter is sprinkled with grains of opacite, and shows somewhat more differentiation of granular quartz. But the two rocks are essentially the same in character, and bear the marks of the same kind of change.

Whether in area, or in the extent and variety of alteration, the most important region of Contact Metamorphism in Devon is the belt of Devonian and Carboniferous rocks immediately girdling the Dartmoor granite. This remark is subject to one great generalization. The contact phenomena are most pronounced on the southern and western skirts of the Moor—least marked on the northern and eastern. In other words, as a rule, the changes effected have been greater in the Devonian than in the Carboniferous rocks. This, however, does not resolve itself into a mere question of stratigraphy or varying petrological conditions. One reason why the metamorphism is most marked on the south is no doubt the fact that the bordering rocks there exposed are much lower in the local series than those on the north, and therefore nearer the focus of eruptive energy. Another is the allied fact, that while on the north the granite appears to have reached practically its vertical limit, on the south it is plain that it extends (and probably at no very considerable depth where the changes are most marked) beneath the sedimentary rocks to a subterranean connection with the granite bosses of Cornwall. Mr. Teall, in the paper to which I have referred, points out that, "other things being equal, the breadth of the contact zone is dependent on the slope of the upper surface of the granite beneath the actual surface."

It is equally in the south that the contact zone is the widest, and that these changes are most decidedly present.

In my paper on the "Igneous and Altered Rocks of South-west Devon," read to this Association at the Plympton meeting, I summarised the changes produced by the granite on the clay-slates in that vicinity, pointing out that the gradual alteration in the normal condition of the slates, as they approach the granite, was best seen in the neighbourhood of Shaugh and Meavy, where also we find the most extreme forms of change. The first step at Shaugh may be noted at a distance of something like a third of a mile from the granite, and consists in the development of a slightly unctuous or of a silky character. In the former case the rock passes on into a form of talcose slate. In the other mica is developed, together with andalusite, or its variety chiastolite. This in its most general form is a "spotted slate"—"Knotenschiefer" of the German geologists; but continues into well marked andalusite- and chiastolite-schist. The continuous development of mica within the andalusite spots, which increase and spread until they form layers, changes the andalusite- into a micaceous-schist; and occasionally the process is carried still further to the production of patches of pseudo-gneiss, with foliations of mica, felspar, and quartz fairly marked. Finally, but not at all points, as the last stage in the complete process, we have the fusion of the altered rock immediately touching the granite into a kind of hornfels, not so changed, however, as to obliterate all traces of the original cleavage structure, or rather of the subsequent foliation; and never incorporated with the granite.

It may be taken as a general rule that the appearance of mica in these slates (commencing—but exceptionally as a special result of original composition—with a sericitic variety at Shaugh) is a proof of contiguity to the granite, and that the quantity of mica increases steadily up to the point of junction. At or near the junction, however, the mica very commonly gives place to tourmaline; but this is a result of changes secondary to the original metamorphism (though not far removed either in time or cause), which affect more or less all classes of rock in this particular zone.

These phenomena, on a general view, are practically the same that may be noted in other granitic districts. The late Mr. Clifton Ward, in describing the altered slate of Skiddaw, said, "On approaching the altered area the slate first becomes faintly spotty, the spots being of an oval form, and a few

crystals of chiastolite appear. Then these crystals become numerous, so as to entitle the rock to the name of chiastolite-slate. This passes into a harder, more thickly-bedded, foliated or massive rock—spotted- (or andalusite-) schist; and this again into mica-schist of a generally brown or grey colour, and occurring immediately around the granite."

Mr. Teall, in the paper to which I specially refer, notes the recognition of three zones of alteration in the clay-slate of the Hartz—a knotenschiefer (spotted-slate) zone, a hornfels zone, and a mica-schist-like-hornfels zone—these three stages representing a gradual increase in the amount of metamorphism as the granite is approached; and he adds, "The general effect of the granites of the West of England appears to have been much less than that of the corresponding rocks of the Hartz. Knotenschiefer, andalusite-hornfels, tourmaline-hornfels, and mica-schist-like rocks are, however, known to occur in both localities, and to bear similar relations to each other and the granite."

It will be seen that while there is a general correspondence in the results of Contact Metamorphism by granite in Devon, Skiddaw, and the Hartz (and indeed elsewhere), there are noteworthy differences in detail and in order. In Cumberland chiastolite slate seems to precede the andalusite, and there is no mention of hornfels. The absence of the latter may be due to defect of metamorphic activity in Cumberland, since it is by no means a constant (and is always an extreme) phenomenon with us, though occurring both in Devonian and Carboniferous rocks. I am inclined to attribute the exchange of andalusite for chiastolite, or the reverse, to variations in the composition of the metamorphosed rock. The real difference between the two minerals is, that chiastolite is andalusite "plus some foreign matter," which has been arranged symmetrically with the crystalline form, "and appears to be derived from the black schist, or other dark matrix, in which chiastolite always occurs."

Casual crystals of chiastolite occur indeed elsewhere, as at Cornwood; but our only well-marked example of chiastolite-slate is a massive blackish slate at Ivybridge. And I am disposed strongly to the belief that while our andalusite-slates are of Devonian origin, this is Carboniferous. If so the interchange of one mineral for the other has no significance as marking a stage of metamorphism, as might be hastily concluded from Mr. Ward's remark, though he would not be responsible for the assumption.

The "lousy killas" from Devon Consols (an early form

of contact change) has somewhat of a talcose aspect. The microscope shows not only that the spots are andalusite, but that little crystals or blades of the same mineral are scattered through the mass, distinct from the groups which form the spots. There is a clear development of felspathic characters in this base as distinguished from the ordinary slate. When the process of metamorphism has been carried further, this differentiation of the felspathic constituent of the slate becomes correspondingly marked; *i.e.*, in the andalusite-slate of Cornwood. It is yet more prominent, and becomes granular —felspar mosaic—in such examples as the chiastolite-slate of Ivybridge. The sericitic-schist of Shaugh, which likewise contains groups of andalusite crystals, and represents so far an early stage of metamorphism—while crowded in parts with the sericitic scales to which it owes its peculiar silky lustre—is seen also to be largely felspathic, and under crossed nicols portions of the ground mass polarise strongly in bands of blue and white.

Another form of Contact Alteration—less frequent, and to some extent apparently abnormal—is the change of clay-slate into a soft talcose-schist. The best examples that I am acquainted with are from Yeoland Consols and Slade; but there is a splintery rock of allied character in the Shillamill Tunnel, near Tavistock; and a talcose facies is by no means an unusual attendant upon what we may regard as incipient metamorphism.

In my paper on the "Rocks of Plymouth"[4] I referred to the occurrence of a very interesting example of altered slate from Ringmoor, near Meavy, in which the andalusite appeared to be developed in little lenticular spots of a pale bluish-green, the spots being very regular in their outline, though not manifesting any approach to crystallization. Further acquaintance with some of the amygdaloidal schistose rocks of the Brent Tor series—particularly their structural features—the aspect of the little lenticular masses, and the character of the slaty laminæ among which they lie, leads me to suggest that the original of this altered Ringmoor slate may have been of this class; but if so it is the only local instance of the Contact Alteration of volcanic rocks known to me.

The essential character of the hornfels zone in the Hartz quite bears out Mr. Teall's conclusion as to the greater comparative force of Contact Metamorphism there; while its absence in Cumberland seems to justify the contrary assumption with regard to that region. If, however, the

[4] *Plym. Inst. Trans.* ix. 245-6.

term "mica-schist-like-hornfels" indicates anything like what I understand—but Mr. Teall notes that the phrase is used loosely—by mica-schist, we have the schistose hornfels occupying the relation to the granite of the Hartz that the compact hornfels (where it appears) does to the granite of Dartmoor.

And this, with another feature of which more hereafter, leads me to doubt whether the occurrence of hornfels is wholly due to the action of the granite, or whether here, too, the original and more fusible composition of the rocks so changed may not have added its quota to the result. And, of course, the normal metamorphic energy of the granite may have been supplemented in other ways.

I should lay stress on the fact that the change is never so great as to obscure the line of junction between the altered and the alteration-causing rock. The thinnest intrusive veins of granitic matter have their clearly-defined walls, even though there may have been reciprocal interaction. And hornfels in which alteration is carried to its furthest limit, to the obliteration for the most part of every trace of original cleavage or schistosity—even in thin section—such as occurs in association with a highly-altered slate at Ditsworthy, in the valley of the Plym, is quite as distinguishable from the granite on one hand as from these slates on the other, which in place are macroscopically mere micaceous aggregates.

We have been dealing with the effect produced in a Devonian area, and wholly upon clay-slates.

Among the Carboniferous rocks affected, we have in addition to the slates frequent bands of grit. So far as I have been able to observe the Contact Metamorphism of the west side of Dartmoor, ranging from Tavistock to Okehampton, in the valleys of the Tavy, the Lyd, and the Okements, I should be inclined to generalise by the statement that the principal change produced in the schistose rocks is one of texture, by way of induration and banding. This may be admirably seen in the upper valley of the Lyd, where we find slates converted into a grey hard semi-porcellanised rock, retaining distinct traces of bedding, and slightly spotted. In the same neighbourhood much the same class of effect is produced by intrusive doleritic rocks, which have thoroughly porcellanised and banded the shales adjacent; the bands ranging—as already noted—in shades of blue and grey. Banding is in short a common characteristic of the altered slates of this region. Next the granite,

the Carboniferous shale is frequently converted into a massive fine-grained black rock with semi-conchoidal fracture—a hornfels in fact; while a few feet further off we have the lamination fairly preserved, but the laminæ coloured in bands. This is well shown in the granulite (or granite—both occur) quarry at Meldon; where the immediate contact rock is of the massive hornfels type, graduating into a dark and light grey banded compact rock of cherty aspect—a schistose hornfels.

Felsites are somewhat rare in the Okehampton district, and while the effects of the intrusion of the granite in metamorphism are less marked, the plutonic activities do not appear to have been so prolonged as on the south.

The ordinary change in the arenaceous rocks of this area is induration. Thus we have grits in the upper valley of the Lyd which have become essentially quartzites. Sandy shales near Meldon are in like manner solidified to the frequent obliteration of the traces of the original bedding; while there is also a tendency to the aggregation of their micaceous constituents. The extreme form of change is the production of banded tourmaline-quartzites in which different shades of grey, ranging up to black, distinguish the original layers—fairly equivalent to the Continental tourmaline-hornfels. Excellently marked examples occur at Great Tor and near Okehampton. Microscopic examination shows that this rock consists essentially of granular aggregates of quartz and tourmaline. The latter mineral is secondary, and no doubt replaces mica; the original rock having been a coarse-grained micaceous grit.

There are many interesting features of Contact Metamorphism associated with intrusive veins, particularly of granitic or granitoid material. They vary so much that it is difficult to lay down any general proposition, with the exception perhaps that a large proportion of the granitoid veins are really pegmatites of various degrees of texture. There seems no reason to suspect a difference in the original magma, so that I have been inclined to attribute this character to the environment during the consolidating process; the vein having cooled rapidly and under equable conditions of pressure.

But whatever the cause of this preponderant development of pegmatite, it is clearly not dependant simply on the volume of the injected material; for there are distinctly granitic veins as small, or smaller at various points, as, for

instance, at Ditsworthy, where beautiful examples occur traversing highly-altered Devonian slate. But granite veins are quite common in many localities.

There is the widest range of effect in the action of these veins on the rocks traversed. Commonly it is small, and does not go much beyond induration. I believe it will be found on examination that many cases which seem more pronounced are chiefly those where the veins are of later origin than the general body of the granite, and traverse rocks already highly metamorphosed. This does not of necessity imply a remote difference in date. The felsites are undoubtedly in great part later than the mass of the granite, which they frequently cut as well as the adjacent rocks; but the granite veins issuing from and connected with the granite massif would merely represent different stages in its development.

A vein stone from Shaugh consists of altered slate, traversed by a vein of pegmatite, side by side with which is apparently another vein of more distinctly granitic character, either indicating two openings of the little fissure, or else resulting from a linear differentiation, which is far less easy of explanation. At the same time there are larger granitic veins which pass into felsite next the slate.

Carboniferous slate on Plaister Down, traversed by numerous fairly parallel veins of felsite graduating into pegmatite (and probably, where the structure is not macroscopically evident, micropegmatitic), is simply hardened and layer-banded, the colour change in the different layers varying apparently with slight differences in their composition.

The greatest alteration I have noted in connection with any intrusive vein was in the Walkham Valley. Here Devonian slate is traversed by what is now a schorl vein, barely half an inch in width. On each side of that vein the slate is changed for an eighth to a quarter of an inch in width into hornfels, graduating thence into pseudo-gneiss. The agency can hardly have been either thermal or hydro-thermal only. The change is different to that produced, probably by the action of highly-heated vapours, in the walls of mineral lodes.

An alteration very nearly as great in extent, though different in character, occurs in connection with a granitoid vein not more than an eighth of an inch in width, traversing Carboniferous slate near Lydford. Not only is the body of the slate indurated, which of course may be due to the general influence of the main mass of metamorphosing rock,

but the vein is accompanied throughout its observed course by two bands of silicified material on each side, one dark and the other light, the latter related to adinole, if not precisely that rock itself. And in this same locality, though the general metamorphism of the rocks is not so distinctive in appearance as near Shaugh and Meavy, a vein of felsite, not thicker than an ordinary post-card, has proved capable of producing a distinct effect immediately contiguous.

On the other hand a vein of griesen at Meavy (where this form of granitoid material is by no means infrequent), occurring well within the zone of medium alteration, appears to have had no individual influence. This, however, may be really due to the effect of subsequent changes on both. It is very remarkable at times to note how thoroughly rocks of quite dissimilar character are affected by a single cause. I have in my possession a junction specimen between schorlite and schorl- or tourmaline-schist. The one is a granular mixture of schorl and quartz, the other a foliated arrangement of the same minerals. One was originally an igneous rock, the other a sedimentary; but both now consist of the same two constituents, and all that distinguishes them is the crystalline texture on the one hand and the foliated on the other, the evidence of their differing origins.

Very remarkable, in the way of negative contrast to some of the more pronounced changes, are the junction phenomena connected with the Cann Quarry elvan, which intersects highly-cleaved Devonian slate—phyllite—at a distance of 2½ miles from the nearest surface granite. Though this elvan ranges up to 30 feet in width, its metamorphic influence is a bare minimum, and in fact is hardly perceptible. Its physical influence, however, is strongly marked in the crushing and contorting of the slaty laminæ along the line of junction, so that the cleavage faces near the elvan are rendered gnarled and ribbed and glossy by the intense pressure. The microscope shows, moreover, that the felsitic matter has been in places injected between the laminæ. It shows also that, while the slate has been little modified by the elvan, the elvan has been modified by the contiguity of the slate, the base near the junction being muddled, with a considerable development of ferrite; while in the body of the dyke the ordinary felsitic characters are well developed.

The alteration produced by the granite on hornblendic rocks is strongly marked, and is the same in character at widely distant points. Thus we find hornblende-slate at

Ivybridge, and at Peek Hill, converted into what has been called "ribbon jasper," a banded green rock which I have ventured to name "prase-schist." What has taken place has been this—the rock has been highly silicified, and the original hornblende changed into actinolite, so that we have a banded green quartzose rock, essentially composed of the form of quartz known as "prase."

We find the development of actinolite a constant feature of the Contact Metamorphism of the original dolerites next the granite, whether in Devon or the Hartz. This is best seen with us in the neighbourhood of Mary Tavy and Tavistock, among the rocks which have commonly been called gabbros, but are now defined as either epidiorites or proterobases, chiefly the former, seeing that the original augite has commonly disappeared. Metamorphism may be traced here in all its stages; and there are no better examples of advanced metamorphism—and so far as Devon is concerned of typical epidiorites—than are to be found at White Tor. Here the augite has given place altogether to uralitic or actinolitic hornblende. The needles and clusters of actinolite crystals, in their matrix of secondary felspar, make a slide of this rock an exceedingly beautiful object. There is likewise a development of pale brown contact mica. The contact phenomena of these rocks are fully described by Mr. Teall in his *Petrography* (pp. 234, 235).

Perhaps after all the most interesting feature of the metamorphism of the granite borders, is connected with the presence of garnets and garnet rock. Garnets occur casually in connection with junctions at Lee Moor and elsewhere—of a microscopic character; but on the north and west of the Moor we have not only well-developed crystals of noteworthy size, but massive garnet in quantity. Mr. T. M. Hall, F.G.S., in addition to Brent Tor, gives Lustleigh and Hay Tor as localities for garnet in Devon;[5] but all the localities, so far as I am aware, are on or near Dartmoor; and they suggest very strongly the direct result of Contact Metamorphism—the varieties found belonging either to the lime-alumina, iron-alumina, or lime-iron-alumina groups. The finest development is at Belstone Consols, where the lode is essentially a course of garnet rock. This is the common brown garnet. The lode is about half a mile from the granite, well within the limits of metamorphism; and was long since noted by the late Sir Warington Smyth, F.R.S., as one of the most

[5] *Mineralogist's Directory.*

typical illustrations of Contact Metamorphism on that side of the Moor. At the same time it is quite distinctive.

While this Belstone garnet is the common brown garnet, in the now abandoned mine at Meldon, about the same distance from the granite, we get the green garnet or grossularia, the only spot at which, so far as I am aware, it occurs in the West of England.

But the most singular occurrence of garnet in connection with Dartmoor is near Leather Tor. At this point we have hornblendic rocks next the granite, partly changed into praseschist by the silification of the body of the rock, and the conversion of the hornblende into actinolite. We also get a laminated rock, which, while compact in mass, weathers on the edges, so as to make the harder layers stand prominently out. I might call it a foliated rock; but its constitution is such that, whether it is termed laminated or foliated, objection might almost equally be raised to either term. The harder layers are, however, garnet—brown garnet commonly; and hence I once thought of calling it garnet-schist.

The microscopic examination, however, made me pause; and the appearances were so peculiar, that I was once more a trespasser on Professor Bonney's kindness. Then it clearly came out that we were dealing with two rocks instead of one, and that the result was altogether anomalous. Part of the slide was a fine-grained schist-like rock, rather suggestive of severe squeezing, probably an altered Carboniferous shale. The other part was a coarse-grained rock, consisting of garnet, epidote, perhaps a pyroxene, quartz, and another mineral possibly allied to zoisite, or an alumina subsilicate. Hence, whatever change the granite had made was wrought out upon two different classes of material, and probably two entirely different original rocks. Nor is the difficulty at all lessened by the fact that there are a dozen such alternations at times in the space of an inch, and that there is no *in situ* section to examine. All that seems clear is the Carboniferous shale. The present state of things may have originated in the intrusion of a dolerite or eclogite, in which case it must have been injected between the layers of the shale in a singularly regular manner. The only other suggestion that occurs to me is, whether these variations may not represent original differences in composition in one sedimentary series, say alternations of calciferous and aluminiferous sandstones, in layers or lenticles, or perhaps the recurring drifts among ordinary silt of fine volcanic material.

The green garnet at Meldon is certainly closely associated,

if not connected, with Carboniferous limestone—no unusual alliance.

In a paper read on the 14th of May last to the Geological Society, written by Miss Gardiner, the important part which garnets play in the Contact Alteration of the Cairnsmore of Fleet granite, New Galloway, is set forth in detail; but the paper is not yet published. Here both Dynamic and Contact Metamorphism appear to have been at work.

At the present moment a controversy is onward touching the origin of certain rocks in the Lepontine Alps—garnetiferous and others. It does not, however, help us, since it is fully admitted that garnets are produced in sedimentary rocks both by Contact and by Regional Metamorphism, and commonly in association with limestones.

In order to make this paper the more complete, I append the results of a comparison of some of our local Contact-Altered rocks with a series of examples from Saxony and the Hartz.

Altered Clay-Slate (Thonschiefer), from Albernau, Saxony.—The laminæ are talcose, with striated faces, and what appears to be an incipient development of andalusite in specks. It closely resembles some of the slates on the outer verge of the zone of alteration in the Shaugh and Meavy area, and is in fact practically identical.

Cambrischer Thonschiefer, Wilkau, Saxony.—A light grey glossy slate, of a type not uncommon in our disturbed Devonian regions generally; but not specially associated with granite.

Fruchtschiefer, Sauschwart Mine, Schneeberg; ditto, Gesellschaft Mine, Schneeberg.—These are two examples of the "spotted slates" (knotenthonschiefer) of the Schneeberg district, one more talcose than the other. The difference between them and the "spotted slates" of the middle stage of alteration in the Devonian zone bordering the granite is simply varietal, the spots having rather the chiastolitic than the andalusitic form. One variety comes very close to the "lousy killas" of Devon Consols.

Phyllite (Phillite Thonschiefer), Lossnitz, Saxony. — A close-grained highly fissile slate, with finely-wrinkled laminæ. It is essentially identical with beds of slate that occur in Devonian areas of Regional Metamorphism.

Augite-Hornblende-Schiefer, Neustadel, Schneeberg.—I can see no difference between this example and some of the altered schistose dolerites of the Mary Tavy district.

Chiastolite-Schist, Gefrees, Fichtelgebirge.—The point of distinction between this and the chiastolite-schist of Ivybridge, is the larger size of the chiastolite crystals in the foreign rock: this difference is essentially varietal, and can be fairly matched from the altered zone of Skiddaw when compared with that of Dartmoor.

Augite-Scapolite-Schiefer, Zschorlau, Sneeberg.—This is a banded grey-green pyritiferous rock, compact and allied to hornfels in texture. It has not been recognised hitherto in Devon; but scapolite was found by Mr. G. W. Ormerod, F.G.S., in connection with a granite vein at Bovey Tracey.

Topaz-bearing Quartz-Porphyry (or Elvan), Saubachschlucht, Schneckenstein.—There is no rock that I am aware of in the West of England that corresponds with this, but topaz occurs as a product of alteration at different points around Dartmoor.

Andalusite-Hornfels, Meisterei Kirchberg, Saxony.

Andalusite-Glimmerfels, Weisser Hirsch Mine, Schneeberg. The main difference between these two rocks is, that the first is more compact, with the andalusite more generally distributed; and that the latter has more of a schistose aspect, with the andalusite in glimmering layers, much like one of the contact mica-schists. So far as I am aware, no rocks precisely answering to either of these occur in mass in Devon—the effects of metamorphism being generally less marked—but near the actual contact similar aspects are often casually put on.

Hornfels, Spitzenberg, Hartz.—A compact, fine-grained rock, with semi-conchoidal fracture. Altered rocks, indistinguishable in general aspect from this, occur near Okehampton; and closely approximating varieties elsewhere.

Tourmaline-Hornfels, Eibenstock, Auesberg, Saxony.—A coarse tourmaline-schist, indistinguishable from varieties to be found both in Devon and Cornwall.

Griesen.—Zinnwald, Saxony.

Griesen, Geyer, Saxony.

In the first of these examples the mica is prominent, though the quartz predominates. The second is almost wholly quartzose. I can match either, so as to be absolutely indistinguishable, from the neighbourhood of Lee Moor and Wigford.

Limestone altered by Granite, Stainz, Steiermark.—The change here is to a highly crystalline and mineral-bearing condition, mica being especially plentiful in the specimen under review. The nearest approach of the granite to the

limestone in Devon is at Meldon, and there it is certainly not close enough to induce such an alteration as this.

Kalk-Silikate-Hornfels, Bosenkleef, Treseburg, Hartz.—This is a compact grey rock, with somewhat of a slaty texture. I am not aware that any such rock has been certainly identified with us; and I have not had time to make any microscopic comparisons: but rocks of similar aspect occur in association with the more compact Devonian lavas; and may be the result of the alteration of calcareous materials there.

Adinole, Heinrichsburg, Hartz.

Spilosite, Heinrichsburg, Hartz.

Dark drab slaty rocks, to all appearance identical with altered slates frequently seen adjacent to interbedded Devonian lavas; but they do not appear to be typical varieties.

Altered Amphibolite (Pistacite and Garnet-bearing) Wolfgangmassen, Schneeberg.—This is a dark slaty-textured veined rock with sub-conchoidal fracture. The precise analogue does not seem to occur; but it is certainly allied to the garnet-bearing schistose rocks of Peek Hill, which have direct amphibolitic connections; and on the epidotic side to the altered diabases of Yarnham and elsewhere. I should not be surprised to find a precisely similar rock in Devon at any moment.

In conclusion, I must apologise for the imperfections of what is after all a very cursory glance at the details of a very big and very complicated subject; but which may have its use in aiding further enquiry.