Byne Hill

[NX 180 945]

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Introduction

Byne Hill is formed by an intrusive body ranging in composition from gabbro at the margins, through dioritic lithologies to a leucotonalite core; the gabbroic margin is chilled against the host serpentinized harzburgite. The leuco-tonalite, one of the key components in the interpretation of the Ballantrae Complex as an ophiolite, was originally described as an oceanic 'trondhjemite.

The site lies at the northern margin of the Ballantrae Complex where a composite intrusive body cuts the Northern Serpentinite Belt and forms a ridge of high ground running SW for about 4 km from the northern flanks of Byne Hill [NX 185 950] to the south-western spur of Grey Hill [NX 158 924]. The majority of the ridge is composed of gabbro which is chilled against the host ultramafic rock, mostly serpentinized harzburgite. This intrusive and chilled relationship can be seen at intervals along the SE side of the ridge; the NW margin of the intrusive mass has been faulted so that the igneous rocks are juxtaposed against either volcanosedimentary components of the Arenig ophiolite complex or younger Llandeilian boulder conglomerate (the Benan Conglomerate Formation of the Barr Group). The intrusive rock becomes progressively more leucocratic away from the chilled (SE) margin so that the gabbro passes transitionally into diorite, quartz-diorite and ultimately into 'trondhjemite', a sodium-rich leucotonalite consisting of quartz and plagioclase (now mainly albite but originally more calcic) with accessory hornblende and/or biotite. The most complete section through this transition is preserved on the SE flank of Byne Hill, the summit of which is composed of leucotonalite. A useful field guide to the area is provided by Bluck and Ingham (1992).

The definitive work on the Byne Hill igneous assemblage is the petrological and geochemical study by Bloxam (1968). However, the passage of gabbro into diorite and granite was first noted by Peach and Horne (1899) and the term 'trondhjemite' was first applied by Balsillie (1932) in recognition of the complete absence from the granite of K-feldspar. Following the detailed study by Bloxam, the presence of 'trondhjemite' in the Ballantrae Complex was identified by Church and Gayer (1973) as a key factor in its interpretation as an ophiolitic assemblage of obducted oceanic crust. The 'trondhjemite' has also been pivotal in dating the complex, providing a well-defined, U-Pb zircon age of 483 ± 3 Ma, taken by Bluck *et al.* (1980) as the time of crystallization of the leucotonalite magma. In modern usage leucotonalite is preferred to trondhjemite.

Description

The outline geology of the Byne Hill area is summarized in (Figure 2.24). The host rock to the intrusive body is serpentinized harzburgite of the Northern Serpentinite Belt; along the SE flank of the hill the intrusive contact is approximately vertical but it is offset by numerous minor faults. A dark-green to black, massive appearance is characteristic of the serpentinite, which was originally mostly olivine, with sporadic, lustrous bronze-coloured relics after orthopyroxene. Within the serpentinite are pale veins of calcium-rich secondary minerals such as hydrogrossular garnet and pectolite, believed to have been produced during the late stages of serpentinization. The veins cross the intrusive contact to penetrate the marginal gabbro establishing that intrusion was an early event preceding serpentinization. This deduction is reinforced by the local metasomatism of the marginal gabbro with the development of the same calcium-rich secondary minerals as seen in the veins.

The chilled margin of the intrusive body is doleritic but this coarsens to a gabbro within a few tens of centimetres of the contact. Olivine-gabbro forms the outermost facies but passes inwards into hornblende gabbro by the gradual loss of olivine and progressive mimetic replacement of clinopyroxene by brown hornblende. Parts of the gabbro are notably pegmatitic with individual crystals up to 5 cm across. The transition from gabbro, through diorite and into leu-cotonalite is relatively abrupt with the dioritic zone rarely wider than 10 m; the transitional lithologies contain distinctively lath-shaped albitized plagioclase, biotite, brown and green hornblende, with accessory quartz and apatite. Bloxam (1968) stressed that gabbroidal minerals and textures survive as relict features in the dioritic transition zone. The inwards increase in quartz is thence marked and, over only 50 cm or so, quartz-diorite passes into the leucotonalite which contains macroscopic quartz and forms the summit area of Byne Hill. It is a pale-pink or very pale orange-coloured rock that weathers white. Quartz and plagioclase (with albitized rims to original oligoclase) together comprise about 90–95% of the leucotonalite with accessory green hornblende, biotite and zircon. The grain size is generally 1–2 mm, ranging up to 3 mm in places. Zircons from the summit area were used by Bluck *et al.* (1980) to produce their U-Pb age of 483 ¯2: 4 Ma. At Byne Hill, the NW margin of the leucotonalite is faulted against the Benan Conglomerate (Figure 2.24) but towards that margin there does seem to be an increase in the proportion of hornblende in the rock. This rather slim evidence may imply that originally the leucotonalite may have formed the core of an elongate body with a symmetrical transition to gabbro towards both the SE and NW margins.

A characteristic feature of the leucotonalite (and to a lesser extent of the quartz-diorite) is the pervasive network of cataclastic zones which traverse the rock. For the most part these are microfractures only clearly evident in thin section but locally they develop into mylonitized zones up to 2 cm across. A wide range of orientations is apparent but there is a preferential NE–SW trend to the macroscopic mylonite zones parallel to the long axis of the intrusive body. This trend is also parallel to the major fault forming the NW margin of the leucotonalite but there does not appear to be an increase in mylonitization towards that structure.

Interpretation

Byne Hill is formed by part of a composite, intrusive igneous body transitional from gabbro at its margins towards a leucotonalite core. The host rock is serpentinized harzburgite and the intrusive contacts are very steep or vertical. From the intrusive contact with serpentinite the transitional passage from gabbro passes through diorite and quartz-diorite into the leucotonalite with no sharp contacts and with gabbroidal min-ends and textures persisting through the dioritic zone and possibly into the marginal hornblendic phase of the leucotonalite. The principal mineralogical changes are reported by Bloxam (1968) to be progressive amphibolitization and albitization of the gabbro accompanied by increases in SiO_2 and Na_2O content. Bloxam considered that these features, coupled with the textural evidence, suggest that the dioritic transitional facies contains hybrid rocks produced by reaction between crystalline gabbro and silicic, Na-rich solutions related to the leucotonalite. However, Bloxam also entertained the possibility that the leucotonalite could be entirely metasomatic in origin. Subsequently, Bluck *et al.* (1980) examined zircons from the leucotonalite and considered them to be of magmatic origin, their age therefore dating the time of crystallization.

The presence of leucotonalite or trondhjemite' within the Ballantrae Complex is one of the key lithological features supporting its interpretation as an ophiolite assemblage formed from obducted oceanic crust (Church and Gayer, 1973). The U-Pb age of 483 ± 4 Ma obtained from the zircons by Bluck *et al*. (1980) is thus of great importance in terms of the evolution of the oceanic crust which became the Ballantrae Complex. The zircon age is broadly early Arenig and intrusion was thus penecon-temporaneous with eruption of the extensive lava sequences. At the margins of the intrusive body gabbro is chilled against harzburgite of the Northern Serpentinite Belt which must therefore have cooled by about 483 Ma. However, Bluck *et al.* (1980) also presented K-Ar age data from amphibolites associated with the metamorphic sole of the ophiolite produced at the base of the Northern Serpentinite Belt during its obduction (see Knocklaugh GCR site). These show that the metamorphic sole was cooling at 478 ± 8 Ma but in terms of error overlap there is no appreciable difference between the ages of lava eruption, ophiolite obduction and leuco-tonalite intrusion; all occurred around the early to middle part of the Arenig epoch. This relatively short time lapse between generation and obduction of the Ballantrae ophiolite encourages interpretation in terms of a back-arc or marginal basin formed close to the site of its eventual obduction onto the Laurentian continental margin. Supporting evidence comes from the chemistry of the gabbro with data presented by Stone and Smellie (1990) compatible with its generation in a relatively mature, oceanic island-arc system.

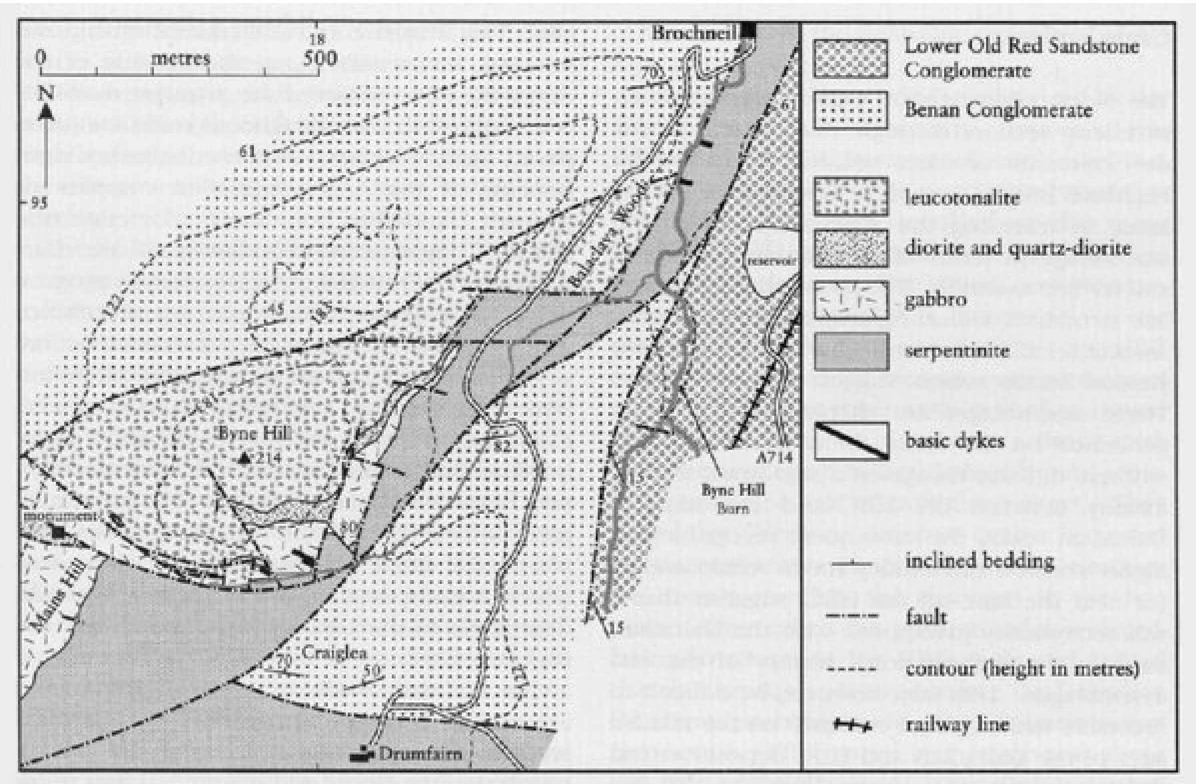
A final discussion point in the interpretation of the Byne Hill body has been its use in constraining the Arenig time-scale. The U-Pb zircon age of 483 ± 4 Ma is accepted as a reliable data point and has been extrapolated by Bluck *et al.* (1980)

to clasts of leucotonalite contained in mélange interbeds within the volcanosedimenta-ry succession of the Ballantrae Complex. Bluck *et al.* regarded these as of middle Arenig age but subsequent biostratigraphical work by Rushton *et al.* (1986) suggests that a lower Arenig age is more likely. Allowing some time for unroofing and erosion it seems most unlikely that lower Arenig strata could contain igneous material with a cooling age as young as *c.* 483 Ma. Nevertheless, the petrographical similarity between the Byne Hill leucotonalite and some of the mélange clasts is remarkable, particularly so in an example from the south of the Ballantrae Complex (the Craig Hill Breccia Formation of Stone and Smellie, 1988). Their relationship and its overall significance remains uncertain.

Conclusions

The Byne Hill site is of great importance in any assessment of the origin and tectonic role of theBallantrae Complex within the Caledonian Orogen. The gabbro-leucotonalite intrusion is one of the key lithological components supporting the interpretation of the complex as of ophiolitic origin. The intrusion has a marginal facies of gabbro, chilled against the serpentinized harzburgite host rock, with an inwards transition to leucotonalite through a narrow dioritic zone. Zircons have provided a reliable U-Pb date of 483 -± 4 Ma for cooling of the leucotonalite magma, thus constraining the age of the complex as a whole. The chemistry of the intrusive body, particularly the gabbro, is compatible with an origin at an oceanic volcanic island arc rather than within oceanic crust (*sensu stricto*).

References



(Figure 2.24) Map of the Byne Hill area (after Bloxam, 1968).