THE
GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. III.

No. V.—MAY, 1916.

ORIGINAL ARTICLES.

I.—THE PETROGRAPHY OF ARRAN.

3. PITCHSTONE XENOLITHS IN BASALT DYKE, DIPPIN, ARRAN.¹

By G. W. TYRRELL, A.R.C.Sc., F.G.S., Lecturer in Mineralogy and Petrology,
University of Glasgow.

THE phenomenon of which this paper treats occurs in a basalt dyke exposed in a small quarry by the roadside north-east of Dippin, near the twelfth milestone from Brodick. This dyke runs from north-west to south-east, and is intrusive into the great teschenite (or crinanite) sill of Dippin. It is probably the one referred to in the Geological Survey Memoir on North Arran, South Bute, and the Cumbraes (1903), p. 119. It averages 12 feet in thickness, although it is extremely irregular, owing perhaps to the difficulty experienced in penetrating the tough, coarse, massive rock of the sill. The contacts are not plane, but abut against the crinanite in a very intricate manner, sometimes along vertical or horizontal joints, sometimes along irregular surfaces unconnected with jointing. Both contacts show thin films of tachylite, which, as the rock is quarried, are left adhering to the irregular surfaces of the sill rock. Another dyke-like mass, 1 foot thick, is seen in the same quarry, and is doubtless an offshoot from the larger dyke.

Within a foot of the northern contact of the larger dyke there are found enclosed several lumps of brown and black glassy rocks containing a few large white crystals of felspar. These lumps range from 1 to 3 inches in diameter, and are each surrounded by a thin film of tachylite, while small clots of a black glass are to be found in their vicinity. Other xenoliths found near by consist of a medium-grained crystalline rock resembling the crinanite of the Dippin sill. These are larger than the glassy xenoliths and are quite evidently affected by heat. They are also surrounded by a skin and sometimes clots of tachylite.

The Dyke.—The dyke belongs to a distinctive group of the Tertiary north-west dykes, which appears to be abundantly distributed about the Clyde Estuary. These dykes have frequently been called 'basaltic andesite' or 'andesitic basalt', and are distinguished by containing beautifully fresh phenocrysts of anorthite or bytownite, in a ground-mass composed of laths of labradorite, augite frequently intergrown with enstatite or hypersthene, and an abundant mesostasis

¹ The first two papers of this series appeared in the GEOL. MAG., Dec. V, Vol. X, pp. 305–9, 1913.

of dark glass. From their abundance in the island of Great Cumbrae, situated in the Firth of Clyde, it is proposed to distinguish them as the *Cumbrae* type of basalt. The Tynemouth dyke of the North of England appears to be an outlying member of the same series.

In thin section the rock from the centre of the dyke shows small but rather numerous phenocrysts of plagioclase feldspar which are occasionally euhedral, but are more often worn and corroded into curious irregular shapes. Whatever the shape, all the crystals possess a narrow marginal zone of different composition orientated similarly to the main mass. The transition between the two parts is usually quite sharp. The measurement of extinction angles shows that the crystals are bytownite (Ab_1An_9) with marginal labradorite. There are also a few phenocrysts of fresh enstatite, showing a good positive biaxial figure in basal section; and fewer still of a yellowish augite. The ground-mass is composed of zonal labradorite laths, intermixed with prisms of augite and grains of iron-ore, with an abundant mesostasis apparently of a feldspathic substance, crowded with black hair-like microlites, and probably representing a devitrified glass.

This rock is an andesitic basalt or basaltic andesite generally similar to the Tynemouth and Cleveland dykes of the North of England. Other dykes of the same character, with slight variations in texture, amount of glass, or abundance of phenocrysts, occur in the vicinity, cutting the Dippin sill and the adjacent Triassic sandstones.

Traced towards the margin of the dyke the rock becomes denser, and contains fewer and smaller feldspar phenocrysts. A specimen taken 3 inches from the margin shows a beautiful variolitic texture in thin section. The feldspars of the ground-mass are reduced to the size of large microlites, and are arranged in irregular radiating bundles or sheaves which involve numerous long prisms of augite and grains of iron-ore.

At the actual margin the rock is tachylytic for a thickness of $\frac{1}{4}$ inch. In thin section the glass is dark, opaque, and almost structureless, with only a few obscure microlites. It contains numerous small spherical amygdaloids of calcite, and a few small phenocrysts of labradorite with the usual rounded or irregular outlines indicating magmatic corrosion.

The Xenoliths.—The great majority of the xenoliths are of pitchstone. In thin section the bulk of this rock is seen to consist of a pure, almost colourless glass, in which hair-like microlites are aggregated into clots or patches, leaving large areas of glass absolutely free from microlites. The phenocrysts are of euhedral quartz, orthoclase, and andesine (Ab_5An_5). The effects of the heat to which this rock has been subjected are striking. Of the three principal minerals orthoclase has suffered the most, andesine much less, and quartz hardly at all. The orthoclase in all cases shows some degree of fusion, which has occurred around the margins and along the cleavages, producing a yellow or greyish glass which contrasts with the lighter glass of the ground-mass. The resulting shapes of the crystals are highly irregular; occasionally the crystal

is separated into two or three pieces by areas of fusion; but in extreme cases the crystal is represented by a 'ghost' in greyish glass, in which only minute shreds of the original orthoclase have survived.

The andesine crystals have apparently only suffered a little softening on the margins and fissuring in the interiors. The quartz has suffered least of all, as the crystals are only fractured. The fact that the broken pieces have occasionally floated away from one another is evidence that the glass of the pitchstone was rendered completely liquid by the degree of heat to which it was subjected.

Each xenolith is surrounded by a skin and sometimes clots of a black glass, which was at first regarded as a tachylyte of the same nature as that on the margins of the dyke. A thin section, however, shows that this material is really a colourless glass which is darkened by numberless lines, streaks, and patches of black dots, arranged with a perfect fluxional structure. The glass contains the same set of phenocrysts as the above-described pitchstone, but much smaller and fewer. Under a high-power objective the black dots which darken the glass are made out to be small, perfectly euhedral, hexagonal tablets of hæmatite, the larger ones translucent and of a blood-red colour.

The difference between this rock and the pitchstone it envelops may be explained thus: the xenoliths have not only been perfectly fused, but the pitchstone glass has intermingled to some extent with the more basic glass of the basalt in which the xenoliths were carried up, the admixture of basalt glass resulting in the formation of swarms of hæmatite microlites. The flow-structure may have been imparted by a rolling motion of the xenoliths, due to differential velocity of the central and marginal parts of the basalt dyke during intrusion. The xenoliths are found within one foot of the margin, where movement would be retarded by cooling and viscosity on the marginal side, whilst proceeding at a faster rate in the more liquid interior.

Conclusions.—The behaviour of the phenocrysts in the pitchstone xenoliths under the influence of heat gives some clue as to the temperature of the basaltic magma in which they were immersed. The orthoclase was partially or wholly fused to a yellow or grey glass, andesine showed signs of softening around the edges, whilst quartz simply suffered some degree of fracturing. The most trustworthy estimates of the fusion-points of rock-forming minerals have been made by A. L. Day and his collaborators in the Geophysical Laboratory at Washington.¹ That of quartz (or rather silica, since quartz is unstable above 800° C.) is given as 1,625° C.; of oligoclase-andesine ($Ab_2 An_1$) as 1,375° C. For orthoclase, however, we have to rely on the estimates of other experimenters.² The average of seven closely accordant estimates by Joly and Cusack, and Doelter, is 1,170° C. These figures are as would be expected from the effects produced by heat on these minerals. Orthoclase, which fuses at 1,170° C., has been converted into glass; andesine,

¹ Clarke, *Data of Geochemistry*, 2nd Ed., U.S. Geol. Surv., Bull. 491, p. 279, 1911.

² Iddings, *Igneous Rocks*, vol. i, p. 85, 1909.

fusing in the neighbourhood of $1,375^{\circ}\text{C.}$, has barely been affected; quartz, fusing at $1,625^{\circ}\text{C.}$, has only suffered fracturing. We may therefore conclude that the temperature of the basaltic magma during intrusion was between $1,170^{\circ}\text{C.}$ and $1,375^{\circ}\text{C.}$, excluding, as seems legitimate, any chemical reaction between orthoclase and the pitchstone glass. The ordinary basalt lava is fusible at about $1,100^{\circ}\text{C.}$, and this is perhaps the ordinary temperature of emission at a volcano, although Daly believes temperatures of $1,200^{\circ}\text{C.}$, or even $1,300^{\circ}\text{C.}$, may prevail in the great volcanoes of Hawaii at periods of intense activity.¹ The fusion of minerals and even rocks has been observed in basaltic magmas by Lacroix and others.² Independent evidence of high temperature upon intrusion in the case of the dyke in question is afforded by its tachylytic selvages. These are due to very rapid marginal cooling, and the rate of cooling depends directly on the difference between the temperature of the country rock and of the magma.

The occurrence of xenoliths of pitchstone in a Cumbræ type of basalt, which itself intrudes a sill of teschenite or crinanite, affords useful evidence as to the relative ages of these three groups of intrusive rocks. A pitchstone dyke with a felsitic centre cuts the Dippin crinanite near Torr an Loisgte, about $1\frac{1}{2}$ miles north-west of the quarry in which the xenoliths are found.³ This dyke trends in a north-west direction, and would therefore, if produced, appear in the vicinity of the quarry, beneath the crinanite sill. It is possible that fragments of this dyke have been brought up by the basaltic magma. The sequence of the three types in time is clearly, first the crinanite sill, then the pitchstone, and finally the Cumbræ basalt. Similar evidence from other parts of the island goes to show that the Cumbræ basalts were one of the latest manifestations of igneous activity in Arran, if not the latest.

II.—A NEW VARIETY OF THE AMMONITE *CÆLOCERAS DAVÆI*, FROM THE LOWER LIAS, DORSET.

By WYATT WINGRAVE, M.D.

(PLATE VIII.)

QUENSTEDT⁴ described three distinct varieties of *Ammonites Davæi*, with nine illustrations. They all belonged to the γ zone of Lower Lias:—

1. *Ammonites Davæi*, whose tubercles are somewhat clavate and with unsymmetrical prorsiradiate ribs.
2. *A. Davæi enodis* is continental. It is a small specimen without tubercles, with fine symmetrical and prorsiradiate ribs.
3. *A. Davæi nodosissimus* is also continental. This variety shows nine large bullate tubercles on each whorl, with close, fine, and symmetrically disposed flexiradiate ribs.

¹ *Igneous Rocks and their Origin*, 1914, p. 212.

² Lacroix, *Les Enclaves des Roches Volcaniques*, 1893, pp. 563-5.

³ A. Scott, "Pitchstones of South Arran": *Trans. Geol. Soc. Glasgow*, vol. xv, pt. i, p. 22, 1914.

⁴ Quenstedt, *Die Ammoniten des Schwäbischen Jura*, 1885.