Calton Hill, Derbyshire

[SK 119 715]

Introduction

The Lower Carboniferous volcanic complex at Calton Hill, Derbyshire (see (Figure 4.11)), provides exposures of fresh basanitic rocks containing relatively abundant nodules of spinel-bearing lherzolite and harzburgite, more generally termed 'olivine nodules'. Derbyshire Stone Ltd and Tarmac Roadstone Holdings formerly quarried this site, 5 km south-east of Buxton, before it became a landfill site. Part of this quarry site is preserved as a SSSI and is also described in the *Carboniferous and Permian Igneous Rocks of Great Britain* GCR volume (Stephenson *et al.,* 2003).

Calton Hill is the location of a 330–340 Ma volcanic vent (Piper *et al.,* 1991) associated spatially with the younger Upper Miller's Dale Lava Member (belonging to the Monsal Dale Limestone Formation of Brigantian age) and the Lower Miller's Dale Lava Member (Walters and Ineson, 1981; MacDonald *et al.,* 1984; Waters in Stephenson *et al.,* 2003). Although much of the vent has been quarried, critical geological features including examples of the spinel-bearing lherzolite and harzburgite nodules have been preserved. These originated from the Earth's upper mantle, from depths of 45–48 km according to Donaldson (1978), and represent the only known examples of mantle-derived nodules found in England. Investigation of the site is of interest historically, as it has attracted the attention of investigators who have contributed significantly to the study of Carboniferous igneous activity in Great Britain.

Description

The Calton Hill basanites (see (Figure 4.12)) are heterogeneous, and descriptions from reports dating back over 100 years reflect the availability of material at the time of investigation. Detailed summary descriptions are given by Aitkenhead *et al.* (1985), and geochemical data have been published by Donaldson (1978), and MacDonald *et al.* (1984). Waters (in Stephenson *et al.,* 2003) summarized the igneous mineralogy and mineral chemistry of the ultamafic lavas and host lava.

First described by Arnold-Bemrose (1894, 1910), the basanite is grey-black, fine-grained and vesicular in texture, with a blocky appearance, and appears to be largely unaltered, although chloritic alteration has been recorded by Sarjeant (1967). It was believed originally to have erupted from a small vent, now exposed as a highly altered and brecciated rock (Donaldson, 1978; MacDonald *et al.,* 1984), although an intrusive origin as a sill has been proposed by Aitkenhead *et al.* (1985).

The ultramafic nodules (0.2–4 cm in diameter) are restricted to the southern side of the basanite intrusion. Hamad (1963) described the nodules as randomly distributed and oval-rounded in form, while Donaldson (1978) reported them to be elongate, tabular in form and angular in section. The nodules have a sharp boundary with the basanite host. In thin-section, enstatite, diopside and spinel have been identified, as well as olivine, together with secondary dark-green chlorite and pinkish-white analcime.

In the host basanite, Hamad (1963) described the presence of augite phenocrysts (bordering olivine crystals) embedded in a groundmass of labradoritic feldspar laths, and crystalline aggregates of idiomorphic augite, magnetite, analcime and calcite, along with traces of limonite. Chlorite occurs as fibrous spherulites (Tomkeieff, 1926; Sarjeant, 1967). Augite is associated with large analcime grains, which occur as spherules and as irregular greyish turbid patches (Hamad, 1963). The outer sections of the analcime grains are bordered by microlites of feldspar and augite. Vesicles within the basalt are also filled with sparry calcite that is also observed in cross-cutting veins, whilst more recently Dyer *et al*. (2001) reported the presence of natrolite as fibrous, radiating crystalline masses filling vesicles up to 10 mm across.

Prismatic jointing is well developed in the centre of the quarry, with more irregular sheet-joints at the margins of the vent. Above these sheet joints, the rock is present as broken 'rubble', suggesting formation by explosive eruption.

Interpretation

Arnold-Bemrose (1910) concluded that the ultramafic nodules were segregations from the host magma rather than enclosures of older rocks. Tomkeieff (1928) studied the volcanic complex as a whole, and suggested that two types of augite exist within the nodules (a normal and a hydrous type) that are possibly members of a continuous series of pyroxenes. The Mg-rich, angular nature of the nodules suggested that they are fragments of a pre-existing peridotite formed under plutonic conditions (Tomkeieff, 1928). The relatively large size of individual mineral grains and the high chromium content of the spinels and dinopyroxenes imply that they did not derive from a basaltic magma. The nodule structure indicates they have been subjected to orogenic stress implying a 'deep-seated peridotite source' for the fragments (Hamad, 1963). Some of the olivine crystals are surrounded by orthopyroxene grains and have convex borders towards them, suggesting that olivine was the first mineral to crystallize. Interstitial fine-grained aggregates of dinopyroxene along the margins of the olivines are thought to have developed from magmatic reaction.

Although direct genetic links between the Calton Hill complex and spatially associated volcanic rocks are not clear, it is believed that volcanic activity in Derbyshire included both submarine and subaerial extrusion (Aitkenhead *et al.,* 1985).

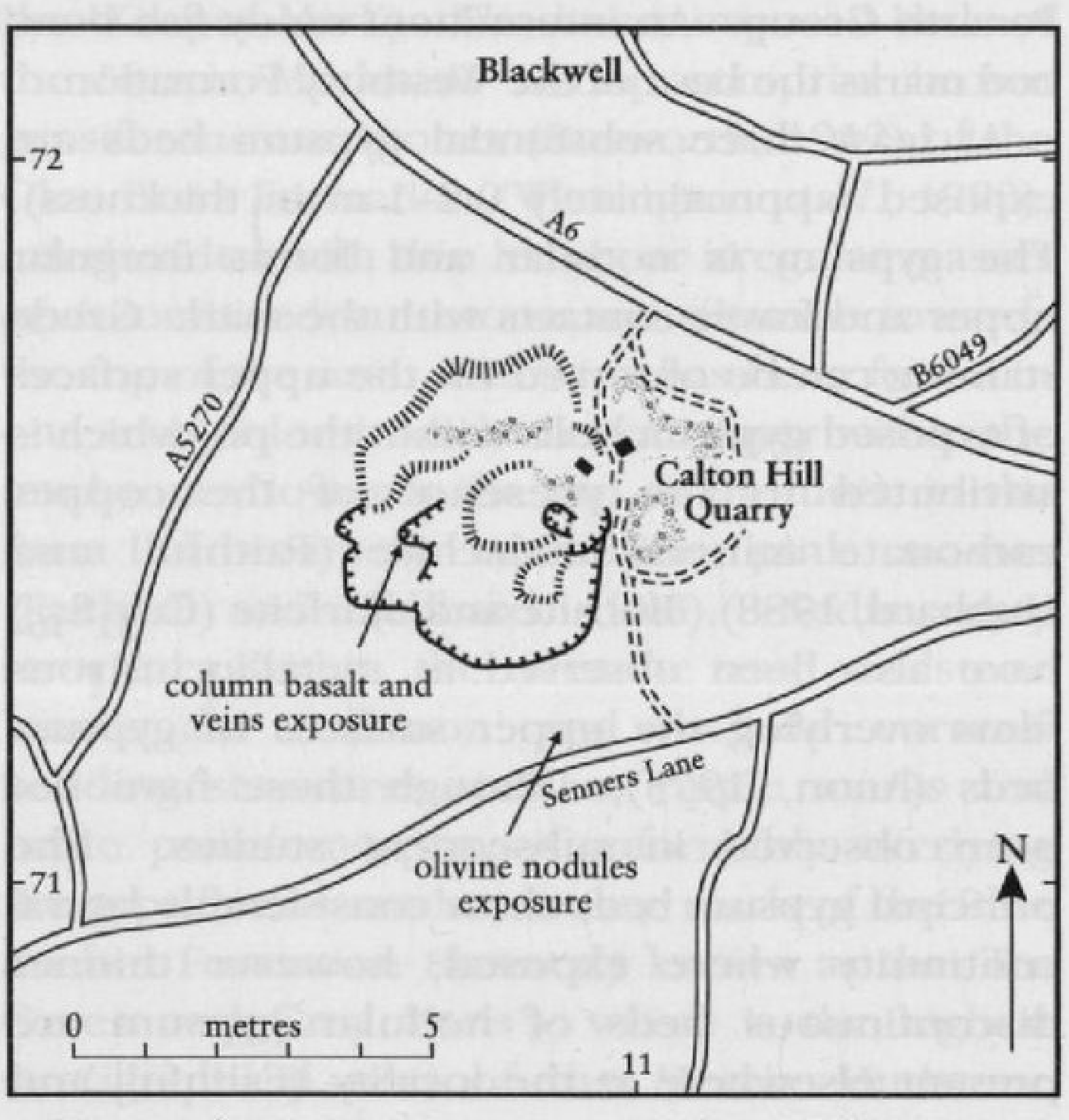
After emplacement, the basanites and lapilli tuffs experienced hydrothermal alteration. The first phase of this resulted in the infilling of the vesicles with calcite, analcime, natrolite and chlorite. Subsequent hydrothermal activity resulted in highly siliceous fluids in the centre of the complex. In the centre of the intrusion occur veins, some 20 cm wide, containing hematite within quartz crystals.

Donaldson (1978) investigated the 'suite of protogranular to porphyroclastic-textured spinels' found at this site, and outlined the petrogenetic history of the lherzolites and harzburgites, based on compositional data. The results indicated the nodules were 'accidental' xenoliths derived from a source at a depth of 45 km, at a temperature of 950°C. Their petro-genetic history involved: (1) formation as residues; (2) admixing with pyroxenite; (3) a complex series of metamorphic cycles of mineral reaction and exsolution, deformation, recrystallization and annealing; and (4) incorporation into the basanite.

Conclusions

The Lower Carboniferous volcanic complex at Calton Hill, Derbyshire, represents a site of international importance, providing exposures of fresh basanitic rocks containing relatively abundant ultramafic nodules, derived from the Earth's mantle. These spinel-bearing lherzolites and harzburgites represent the only known examples of mantle-derived rocks found in England.

References



(Figure 4.11) Location map of Calton Hill Quarry

(Figure 4.12) The exposure at the Calton Hill GCR site. (Photo: C. Hughes.)