Haweswater

[NY 480 140]–[NY 500 167]

D. Millward and B. Beddoe-Stephens

Introduction

The group of cleaved and presumably related, mainly mafic, intrusive rocks that crop out within an area of about 19 km^2 around the northern part of the Haweswater Reservoir collectively form the Haweswater 'Complex' of Nutt (1966, 1970, 1979). This is the largest group of mafic intrusions within the outcrop of the Borrowdale Volcanic Group (BVG) and the GCR site includes excellent examples of the principal rock types, including layered dolerite and gabbro (Figure 4.42). Marginal intrusive breccias are a significant feature. The presence of dolerite in the Haweswater area was reported by Dakyns *et al.* (1897) and Walker (1904), and the rocks were described by Green (1915b), Hancox (1934) and Nutt (1979). Nutt (1979) interpreted the intrusions as a subvolcanic magma chamber and the focus of an eruptive centre for the BVG.

Description

Geological maps and descriptions of the Haweswater intrusions by Hancox (1934) and Nutt (1970, 1979) show a group of dolerite and related rocks cropping out around the Haweswater Reservoir, encompassing part of Bampton Common and Naddle Forest from Willdale Beck in the north to Whelter Knotts [NY 472 134] in the SW and Harper Hills in the SE. The intrusions comprise a combined outcrop area of about 2.6 km^2 within a total area of 19 km^2. The host rocks are lava and pyroclastic formations within the 3200 m-thick succession of the BVG in the eastern Lake District (Nutt, 1979). The major fault along Haweswater, interpreted by Nutt (1970) as separating intrusions within the lower part of the BVG succession tothe NW from those within the upper part to the SE, is not supported by recent mapping of the area by the British Geological Survey (Figure 4.42); the same volcanic formations are present in both areas.

The intrusions are dominantly dolerite, with subordinate fine-grained gabbro, microdiorite, intrusive breccia and locally abundant aplitic veins. The dolerite ranges from leucocratic to melanocratic, with the more mafic rocks occurring NW of Haweswater. Leucocratic microgabbro crops out, for example, on Wallow Crag [NY 495 151], and dolerite and gabbro on and below Wallow Crag are compositionally layered with vertical bands 2–30 cm thick. Most contacts of the intrusion with the host rocks are near vertical or vertical. Exceptions include horizontal contacts east and NE [NY 490 145] of Kit Crag. Xenoliths are present locally within the contact zone.

North-west of Haweswater, some dolerite masses are associated with andesite along a significant fault-zone. Both NW and SE of the reservoir, marginal zones to the dolerite locally exhibit a microporphyritic texture. Microdiorite ('augite-porphyrite' of Hancox, 1934), interpreted by Nutt (1979) to have formed from the alteration of dolerite, is a minor component associated with dolerite SE of the reservoir, but forms a large body on the NW shore, south of Great Birkhouse Hill. Small garnets are a rare accessory mineral in the microdiorite.

Mineralogical alteration is moderate to intense, though original textures are preserved: most rocks are typically subophitic, intersertal or intergranular, and commonly porphyritic; locally, ophitic texture and ophimottling are present. Plagioclase is generally replaced by albite and/or mats of sericite, epidote and chlorite. Fresh clinopyroxene is present in some areas, though this is more typically replaced epitaxially by amphibole or chlorite and fibrous amphibole. Unaltered clinopyroxene in gabbros is accompanied by pseudomorphs of chlorite and/or fibrous amphibole, possibly after orthopyroxene. Interstitial quartz is common in thin-section; locally intersertal orthoclase and microperthite are present associated with micrographic intergrowths with quartz. Accessory minerals include opaque oxide, apatite, biotite and tourmaline.

Thin microcrystalline veins are abundant locally. One type comprises cloudy albite laths with amphibole, chlorite and minor secondary quartz ('doleritic aplite' of Hancox, 1934 and Nutt, 1979). Other veins consist of quartz, perthite, minor albite and accessory tourmaline ('granitic aplite' of Nutt, 1979). Hancox (1934) also described fibrous chloritic veins.

Intrusive breccia forms the marginal rocks of the faulted intrusion south of Wallow Crag (Figure 4.42). Also present is a narrow dyke on the NW shore of Haweswater [NY 476 140]. The breccia comprises fragments of dolerite and gabbro, as well as wall-rocks of andesite, rhyolite and devitrified welded tuff. The intensely altered matrix is feldspathic and andesitic. The vertical pipe of andesite breccia cutting dolerite by Low Goat Gill [NY 506 142], SE of Naddle Beck, described by Nun (1979, p. 729), has been reinterpreted during the recent mapping as auto-brecciated andesite within the BVG country rock, capping an irregular top to the intrusion. Clasts within the breccia are wholly of andesite.

Interpretation

The age of the intrusions is poorly constrained and no radiometric age determinations have been published. Green (1915b) stated that the rocks are not cleaved and are thus implicitly post-Acadian. Later, he reported having seen samples that are cleaved, thus establishing the Early Palaeozoic age (Green, 1917). The cleavage, the regional association, and similarities in alteration styles and geochemistry with the volcanic rocks, indicated to Hancox (1934) and Nutt (1979) that the intrusions were emplaced before the regional cleavage-forming event and are Ordovician in age.

Though the Haweswater intrusions were not distinguished by the primary geological survey, Dakyns *et al.* (1897, pp. 20–21) described a dolerite, locally porphyritic and containing much augite, forming Wallow Crag and compared this with similar rocks from Measand and Colby (now submerged beneath the reservoir at *c.* 493 157), on the north side of Haweswater (Figure 4.42). Though they felt that the Wallow Crag mass is intrusive, the Measand rock was interpreted as lava.

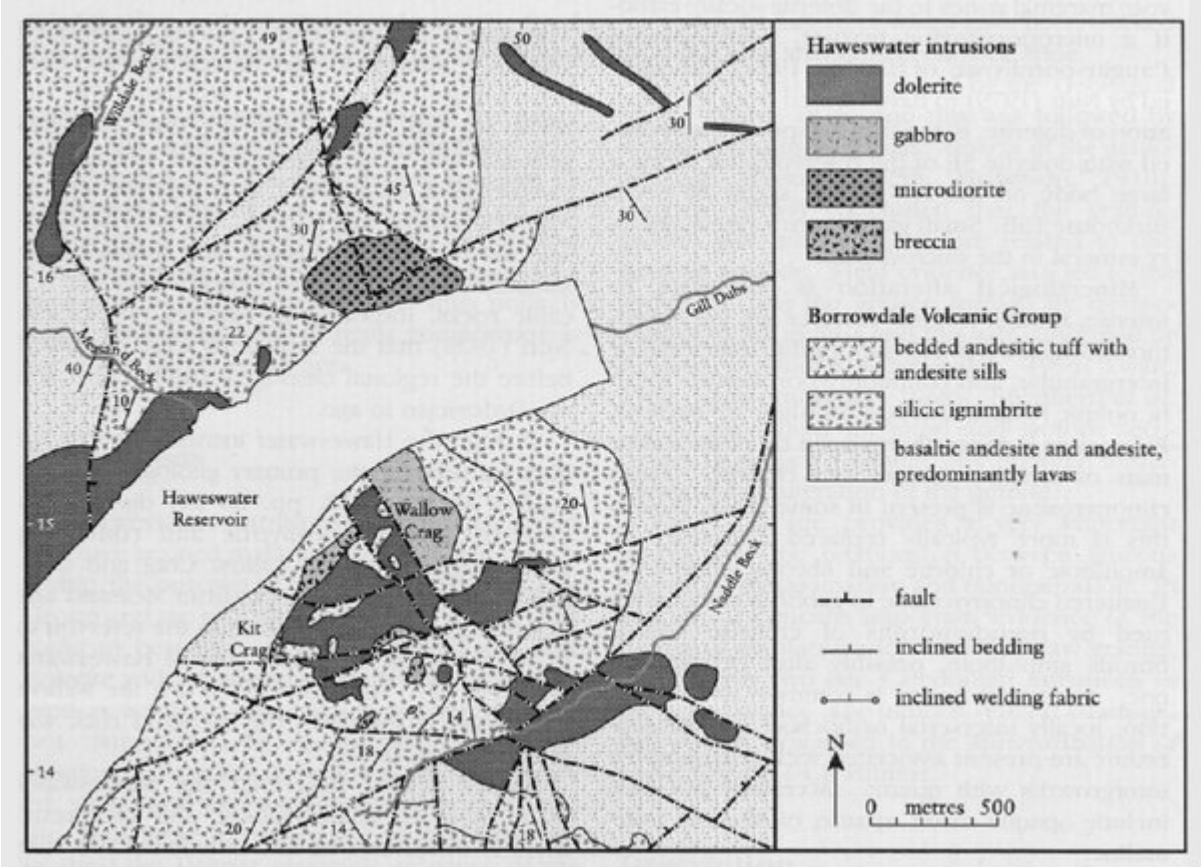
Walker (1904) described the Haweswater mafic rocks as 'quartz-diabase' and interpreted them as intrusions; he also concluded that they are part of a large body, and similar to the lavas of Eycott Hill, which are now interpreted geochemically as tholeiitic (Fitton, 1971). Green (1915b) used 'hypersthene-dolerite' for the Haweswater rocks, and he and Hancox (1934) both commented on the presence of orthopyroxene along with interstitial quartz and K-feldspar, characteristics that might suggest a tholeiitic affinity. However, Fitton (1971) and Nutt (1979) concluded from geochemical analyses of the intrusions that they are indistinguishable from, and thus compatible with, the calc-alkaline BVG. This conclusion does not accord with the preliminary interpretation of new, and as yet unpublished, geochemical data for the Haweswater rocks (University of Lancaster: R. Macdonald, pers. comm.), which indicate that a tholeiitic affinity is possible. If this is substantiated by further work then the dolerites cannot have been a magma chamber and vent site for the BVG. However, the Haweswater rocks do not have the high Ti values of the tholeiitic rocks of the Eycott Volcanic Group and Carrock Fell Complex in the north (Hunter, 1980), and pre-cleavage dykes cutting the BVG and Eskdale granite in the west (Macdonald *et al.,* 1988).

Surface contact exposures indicate steep-sided bodies and previous workers concurred that the widespread group of intrusions is linked at depth. Density values for representative rock types from the intrusions fall within the range for the BVG and Lee (1986) found that the gravity anomalies over the Haweswater area can be interpreted best if the mafic intrusions are underlain, at depths of as little as 1 km, by low density material, probably a granitic mass associated with the Shap granite. It is thus unlikely that a substantial body of mafic composition is present at depth in this area.

Conclusions

The Haweswater intrusions are a unique group of coarse-grained mafic and intermediate masses within the outcrop of the Borrowdale Volcanic Group and are probably Ordovician in age. The rocks are best exposed within the GCR site. The dolerite and associated rocks have been considered as a subvolcanic magma body, but this is not supported by geophysical evidence. Moreover, if studies in progress are substantiated, suggesting that the complex may be tholeiitic, then these intrusions are further examples in the Lake District magmatic province of the association between calc-alkaline volcanic and tholeiitic intrusive rocks.

[References]



(Figure 4.42) Map of the Haweswater intrusions, based on unpublished British Geological Survey maps by D. Millward and B. Beddoe-Stephens.