GEOLOGICAL NOTES ON THE SOUTH-WESTERN LINE BETWEEN LYDFORD AND DEVONPORT.

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ONE of the most interesting geological districts in Devon lies between Lydford and Tavistock, thence to the Tamar westward, and to the Three Towns southward; taking a three-mile belt of country north-west of the Tavy to its junction with the Tamar, and then following down the eastern bank of the latter river to its lower estuary. It is peculiarly attractive to the stratigraphical geologist, because it includes a disputed frontier between the Carboniferous and Devonian systems; while it yields to the petrologist an unusual variety of igneous rocks. The paucity of fossils, so marked as to be surprising, deprives us practically of the aid of the palæontologist in settling the boundaries, and hitherto there has been a remarkable absence of good sections. The construction of the new line of railway from Lydford to Devonport, following the higher ground commanding the valleys of the Tavy and the Tamar throughout the greater part of its course, and comprising in its total length of 22 miles 22 chains many cuttings, in some cases as much as 75 feet in depth, has, however, supplied unrivalled facilities for study; and I have to lay before the Association some notes on what I have observed during repeated visits while the works—still incomplete—have been in progress.

I can only regret that these notes are not more exhaustive, and my conclusions more definite. If, however, I have gleaned little else, I have learned that the problems involved are yet more complicated in their details than they seemed; and that while I think we can see the direction whence our queries are likely to be answered, nothing short of a patient study of practically every yard of the exposures will give the best-skilled geologist material for a conclusive solution, while even then the knowledge gleaned may be incomplete.

There are two very great difficulties, apart from questions of interpretation, in dealing with the geology of this district. The bulk of the rocks consists of slates, so cleaved that it is not always easy or even possible to distinguish between cleavage and bedding. Nevertheless, there is fair reason to believe that their cleavage and lamination generally agree in direction; and Mr. Ussher has noted the very occasional occurrence of crinoid joints on cleavage faces as leading to the same conclusion. The other difficulty has been already mentioned—the almost absolute absence of fossils, though here and there, in what appear to be continuing beds on the east and the west, they sporadically occur.

The current Geological Survey Map of this part of Devon represents practically the work and conclusions of Sir Henry de la Beche, and carries the southern boundary of the Carboniferous rocks west of Dartmoor, along an undulating horizon from near Lezant, a little south of Dunterton, north of Milton Abbot, curving down by Churlhanger, to the granite near Cocks Tor—the line being taken for the greater part of the distance along the southern edge of a band of igneous rock stretching from Dunterton through Milton Abbot. A band immediately to the south, ranging from Endsleigh, by Lamerton and Kilworthy, to Sowtentown, Sir Henry treated as being wholly in the Devonian. Dr. Harvey Holl[1] regarded these and other strips as being repetitions of the same bed or set of beds; and Mr. Rutley, accepting that view, connected them with Brent Tor, and suggested that the bands of schistose lavas, &c., at Saltash might belong to the series, in which case, as the Saltash lavas are undoubtedly intercalated in Devonian strata, Brent Tor and its products must be Devonian also. Hence the interest which, in Mr. Rutley's opinion, attached to the "tract lying between Tavistock on the south and Lydford on the north,"[2] which the first six miles of this new railway traverses. He was especially anxious that palæontological data should be forthcoming, but on that head I regret that there is no new light.

The difficulty experienced in tracing the boundaries here is, as Mr. Teall says, "undoubtedly to be attributed in great

[1] *Quar. Jour. Geo. Soc.* xxiv.
[2] *Ibid.* xxxvi. "Schistose Volcanic Rocks."

measure to the powerful character of the post-Carboniferous earth movements. These have so masked the original junctions, modified the strike of the earlier rocks, and metamorphosed the sediments, that what appears now as a geological unit may be a complex of different formations."[3] I think we shall see that it is.

Dr. Holl carried the Carboniferous boundary immediately south of Tavistock, from the granite a mile north of Sampford Spiney, westward by Tavistock, Stiles Wick, and Hartwell, to Stokeclimsland; and included all the volcanic rocks of the Tavistock and Brent Tor area in that system. All north of this in the Tamar and Tavy area he treated as Carboniferous; all south as Devonian. But whether Mr. Rutley is or is not right in his hypothesis of the connection of the Tavistock and Saltash lavas, we shall find that Dr. Holl is in error in this latter particular, and that we can accept neither his view nor that of Sir Henry de la Beche; while Dr. Holl was equally mistaken in imagining that the local igneous rocks were all of a contemporaneous character.

The new line begins at the joint Lydford Station, on the lower edge of Blackdown, and keeps the Great Western rail close company on the east all the way to Mary Tavy Station. For much of this distance it is really a surface line (both railways follow down the valley-bottom of a little tributary of the Tavy), and there is not much cutting. What there is, with one exception, exposes slates and grit bands, which we can hardly be mistaken in regarding as Carboniferous. In fact upon this point, so far as I am aware, there is no difference of opinion. With the exception noted the volcanic rocks of the Brent Tor series keep to the westward of the stream, though they approach it closely. They are cut, however, near the Brent Tor Station for about 120 yards in length. The exposure is not laid down in the Survey Map.

This section at Brent Tor Station affords admirable examples of the Brent Tor series. The prevailing hues are dark chocolate-brown, and green, and both amygdaloidal and schistose textures are represented. The amygdaloidal varieties or the true lavas are chocolate-brown, and some examples of these take the form of nodules embedded in schistose rock, which is commonly green. Other varieties of the schistose kind are mainly made up of irregular brown and green laminæ, with occasional lapilli, and show signs of considerable

[3] *British Petrography*, p. 229.

crushing. This is the case also with some of the amygdaloidal rock, in which the kernels have been squeezed into impersistent laminæ. The more compact schistose portions appear to have been formed by the consolidation of fine volcanic ejectamenta, such as is frequently associated with lava flows.

One roughly-schistose variety shows shining ovoid patches of green on the dull-brown ground of the faces of the laminæ. These patches are a talcose lining to the gas cavities which are now amygdaloids; and are of somewhat frequent occurrence in other portions of the rock. Serpentine is present with talc and chlorite in the green schists, and the brown rock, which is exceptionally heavy, is evidently coloured by iron.

The amygdaloids vary greatly in size, ranging from the hundredth of an inch up to an inch and a quarter in diameter, while irregular fillings occur two inches in long diameter and more. The filling material is commonly calcite, but zeolites, calcedony, and crystalline quartz occur, at times associated. Green earth is also occasionally present, and apparently felspar.

The important point to note here is one to which attention was called by Dr. Holl, that the immediate Brent Tor area is disturbed by several faults. "These faults carry the country on the east further to the south, or rather south-east, and reverse the dips along the valley of the Tavy, where the beds rise to an anticlinal axis, which crosses the railway in a N.N.E. and S.S.W. direction, midway between Ford Gate and the Mary Tavy railway station."[4] Mr. Rutley points out that the chief faults of the Mary Tavy basin have a western downthrow, the Tor being on the downcast side, and that to this faulting the preservation of the Tor is due.

Now while the grit bands in the Blackdown beds are characteristic of the Carboniferous rocks in this locality, near Mary Tavy station we get into slate which has a more Devonian facies. Dr. Holl suggested that the band of volcanic rock extending from South Brent Tor to Burn, parallel to the railway, was "the continuation of the Milton Abbot ash-bed faulted off at Burnford Farm, and thrown over to the westward of the anticlinal axis of Blackdown;" so that the undoubtedly Carboniferous rocks of this locality are bounded by members of the volcanic series, whether we call them Devonian or not. In the cutting immediately south-east of Mary Tavy station we find ashy matter with the slates; and a little further on we come to one of the

[4] *Op. it.*

most interesting features of the line—an intrusive mass of dolerite, showing well-marked columnar structure. There are two exposures, one of minor importance. The chief is near Burntown. The section at its best was a very fine one, the band being irregularly divided laterally into five or six ranges of columns, dipping twenty to forty degrees to the southward. The columns averaged four to seven feet in length, joint to joint, but varied far more in diameter. Some were as much as three feet on the longest axis. They were, with few exceptions, pentagonal, and many well shaped, but others were most irregular. A fair sample of the larger columns measured 11 inches on two sides, 16 inches on two, and 19 inches on one. Many of the corners were rounded, but the faces were generally clean. When first found, these columns were popularly spoken of as basaltic, from an idea that columnar structure was confined to basaltic rocks. It was at once evident, however, on examination that they were not entitled to that name. Macroscopically, the rock is drab-grey in colour, fairly compact, but with a tendency to scale. When sliced, it proved of so indefinite a character that I gladly availed myself of the kind help which Professor Bonney has always been so ready to give. It turned out to be "one of those abominably-altered dolerites that nature seems to have prepared to bother geologists." Almost all the original constituents are gone to the bad except iron oxide, hematite, and possibly ilmenite; and though plagioclase felspar, and augite appear to have been present, they cannot now be identified. Professor Bonney remarks, "I fancy that the rock has been vesicular, and is now amygdaloidal, the cavities being also filled by miscellaneous secondary products. I think the rock has been holo-crystalline, with ophitic structure. . . . I have little doubt it has been a dolerite, so it is now a kind of diabase. . . . I think I should call it a grey diabase."

In association with the diabase, Burntown yielded a curious mixture, consisting of crystalline quartz, chalybite, mica, a mottled whitish compound of quartz and chalybite, and chlorite. Hematite, and apparently ilmenite, also occurred.

Some of the shale in this cutting contains much quartz, and shows marked signs of alteration.

Near Wringworthy the track crosses the Great-Western line and the stream by a bridge, and after running along the hillside a space enters a deep cutting through a boss of igneous rock, which, according to the map, may be regarded as part of a band extending to Mary Tavy, and described as greenstone. This is succeeded by a hard black slaty rock with many quartz veins, irregularly figured black and white, possibly, indeed probably, the result of powerful causes of alteration. The cutting passes out of the hill in ordinary clay slate.

The Wringworthy boss is dark-green, heavy, crystalline, with slickensided joints; mostly massive, but occasionally schistose. A green epidotic mineral occurs in some of the joints and in veins. There are also calcite and iron oxide. Microscopic examination shows this to be one of the altered igneous rocks of the border of the Moor, of which Cocks Tor and White Tor afford typical examples, and which have been commonly classed as gabbros, but have been divided by Mr. Teall into proterobases and epidiorites. Essentially consisting, in the first place, of plagioclase felspar and pyroxene — sometimes diallage, sometimes augite — with ilmenite and magnetite, these rocks are now chiefly characterised by the development of hornblende, at the expense of the less stable pyroxenic constituents. In the Wringworthy example the chief features are lath felspars, and uralitic and actinolitic hornblende. The ilmenite is mainly seen in ragged patches, partly changed into leucoxene. There are some porphyritic felspars; and as granules of augite occur, this special exposure must be classed among the proterobases, but it would require little variation to make it an epidiorite, and it very well serves to illustrate the ease with which one of these forms passes into the other.

Crossing the adjacent valley on a high bank, we come to a long cutting traversing the extension of the mapped Lamerton and Kilworthy volcanic bands. The hill is, however, slate or killas of ordinary type, with a southerly dip, and the igneous rocks are represented by a couple of lava flows, generally five or six feet in thickness, and dipping with the hill. At the northern entrance of the cutting the under flow is seen high up on the right, alone, but it gradually descends as we proceed, and the upper flow then comes in. Some distance further the two meet, but at once separate again, and continue on about five feet each in depth, divided by a broader band of killas. The two appear to terminate at a small fault; and thenceforward there is one only, with a thickness in parts of twelve to fifteen feet. This also declines with the continuation of the cutting, until it passes out of sight near the southern face of the hill, and clay-slate alone remains.

The upper band is a light-grey rock, weathering rusty brown, with a quasi-granular texture; the lower is a compact, fine-textured, drab-grey rock, spotted with pyrites. The former yields very little information to the microscope, in consequence of the extent to which its original characters have been obscured. There appear to be traces of felspars, and of a few augite granules, but the most recognizable constituents are the iron oxides, some of which are seen as ragged rod-shaped bodies. The lower band is more communicative, and proves to be a dolerite, which the development of chlorite among other alteration-products has made a diabase. It contains lath and porphyritic felspars, viridite, pyrites, augite, and a few grains of quartz.

The cutting beyond Wilminston is no doubt through the Carboniferous series. The beds dip southerly at high angles—slates, with quartz veins and thin seams of chert. The killas of the next hill has a different aspect; it is mostly in thin layers, but some is thick-jointed, and there is considerable variation in the dip, though in the main continuing southerly.

This brings us to Indescombe. The cutting here north of the Wallabrook yields igneous rocks with well-marked characteristics—one variety a greenish ash, the other compact, with slickensided joint faces. Only one band is mapped; and the cutting shows that Mr. Rutley was right in the suggestion made in his Survey Memoir on Brent Tor. The belt of greenstone shown from Longford, by Hurdwick and Kilworthy, on to Sowtentown is constricted near Indescombe; and Mr. Rutley noticed that while on the east this band yielded gabbro, on the west it was a volcanic ash—the one an intrusive, and the other an interbedded rock. Not being able to conceive a passage between them, he was disposed to think that the constriction shown might amount to an actual separation of the two; and added, "that they may inosculate seems possible, as the two strips trend in the same east and west direction."[5] And this is precisely what we find.

The compact rock is greenish-grey, with some schistose tendency. Certain of the joint faces show chrysotile. Pyrites is prominent. There is no difficulty in deciding its character, for in addition to plagioclase felspars, pyrites, and serpentine

[5] *Brent Tor*, p. 16. Some of the Hurdwick rock is, however, a schistose lava.

(an alteration product), we have augite present, both in granules and in plates. The rock is thus an ophitic dolerite.

Mr. Rutley cites two sections of specimens taken by him from points very near the course of the railway here; and there is evidently much variation within comparatively narrow limits.

The first, from Indescombe itself, he describes as "a greenish-grey crystalline rock, containing dark green, imperfectly-developed crystals of a pyroxenic mineral. . . . The component minerals appear under the microscope to be decomposed felspars (plagioclase), pyroxene (probably augite), some magnetite, and a little quartz. It is a rock closely allied to, if not basalt. If chlorite were present, it might be regarded as diabase."

The other example, taken about half a mile east, is "rather more coarsely crystalline than that occurring at Indescombe, but bears a strong resemblance to it, both in its colour and general aspect." Authorities differed as to whether the pyroxenic constituent was diallage or augite, and whether therefore in the nomenclature employed by Mr. Rutley it was a gabbro or a basalt.

Passing the fine viaduct over the Wallabrook at Two Bridges, we enter a cutting in very hard altered slate or killas, suggesting the contiguity of the igneous rocks which quickly reappear. The first of these is an altered dolerite of the usual type, save that it seems unusually heavy. It is greyish-green in colour, and perhaps may fairly be termed a diabase. Further on, behind Parkwood, at the earthwork commonly called the Roman Camp, we get admirable examples of concentric spheroidal structure, some of the spheroidal masses ranging up to three and four hundredweight. This exposure yields also fair specimens of asbestos, and exhibits considerable variation in character. In one part there is a much-decayed band, the solider portions of which are a rusty brown rock, in which the forms of crystals of hornblende changed into asbestos are fairly preserved. On the higher part the rock is decomposed to an unusual depth from the surface—20 to 30 feet—into a ferruginous soil. The cuttings at this point are not complete, so that it is hardly safe to assume that igneous rocks continue on. But at Old Wooda the columnar form is assumed for some 16 yards, dipping 45 degrees southerly, by an altered vesicular (?) rock of the doleritic group. Some parts of this exposure are so changed that they may be casually taken for tuffs without close examination, and the columnar structure is merely a passing phase.

For a short distance beyond this point the line is carried in bank, and the connection is not clear with the next section, which is in a siding cut into the hillside at the entrance of Tavistock station yard. This is noteworthy. Slate of a more usual type is succeeded by a massive, well-jointed blue-black "killas," which abuts against an intrusion of doleritic rock broken by veins of quartz. The junction is faulted; and nipped in between the killas and the dolerite is a wedge of loose-textured grey slate (passing out upwards, but apparently developing in depth), which, if lithological characters are to be trusted, is Devonian. But for this little side cutting into the hill nothing would have been known of this interesting point, and it will serve to indicate the gaps yet left in the story the line has to tell.

Slate rocks continue hence through the Tavistock station, with a general southerly dip. The slate varies in character somewhat, but has generally a Carboniferous aspect. Mr. Rutley mentions the occurrence near the "Cottage Inn," on the Lydford road, of a "black gritty shale, much veined, and containing little cubes of pyrites;" and a rock precisely answering this description occurs at the station. I am not at all sure that it does not contain volcanic material, and that it may not be a finely-comminuted redeposited ash. In addition to the pyrites, it has granules and fragments of quartz and felspar. Except that it is schistose and less compact, this rock has a great resemblance in aspect to the calcareous ash, noted by De la Beche, near the old station, but differs from it in composition in the very material point of the absence of calcareous matter.[6]

The most noteworthy feature here, however, is the intrusion of a mass of dolerite on the brow of the hill immediately above Bannawell Street. It is unmapped, and runs north-east and south-west. Between it and the station buildings the slates are much broken and disturbed, and then highly tilted, with faulting. Next to the dyke is a thin bed of greenish ash, much resembling that of Hurdwick; and a similar rock was exposed in the valley beneath, on the other side of the dyke, in digging foundations for Bannawell viaduct. The dolerite thus seems to have been intruded in the ash. It is much altered, but contains the characteristic lath forms of plagioclase felspars, pyrites, apparently ilmenite, viridite, and some granular augite, though the pyroxenic

[6] See *post*.

element has undergone great change. This rock is much like the Wilminston.

The cutting in the hill by Watts's Road, on the other side of the valley, is in Carboniferous shales. Here and there it contains veins of quartz and iron ore—some of the latter beautifully crystallised in quartz cavities and iridescent.

The indications here and at the Great Western Railway station are clear that Tavistock is mainly, though not wholly, on the Culm-measures. Mr. Ussher notes the junction with the Devonian as being marked by a fault (with black mud) in a cutting south of the town. Dr. Holl traced the Carboniferous series with characteristic grit-bands across the Tavy here, the southernmost limit being near Fitzford; and he also noted the important fact that "a little north of the railway (Great Western) station thick bedded grits, dipping north-west, are faulted against a bed of highly-calcareous volcanic ash, dipping in the opposite direction." The slates southward, by Whitchurch, generally undulate at low angles, and seem free from the disturbing influences of the Tavy valley. Query their horizon.

The slates in the cutting south of Tavistock, crossed by the Launceston road, vary in dip from north-east to north-west, but present no peculiarities; they are mostly thick bedded, and grey or brown. In the first field-cutting in the hill opposite Abbotsfield they gradually become more massive, and are jointed into "junks," closely recalling the leading features of the rocks traversed by the Great Western line near Horrabridge. These characteristics are fairly maintained in the sections on to the Crowndale Valley, and they are distinctly Devonian. The prevailing dip here is south-easterly. Some of the slates in this locality have round or oval ferruginous or clayey coats or patches on cleavage faces, the character of which it is difficult to decide. At first they suggested the result of the decomposition of magnetite or other iron oxide; but some of the smaller ones seem associated with traces of organisms, though both fragmentary and obscure. Mr. A. Mitchell kindly called my attention to these markings, which he had observed before I visited the locality.

A point of considerable interest in connection with the more recent geology of this valley is the occurrence in the soil above the first cutting of this series, of boulders and pebbles, ranging up to 15 lbs. in weight—the relics of an early stage in the denuding operations of the Tavy. The boulders consist of schorl and quartz rock, hornblende-schist, and "gabbro," identical with rocks that occur *in situ* at Peter and Mary Tavy. The special importance of the fact lies in the great height of this deposit above the present level of the river. It occurs at an elevation of 400 feet over Ordnance datum, or practically 250 feet above the river-bed.

Crossing the Crowndale Valley we find a gnarly micaceous slate with quartz eyes, bluish in colour, and identical in general appearance with slates that may be traced from Virtuous Lady Mine to the Morwell Rocks. The pioneer geologists of the West regarded these slates as "transition." Dr. Holl held that there could "be no question about the rocks of Hingston Down and the vicinity of Buckland Monachorum being the lowest" in this district, having been "upraised" between the granite of Dartmoor and the Tamar in the vicinity of Buckland Monachorum, Berealston, and Roborough Down." In general terms this is a point on which there should be no doubt, and the probability is, that the granite of the one region passes to the other at no considerable depth below.[7]

This is indicated to some extent by the fact that only here are the rocks within our purview traversed by elvans, which are generally indicative of a near approach to the granite laterally or in depth. It is also indicated, as we shall see hereafter, by the character of these elvans.

Just beyond the junction of the Lumber brook with the Tavy the line cuts through the Shillamill elvan, which has a general east and west direction. This is a singularly interesting section, from the great range of character exhibited. In the centre the elvan is granitoid and porphyritic, much resembling the Grenofen; other parts are more even-grained and felspathic, and the outer portions more quartzose. Different examples from this one dyke might well be taken to represent half a dozen different felsites, varying in texture as described, and in colour from warm buff through shades of brown and cream colour to plain grey and greenish-grey. Various sections show the differences to be mainly dependent on the physical condition of the ground-mass. In one variety the felsitic base is fairly sprinkled with even-sized granules of quartz; while the same mineral is porphyritically

[7] The contiguity of granite underground, not far distant, at Devon Consols, is very well shown by the altered talcose slate with its andalusite crystals, which the miners call "lousy killas."

developed, with felspars which are partially kaolinised. Mica occurs porphyritically and in tufted scaly clusters here and there in the base. A vein of quartz and green hornblende traverses the slide. Another variety is more quartzose and crystalline, but less porphyritic, and appears to contain a little plagioclase; mica is also more generally diffused. A third is less differentiated, and has a more muddled aspect, though mica and quartz are more generally exhibited. A fourth has an evener-textured ground-mass than either of the others, and is more definitely crystalline. Green pseudomorphs, after porphyritic felspars, appear to be partially chlorite and partly hornblende.

Touching the Shillamill elvan as seen in an adjacent quarry, Mr. Rutley writes: "On the south side of the quarry the rock is of a dark grey colour, with irregular dark greenish-black patches imbedded in the grey, granular, felsitic matrix; but farther to the north of the quarry it becomes a quartzose felspar-porphyry of the usual elvanitic type. In places the rock contains a little pyrites or mispickel, and also specks of copper pyrites and some chlorite." He likewise describes three sections as differing greatly in their external aspect, but identical in their original composition. A light porphyritic variety shows the components to be "orthoclase mainly decomposed, quartz, and magnesian mica. The matrix is felsitic; crystals of magnesian mica are in places seen to lie within the crystals of orthoclase, and also a few crystals of quartz. . . . Crystals of magnesian mica are to be seen lying within quartz crystals. From this it would appear that the mica was the mineral which first crystallised."[8] In a section of a dark compact variety "magnesian mica lies within the quartz crystals. The felspar is in all cases converted into felsitic matter. . . . In some instances quartz appears to be pseudomorphous after felspars." The third variety is chiefly marked by a different change in the felspars, which are kaolinised in the first, changed into felsitic matter in the second, and in the third "replaced partly by a micaceous mineral, now greatly decomposed, and probably represented by limonite and partly by felsitic matter." The new sections carry these variations still further.

Following along the hillside the Shillamill Tunnel is quickly reached. This penetrates the lowest rocks, probably,

[8] *Brent Tor*, pp. 24, 25, 41, 42.

cut on the railway. It is 600 yards in length, and is for the most part through slate, varied in texture, much disturbed, and traversed by a copper lode. Some of the slate is peculiar —a light-grey, soft, talcose material, which splinters and powders easily. The only points at which I have met with rock of similar character in South Devon are in superior contiguity to the granite, as at Crownhill, and near Yeoland Consols; but some of the "lousy killas" from Devon Consols has much the same general aspect, apart from the crystal development.

The leading feature in this tunnel is, however, that it cuts the continuation of the Grenofen elvan. This was first met in the roof of the tunnel, 8 chains 44 feet in from the Devonport or southern end, and was lost in the bottom at 11 chains 28 feet.[9] It underlies, however, considerably to the northward, and its width may be put at 40 yards. The point to be noted is, that this elvan, which at Grenofen is porphyritic, with a little interstitial felsitic matter, is here in depth, nearer its source, more distinctly granitic, and in fact is essentially a loose-textured decomposed granite. Some of the slate next the elvan is very hard and quartzose.

The cutting of the Morwell Down tunnel of the Tavistock Canal, according to the details given to the Geological Society by Mr. J. Taylor,[1] if the nomenclature is accepted in the modern sense, shows either that there are more elvans in the rocks there than are found on the railway to the east, or that our two main elvan courses are divided into branches. But if we group these details, it seems probable that whatever local variation there may be, and whatever confusion of nomenclature or identification is suggested, we are practically dealing with two elvan systems only.

Going from north to south the tunnel first traverses 622 yards of killas or clay-slate; then 156 yards grouped as—elvan, chlorite, and quartz, 22; killas, 46; growan, clay porphyry, 12; killas, 24; growan, 52: then 872 yards of killas: then 54 yards grouped as—elvan, 30; killas, 6; growan, 14; elvan, quartz granular and crystalline, 24: finally 816 yards of killas.

On the assumption that we have here two elvan systems, the growan being as distinctly a granitoid rock as the ordinary elvan, and exhibiting no greater change of character than is often seen in one elvan course, there is in the one instance

[9] I am greatly indebted for this, and for much other valuable information, to the ready courtesy of Mr. W. W. Szlumper, engineer of the line.

[1] *Trans. Geo. Soc.* iv. 1817.

seventy yards of intercalated killas to account for, but in the other only six. If this rock is rightly described as killas, then it seems to me the more reasonable hypothesis that the northern elvan branches; in the southern there may be simply an inclusion. I am not at all sure, however, that killas may not have been used in a vague way which might cover a modification of the elvan itself. The rocks described distinctly as elvan in the canal tunnel would not of themselves make up the thickness of the two elvan courses as cut through on the railway.

From the Shillamill tunnel the line continues along the valley of the Tavy at a considerable elevation, chiefly through a series of cuttings in slates closely resembling in massiveness and jointing those further east on the Great Western Tavistock line. No doubt they are a part of the same series. The dips first vary from southerly to northerly; then we find the face of the hill full of contortions. The rocks have evidently been subjected to enormous pressure, and are crumpled and waved in all directions. They also contain numerous quartz eyes—of secondary formation.

The difference between these rocks and the reddish-tinged evenly-bedded slates in the next cutting, which dip south at low angles, is very marked. Here the line leaves the valley of the Tavy, and crosses Morwell Down to that of the Tamar. The Hocklake cutting, next in order, traverses a lode system laid down on the Survey Map by Sir Warington Smith. Two lodes meet near the point of intersection. They are the ordinary east and west lodes, but the southernmost of the two has a southward trend at the fork, which was somewhat deceptive. Where cut they are composed of massive quartz containing some pyrites.

To this succeeds a cutting through splintery rotten slate, with regular dip, which carries us over the summit of the Down, and is followed by a shallow section in the side of the hill overlooking the Tamar. Here the slate contains thin layers of quartz dipping westward, and cut off by fault.

From this point to near Berealston the line traverses nothing but slates of varied character, generally classable as killas, and with varying dips. The colours range from grey-green and blue to drab and reddish, the textures from massive to splintery; and nothing but the most careful survey, when the whole of the excavation is finished, can give any satisfactory conclusions. The general aspect is, however, Devonian.

A cutting near Halson opens in massive reddish slate, dipping at high angles west. Beds which are nearly horizontal succeed, and they are followed by others dipping southerly. The central division is occupied by slates of ordinary character; but at the further end there is a ferruginous splintery shale, with seams of whitish clay.

The most important section on this part of the line is the cutting at Gold-Street Farm, where Mr. Ussher was fortunate enough to discover and identify a mass of grey Culm-measure sandstones and slates faulted down in the Devonians.[2] The Carboniferous rocks consist of grey sandstones with shales and slaty beds, and they are faulted against greenish Devonian shales with a characteristic igneous rock — a greenish-grey amygdaloidal lava, the cavities filled with silicious matter.

There occurs here also a fair example of a rock not elsewhere represented in the district—a mica-trap or lamprophyre. It consists of nearly equal proportions of a cream-coloured felspar and a dark mica, irregularly mixed, with an occasional grain of quartz. Probably it is an extreme local phase of dolerite; for a variety of dolerite closely resembling it is found at Ernesettle, on the south; and at Weard, on the west, a pink felspathic doleritic vein curiously simulates syenite.[3]

The cuttings in the Bere promontory are even for this line exceptionally heavy. Berealston cutting is 75 feet in depth, and contains among the slates a decomposed dyke of igneous rock following the general east and west trend of the neighbourhood. It is a coarse-grained compound of pink felspar, and what seems a chloritic replacement of augite.

Near Bereferrers we get the ordinary drab slate; but the chief cutting between Bereferrers and the Tavy begins in drab slate, and passes to hard blue massive slate, with quartz veins and segregations, some highly crystalline—also calcite. Much of the rock here is thick-bedded and imperfectly cleaved. There is great contortion and some faulting. At one spot beds dipping at a low angle east, and then undulated, suddenly become vertical. Some of the vertical beds strike south-east. At no point of the line, not even excepting that in the valley of the Tavy near Virtuous Lady Mine, is

[2] Dr. Holl identified Culm-measure patches further west at St. Mellion.

[3] A syenite occurs at no very great distance. I have found fragments, though not *in situ*, of what is apparently a syenitic vein in Devonian strata at Mount Edgcumbe—mainly reddish felspar, with a little quartz, and a small but marked proportion of hornblende.

disturbance without the actual presence of a disturbing cause so strongly marked. Further up the Tavy valley, near Milton Coombe and Lophill, while the slates have a prevailing southerly dip, the dips vary considerably in amount, and have a wide range of deviation east and west, so that these disturbances are not purely local. Probably we have here a centre of special stress during the great earth movements that gave this district its main features of configuration.

The cutting passes out in ordinary drab slate, and the next is through a still looser drab shillet, but it is shallow. These drab slates are evidently weathered and changed by surface percolation.

I am indebted to Mr. Henry Clark, under whose direction the bridge over the river Tavy, and that over the Tamerton Creek, have been carried forward, for valuable details concerning the beds of these two channels.

The width of the waterway in the Tavy at high-water springs is nearly 500 yards, of which the deeper portion, or what may be regarded as the channel proper, is about 300. The rock on each shore is a loose-textured purplish shale or "shillet," and there seems reason to believe that this is fairly, if not wholly, continuous. The river-bed is filled up to within a general average of some 20 feet of high-tide level with mud, intermixed at the surface with irregular beds and lenticles of sand, three to four feet deep. Nearly the whole of this surface is laid bare at low tide, leaving a narrow passage for the river water, nearer the Warleigh than the Bere side.

The approaches to the viaduct proper are in masonry arches, the foundations being laid on shallow slopes of slate rock on either side of the main channel. The piers of the bridge itself have been formed by sinking iron cylinders to the bed rock, removing the mud, sand, and gravel from within, and then filling with concrete. In carrying out this work the contour of the bottom has been accurately ascertained.

For about fifty yards from the Bere shore the rock slopes gradually, until it reaches a depth of some 18 feet below high-water springs. It there makes a sudden descent, so that within another thirty yards a depth of 80 feet is reached, which is the deepest point. Then for a hundred yards the depth does not vary much, but it gradually lessens towards the Warleigh end, though for nearly another 200 yards a depth exceeding 50 feet is maintained. Thence the rise of the bottom is more rapid. The shore shallow begins at a distance of 120 yards from the Warleigh end, from which point to the bank the depth is under 25 feet. The mud and associated deposits have a maximum depth of 75 feet.

The surface beds of sand already alluded to excepted, nothing but mud was met with in sinking the cylinders until near the bed-rock, which was found to be covered to a depth of two feet, ranging in parts up to four feet, with a layer of boulders and gravel in hard yellow clay.

This bed-rock, as already noted, consists mainly, if not wholly, of a purplish shale, well jointed and closely cleaved, the cleavage faces being finely wrinkled. Another example of rock from the bottom of one of the cylinders, but which it is impossible to pronounce definitely *in situ*, is a hard, close-grained, grey, micaceous sandstone, with ferruginous joints. This is traversed by transverse parallel veins in two groups, which may represent bedding-planes, but are quartzose.

Among the rocks in the bottom deposit, I have had examples of the following, mostly from boulders:

(1) Uneven-coloured drab and warm-grey granite, with porphyritic felspars, schorl, and apparently a little hornblende.

(2) Water-worn fragment of elvan, dark-grey on the exterior, with reddish-brown centre. Matrix chiefly felspathic, with porphyritic felspars, pyrites, a little quartz and hornblende, but no visible mica. Looks like a fragment of a very thin dyke or vein.

(3) Warm light-brown elvan, matrix sub-vitreous, with porphyritic felspars, some kaolinised, a little quartz, black mica, and hornblende.

The recurrence of hornblende in each of these examples is interesting and significant.

(4) There are also a fragment of "gabbro" of the Horndon type (fifteen miles up the course of the river); (5) pieces of quartz veinstone; and (6) of gnarled slate, with quartz eyes invested by metallic-lustred talcose coatings.

On the shores of the Tamar, south of the Tavy, coralline limestone occurs among the slates, and may be recognised at a distance by the difference in the character and dip and strike of the beds. On either side there are greenish and red slates, against which, Mr. Ussher suggests, the limestone (as observed by him west of the river on the opposite shore) is probably faulted. This limestone is no doubt the same that occurs at Moditonham, where it used to be worked for lime.

The cutting across Warleigh Point is, however, wholly through slate. Olive-drab gives place to blackish, succeeded by a bluish-grey, which somewhat resembles in appearance that at Shillamill tunnel, but is not so friable. Solider rock of the ordinary cleaved killas type succeeds, and the prevalent southerly dip continues.

Tamerton Creek is crossed by a bridge starting from banks on each side. The bed of the creek is shillet or shaly rock, covered by mud in some parts to a depth of over 30 feet. At low water the whole of this mud is left bare, with the exception of a narrow waterway 40 feet wide, and at the most five feet deep. As in the Tavy, the rock has been excavated most deeply nearest the northern bank, and rises most gradually towards the south.

The cutting through the high land of the headland south of Tamerton Creek traverses a long series of red and green slates, intermixed with drab and lead colour, with apparently sundry repetitions.

The earlier dips are mostly to the south-east, but there is some disturbance and crushing, and north-easterly dips speedily succeed. Some of the slate rock is thickly jointed and much broken by quartz-veins, which carry with them at times a noteworthy proportion of chloritic associates. These quartzose portions here, as elsewhere, afford excellent indices of the extent to which the rock has been crushed and contorted, the quartz having been developed along the lines of fracture; and in the opened folds some of the quartz eyes give fine examples of what may be called concentric brecciation, and are strongly slickensided. At times the veins contain specks of galena, copper ore, and mundic.

This section is calculated to raise grave doubts as to some of the identification of the bedding. During its progress, what appeared to be joint faces were exposed, running generally north and south, but they might have been equally regarded as bedding planes.

Professor Phillips, in his *Palæozoic Fossils of Cornwall, Devon, and West Somerset* notices the existence of an anticlinal near Whitleigh, between Tamerton Foliott and St. Bude; and this anticlinal the cutting next traverses. As we approach the axis there is some undulation, next the dip of the purple slates swings round to the south, and then with some contortion and crushing we get the normal southerly dip of the district, which becomes continuous for the section, sometimes tending more to the east and sometimes to the west.

A careful study of this cutting will show how little reliance can be placed upon mere surface observations in these disturbed slates. A hundred yards will yield illustrations of dips to every quarter of the compass, and of almost any amount; and yet, a little deeper, the general run of the rocks may be clear enough.

There is another section on this axis two miles to the eastward, where the road to Tamerton Foliott has been carried in a deep cutting by Old Wheal Whitleigh.

Here, so far as lithological characters go, both Carboniferous and Devonian slates may be represented. There is a massive badly-cleaved quartzose slate, dipping 45° south-west; a massive well-jointed drab slate, nearly horizontal; some ferruginous slate; and some black rotten slate. The southerly dips are at the southern end of the cutting; at the northern end the dip is north-west.

Following these beds along their strike, as well as may be, by the road behind Whitleigh, we get purple and green slates (which become characteristics members of the series further south), then talcose and quartzose slates, and further on purple slate on the crest of the anticlinal. The railway section therefore is fairly characteristic of the rocks for some distance.

From the Tamerton Creek or Butshead cutting the line is carried along the reclaimed flat of Ernesettle until it reaches the point immediately north of the Albert Bridge. This is composed of a hard, compact, closely-jointed olive-grey slate, dipping at a very high angle southward, and in parts vertical. Further in the hill the olive tint becomes stronger, and some portions of the rock are distinctly green. This hill is intersected by a dyke of dolerite, which crops out on the beach beneath, where it seemed to have indurated the slaty rock in contiguity. The railway section shows, however, that the induration is too extensive and pronounced to be due to this cause; and on further investigation we are led to the conclusion that these olive slaty rocks are of igneous origin, and have been subjected to dynamic metamorphism of a very marked kind, which has almost wholly obscured their original characters. The bulk appear to have been originally a very fine-grained volcanic dust or ash, but there are traces of tufaceous bands, of finely vesicular lava flows, and further east at St. Bude they contain recognizable lapilli. There is no locality in the neighbourhood where our volcanic rocks are so much altered, and the extreme form of metamorphosis which they have undergone affords strong contrast to the little-changed ash beds of the Tavistock area; and yet, curiously enough, throughout all they have retained much of the irregular jointing so characteristic of rocks of igneous origin.

The doleritic dyke is about ten yards in diameter, and is bounded on each side by a fault partly filled by brecciated material and partly by more recognisable tuffs. It is decayed more or less throughout the exposure to a dark rusty-brown, and its most interesting feature is the development of spheroidal forms in masses from an inch or two in diameter to pseudo-boulders bigger than a man's head. Some of these are noteworthy examples of concentric structure; and one in my possession, about 2½ inches in diameter, has certainly five and twenty concentric layers folding round the nucleus. This dolerite is largely felspathic, and in its unweathered portions prominently crystalline. It contains plagioclase felspars, mica, augite, viridite, apatite, and ilmenite, and has been described by Mr. Teall as an "ophitic mica-bearing diabase containing much apatite"—the abundance of apatite in the dolerites of this group (chiefly west of the Tamar) being a noteworthy feature. These dolerites, by the way, are as a rule much "fresher" than those of the Tavistock district; and are commonly differentiated also by the presence of mica.

The railway section throws no light on the question, whether we are to regard as part of this dyke or associated with it a boss of felspathic rock at St. Bude, first described by Mr. John Prideaux as a felspathic rock with needles of schorl, and accepted by me as such. The spiculæ are much decayed, however, and I am not sure that they do not represent hornblende. Perhaps a fresher example may some day turn up. Meanwhile the rock has certainly a granitoid character in its development of well-charactered twinned crystals of orthoclase.

The cutting at Saltash Passage, which comes next in order, is of exceptional interest. Three bands of igneous rock are shown on the map traversing its line, and a fourth as approaching it; but this does not represent the full facts, which indeed only an excavation of such magnitude could reveal. The cutting is mainly through slates—dark-brown, blue, and grey (black near intrusions), in part ferruginous, and associated with both interbedded and intrusive rocks of volcanic origin. The general dip is southerly, and there is much local disturbance.

The first appearance of igneous rock in the section from the north was a striking band of massive felstone, dipping at a high angle, with a curiously-rippled face. This is a typical tuff, with fragments of lava and broken crystals in a matrix of fine sediment, forming a network; and if the ripple mark was what it seemed to be, then here, at any rate, bedding and cleavage practically coincided.

A short distance beyond this was a distinctly-intrusive white rock of peculiar character, unlike any other in the district. It was first cut into as a boss, but as the excavation progressed veins, thrown off from the central mass, only were left. All round this intrusion the slates were much disturbed, crushed, crumpled, and blackened. There were also veins of white quartz; and at one spot a mass of very hard granular, pinkish rock occurred, which, by the pink veins traceable when I first saw this section, seems to have been a mass of granular felspar.[4]

The white rock is veined by steatite, and has the same mineral on the joint faces, and its general character seemed that of a potstone. It turned out, however, to be a much-altered amygdaloidal lava. Spots of galena, chalcopyrite, and mundic were visible in the adjacent rocks, and pyrites in the rock itself.

Still further south a dome-like mass of intrusive lava was met with—dark greyish-blue and amygdaloidal. Over and round this hard, compact, blackened slates, converted into an investment allied to Lydian stone, closely mantled; but at a short distance above and on either side the normal strike and dip continued. Here also there was much crushing. This intrusion seems to be on the line of the band mapped as extending from near the Passage to Honicknowle, where trappean rock is largely quarried for road metal. Rock of precisely similar character occurs at Honicknowle, and the slates there are similarly affected by its intrusion.

Hard blue slate, so massive as to be a useful building stone, is found further on; and towards the end of the cutting the slates give place to a thin band of interbedded

[4] Unfortunately nearly all the characteristic features of this cutting have been worked away. At many points on the line the sections here described are no longer what they were when visited first.

vesicular lava and ash beds, of the ordinary "dunstone" or "schalstein" type, including a well-charactered tuff, made up mainly of broken felspar crystals with slaty matter, giving a fresh face an evenly-speckled aspect.

Black slate is intermixed with the customary drab in the cutting where the road branches off to Bull Point, and hard by is purple, but not in quantity.[5]

The line is carried in cutting through the point of high land between the Saltash Road and the Weston Mill Lake, and traverses bands of igneous rocks, which have been quarried for "metal" by the side of the road below.

The prevailing colour of all the rocks in this cutting is a warm ochry-drab or brown. There are three narrow dykes or indentifiable bands of igneous rock, running east and west—so similar in character that they are certainly part of the same series, if not repetitive—cut off from the slates by vertical faces, or inclined at very high angles. These dykes are partly schistose, partly massive and jointed. The middle one appeared to indicate an approach to semi-spheroidal structure, being divided vertically by parallel master joints, and then into terminally-curved layers approximating the cleavage planes. Some of these layers were compact throughout, but others seemed to graduate into ashy matter, which was, however, the result of the decomposition of the more solid felstone. It is not easy to decide whether these dykes are interbedded or intrusive from their general aspect, but when they are examined under the microscope they turn out in the main to be ashes rather than tuffs, highly altered, but still retaining shadowy features of their original fragmental structure, with wavy and impersistent brown strings running laterally through them, giving the appearance of fluxion. In parts they enclose small slaty patches—a characteristic of some tuffs at Crabtree, near Plymouth.

There also occurs here what may be described as a granular schistose tuff—the distinctly fragmental matters in which are disposed between irregular plates or films of talcose matter, some of which has a greenish hue, and is translucent.

Yet another fragmental form is an agglomerate—small bits of rock, some pebbly, others flat, but all with the edges more or less rounded, in a friable base. It has been subjected to considerable pressure, and belongs to the original series,

[5] A toad brought down with the *débris* here while blasting was said by the "navvie" to have been found in the solid rock—said rock at the point in question being a schistose lava!

for one of the joint faces, which is ferruginous, is slickensided. The character of the fragmental matter is not quite clear, but the bulk of it, at any rate, may be pronounced as of igneous origin.

The line is carried across the Weston Mill Lake mainly by embankment. The mud here is of very great depth, and large quantities of the "spoil" have sunk into it, forcing up the silt on either side.

From the creek to the spot where the line crosses the Saltash turnpike the cutting is wholly in slate. Quartz veins and eyes occur at various points, and here and there small thrust faults; slickensides are frequent. We meet also with the purple and green slates. I have no doubt that these coloured slates are repetitions of one band, but they seem to be repeated in major folds as groups, as well as more individually in minor plications.

The long cutting at Ford is hardly less interesting than that at Saltash Passage. It commences in drab slate, dipping a little west of south, but disturbed in places. Black slate follows, and this becomes quartz-veined. Hard blue slate succeeds, fine-grained and compact, which behind the Devonport Workhouse dips southerly at an angle of 55°. In the upper part of the cutting, as at the commencement, the slates are mostly drab, changing more or less suddenly to the darker shades; and this surface action extends to a depth of about twenty feet.

Beyond the blue slates igneous rocks again appear, the first indication being an intrusive wedge of lava-breccia thrust up into the slate at an angle corresponding roughly with the dip, and with an investment of a thin crust of altered slate. This lava-breccia is yellowish-grey, composed of fragments of volcanic rock of various sizes set in a matrix of finer material, apparently of the same description, with slaty particles. I can imagine such a rock being formed by powerful intermittent intrusive action.

It is succeeded almost immediately by the ordinary interbedded volcanic or "schalstein" series, in which massive porphyritic-felspar lava, vesicular and amygdaloidal lava, and tuffs, are alternated with slaty beds; the last, no doubt, in part simply cleaved portions of the igneous members. These rocks are much decomposed, with great development of loose ferruginous matter. Much steatite is seen on joint faces and in veins.

The lava-breccia comes in at various points in little bosses. It is a peculiar rock, and occurs nowhere else in the locality. There is also a grey amygdaloidal lava which seems of the same composition.

These igneous rocks continue to the northern end of the viaduct across what was formerly the Keyham Lake. At the southern we get the purple and green slates again, associated with drab slates containing quartz veins. There is disturbance here, too, and at one point the slates are traversed by thin beds of hard rock, which at first sight suggest a compact lava. They are, however, quartzose, and are really highly altered grits, representing layers of fine sediment of quartz and felspar, and some opaque mineral, which has a fancy for segregation. The grains are rather ovoid than spherical, and are little worn, many being angular, and several with a ragged outline. There are casual occurrences of this rock in slates near Bere, and it evidently represents layers and patches of sand among the prevailing silts.

From this point the line proceeds mainly in tunnel to the Devonport Station. There is one open cutting which exposes drab iron-jointed slates; but the red and green slates occur at various points, and are last met with towards the southern end of the Devonport Park section of the tunnel.

We may sum up these observations generally as follows:

I.

A. The line is carried through a great series of slate rocks differing much in character, almost wholly unfossiliferous, and with a prevailing, though by no means universal, southerly dip.

B. These slates contain interbedded lavas, ashes, and tuffs at various points, and are traversed in the same areas by dolerites; while intrusive volcanic rocks are also found.

C. Grit beds and chert occur occasionally.

D. Quartz veins are common in certain localities, and are specially prominent where there is contortion.

E. In one area the slates are traversed by elvans, and metallic lodes also occur.

II.

We may group these rocks in the following natural divisions:

1. The slates and grit bands beyond the interbedded lavas, near Brent Tor Station, to Mary Tavy. These are

free from igneous association on the track of the line, and are undoubtedly Carboniferous.

2. The slates with their interbedded and intrusive igneous rocks from Mary Tavy to Tavistock. These, as it seems to me, while partly Carboniferous, are in all likelihood also partly Devonian. There are no fossils to help us; and with the exception of chert bands in the cutting near Wilminston and the characteristic grit seams at Tavistock there is little evidence in the sedimentary lithological direction. But the igneous members of the series seem to afford some clue. If the suggestion is right that the interbedded lavas, ashes, and tuffs of this district are identical with those that appear in the Devonians near Plymouth and elsewhere in South Devon in rocks of similar age (and physically they are in many instances indistinguishable)—then we must rank the slates of this volcanic group Devonian also, and account for the present intimate association of Devonian and Carboniferous rocks near Tavistock by the complicated plications consequent on the formation and upheaval of the Dartmoor granite, lifting and thrusting rocks which had already been seriously disturbed by the intrusion of the gabbros (now epidiorites) on the borders of the Moor, and the associated dolerites. This is of course hypothetical; and if the point is to be definitely solved by observation, it can only be done by the most careful and detailed survey, with the ever present possibility that the key or keys may lie in areas of which no section is available.

In this connection it seems to me worth considering whether it is probable that the conditions which must have governed the production of the interbedded volcanic rocks in the Devonian slates near Plymouth could have been so exactly reproduced in the Culm-measure era, as they were if the lavas, ashes, and tuffs of the Tavistock area are of Carboniferous date. It is of course possible, but I hardly think it likely. These Devonian rocks point to the existence of volcanic activity over a very lengthened period, adjacent to a shallow sea, into which the lava flowed which was disintegrated to form the tuffs, and in which the finer sediments—volcanic dust and sub-aërial detritus—were thrown down, until the gradually-raised sea bottom became the foundation of limestone reefs. Then came a period of at least comparative rest, during which these strata were brought to the surface, to be depressed again beneath the waters of the Carboniferous sea. This whole process must have been repeated in close detail, if the Tavistock volcanic series is distinct from the Plymouth—the one Devonian and the other Carboniferous. It seems more reasonable, in the absence of direct evidence to the contrary, to believe that the Carboniferous period is represented with us by grits and shales, until the later day when another earth movement was followed by the intrusion of those gabbros and dolerites which we find traversing the sedimentary and volcanic interbedded rocks alike.

3. From Tavistock to near Berealston the rocks appear to be wholly Devonian, the lowest beds exposed on the line being brought up in the lap of granite connecting Dartmoor at Walkhampton with Kit Hill and Hingston Down, between which the Grenofen, Shillamill, and Morwell elvans form an almost continuous link. There is no instance, that I am aware, in South Devon of elvans occurring in other than Devonian rocks. Elvan-bearing rocks may thus be claimed as characteristically Devonian, and among the lower members of the local series. The southernmost elvan is at Cann Quarry, near Plym Bridge; but the Roborough elvan crosses the Tavy at Lophill, within a mile and a half of Bereferrers; and there is no evidence of any but Devonian rocks on the Tavy from Tavistock to its junction with the Tamar.

4. From Berealston to Tamerton Creek we are on somewhat debateable ground. It is quite certain that both Devonian and Carboniferous rocks occur, but their general boundaries are not clear. Mr. Ussher has fortunately worked out the faulted-down Culm-measure shales and grits of the Gold-Street Farm cutting, hitherto wholly unsuspected. And here, too, it is significant that we come again on the "schalstein" series, though immediately after, as it appears to me, we are among the lower beds of the Middle Devonian. I do not, however, feel sure of the horizon of the Tamar limestone. The purple and green slates exposed on the anticlinal to the south in bulk underlie the great Plymouth limestone, and limestones do occur here and there far away from the main mass.

5. From Tamerton Creek on we have a set of rocks corresponding remarkably in leading features with those between Mary Tavy and Tavistock, but at the same time with some important differences. In both we have a great slaty series containing interbedded volcanic rocks, and with intrusive dolerites, though the Plymouth dolerites are fresher than the Tavistock, and have no associated gabbros or epidiorites. But it must be remembered that they are removed from the great intrusive centre of Dartmoor. Near Plymouth there

are no positively identifiable Carboniferous rocks, though their presence is possible. We have the purple and green slates, which may be traced at many points in South Devon and East Cornwall. And we have also what was unsuspected before the line was cut, intrusive volcanic rocks later than the "schalsteins." This seems to indicate the existence of a period of igneous action hitherto unrecognised in South Devon; unless we are able to associate these intrusions with the so-called Triassic outbursts, of which an example occurs on the east of Plymouth Sound. The plications near Plymouth seem to be at once more complex and more local; and I have been led to attribute this to the resistance afforded to the Dartmoor thrust by the great buttress of Archæan rock now represented in remnant by the Eddystone reef.

III.

The one great characteristic feature of the series is the almost entire absence of fossils along the whole route—a fact so strange as to be wholly inexplicable on the hypothesis of anything like a regular succession. And even when we lessen the time required for the formation of this enormous body of rocks by calling in the aid of repetition, the existence over the shortest assignable period of such all-but-lifeless seas is startling. However, life was by no means wholly absent, though it was greatly localised. Traces of crinoids, as we have seen, do occur among the slates here and there; and the cast of a mollusc of large size has been found in tuff at Honicknowle. The probability seems to be that the lowest rocks of the series were formed in very deep water, and that such traces of life as they once contained have been greatly obscured—in fact, all but obliterated—by subsequent changes. For the rest, the existence of continuing, though intermittently operating, volcanic forces, must have been fatal to life near the centres of activity.

I hardly think it wise to venture an opinion as to the proportion between the actual and apparent thickness of the rocks under review. The bedding is not always clear, the evidence is imperfect, and we have to deal not merely with major, but with minor folds. Dr. Holl suggested some half-dozen between Stowford and Mill Hill, varying widely in sharpness and breadth.

But I may just note the fact—passing by the middle section—that from the Tavy to Plymouth there is some evidence of sixfold repetition: in the recurrence of purple slates in the bed of the Tavy; at Butshead, on the south of Tamerton Creek; near Bull Point; in the cutting east of Weston Mill Creek; at Haddington Road, Stoke; in the Devonport Tunnel: and in the presence of volcanic rocks of the "schalstein" series (beyond the small exposure faulted against the Culm-measures at Gold-Street Farm,) at Ernesettle; the Albert Bridge; the southern end of the Saltash Passage cutting; Camel's Head cutting; at Ford; and again south of the Devonport tunnel next the limestone. The character of the folding, and the extent of denudation, would account for the wide variations in the breadth and importance of these exposures; and where these rocks run in groups (as the tuffs in the Camel's Head cutting), we may be dealing also with minor plications. But when we find in a space of little over four miles a sixfold repetition of this sort—duplicated, and with some approach to regularity of interval—it is perfectly safe to assume that the apparent thickness is enormously less than the real; and that instead of being (allowing for dip in the section of the country now under consideration) about 6000 yards, it really does not reach 1000. The application of the same method at the Tavistock end, which I suggest as in part repetitive of the Plymouth, and in the central section, would bring the South Devon Devonians into reasonable compass.

As a record of observed facts, I trust that this paper may be of some use. For the rest, it has no claim to be other than suggestive. The man who will finally unravel this tangled geological skein must have more spare time, and more of the critico-imaginative faculty, than I possess.

In conclusion, I most heartily thank Messrs. Relf and Pethick, the contractors, for facilities kindly afforded.