36. *On the BASALTS and ANDESITES of DEVONSHIRE, known as 'FELSPATHIC TRAPS.'* By BERNARD HOBSON, Esq., M.Sc., F.G.S., Lecturer in Geology in the Victoria University, Owens College, Manchester. (Read June 22nd, 1892.)

CONTENTS.

	Page
I. Previous Literature.....	496
II. Evidence of the Contemporaneous (non-Intrusive) Character of the Rocks	497
III. Improbability of the Former Existence of these Lavas in the Area of the Dartmoor Granite	498
IV. Intrusive Dykes in supposed New Red Trap near Plymouth	499
V. Other alleged Intrusive Dykes in the Lavas.....	500
VI. List of Localities examined.....	501
VII. Macroscopical and Microscopical Characters of the Rocks.....	502
(a) Olivine-basalts.	
(b) Quartz Inclusions.	
(c) Mica-augite-andesite of Killerton.	

I. PREVIOUS LITERATURE.

1797. W. G. Maton. Observations relative chiefly to the Natural History, Picturesque Scenery, and Antiquities of the Western Counties of England. Salisbury, vol. i. pp. 95-97 (describes the Thorverton stone).

1811. J. F. Berger. Observations on the Physical Structure of Devonshire and Cornwall. Trans. Geol. Soc. vol. i. pp. 100-102 (describes the amygdaloid of Poucham [probably Poccombe], Upton Pyne,¹ and Thorverton).

1821. Rev. J. J. Conybeare. On the Geology of the neighbourhood of Okehampton, Devon ("memoranda on the Red Marle" at end); Annals of Philosophy, new series, vol. ii. pp. 165, 166 (describes the amygdaloid of Thorverton, Silverton, and Radden [Raddon Court] quarries).

1835. Sir H. T. De la Beche. "Note on the Trappean Rocks associated with the (New) Red Sandstone of Devonshire," Proc. Geol. Soc. vol. ii. (1833-8) pp. 196-8 (mentions the trappean rocks "near Tiverton, Thorverton, Silverton, Kellerton Park, Crediton, and Exeter," and gives the geological history of those at Washfield, near Tiverton).

1839. Sir H. T. De la Beche. Report on the Geology of Cornwall, Devon, and West Somerset (Geol. Survey Memoir) pp. 199-204, 211, 212, 215, 216, 489.

1839? (no date). One-inch Geological Survey Maps, Sheets 21, 22, 24, 26 (almost all the important exposures are included in Sheets 21 and 22).

¹ Later observers do not mention Upton Pyne. I have not visited the locality.

1865. W. Vicary, F.G.S. On the Feldspathic Traps of Devonshire. Trans. Devon. Assoc. vol. i. pt. iv. pp. 43-49 (gives additional localities and fuller details of the macroscopical characters of the rocks).

1890. R. N. Worth, F.G.S. The Igneous Constituents of the Triassic Breccias and Conglomerates of South Devon. Quart. Journ. Geol. Soc. vol. xlv. pp. 69-83.

1892. W. A. E. Ussher, F.G.S. Permian in Devonshire. Geol. Mag. pp. 247-250.

The present paper is the result of a visit to the localities in July 1890.

The most satisfactory accounts of the Devon 'felspathic traps' are contained in the above-cited report of De la Beche, in Mr. Vicary's paper, and in Dr. Hatch's notes to Mr. Ussher's paper. As is well known, they are a series of volcanic rocks, of post-Carboniferous age, which are exposed at numerous localities in the south of the county. All those *microscopically* described in the present paper, except the rock of Killerton, N.E. of Exeter, are olivine-basalts.

II. EVIDENCE OF THE CONTEMPORANEOUS (NON-INTRUSIVE) CHARACTER OF THE ROCKS.

Sir Henry De la Beche held them to be "sections of erupted igneous matter contemporaneously intermingled with the red sandstones and conglomerates with which they are associated."¹ Mr. Vicary, on the contrary, states that they "commonly appear as dikes, filling fissures in the earlier rocks."² The following considerations lead me to take De la Beche's view rather than Vicary's.

1. At Washfield the rock is, as Mr. Vicary himself states, "vesicular throughout." I observed vesicles over 2 inches long, and the whole rock is as full of cavities as a sponge. At "Beere, Thorverton, Rew, and the neighbourhood of Silverton" the rock is, as Mr. Vicary says, "more or less vesicular from top to bottom of the present workings." In almost every other case the top or bottom of the lava or both are vesicular.

2. In some cases, as at Pocombe, and, according to De la Beche,³ between Ide and Dunchideock, the basalt intervenes between the underlying Carboniferous and the overlying Permian (or Triassic) rocks. This is most naturally explained by supposing it to have been erupted to the (probably sub-aqueous) surface in the interval between the deposit of the under- and the overlying rocks.

3. The lavas usually form horizontal or nearly horizontal beds, not vertical or highly inclined dykes. At Killerton, Dunchideock, and Posbury these beds are in each case many acres in extent, and at Western Town Mr. Vicary "caused a pit to be dug in the trappean floor of the quarry and beneath it found a layer of hard sandstone."

4. According to De la Beche,⁴ "along the range of the igneous rocks, particularly on the north, a sand occurs, here and there

¹ Report, p. 201.

³ *Ibid.* p. 203.

² *Op. supra cit.* p. 46.

⁴ Report, p. 200.

mingled with the more common red sandstone, which bears a very great resemblance to a volcanic product."

The Rev. A. Irving¹ says:—"What I have seen in the field, particularly in the Crediton Valley, referred to in my 1888 paper (p. 159), points to the existence of true volcanic agglomerates forming locally integral portions of the Breccia series." Tuff is mentioned by Prof. Bücking, in Mr. Ussher's paper, as occurring at Yeoton, near Crediton. I was unfortunately prevented by the bad weather from properly examining the quarry there.

5. There is a very close agreement in mineral composition and both macroscopic and microscopic characters between the rocks of all the localities, except Killerton and Long Lane, Loxbear, so that, as many of the rocks are clearly contemporaneous, the probabilities are all in favour of the rest being so.

I therefore feel no doubt of the contemporaneous nature of the lavas exposed in all the localities visited, without for a moment denying the probability that the necks by which they ascended may be hidden beneath the surface-flows; indeed, De la Beche² figures dykes of 'felspathic trap' at Cawsand in Plymouth Sound intrusive in Devonian rocks, though the evidence that the trap there is of Permian (or Triassic) age is not quite conclusive, and I agree with the opinion expressed to me personally by Mr. Worth that the schistose dyke figured by De la Beche on p. 279 of the Report is most probably of much earlier age than, and quite distinct in character from, the main mass of the Cawsand 'trap.'

As mentioned by Mr. Vicary, "it is a fact of large generality that the strikes of the two formations [trap and Trias (or Permian)] coincide in direction." Examples of this occur at Silverton, Thorverton, Pocombe, &c. The greatest length of outcrop also usually coincides with the direction of strike, but this does not seem to me to be any reason for doubting the contemporaneous nature of the 'trap.' It appears to me that whether a rock be sedimentary (*e.g.* the Millstone Grit 'edges' of Derbyshire), contemporaneously interbedded igneous rock, or igneous rock intruded along bedding-planes, it will naturally tend to have its greatest length of outcrop in the direction of strike, as soon as it is tilted out of the horizontal and denudation sets in.

III. IMPROBABILITY OF THE FORMER EXISTENCE OF THESE LAVAS IN THE AREA OF THE DARTMOOR GRANITE.

Mr. R. N. Worth, having adopted the theory that the granite of Dartmoor and the elvans in its neighbourhood are the relics of the base of a gigantic volcano, argues³ in favour of the previous existence

¹ 'Suppl. Note to Paper on the Red Rocks of the Devon Coast Section (Quart. Journ. Geol. Soc. 1888),' Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 76.

² Report, p. 212; see also R. N. Worth, Trans. Roy. Geol. Soc. Cornw. 1886, p. 228, &c.

³ Quart. Journ. Geol. Soc. vol. xlv. (1890) p. 80.

of 'felspathic traps' in the Dartmoor granite area from the fact that in the Triassic (or Permian) breccias near "Dawlish and Teignmouth and thence to the southward" fragments known to be of Dartmoor origin are associated with undoubted 'felspathic-trap' fragments. He says, "The fact that these fragments came from the direction of Dartmoor, coupled with the absence of any locality between Teignmouth and Dawlish and their vicinities and Dartmoor whence they can have come, thus points directly to Dartmoor itself as their source."

The objections to this view appear to me very strong, namely:—

1. It seems to be a *non sequitur*, as there is no necessity for believing that the granitoid and 'felspathic-trap' fragments came from one and the same area; and there is plenty of 'felspathic trap' in place near Dunchideock, $7\frac{1}{2}$ miles north-west of Dawlish.

2. Almost all the 'felspathic traps' being olivine-basalts, they cannot be the effusive equivalents of granite.

3. No necks or dykes of 'felspathic trap' are known to penetrate the Dartmoor granite.

4. It is highly improbable that the granite of the core and the lavas of the surface of the supposed volcano were simultaneously exposed to denudation.

5. The alleged facts with regard to the existence of quartz-porphyrries among and also intrusive in the 'felspathic traps' of undoubted Permian (or Triassic) age will be shown in a subsequent part of the present paper to be at least very doubtful.

It is true that Mr. Ussher mentions a "quartz-porphyry giving place upwards and outwards to a rock resembling a mica andesite"¹ associated with the Thurlstone New Red outlier, and Mr. Worth himself describes a "trachytic quartz-felsite" passing into a "rhyolitic pitchstone" as occurring at Withnoe, in Whitesand Bay, and "undoubtedly continuing to a junction in depth with the main mass"² of the 'trap' of the Cawsand New Red outlier, but the evidence that these rocks belong to the same series as the 'felspathic traps' is not quite conclusive.

IV. INTRUSIVE DYKES IN SUPPOSED NEW RED TRAP NEAR PLYMOUTH.

[Since the present paper was read, the writer has visited the Plymouth district, and hopes shortly to be able to publish more precise information on the subject.]

Meanwhile the following notes, based on field observation only, may be of interest. The main mass of the Cawsand rock is red or pinkish, and contains a good deal of brown mica. The evidence in favour of its Permian (or Triassic) age is its macroscopical resemblance to some of the weathered olivine-basalts of that age (this is not worth much) and the occurrence at Sandway Point (6-inch map,

¹ *Op. supra cit.* p. 249.

² 'Additional Notes on the Cornish Trias,' Trans. Roy. Geol. Soc. Cornw. 1891, p. 338.

Cornwall, 55 N.W.), a few yards north of the Cawsand rock, of an outlier of New Red breccia.¹

One of the most remarkable points about the Cawsand rock is the presence everywhere in it of macroscopically evident flow-structure. The Withnoe rock, described by Mr. Worth, is exposed in a small quarry on the east side of Cliff Lane, leading southwards from Withnoe to the cliffs of Whitesand Bay (6-inch map, Cornwall, 54 N.E.). It certainly resembles the Cawsand rock macroscopically, and shows the same evident flow-structure, which is vertical or highly inclined. The same Withnoe rock is much better exposed in a quarry 450 yards S. 35° W. of the five cross-roads at Withnoe, a few yards north of the "Old Quarry" on the 6-inch map, on the N.E. side of the military road running along the cliffs. Here it is seen to be intrusive in the Devonian slates, but the most interesting point is the occurrence in this quarry of four dykes (perhaps not all separate) from 1 to 4 feet wide, of *apparently* quartz-porphyry intrusive in the Withnoe rock, cutting across the almost vertical flow-structure. The quartz-porphyry is pinkish grey to purplish, with phenocrysts of sanidine-like feldspar (measuring as much as $1 \times \frac{1}{2}$ inch), kaolinized feldspar, dark mica, and quartz in a compact groundmass.

V. OTHER ALLEGED INTRUSIVE DYKES IN THE LAVAS.

Mr. R. N. Worth remarks with regard to the 'felspathic traps,' "They are traversed at so many points by felsitic dykes that this association has a constant and not a merely casual character. Mr. Vicary noticed these dykes and their strong resemblance to elvan courses, though, as 'a matter of convenience,' calling them sandstone."²

As a matter of fact, I believe that there are no felsitic dykes traversing the undoubtedly Permian (or Triassic) 'felspathic traps,' but I have not examined every exposure minutely enough to assert positively that there are none. The so-called felsitic dykes are nothing but exceedingly calcareous sandstone-veins, or veins of calcite stained red. Such veins are of common occurrence in rocks erupted sub-aqueously and overlain by sandstones.³

I observed these veins at Posbury, Raddon Court, Orchard Copse at Dunchideock, and at Pocombe. They vary from pink to brick-red in colour, and from a fraction of an inch to 3 inches in breadth. In some cases compact-looking, in others, *e. g.* at Posbury (No. 929D), they show sand grains when examined with a lens. These grains

¹ W. Pengelly, *Trans. Devon. Assoc.* vol. ix. (1877) p. 418; R. N. Worth, *Trans. Roy. Geol. Soc. Cornw.* 1886, p. 231.

² 'The Igneous Constituents of the Triassic Breccias,' &c., *Quart. Journ. Geol. Soc.* vol. xli. (1890) p. 80.

³ See A. Geikie, *Explanation of Sheet 14* (p. 13) and *Sheet 13* (par. 5), *Geol. Surv. Scotland*; also in *Geol. Mag.* for 1886, p. 244, *Anniversary Address to Geol. Soc.* 1892, p. 82 (p. 58 of separate copies), 'Text-book of Geol.' 1885, p. 549; and R. D. Irving, 'Copper-bearing Rocks of Lake Superior,' *U. S. Geol. Survey Monograph*, 1883, pp. 137-140.

were seen under the microscope to be chiefly angular quartz.¹ In order to make quite certain, a fragment of No. 929 D was roughly powdered, dissolved (with strong effervescence) in HCl, and the specific gravity of the isolated grains was determined. It agreed with that of quartz.

VI. LIST OF LOCALITIES EXAMINED.

As many of the quarries in which the 'traps' are exposed are no longer worked, are much overgrown, and tend to become obliterated, I give a list of those examined by me, with exact indication of their position, premising that the numbers preceding each locality are firstly a number for reference in the subsequent petrographical description, and secondly, the number of the quarter-sheet of the 6-inch Ordnance Survey maps (pub. 1887-90) on which they are indicated.

No. 889 (34 S.W.). Washfield, $2\frac{1}{8}$ miles N. 35° W. of Tiverton. Quarry in Mousebeare Lane, 383 yards west of church.

No. 891 (34 S.W.). Exposure in roadside, Long Lane, 1325 yards S. 28° E. of Loxbear Church, N.W. of Tiverton, and 392 yards west of lane turning down to Lurley.

Nos. 895 A, 895 B, 896, 897, 898 (56 S.W.). Raddon Quarry, 1733 yards S. 84° W. of St. Thomas à Becket's Church, Thorverton, 6 miles north of Exeter.

Nos. 899 A, B, C, & D (68 N.E.). Quarry in Quarry Lane, Lower Budlake, 6 miles N. 37° E. of Exeter, 667 yards east of Killerton (house).

No. 900 (68 N.E.). Killerton Park, $5\frac{1}{2}$ miles N. 33° E. of Exeter. 'Old Quarry' on east side of park, 705 yards N. 25° E. of Killerton (house).

No. 901 (68 N.E.). Old quarry at 'Remains of Camp,' Dolbury, Killerton Park.

No. 902 (68 N.E.). Old quarry, 127 yards S. 61° W. of northern lodge, Killerton Park.

No. 903 (68 N.E.). Quarry at Dunsmoor (Densmoor), 1302 yards south of St. Mary's Church, Silverton (Silverton is $6\frac{2}{3}$ miles N. 17° E. of Exeter).

No. 904 (68 N.E.). Quarry (Rew Quarry?), on road from Silverton southward to Rew, 600 yards N. 81° W. of Heazille Barton.

Nos. 906, 906 A (68 N.E.). Quarry in Columbjohn Wood, 1008 yards N. 83° W. of Killerton.

No. 907 (68 N.E.). Moss-grown quarry, 195 yards N. 83° W. of Killerton.

No. 908 A (68 N.E.). Old quarry at Beare Farm, 1575 yards N. 58° E. of Killerton.

No. 909 (56 S.E.). Old quarry (now a pond) in the grounds of Silverton Park (Combe Sacheville), 195 yards west of house.

¹ The appearance of the section is quite like pl. xi. of R. D. Irving's monograph, 'The Copper-bearing Rocks of Lake Superior.'

No. 911 (80 S.W.). Old quarry, 108 yards west of Barley House, $1\frac{1}{2}$ mile S. 75° W. of Exeter.

Nos. 912 & 912 A, B, C (79 S.E.). Knowle Quarry, $3\frac{5}{8}$ miles S. 54° W. of Exeter, 1000 yards S. 75° E. of Darniford (house).

No. 913 (79 S.E.). West Town Quarry, 1245 yards S. 87° W. of St. Ida's Church, Ide, near Exeter.

Nos. 914, 914 A (91 N.E.). Quarry behind Webberton Cottages, 467 yards N. 81° W. of Haldon House, near Dunchideock, S.W. of Exeter.

No. 915 (91 N.E.). Old quarry by roadside in 'School Wood' or 'Great Plantation,' 703 yards N. 66° W. of Haldon House.

No. 916 (91 N.E.). Old quarry in Orchard Copse, 203 yards N. 62° W. of Holy Trinity Church, Dunchideock.

Nos. 918 A, B, C, D (80 S.W.). Large quarry at Pocombe, close to Crossmead, $1\frac{1}{2}$ mile S. 60° W. of Exeter (cathedral).

No. 919. Old quarry at West Clist ($3\frac{5}{8}$ miles N. 60° E. of Exeter), opposite road turning off to Poltimore Park.

Nos. 928 A & B (65 N.E.). 'Stone Quarry,' 545 yards N. 40° W. of Crooke, and about 1 mile E.S.E. of North Tawton.

Nos. 929 A, B, & C (67 S.W.). Large quarry, 220 yards N. 54° E. of St. Luke's Chapel, Posbury, near Crediton.

VII. MACROSCOPICAL AND MICROSCOPICAL CHARACTERS OF THE ROCKS.

Most of the 'felspathic traps' examined by me are altered olivine-basalts, but the rock of Killerton (Nos. 900, 901, 902, 907) is an altered andesite, and appears to differ from that at Columbjohn Wood (No. 906) on the west and of Lower Budlake (No. 899 A, &c.) on the east of it, although the Geological Survey map makes of them all one continuous mass.

(a) *Altered Olivine-basalts.*

These would be termed melaphyres according to the nomenclature of Prof. Rosenbusch,¹ but since it is now pretty generally admitted that the pre-Tertiary geological age of an igneous rock is no sufficient reason for giving it a different name, and since the use of the term 'melaphyre' for an altered basalt² or olivine-basalt³ only tends to conceal the relationship of basaltic rocks, I prefer to call them basalts.

Although on the whole there is a considerable resemblance between the macroscopical characters of the 'traps' from the different localities, yet the appearance of the rock varies so much even in one and the same quarry, according to whether the freshest non-vesicular or the most altered and amygdaloidal specimens are taken, that no one description will apply to all cases.

Type 1. Freshest non-vesicular rocks. Their colour varies from

¹ Mikr. Physiogr. d. Massig. Gest.' 2nd ed. 1887, pp. 484, 506.

² F. H. Hatch, 'Introduction to the Study of Petrology,' 1891, p. 112.

³ G. A. J. Cole, 'Aids in Practical Geology,' 1891, p. 237.

dark reddish to bluish purple, frequently resembling that of some specimens of Cambrian slate from Penrhyn Quarry, North Wales. Texture almost compact, with here and there a porphyritic plagioclase (Nos. 912 A, 913, 914, 915, 928 A & B, 929 A & C). Quartz inclusions are abundant in some specimens, as in Nos. 912 A, 913, 928 A & B, and present in Nos. 914, 915, 929 A & C. In the case of the four rocks just mentioned, ferruginous pseudomorphs after olivine are visible.

Type 2. Light reddish or pinkish purple to brown weathered rocks, full of vesicles drawn out in the direction of flow. Specimen No. 889 is as vesicular as a sponge, and is crowded with small red or yellow pseudomorphs after olivine. Specimens No. 897 (from upper surface of bed) and No. 908 B do not contain such large vesicles as No. 889, and few pseudomorphs are visible in them.

Type 3. This includes the great majority of the specimens, which are evidently weathered rocks varying from dark purplish red to lilac or pinkish in colour, sometimes very amygdaloidal, as in No. 912 B (within 3 feet of the upper surface of the bed) and No. 904, but often with few or no amygdules. Reddish pseudomorphs after olivine are often visible, *e.g.* in Nos. 899 A & B, 916, 918 A, B, & D, 929 B.

As to the microscopical character of these rocks, their structure is porphyritic in the sense of Rosenbusch.¹

Phenocrysts.—Olivine and in some cases plagioclase. Brown mica in No. 889.

Groundmass.—Plagioclase. Augite in Nos. 914, 915. Magnetite or ilmenite. Brown mica in No. 889.

(i) *Olivine Phenocrysts.*—Unaltered olivine, colourless in thin section, does not occur. The olivine has in most cases undergone the alteration described by Rosenbusch,² it is “changed to a red transparent substance of laminated structure and mica-like habit; the lamellæ appear to lie parallel to the brachypinacoidal (010) cleavage-cracks. The substance is very distinctly pleochroic, and absorbs rays vibrating parallel to the lamination much more strongly than those perpendicular to it. The colour of this substance is intermediate between that of specular iron ore and that of pseudobrookite” [translation]. The change just described is very well shown in Nos. 928 A, 914, and 929 A.

The pseudomorphs are often a dark reddish-brown in colour and semi-opaque. In some cases the margin consists of magnetite, as in Nos. 909, 911, 918 A. Sometimes almost the whole of the original crystal is replaced by a granular aggregate of a zeolite showing the grey interference-colour of the first order, as in No. 918 D, and accompanied by calcite in No. 929 A. The pseudomorphs in No. 928 A consist of calcite with a reddish-brown margin of the material before mentioned, described by Rosenbusch.

Section 929 A illustrates excellently every intermediate stage between forms 1·15 millim. in diameter with reddish-brown trans-

¹ *Op. supra cit.* p. 340.

² *Ibid.* p. 489.

lucent margin and calcite centre (evidently pseudomorphs after idiomorphic olivine), and minute patches 0·09 millim. in diameter or less, with a black margin of magnetite, having sometimes the outline of an olivine crystal, but often irregular and occupied by calcite in the centre with irregular bands of magnetite across it. The same transition is visible in No. 916. These minute pseudomorphs are plentiful in Nos. 929 B, 912 A, 912 C, 913, 928 B, 895 B, &c.

The pseudomorphs after olivine are frequently corroded by the groundmass, and very irregular fantastic forms thus arise, as in Nos. 928 A and 916, so that almost all trace of idiomorphism may be lost. In nearly every case the pseudomorphs are fairly abundant, though, as their size is not generally large, they hardly make up a notable percentage of the rock. The maximum size observed was 3·97 millim. in diameter in No. 928 A, but the usual size is about 0·8 millim. $\times$ 0·4 millim. in the case of the more obvious pseudomorphs, and about 0·09 millim. diameter in the case of the numerous small magnetite pseudomorphs.

The only section in which olivine pseudomorphs were not made out was No. 906 A, and it is uncertain whether they are not present in that case as minute magnetite pseudomorphs, since they are present in No. 906.

(ii) *Plagioclase phenocrysts* are present in Nos. 912 A, B, & C, 913, 914, 915, 928 A & B, 929 A & B. They give in general nearly square sections, but are never abundant. Though they are idiomorphic, they have been both corroded by the groundmass so as to alter their external contours and minutely honeycombed by the interstitial matter. In some cases the whole interior is honeycombed, in others a central patch remains free from attack, but in nearly all examples there is a narrow outer margin free from honeycombing. I take the explanation of this to be that the crystals were formed in the intratelluric period, that owing to the relief of pressure upon the rise of the rock to the surface they were corroded and honeycombed (as relief of pressure acts like increase of temperature), and lastly, as the rock cooled slowly the crystals renewed their growth, though not vigorously enough to obliterate the traces of the corrosion of their contours.

Brown mica occurs sparingly in No. 889. It is corroded and surrounded by hæmatite grains (probably altered magnetite due to resorption).

Groundmass.—Plagioclase is by far the most important constituent of the groundmass. It occurs in forms giving mostly lath-shaped sections. The largest average size of the crystals observed was in No. 904, namely, 43 millim. $\times$ 0·09 millim.

The only sections (except Nos. 928 A & B) in which augite occurs in the groundmass are Nos. 914 and 915. In both cases it is distinctly ophitic, but on a very microscopic scale, the allotriomorphic crystals having an average diameter of 0·08 millim. and being usually penetrated by only a single felspar. Traces of augite are seen in Nos. 928 A & B. Calcite, most probably replacing augite, occurs in Nos. 896; 918 A, 928 A & B, 929 A & B. It is accompanied by

chlorite in No. 909, and chlorite, probably replacing augite, occurs in Nos. 903, 904, 906, 919.

Brown mica occurs in the groundmass of No. 889.

Magnetite is very abundant; indeed, it often occupies the greater part of the angular spaces between the felspars, especially in the less crystalline portions of the rocks, usually near the upper or lower surface, *e. g.* in Nos. 897, 906 A, 908 A, 911, 918 D. It is very generally altered to reddish ferruginous matter, which gives most of the rocks a reddish colour even in the thinnest sections.

Bronzite is mentioned by Prof. Bücking¹ as a constituent of the rock of Dunchideock (locality not more precisely given). I have not observed it in any of the specimens that I have examined.

Amygdules are very common. They are most frequently occupied by calcite or by zeolites (showing a grey interference-colour of the first order) or by both.²

(b) *Quartz Inclusions.*

As already mentioned, these occur in Nos. 912 A, 913, 914, 915, 928 A & B, 929 A & C, also in 912 B. They vary in size, from 2 to 3 millim. diameter and less, are usually of a rounded form, and are encircled by a rim of small augite-crystals, often obscured by secondary calcite. Each inclusion consists as a rule of a single individual, but aggregates of numerous individuals with interlocking margins, as in a quartzite, occur, *e. g.* in No. 912 C. The evidence in favour of regarding these quartz-crystals as inclusions is:—

1. The basic nature of the rock, shown by the presence of olivine and plagioclase.
2. The rounded form of the crystals.
3. The presence of reactionary rims of augite-crystals.
4. The complete want of any uniformity in the distribution of the quartz-crystals throughout the rock, which is in some places rich in them, in others free from them.
5. The fact that the rocks are interbedded with sandstones, whence the quartz could be obtained when the rock was erupted through the underlying beds.
6. The most convincing proof is the presence at Knowle Quarry (No. 912) of an oblong eye of quartz about 3×1 inch embedded in the rock. I have the specimen in my possession.

I am aware that Mr. J. S. Diller does not regard points 1 to 3 as proof that quartz is not (in some cases) an original constituent of basalt; indeed, they are all present in the case of the quartz-basalt of Cinder Cone, 10 miles N.E. of Lassen's Peak, California, which he describes,³ and with a section of which I have compared the Devon basalts, but when combined with points 3 to 6 the evidence appears convincing.

¹ In Mr. Ussher's paper, p. 248.

² In the 'Challenger' Report, Deep-sea Deposits, 1891, pl. xviii. fig. 4 gives a good idea of the zeolites in No. 928 B, and figs. 2 and 3 of those in No. 929 A.

³ 'A late Volcanic Eruption in Northern California and its peculiar Lava,' Bulletin U.S. Geol. Survey, No. 79 (1891), pp. 24–28.

The presence of quartz (or 'glassy feldspar') in the rocks of Stone, Knowle, and Western Town is mentioned by Mr. Etheridge in Mr. Vicary's paper before cited. It was previously noticed by De la Beche as follows¹:—"Above Ideston and Knole we find porphyries sometimes containing crystals of quartz, at others of felspar, and occasionally of both together—a very interesting fact, inasmuch as it is the only locality with which we are acquainted where any portion of those quartziferous porphyries, of which fragments are so commonly found in the red conglomerate between Exeter and Teignmouth, occurs in place;" and again (p. 217) "the quartziferous porphyry near Dunchideock." I hold that De la Beche was misled by the quartz inclusions in these basalts into regarding them as quartz-porphyries.

A mass of genuine quartz-porphyry measuring about 4 feet $\times$ 1 foot is exposed on the west side of the road opposite to the entrance-gate of Dunchideock House, but it appears to belong to the New Red Breccia.

Dr. Hatch has described² some of the rocks which I term olivine-basalts as porphyrites (andesites), viz., Western Town, Ide (his No. 943 = my No. 913), Quarry N.E. of Knowle, N.E. of Holcombe-Burnell (his No. 946), and Knowle Quarry, W. of Dunchideock (his No. 949). It is difficult to identify the localities of Nos. 946 and 949. If the Geological Survey and 6-inch Ordnance maps are to be trusted, there is no 'trap' N.E. of Holcombe-Burnell. Probably S.E. of Holcombe-Burnell is meant, in which case Dr. Hatch's No. 946 is probably the same as my No. 912. No 'Knowle Quarry' is shown on the maps W. of Dunchideock. Probably that at Orchard Copse (my No. 916) is meant.

Obvious pseudomorphs after olivine phenocrysts are plentiful in No. 916, but in No. 913 only one *red* pseudomorph 0.47 millim. in diameter and in No. 912 B only two above 0.3 millim. in diameter are present, though smaller ones are numerous in No. 912 B; but in Nos. 912 A, B, C, and 913 magnetite pseudomorphs about 0.09 millim. in diameter, which I take to be after olivine (as previously described), are abundant.

The rock of Long Lane, Loxbear (No. 891), differs so much from the rest as to deserve separate description. The hand-specimen is whitish and very micaceous. Microscopically the rock is seen to contain pseudomorphs after idiomorphic olivine, consisting of brownish alteration-products outlined by black opaque iron ore; brown mica (very abundant), apatite in short prisms, much opaque iron ore, and felspar. The mica is often allotriomorphic towards the felspar, but sometimes the reverse relation appears to obtain. It is very full of inclusions of hæmatite, black as seen under a low, but red translucent under a high power, often arranged in a series of lines crossing one another at about 60° as seen in a basal pinacoid section. These are probably pseudomorphs after magnetite, as

¹ Report, pp. 203, 204.

² Notes to Mr. Ussher's paper, *Geol. Mag.* for 1892, p. 250.

is much of the iron ore in the rest of the rock. Although some of the felspar is undoubtedly plagioclase, I am uncertain whether it is all so.

(c) *Mica-augite-andesite of Killerton.*

This rock would be termed mica-augite-porphyrite by Rosenbusch. I can hardly describe it better than by saying that it looks like a minette, but is lighter in colour than most minettes. Specimen No. 907 is very micaceous, and the abundant small glistening flakes of mica have the same brown colour as the compact groundmass. Specimens Nos. 900, 901 are bluish to purplish grey and contain the same brown mica much less abundantly. Specimen No. 902 is light purplish grey, with comparatively few visible flakes of mica and numerous small narrow elongated cavities. Sp. gr. 2·57.

Phenocrysts occur of augite, brown mica, apatite, and iron ores. Groundmass of felspar.

The augite phenocrysts are almost colourless or faintly greenish, 0·5 millim. in diameter or smaller, and are often partly altered to calcite. Brown mica is abundant. In one case it was included in the augite. On the other hand it frequently contains apatite and iron-ore inclusions. Apatite occurs in numerous small crystals, and iron ore is generally distributed.

Mr. Edward Haworth has kindly made for me in the Chemical Laboratory of Owens College the following analysis (A) of the rock, No. 900 :—

	A.	B.
SiO ₂	48·37	51·20
Al ₂ O ₃	20·74	20·03
Fe ₂ O ₃	6·56	7·57
FeO	·63	
MgO	6·35	6·75
CaO	7·77	10·52
Na ₂ O	1·70	1·71
K ₂ O	—	0·51
H ₂ O	1·60	1·70
P ₂ O ₅	·94	—
CO ₂	6·00	—
	100·66	99·99

It is evident from analysis (A) that the felspar of the groundmass is plagioclase. The analysis (B) is that of the Morpeth dyke, Morpeth, Northumberland, by Mr. Stead, of Middlesbrough, quoted from Teall, 'British Petrography,' 1888, p. 206, for comparison.