33. *On some ERUPTIVE ROCKS from the NEIGHBOURHOOD of St. MINVER, CORNWALL.* By FRANK RUTLEY, Esq., Lecturer on Mineralogy in the Royal School of Mines. (Read June 9, 1886.)

[PLATE XII.]

AMONG the numerous exposures of eruptive rock occurring in the vicinity of St. Minver, near Padstow, those at Cant Hill and Carlion are conspicuously represented on Sheet 30 of the Geological Survey map.

In both cases these rocks occupy high ground, and in both they are mapped as "greenstone;" but a casual glance suffices to show that they are very different from one another, although at their nearest points they are little more than half a mile apart.

The surface of the ground is undulating, and the hills are, as a rule, smooth and under cultivation, so that it seems probable that the boundary lines of these eruptive rocks have been partly mapped from superficial features, the exposures being neither large nor numerous. If it were not for two or three small quarries which have been opened, there would be very little eruptive rock visible, and in no case did I see any contact with the adjacent slates. I am therefore unable to state what is the relation which the former bears to the latter, although, from an inspection of the Survey map, I hoped that it would have been possible to gain some information upon this point at the base of Cant Hill, on the eastern side.

With this object in view I examined the foot of the hill, passing from St. Michael along the bank of the estuary to the small cove near Cant Farm, but, at the spot where, judging from the map, the eruptive rock might be expected to be visible in place, nothing but loose fragments of it were to be seen. The journey round the base of the hill being dependent on the tide, and the time at my disposal being limited, it seemed scarcely worth while to repeat the visit; but it is just possible that more diligent search, hereabout, might afford useful information.

The impression which I first received, on examining sections of the Cant-Hill rocks microscopically, was that they were tuffs composed of basic lavas and fragments of vesicular glassy rock; but Prof. Renard, to whom I forwarded the sections, having kindly examined them, favoured me with his opinion that they were vitreous lavas of a diabasic type, and, after much time spent in further examination of them, I have arrived at a similar conclusion. My thanks are therefore largely due to Prof. Renard for his useful suggestion. I am, however, still not fully satisfied that the clastic appearances visible in some of these rocks may not be due to the presence of volcanic ejectamenta, although it is also possible that these appearances might result from the crushing of a lava by the pressure of superincumbent masses. And here another difficulty steps in, for we sometimes meet with beds of volcanic ejecta

consisting of identical or unmixed lava fragments, in which case it is hard to distinguish such a deposit from a similar coulée of lava which has undergone crushing *in situ*.

To Mr. Grenville Cole, whose knowledge of vitreous rocks is both extensive and exact, I am also indebted for a confirmatory opinion*.

The following is a short account of the nature of these rocks:—

No. 1. *Cant Hill, East end, at top of hill* (Plate XII. fig. 1).—This is a light brown, roughly fissile rock with greyish or yellowish-white porphyritic crystals, chiefly less than an eighth of an inch in diameter. On a surface cut transversely to the direction of fission, the general structure of the rock is rendered apparent by exceedingly delicate sinuous streaks of three kinds, namely dark green, reddish-brown, and grey. These fine streaks are seen here and there to be traversed by very delicate veins of a dark-green colour.

Under the microscope the finely-streaked appearance of the section is at first sight strongly suggestive of the fluxion structure seen in lavas. There are bands and small knots of felsitic matter (micro-crystalline) separated by bands of translucent greenish-yellow or brownish-yellow serpentine†, and more delicate opaque streaks, some of which are reddish brown or rust-coloured, while others appear snow-white. These opaque streaks seem to indicate, in part, an original fluxion-structure in the rock, especially in the case of the snow-white markings. In one part of this section there occurs a thin vein of greenish-yellow to brownish-yellow serpentine, which is traversed by the opaque rust-coloured strings, while the opaque white streaks are distinctly separated by the vein ending abruptly against its edges. This clearly shows that we have to deal with two distinct sets of opaque streaks—the one set having been formed before, and the other after the formation of the vein. The white streaks represent the earlier and the rust-coloured streaks the later structures. That the rust-coloured markings do not represent fluxion-structure is evident, since, if they did, they would be interrupted by the vein of serpentine; but they traverse it. The white markings, on the other hand, do not cross the serpentine vein, and it is therefore possible that they indicate an original fluxion-structure in the rock. Both sets of these opaque strings run confusedly together, and interlace in a complicated network, except where the vein occurs.

The greenish-yellow serpentinous films and strings which follow the general striping of the section are found, when examined in polarized light, to be actually continuous with the similar substance of the vein which traverses them, as shown at *aa* in the accompanying woodcut (fig. 1), while the black markings indicate the opaque

* Shortly before the reading of this paper Prof. Bonney also examined these specimens and sections, and kindly gave me his opinions on them. In the main his conclusions agreed with those already arrived at. One or two of the points upon which he differed have since been recorded in supplementary notes.

† Prof. Bonney, who favoured me with an opinion upon these sections, regards much of the substance which I have here called serpentine as a palagonitic material.

strings, some of which (opaque white) are cut off by, while others (rusty-coloured) traverse the vein.

Fig. 1.—*Cant Hill, East end, at top of hill.*

a a. Greenish-yellow to brownish-yellow scaly serpentinous matter.

The sketch shows the continuity of bands of this serpentinous substance with the cross vein of the same material. In the vein the scaly character is better seen than in the bands, since in the vein the scales lie confusedly in all directions, while in the bands they are approximately parallel.

In the felsitic portions of the preparation numerous small circular and lenticular spaces occur, filled sometimes with quartz and at others with serpentine. These have apparently been vesicles, and from these, and from the appearance of fluxion-structure, there seems little doubt that the rock was originally a lava. In one or two places there seems to be evidence of a banded, and perhaps spherulitic structure, as shown in the middle of fig. 1, Plate XII. We have now advanced far enough in our examination to assume that we are dealing with a banded vesicular lava. The next point to ascertain is the nature of the assumed lava.

Porphyritic feldspars are present in tolerable quantity, but they are often considerably altered. Where they are sufficiently fresh to exhibit distinct optical properties they are seen, from their extinctions, to be triclinic, the extinction-angles often approximating to those of labradorite. The next point of interest is the profusion of serpentine which is present in the rock. It occurs chiefly in irregular or lenticular patches which fade away into filaments, granular specks, or stains. The general appearance, however, is that of very irregular bands, and it seems probable that their more expanded portions represent pseudomorphs after pyroxene or olivine which have been reduced to lenticular forms by pressure. The opaque rusty-coloured matter in the rock is limonite; the opaque white substance kaolin, or perhaps leucoxene in part. We have therefore, with the exception of a few imperfectly altered crystals of triclinic feldspar, nothing but decomposition-products. If from these secondary materials we endeavour to speculate on the original mineral constitution of the rock, we have triclinic feldspar (labradorite

in part) and its secondary products kaolin and felsitic matter, the secondary product serpentine, which has probably resulted from the decomposition of pyroxene or olivine, and the secondary product limonite, which may have been derived from the alteration of magnetite or ilmenite. The normal constituents of the rock may therefore be regarded as those of a basalt or an andesite, while the greater part of the felsitic matter present most likely represents the alteration of a glassy base. We therefore seem justified in regarding this rock as a once vitreous lava of a more or less basic type. To some extent I feel confirmed in this view by remarks made by Professor Renard, who kindly examined these sections and gave me the benefit of his "impressions" concerning them; and, although I had previously arrived at similar conclusions regarding the mineral constitution of these rocks, I must admit that I was inclined to regard them as tuffs composed of fragments of once vitreous basic lavas, rather than true coherent lava-flows. As it is, I cannot help thinking that they have in many cases experienced considerable crushing; but, if so, it has been from pressure normal to the planes of foliation, and the foliation is due, first to decomposition of certain mineral constituents, and secondly to pressure; but I can find no evidence that any shearing action has been implicated in the production of the structure which now exists in the rock. The evidence afforded by the small serpentine veins transverse to the direction of foliation negatives such a supposition.

No. 2. *Cant Hill, East end, at top of hill* (Plate XII. fig. 3).—This specimen was collected from the same locality as no. 1, in a small grubbing not more than four or five feet deep. It is a pale greenish-brown or greenish-grey rock, with numerous pale grey or yellowish-white porphyritic crystals or flecks ranging from about a fifth of an inch to quite microscopical dimensions.

On a smoothly cut surface very delicate, wavy, but roughly parallel streaks of a dark green colour are visible. A vein of a dark green serpentinous substance cuts obliquely across the banding in this specimen. The green matter has a hardness of about 3 or slightly less. The rock weathers with a rusty brown surface.

Under the microscope it presents the appearance of a vesicular lava with a more or less devitrified ground-mass, and contains numerous porphyritic triclinic felspar crystals, which have frequently a fragmentary aspect. The vesicles are extremely numerous, in most cases their sections are circles or ellipses, although they are sometimes of irregular form, and they are for the most part filled with serpentine, chalcedony, or quartz. The section is impregnated with much opaque, yellowish-white matter, apparently kaolin. A drawing made from this preparation, as seen by ordinary transmitted light under an amplification of 25 diameters, is shown in fig. 3, Plate XII. There is, in many parts of this section, an appearance of contorted fluxion-structure. The extinction-angles of some of the porphyritic felspar crystals indicate labradorite, others anorthite. Some of these seem to have undergone a certain amount of corrosion, as suggested by Prof. Renard.

No. 3. *Cant Hill, West end, at top of hill* (Plate XII. fig. 2).—This is a purplish-grey rock with a somewhat fissile structure and little greyish-white specks of irregular form. It was derived from a small quarry which has been opened out on the top of the hill. The rock in this quarry is strongly jointed, and appears to be fresher than that occurring in the small grubbing from which the specimens nos. 1 and 2 were procured. The stone here still seems, however, to be considerably weathered*. A section of this rock seen under the microscope appears as a clear, almost colourless, glassy lava full of small vesicles, frequently bordered by minute round granules or moniliform edgings of an opaque snow-white substance. The glassy matter also contains irregular nests, strings, and nebulous segregations of minute yellowish-green granules, which appear to be epidote (fig. 2, Plate XII.) The vesicles give circular and elliptical sections in some places, while in others they are greatly elongated in uniform directions, sometimes occurring close together, so as to form vesicular streams, which are frequently sinuous and indicate fluxion. There is also a wavy, thread-like structure in the glass, which is not very clearly to be recognized except between crossed nicols under a moderately high power, when the fibres are seen to depolarize in feeble greyish-blue tints. At first sight it would seem that this substance might be serpentine, but it is probably a felsitic substance ("microfelsitic basis" of Rosenbusch). In many places the glass is almost unaltered. Small crystals of triclinic felspar occur in this glassy or once glassy ground-mass. The rock appears to have been somewhat crushed, and contains a considerable amount of calcite, a little quartz, and a few dark opaque grains, which are either magnetite or titaniferous iron; possibly there is a little serpentine. Much of the opaque white or faintly rusty-stained matter in the section I am inclined to regard as leucoxene, resulting from the complete decomposition of ilmenite. We have here, then, a partially devitrified lava of a highly vesicular character, in which the felspars are triclinic, while the secondary products, epidote and leucoxene, indicate that pyroxene, possibly olivine, and ilmenite were once present as original constituents. The rock, therefore, may be assumed to have been a vitreous basic lava, and may very likely be coeval with the lavas erupted in the Brent-Tor district, which, although mapped as occurring in the Culm series, are probably of Devonian age.

No. 4. *Cant Hill, West end, at top of hill*.—This specimen was taken from the same quarry as no. 3, which it closely resembles, but shows a considerable amount of ochreous matter, which is distributed in small patches and films throughout the rock. Calcite seems, however, to be absent from this specimen, and there is a large proportion of serpentinous matter, so large, indeed, that by burnishing a smoothly cut surface of the rock with an ivory paper-knife, a fairly good polish can be communicated to it.

* I would here acknowledge the courtesy of Mr. Wm. Buller, of Cant, in giving me useful information concerning the quarries in the neighbourhood.

When we examine a section of this rock under the microscope, we find that some of the original glassy basis has to a large extent been converted into serpentine, especially along lines which seem to indicate fluxion-structure. How far this process of alteration has taken place in the glass it is difficult to determine. There may be a little unaltered glass still remaining; but this is a doubtful point. The glassy or once glassy portions of the rock are of a yellowish-brown or coffee-colour, and are full of vesicles which are frequently filled with chalcedony and often give the dark cross common to radiate crystallizations when viewed between crossed nicols. There is, in addition to the serpentine, a large proportion of kaolin present.

Nos. 5 and 6. *Cant Hill, East side, at foot of hill, not in place.*—In sections nos. 5 and 6, cut from specimens collected from debris on the shore, on the east side of the hill, nearly opposite the slate-quarry, we find the same vesicular lava, devitrified and in a more or less crushed condition*, with a very considerable admixture of calcite, serpentine, and some felsitic matter. Quartz often occurs in the vesicles. There seems, then, no doubt that the upper portion of Cant Hill, which has been mapped as "greenstone," is really composed of a basic lava of a once vitreous character, but so altered that its original mineral constitution cannot be inferred with precision. Whether the patch mapped as greenstone on the western side of the estuary, stretching from Oldtown Cove to Tregony, and the exposures on the east of Cant Hill, touching Tregenna and Dinham House, are extensions of this lava of Cant Hill, I am unable to say, as I did not visit those localities; but, judging from their relative positions on the map, it seems by no means an improbable supposition.

No. 7. *Carlion, near St. Minver.*—These specimens were collected in a small quarry on the top of a hill situated close to Cant Hill, a road leading down from this quarry to Cant Farm being at the time mended with some of this freshly broken stone.

It is a compact, greyish-green rock, with dark green or greenish-black blotches, which, when it is roughly broken for road-metal, look at first sight like rain-spots on an absorbent stone. Here and there these spots show glistening cleavage-planes.

Under the microscope the constituents are seen to be augite, triclinic feldspars (apparently labradorite), ilmenite, a considerable amount of felsitic matter, a little chalcedony, and, in some cases, serpentine. The most striking features of the sections are the crystals of augite. These are seen to be broken up into exceedingly irregular patches, in places somewhat like the pieces of a dissected puzzle, loosely shuffled together or slightly pushed apart (fig. 2, p. 398); this is due to the augite crystals having enveloped small feldspar crystals and feldspathic portions of the rock during the process of crystallization, and not to any corrosive action.

In most cases the enveloped feldspars have been converted into felsitic matter, a fate which many of the larger feldspar crystals have also shared.

* Prof. Bonney is strongly inclined to regard no. 6 as an ash.

That these irregular patches and labyrinths of augite represent individual crystals and not aggregates of crystals, there can be no doubt whatever, since extinction takes place simultaneously and uniformly, both over the connected and the isolated portions of each patch or labyrinth.

Fig. 2.—*Augite-andesite** from Carlion, near St. Minver, Cornwall.

The figure shows one of the remarkably labyrinthine crystals of augite as it appears in a position of maximum extinction between crossed nicols. Part of another crystal of augite, lying in a different azimuth, is represented in the lower left-hand corner of the drawing. The interstitial portions consist of altered felspars and felsitic matter.

Specimen no. 7, $\times 25$. Crossed nicols.

Here, then, somewhat as in the case of micropegmatite, we have a well-marked instance of interruption in the development of individual crystals by the synchronous formation of smaller crystals of another mineral†.

Similar interruption in the development of crystals is, indeed, a very common feature in crystalline eruptive rocks; but it is seldom seen to occur in so striking a manner as in this rock from Carlion. Different grades of such interrupted crystallization are shown in Prof. Judd's recent paper on the "Gabbros, Dolerites, and Basalts of Ter-

* In using this term, mineral constitution only has been taken into consideration.—F. R., June 28, 1886.

† In this case, however, the mineral causing the interruption consists of small individual crystals, thus differing from micro-pegmatitic structure, which is due to interruption of crystallization in *both* of the minerals concerned.

tiary Age in Scotland and Ireland," pl. v. figs. 1, 3, and 5; and Prof. Green has lately shown me some good examples from Rhobell Fawr occurring in rocks, probably of Llandeilo age, and from another spot two miles E.N.E. of Dolgelly, intrusive in Lingula-flags.

Taking certain parallel lines as traces of cleavage-planes, parallel to the vertical axis, we get the maximum extinction in some of the

Fig. 3.—*Augite-andesite from Carlion, near St. Minver, Cornwall.*

The black labyrinthine patch in the middle of the drawing is ilmenite; whether this patch consists of a single crystal or of an aggregate of crystals of ilmenite is uncertain. The remainder of the drawing represents triclinic feldspars (more or less altered), felsitic matter, augite, and serpentine.

Specimen no. 7, $\times 25$. Ordinary substage illumination.

augite sections in the Carlion rock at an angle of 39° from this direction. In other sections the angle varies, but usually ranges from 30° to 40° . Tested with a single nicol, the thin sections of this mineral show little or no appreciable trace of pleochroism. These crystals depolarize in vivid colours, and, when seen by ordinary transmitted light, appear of a pale greenish tint. It is also noteworthy that in sections of this rock the ilmenite frequently presents a similar labyrinthine appearance, as shown in fig. 3; but owing to the opacity of this mineral and the irregular outlines which these ilmenite patches present, it is difficult to say whether we are dealing with one crystal or with many.

The rock itself is an augite-andesite* (so far as its mineral con-

* Many petrologists may object to the application of the name andesite to this rock, since it is holocrystalline; but if, in defining an andesite, we admit and require the presence of a ground-mass, we then have two terms for one rock,

stitution is concerned), or what, a few years ago, we should have called a basalt or dolerite; and if a name based upon colour be worth anything, it is also a very good greenstone, and as such it was formerly mapped by the Geological Survey. The other exposures of eruptive rock in its immediate neighbourhood have, however, been coloured alike; but, although we can see at a glance that the rocks of Cant Hill and Carlion are not of precisely the same character, there is a certain rough justice in this generalization, which was absolutely necessary in the early days of the Geological Survey, since both are rocks which apparently possessed a somewhat similar mineral constitution in the first instance. In the case of rocks which present such frequently ambiguous characters as those of Cant Hill, the work of the microscopist would be more sure if controlled by observations made in the field; but Cant Hill to-day is probably much the same as it was when the Survey mapped it, and there seems little more to be learnt until fresh quarries are opened out.

There are, however, probably points concerning the relation of the eruptive rocks to the slates which would well repay further investigation. If the foregoing remarks should throw any faint glimmer of light on the nature of the rocks at Cant Hill and Carlion, I trust that they may be accepted rather as a slight addition which Sir Henry De la Beche would have made to his own "Geological Report on Cornwall," than as an attempt to correct the work of one of our old masters.

EXPLANATION OF PLATE XII.

Fig. 1. Devitrified basic lava, showing fluxion-structure and vesicles. A large proportion of this section consists of a clear, greenish-yellow to brownish-yellow serpentine. The opaque central band is probably an altered spherulitic structure.

Cant Hill, near St. Minver, Cornwall; east end, at top of hill.

Specimen no. 1, $\times 50$. Ordinary transmitted light.

2. Devitrified basic lava, showing portion of the original glass, slightly altered, a fibrous structure being visible in it when seen between crossed nicols. The extremely vesicular character of the glass is shown in this drawing. The greenish granular matter in the upper right-hand corner is probably epidote.

Cant Hill; west end, at top of hill.

Specimen no. 3, $\times 50$. Ordinary transmitted light.

3. Devitrified basic lava, showing porphyritic crystals of felspar, some of which appear corroded, and numerous small vesicles filled with quartz and serpentine.

Cant Hill; east end, at top of hill.

Specimen no. 2, $\times 25$. Ordinary transmitted light.

DISCUSSION.

The PRESIDENT remarked on the characteristic treatment by the Author of a difficult subject. He had laid many sides of the question before the Society with the greatest candour.

Mr. TEALL remarked that the specimens from Cant Hill were

viz. andesite and porphyrite. In its relation to structure the latter term is preferable when a ground-mass exists.—F. R., June 28, 1886.

1.

x 50.

2.

x 50.

3.

x 25.

Frank Rutley del.

Mintern Bros. Chromo lith.

DEVITRIFIED BASIC LAVAS OF CANT HILL.

schistose. He regarded the schistosity as due, in all probability, to the post-Carboniferous earth-movements, which had undoubtedly produced great structural and mineralogical changes in the pre-granitic rocks of the west of England. He called attention to the fact that many of the so-called "greenstones" of Cornwall and Devon which had been described by Messrs. Allport and Phillips were similar to the proterobases and epidiorites of Gumbel, and to rocks from the Hartz which had been shown by Lossen to be plagioclase-augite rocks in which the augite had been partially or wholly changed to hornblende by contact- or regional (pressure-) metamorphism.

Mr. COLE agreed with the Author that these substances originally contained glassy matter of a basic character, and remarked that whilst the altered glass of the acid lavas had long been recognized, we should have to look for the results of the alteration of the more basic glass in these soft products of yellowish serpentinous matter.

THE AUTHOR, in reply, said that there was in this case no direct evidence of alteration from the proximity of granite, nor from the action of shearing, and he showed that in a certain instance there was no displacement of a vein. There had been a disturbance producing a more or less vertical squeeze. He spoke of black as well as of the green alteration-products alluded to by Mr. Cole; the former would result from the separation of magnetite from these basic glasses.