D4 Hannaborough Quarry

[SS 529 029]

Highlights

This is one of the best exposures of a minette-type lamprophyre of the post-Variscan volcanics; an associated breccia has been variously interpreted as a vent agglomerate and as a debris-flow infill.

Introduction

The site occupies the old, disused, overgrown and partly water-filled quarry 2 km south-west of Hatherleigh. The most accessible part of the quarry is a small 5-m-high face that (photographed in better condition) is illustrated in the *British Regional Guide to South-west England* (Edmonds *et al.,* 1969; plate 8A).

The post-orogenic Stephanian–Permian volcanics of the Exeter Volcanic 'Series' can be divided petrographically and chemically into a basaltic group and a potassic group (Knill, 1969; Cosgrove, 1972). The latter includes K-feldspar-rich lamprophyres of the minette type, which are exhibited at the Hannaborough Quarry site. The site and the rock type has been described previously as representative of the lamprophyre group (Ussher, 1902; Tidmarsh, 1932; Knill, 1969), although it differs from other minette localities in being olivine-, as well as biotite-phyric. The other feature noted by previous workers is that fissures within the minette are filled with 'vent agglomerate', which quarrying in the past has left as a small knoll or peak within the northern face (Edmonds *et al.,* 1968).

The actual form and mode of emplacement of the Hannaborough minette is not clear. Tidmarsh (1932) referred to it as a lava flow, and it is generally depicted as such on geological maps, although the dominant and gently dipping 'floor joints' suggest a sheet-like intrusive body relative to the adjacent sediments. Magnetic and resistivity surveying (Edmonds *et al.,* 1968) suggest that the body is largely restricted to the quarry area, and that it is either a vertical neck (which is at variance with the subhorizontal tabular jointing) or truncated by faults.

Chemical data by Cosgrove (1972) showed that it has a composition similar to other lamprophyres in the Exeter area, being highly enriched in incompatible elements, especially those of the large-ion-lithophile group. On the basis of the highly potassic nature of these rocks generally, it was considered by earlier workers (Tidmarsh, 1932; Knill, 1969) that they were generated from basic/ultrabasic magma contaminated by K-rich fluids or materials, possibly related to the nearby Dartmoor Granite. More extensive chemical data (Cosgrove, 1972; Thorpe *et al.,* 1986; Thorpe, 1987; Leat *et al.,* 1987), however, have demonstrated that the lamprophyres exhibit a strong subduction-related chemical signature (for example, negative Nb–Ta anomalies) that is typical of many continental lamprophyric rocks.

Description

The minette is generally massive throughout, and in the present exposure does not exhibit features clearly indicative of a lava flow. However, in the vicinity of the 'vent agglomerate' peak, the minette shows concentrations of small, yellow sediment blocks that may have been derived from a thin (20–60 mm), subhorizontal, yellow, baked siltstone lens just below. The attitude of the sediment lens suggests that it might be the remnant of an interflow sediment horizon, rather than an inclusion, although this is open to question. The minette outcrop is stucturally dominated by strong, shallow-dipping (25–35°) joints, although there is no evidence to suggest they are related to the emplacement mode of the body.

One of the major features of this site is the presence of the coarse breccia that rests on the minette and has generally been considered to be a 'vent agglomerate'. A number of east–west-trending fissures in the minette are filled with the breccia, the most prominent of which can be traced for about 85 m west of the quarry (Edmonds *et al.,* 1968). Whether this breccia is really a volcanic agglomerate filling a small vent cut through the minette, is questionable. The breccia appears to cut down into the minette along a sharp, but irregular junction, which is probably an erosion surface. The breccia fragments are mainly angular, poorly sorted (<0.10.15 m in size), baked mudstones, laminated siltstones and fine sandstones in a reddish clay matrix. It is predominantly a chaotic, matrix-supported deposit, with only crudely developed layering near at the base, and could represent a sediment-rich debris flow. Lamprophyre clasts are virtually absent, although Tidmarsh (1932) suggested the clay matrix might have been originally devitrified glass.

The pale, purplish-grey, non-vesicular, fine-grained lamprophyre is an olivine–biotite-phyric minette that has been variably oxidized and altered. The matrix is often obscured by secondary hematite, carbonate and clays, although primary minerals, either observed or inferred, are olivine, K-feldspar, biotite, apatite and possibly plagioclase. Phenocrystic olivine is always replaced by hematite–carbonate (seen as red spots in hand specimen), whereas biotite may be corroded and partially replaced by chlorite. Rounded and apparently corroded quartz xenocrysts are also present, and these probably represent disrupted sandstone clasts incorporated by the magma upon emplacement.

Interpretation

The site is representative of the minette-type of lamprophyre of the Exeter Volcanic 'Series' potassic group. However, it is atypical in that it also contains phenocrystic olivine, unlike the more normal biotite-phyric minettes of the Exeter area. Whether the minette body here is intrusive or extrusive is not clear, although it is generally assumed to be a lava flow, as inferred from its very fine-grained nature and subhorizontal baked sediment interlayers. It has also suffered extensive oxidation, with the production of hematite that gives the body its predominantly reddish-purple colour. Comparison with similarly reddened, but proven lavas in the general area, suggest this could have been due to subaerial weathering during the Permian.

Of questionable status is the so-called 'vent agglomerate' that rests on the minette. The chaotic nature of the deposit and its composition suggest that it is a sediment-dominated debris-flow deposited on a pre-existing erosional surface of the lava, rather than a volcanic vent blasted through the body and subsequently filled with debris. Under New Red Sandstone environmental conditions, such debris flows deposited by flash floods would have been common, scouring and transporting local sediments and subaerial flows alike.

In common with the Exeter Volcanic 'Series' potassic group, the minettes of the local area (and elsewhere in South-west England), exhibit a LIL-enriched chemistry similar to lavas found in a subduction-dominated tectonic setting. In this sense they are similar to other, earlier, continental lamprophyres as seen in the Caledonides of northern Britain (Macdonald *et al.,* 1985), that were generated in a similar, post-tectonic environment. Previous ideas that the high large-ion-lithophile enrichment of these rocks was due to the specific involvement of a facies of the potassic Dartmoor Granite are no longer considered to be viable (Floyd *et al.,* 1983). More recent petro-genetic models for the potassic group involve the melting of subcontinental lithosphere previously enriched via a subduction process (Thorpe *et al.,* 1986). On the other hand, Leat *et al.* (1987) suggest that another source for Cornubian post-collision minettes could have been highly variable lithosphere (different aged crust and mantle) downthrust during ocean closure and crustal shortening. Hydrous melting of this chemically heterogeneous material would have generated incompatible-element-enriched potassic melts distributed over a wide area of the resulting fold belt. On the basis of chemical studies of potassic lavas and lamprophyres elsewhere (for example, Backinski and Scott, 1979), it seems more likely, that the specific enrichments exhibited by the Cornubian minettes were a consequence of source enrichment processes rather than subsequent involvement by the Dartmoor Granite or its fluids. It seems likely, therefore, that they were generated by the melting of mantle that had been metasomatically enriched in LIL elements during a previous subduction episode, rather than via some form of crustal contamination process.

Conclusions

This old quarry shows evidence for volcanic eruptions during the Permian Period, that is around 280 million years before the present. Here a body of rock, assumed to be a thick lava flow, occurs and is part of a suite of lavas collectively called the Exeter Volcanic 'Series'. The Hannaborough lava is a lamprophyre composed of abundant feldspar and mica, as well as being characteristically rich in incompatible elements. Cutting down through the lava is a body of angular blocks (a breccia), composed mainly of sedimentary rocks and a few lamprophyre clasts. In the past, this breccia has been interpreted as a vent agglomerate refilling a feeder (vent) for surface eruptions. However, this has been disputed, and current ideas indicated that the breccia represents an infill of the eroded and irregular top to the lava flow. Chemical analyses of the lamprophyres in the Exeter area have been the subject of debate, and various origins and settings have been proposed to explain their specific features. In particular, it is proposed that they were derived from a specific mantle composition and/or genesis involving the melting and contamination of crustal rocks. This site is important for chemical studies of late-stage subaerial volcanism associated with the stabilization of continental crust after the Variscan Orogeny.

References