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ORIGINAL ARTICLES.

I.—ON CERTAIN AFFINITIES BETWEEN THE DEVONIAN ROCKS OF
SOUTH DEVON AND THE METAMORPHIC SCHISTS.

By A. R. HUNT, M.A.

PART I.

(PLATES VI. AND VII.)

IN submitting the following paper to the readers of the GEOLOGICAL MAGAZINE, I am conscious that some apology is needed for entering upon so difficult a subject. My position is as follows:—In 1879 the late Mr. E. B. Tawney joined me in the investigation of a series of detached blocks trawled from time to time by the Brixham fishermen. The character of certain of these stones having suggested to Mr. Tawney the idea that the schists of South Devon might possibly be of pre-Cambrian age,¹ he visited the district in 1880, with the expectation of being the first to advance that hypothesis. The evidence of the schists themselves failed to satisfy Mr. Tawney on the point in question, and his premature death prevented his attacking the problem on a subsequent occasion, as he had hoped to be able to do.

On Mr. Tawney's death in December, 1882, Prof. Bonney was good enough to take his place in supplying me with microscopic analyses of the Channel blocks. In the following Easter, a week spent among the metamorphic rocks of South Devon resulted in a paper published in the Quarterly Journal of the Geological Society, in November of the same year, in which Prof. Bonney expressed the opinion that the South Devon schists might be safely regarded "as Archæan, and as a prolongation of the *massif* so distinctly indicated in the Lizard, to which also belonged the gneiss of the Eddystone," Q. J. G. S., vol. xl. p. 23.

It may be observed that the original investigation of the Channel blocks was undertaken for the purpose of elucidating, if possible, the Start and Bolt problem, and that my first paper was lent to Mr. Pengelly in MS. for use in preparing his own paper, "The Metamorphosis of the Rocks extending from Hope Cove to Start Bay." The two were published in sequence at the Ilfracombe meeting of the Devonshire Association in 1879.

In 1879 Mr. Pengelly maintained the Devonian age of the metamorphic schists. During 1880–82 Mr. Tawney reserved his opinion,

¹ Trans. Devon Assoc. vol. xxi. p. 468.

having failed in his search for evidence of their pre-Cambrian age. In 1883 Prof. Bonney, without much hesitation, proclaimed the Archæan age of these troublesome rocks.

Under these circumstances there seemed nothing for me to do but to continue collecting facts, and to await the issue of events.

In 1887, 1888, and 1889, Mr. A. Somervail published three papers in the Transactions of the Devonshire Association, in which he suggested that the chlorite schists might be the representatives of the Devonian diabases which appear on the coast line of Start Bay, and in the neighbourhood of Dartmouth.

Early in 1891, Mr. W. A. E. Ussher was good enough to allow me to accompany him on two occasions when mapping the Devonian rocks between Dartmouth and Slapton Sands. Being much impressed by the many obvious analogies between these rocks and the metamorphic rocks further south, I determined to examine and compare as many varieties of the two sets of rocks as I could obtain.

My self-appointed task, then, has been to endeavour to ascertain what affinities, if any, can be detected between the metamorphic rocks of South Devon and the slates grits and volcanic rocks which lie to the northward of them; the green rocks being compared with the volcanics, the mica-schists with the slates, and the quartz-schists with the fine grits or sandstones.

At first sight the quartz-schists and grits seemed the least promising of the different rocks selected for comparison; but on Mr. Harker finding detrital tourmaline in one of the Devonian grits, and the same mineral being subsequently detected by myself in a quartz-schist from near Start Point, these siliceous rocks took a foremost place in the investigation.

THE QUARTZ-SCHISTS AND GRITS.

A geologist examining the classical area of Devonian rocks which forms the northern shore of Torbay between Hope's Nose and Hesketh Crescent, will not fail to notice the frequent interbedding of slates and grits (the latter often in bands too thin to be dignified by the name of sandstone), and that both rocks are often more or less micaceous.

A slice of a brown sandstone from the quarry on the path east of Kilmore is seen in the microscope to be composed chiefly of fine grains of quartz, of which the larger average about $\frac{1}{100}$ inch in diameter, some of them being splinters with angles absolutely unaffected by attrition or solution; among these may be noticed an occasional flake of white mica, a few scattered fragments of tourmaline, and two or three grains of triclinic feldspar.

Another specimen from the same quarry is a fine hard lead-coloured sandstone bedded in well-marked laminae, which determine its fracture under the hammer; the surfaces of these planes of fracture being highly micaceous.

The bands of grit between slates are sometimes crossed by quartz-veins which do not invade the adjacent slates.

In the cliffs at the north-east end of Slapton Sands we meet

with slaty rocks with interbedded grit bands, in which latter mica is occasionally very conspicuous. The rocks here are less generally micaceous than those between Hope's Nose and Meadfoot in Torbay, but a reddish grit-band sliced for the microscope proved almost identical, except in colour, with the brown Kilmorie sandstone already mentioned; even to a few grains of triclinic felspar.

The cliffs at Torcross are passed unexamined, as there are some seven volcanic bands of more or less importance in them, and the sedimentary rocks in consequence liable to intermixture with volcanic ejectamenta.

Just south of the village of Beesands some interesting grits occur, about the spot where Sir Henry de la Beche placed the boundary-line of the metamorphic rocks. Again we meet with fine sandstones and interbedded grits and slates, the sandstones and grits occasionally containing tourmaline and mica, like the rocks at the north-east end of Slapton Sands, and those in Torbay, already described.

At a point on the coast, south of Start Farm and west of Start Lighthouse, among schists much crushed and altered, there occur occasional bands of quartz-schist, which in general appearance, in their constituents of quartz-grains, mica, and tourmaline, as well as in their intercalation between beds of a more slaty nature, recall to mind, both macroscopically and microscopically, the micaceous and tourmaline-bearing grit-bands of Torbay, Slapton Sands, and Beesands.

The undoubted Devonian sandstones may be traced into the undoubted metamorphic quartz-schists by four independent lines of inquiry, viz. by way of iron ores, tourmaline, mica, and quartz.

Iron Ores.

A slice of a grey micaceous sandstone (No. 5) from south of Beesands contains much brassy-looking pyrites crystallizing in cubes, rectangular prisms, and derivative forms.¹ The pyrites is occasionally seen to pass into red hæmatite. With strong oblique sunlight on the slide the characteristic colours of these minerals are well seen.

A slide (No. 22) from a grit-band between slates on the north shore of Southpool Creek, not far from the metamorphic boundary, contains a minute rectangular prism of pyrites, and flakes of red hæmatite.

In Hope Cove, south of Hope Headland, and therefore within the metamorphic boundary, a siliceous band occurs which, while showing no trace of its original quartz-grains, retains its pyrites in cubes and rectangular prisms.² The majority of these crystals display the brassy colour of pyrites, and occasionally characteristic striæ are seen. In one group of twinned crystals, a crystal is composed partly of yellow pyrites and partly of bright red hæmatite—whether in this case the latter is a pseudomorph or only a surface incrustation is uncertain.

In a slide from one of the slightly altered bands of quartz-schist south of Start Farm (No. 6) a cube of red hæmatite occurs which is

¹ Plate VI. Fig. 3.

² Plate VI. Fig. 4.

apparently a pseudomorph after pyrites, as the latter mineral has not been noticed in either of my nine slides of these quartz-schists, whereas red iron oxides are abundant.

Black granules and streaks, apparently magnetite, occur in all the above four slides, but as they in no instance exhibit the characteristic octahedral crystallization of that mineral, their evidence is only of minor importance. It is well worthy of notice that in three of these four slides, two being from the metamorphic district, and one from outside the boundary, we have pyrites intimately associated with hæmatite, either in the same crystal, or as a pseudomorph; and further, that on either side of the boundary we find pyrites crystallized in the somewhat uncommon form of rectangular prisms.

Tourmaline.

Tourmaline has been noticed in ten slides from the following six Devonian localities, viz. quarry near Kilmorie, Torbay; north-east end of Slapton Sands; cliffs south of Beesands; grit band in Southpool Creek; near East Charleton; and Aveton Giffard: and in eight slides from two bands of quartz-schist on the coast south of Start Farm, in the metamorphic area. In every case the larger grains are clearly of detrital origin, the only exception being in one or two instances in the quartz-schist, where secondary tourmaline has crystallized on the original grains, and these secondary crystals have been swept to a distance by differential movements in the rock.¹

No alteration by pressure or solution has been observed in the tourmaline grains in rocks north of Beesands, the first indication noticed being south of that village.

In a reddish grit containing much hæmatite (No. 59), a well-characterized light-brown crystal of tourmaline is broken sharply in two, and slightly dislocated. Clear quartz fills the intervening gap without in the least dissolving the edges of the tourmaline crystal.²

A grain of tourmaline in another slide from the same neighbourhood (No. 5) is slightly, albeit distinctly, affected by solution, with indications of the re-crystallization of secondary tourmaline.

In a slice (No. 16) of one of the quartz-schist bands south of Start Farm, two crystals of tourmaline may be especially noticed: one, a longitudinal section, with characteristic transverse cracks; the other a basal section. In each case there is a considerable growth of secondary tourmaline on the original crystals; and in each case also, by a slight differential movement of the rock, fragments of this secondary tourmaline have been detached and moved to a small distance from the parent crystal.

We have thus close together in the same field of view detrital tourmaline and induced tourmaline.³ The origin of the latter would be obscure, were not all the steps of the process so clearly set forth. Tourmaline occurs in many forms and colours; but the tourmalines of Beesands and the Start coast are identical.

¹ Plate VI. Fig. 2.

² Plate VI. Fig. 1.

³ Plate VI. Fig. 2.

Quartz-grains.

The quartz-grains in the sandstones north of Beesands do not call for particular notice. Just south of Beesands we have seen quartz filling the interstices of a broken tourmaline, and in another case a grain of tourmaline slightly affected. Professor Bonney's description of a rock from the same locality seems exactly to cover the case, viz. : "The rock has evidently been much compressed, and some slight amount of mineral change has taken place" (Q.J.G.S. vol. xl. p. 18). An occasional quartz-grain contains liquid inclusions and bubbles, but without any distinguishing features.

A slide of a Devonian grit-band from Southpool Creek (No. 22) contains more than one quartz-grain of interest. One grain showing considerable solution at the edges abounds in hair-like inclusions together with an occasional fluid inclusion with bubble. Another grain is crowded with fluid inclusions, some of which contain very active bubbles, while others take the form of negative crystals.

In a slide (No. 8) cut from the specimen of quartz-schist from Start Farm, given me by Mr. A. Somervail, we find a quartz-grain with hair-like inclusions; and in another slide from the same stone (No. 10) we have a grain with bubbles in negative crystals. These two grains resemble the two in the Southpool Creek slide already referred to.

However, the most interesting feature in the quartz-schist lies in the fact that the rock has not been submitted to pressure and heat sufficient to obliterate entirely the original tourmalines and quartz-grains, and that a comparison with the sandstones and grit-bands of Beesands and Southpool Creek is still possible. In the case of the quartz-schists at the Bolt Head, further west, tourmaline is absent, and the obliteration of original structures in the quartz is complete; thus a comparison with the Devonian sandstones on this particular point is not possible.

Mica.

On first collecting the Devonian micaceous sandstones for comparison with the Start schists, the possibility that the mica in either case might be detrital had not been entertained. On Mr. Harker pronouncing the Slapton Sands mica detrital,¹ and that in the Start quartz-schists possibly so,² the origin of the Devonian and metamorphic micas became a problem of importance.

If the metamorphic rocks were micaceous before their alteration, the presence of much of their mica might be accounted for with much less dynamical and chemical metamorphosis than is at present demanded for them.

In the case of the sandstones and quartz-schists, it is easy to find Devonian sandstones much more highly charged with mica, than the Start quartz-schist under consideration, in which, as Mr. Harker remarks, the mineral is only sparingly present, *e.g.* the sandstones and grit bands of Kilmorie, Meadfoot, Slapton Sands and Beesands,

¹ Appendix, Slide No. 3.² Appendix, Slide No. 8.

to go no further a-field than the coast-line. Both the sandstones and quartz-schists contain mica varying between the minutest filmy flake, hardly seen in the microscope, and flakes sufficiently apparent to the naked eye. Given a small amount of solution in the silica of the quartz-grains, so that the mica flakes might be free to partially rearrange themselves, and there seems to be no reason why the Start quartz-schist under consideration should not have been derived directly from such a rock as the Kilmore sandstone, without any development of newly-formed mica.

So far as I understand it, a theory held by some is that the Devonian slates and sandstones when micaceous are with very few exceptions "Phyllites," in which the mica is considered to be an induced product; and that the mica-schists are rocks in which the mica has also been induced but to an incomparably greater extent, so that the rocks differ in kind. It seems, however, possible, that the converse of this may be true, and that with some exceptions the mica in both the Devonian and metamorphic rocks is, or was, originally, detrital, the deposition of micaceous sediment being much more general in the southern area than further north. Irregular deposition is occasionally exemplified in the Torbay rocks, in which worm-tracks in slates are filled with fine micaceous silt.

In the foregoing pages the iron ores, tourmaline, micas, and quartz-grains of the Devonian sandstones have been connected with the iron ores, tourmaline, micas, and quartz-grains of the metamorphic quartz-schists. It cannot be doubted that were the rocks further examined by a competent mineralogist, other points of resemblance would be noticed, for minute grains of felspar, unless well defined, and the rarer minerals, are beyond the power of my microscope and knowledge to distinguish.

One noticeable feature which the grits and quartz-schists possess in common is the abundance of laminae of iron oxides: at Hope's Nose, black; at Kilmore, brown; at Slapton Sands, red; at Beesands, black and red; at the Start, black and red. The colours being probably due to the brown, red, and black, oxides of iron. The following remark of M. Daubree is worth noticing, although the black oxides of the Start schists do not take the form of crystallized magnetite:—

"Dans certaines localités des Ardennes, les cristaux de fer oxydulé, qui imprègnent les ardoises se sont logés suivant les longrains, et font ainsi ressortir des joints rudimentaires qui, ailleurs, ne sont pas reconnaissables à la vue."—*Geol. Experimentale*, vol. i. p. 336.

At the Start we find the quartz-schist traversed by numerous little cracks cemented by opaque iron-ores.

THE MICA-SCHISTS AND SLATES.

The mica-schists of the metamorphic district, as distinguished from the schists in which quartz is the most prominent mineral, have not been examined to any extent.

One specimen of a red schist, which I thought might compare with the red Devonian slates, is described by Mr. Harker as a rock

which "may have been originally a shale or slate with some gritty bands."¹ Mr. Harker could not have more precisely described the cliffs at the north-east end of Slapton Sands, with whose shales or slates I desired to connect the red mica-schist from the Start, had he been intimately acquainted with the locality instead of being a perfect stranger thereto.

END OF PART I.

EXPLANATION OF PLATES VI. AND VII.

PLATE VI.

- FIG. 1.—Crystal of tourmaline in fine Devonian Sandstone, four chains south of Beesands. (59) Magnified about 37 diameters.
 FIG. 2.—Crystal of tourmaline in quartz-schist, Start Farm. Formation of secondary tourmaline with partial dislocation of same. (16) Magnified about 37 diameters.
 FIG. 3.—Rectangular iron pyrites in fine Devonian Sandstone, north of Tinsey Head. (5) Magnified about 18 diameters.
 FIG. 4.—Rectangular iron pyrites in siliceous band, South of Hope Headland. (52) Magnified about 18 diameters.

PLATE VII.

- FIG. 1.—Quartz-schist, Start Farm. Remnants of original quartz grains. (Compare "Grain of Quartz-sand in the Mica-schist of Arroquhar." Presidential Address of Dr. Sorby, F.R.S., Proc. Geol. Soc. 1880, p. 86, Fig. 9.) Magnified about 12 diameters.
 FIG. 2. Fine Devonian Sandstone, north of Tinsey Head, with schist-like alinement of iron ores and greenish mica. Magnified about 12 diameters.

I am much indebted to my friend Mr. W. M. Baynes, of Torquay, for valuable assistance in the preparation of my photographs for publication.

(To be continued.)

II.—PERMIAN IN DEVONSHIRE.

By W. A. E. USSHER, F.G.S., ETC.

(By permission of the Director-General of the Geological Survey.)

IN the course of a visit to the Hunsrück district between Treves and Bingen in the spring of 1890, in company with Professor Gosselet, Mons. C. Barrois, Herr von Reinach and Herr Grebe, I was struck by the resemblance displayed by the Permian quartz porphyry of the valley of the Nahe, between Birkenfeld and Bingen, to fragments contained in the breccias of Teignmouth. In discussing the South Devon section with the two gentlemen last named, on that occasion, they both gave it as their opinion that the lower beds of the Devon section might prove to be representatives of the Rothliegende.

In the pressure of other geological work, I had no time to carry the matter further, until May, 1891, when Herr von Reinach spent a week with me in examining the South Devon coast section and the eruptive rocks in the vicinity of Exeter and Crediton. He then expressed the opinion that certain parts of the lower New Red rocks of Devon corresponded very closely with members of the German Permian, but that this correspondence was not borne out in con-

¹ Appendix, Slide 24.