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# Beinn an Dubhaich

## Highlights

Spectacular calc-silicate and skarn mineral assemblages are developed in carbonate sediments at the granite contacts, along with a limited development of alkali granite. The mineralogy of the granite provides a link between the minerals of rhyolite lavas and plutonic granites. Striking deformation of the carbonate sediments and pre-granite Tertiary dykes has occurred over a limited area close to the western end of the granite intrusion.

## Introduction

The site contains the major Beinn an Dubhaich granite intrusion which has been emplaced into Cambro-Ordovician limestones and dolomites overlain by Mesozoic sediments and cut by pre-granite Tertiary basaltic dykes (Figure 2.18). The granite has caused thermal metamorphic and metasomatic alteration of the carbonate sediments and there has been a small, locally spectacular amount of structural disturbance of the sediments and dykes. The Beinn an Dubhaich Granite, with its aureole, is one of the most intensively studied small intrusions in Britain. Following the regional investigations of Harker (1904) and Richey (1932), Tilley (1951) and Hoersch (1981) investigated the contact phenomena, King (1960), Whitten (1961) and Hoersch (1979) worked on the structure of the granite, and Raybould (1973) showed the granite to be a multiple intrusion. Stewart (1965) summarized much of the earlier work and a review of current ideas is contained in the field guide by Bell and Harris (1986). The granite mineralogy was also intensively studied (Tuttle and Keith, 1954; Tuttle and Bowen, 1958).

## Description

The Beinn an Dubhaich Granite is the dominant feature of the site and is one of a group of intrusions which comprise an outer granite mass in the Eastern Red Hills centre. This granite mass extends from Beinn na Cro in the west to Beinn an Dubhaich and the Allt Fearna Granite to the south and east of Beinn na Caillich respectively (Bell and Harris, 1986). The contacts of the Beinn an Dubhaich Granite with the Cambro-Ordovician sedimentary country rock are well-exposed; the sediments have been folded into a broad anticline (the Broadford anticline; Bailey, 1954) and the granite intrusion is approximately coincident with the anticlinal axis. The Cambro-Ordovician strata have also suffered earlier Caledonian tectonism and to the north-east, on the Beinn Suardal summit area on the edge of the site, Torridonian sediments have been thrust over them. To the south, the Lower Palaeozoic and Precambrian sediments are unconformably overlain by Mesozoic (Triassic–Lower Jurassic) strata.

At its western end, and on the headland at the southern end of Camas Malag [NG 583 189], the granite is in steep contact with the Cambro-Ordovician sediments. However, to the east of the Beinn an Dubhaich summit area, and particularly in the vicinity of Kilchrist [NG 616 201], the relationships between the granite and metamorphosed carbonate sediments are complicated; individual contacts exposed in old quarries and pits often appear vertical, suggesting that many steep-sided rafts of limestone lie within the granite and that the granite–limestone contact is extremely irregular. The complex pattern of outcrops has resulted in numerous differing interpretations as to the form of the granite. These are discussed below.

The granite is a typical high-level Tertiary granite and has been the subject of extensive petrological investigation by Tuttle and Keith (1954) and Tuttle and Bowen (1958). It consists essentially of coarsely-perthitic alkali feldspar (including orthoclase cryptoperthite and sanidine cryptoperthite varieties), quartz and some oligoclase. Whitten (1961) examined modal variation in the intrusion and suggested that there was a definite stratification within the granite, with more basic lower parts merging upwards with more quartz-rich lithologies.

Raybould (1973) has distinguished at least four granite types forming a crude ring-structure within a small area near to the summit of Beinn an Dubhaich. In this area, the main type is a grey-coloured, porphyritic microgranite with a very

fine-grained groundmass. The other types are: yellowish, sparsely quartz-phyric granophyre, greenish medium-grained pyroxene-bearing, granite and medium-grained, hornblende granite.

The intrusion of the granite into the Cambro-Ordovician country rock has resulted in significant thermal metamorphic and metasomatic alteration of the cherty, dolomitic limestones. Within the carbonate country rocks immediately adjacent to the granite there are skarn zones up to 3 m wide which are characterized by assemblages of pneumatolytic minerals. Beyond this zone lies an aureole of marble. Tilley (1951) recognized two groups of skarns: Group 1, at the granite-country rock contact not containing boron-fluorine-bearing minerals, and Group 2 on the country rock side of Group 1 associated with boron-fluorine-bearing minerals. (Table 2.4) shows the mineral assemblages recognized by Tilley within the skarn zones and in the outer aureole.

**(Table 2.4) Minerals present in skarn zones** (after Tilley, 1951, Table 1)

	Skarn zones	Skarn zones	
Aureole beyond the skarn zones	Group 1 Primary skarns	Group 2 Boron-fluorine ore skarns	
Talc	Grossular-andradite*	Magnetite*	Grossular-andradite
Tremolite	Wollastonite solid solutions*	Tremolite	Hydro grossular
Forsterite	Diopside-hedenbergite	Forsterite*	Idocrase
Diopside	Spinel	Diopside*	Bornite
Periclase	Plagioclase	Monticellite*	Chalcocite
Wollastonite	Idocrase	Cuspidine*	Covellite
Spinel	Xanthophyllite	Fluorite	Chalcopyrite
Idocrase	Phlogopite	Chondrodite*	Pyrite
Grossular	Orthite	Humite	Blende
Phlogopite	Clinozoisite-epidote	Clinohumite	Galena
Brucite	Prehnite	Ludwigite	Chessylite
Serpentine	Apophyllite	Fluoborite	Malachite
Chlorite	Pectolite	Szailbelyite	
Hydromagnesite	Xonotlite	Datolite	
		Harkerite	

\* most abundant minerals

The discovery of magnetite led to the search for workable deposits, which included a ground magnetometer survey by Whetton and Myers (1949), which recorded numerous bodies of lenticular shape lying along the limestone-granite contact. Samples from these bodies proved to be relatively pure magnetite, accompanied by trace amounts of copper carbonate and sulphide.

Hoersch (1981) made a systematic study of cherty nodules in the carbonates which have reacted with the surrounding rock to produce reaction rims of calc-silicate minerals. Four mineralogically distinct zones of increasing temperature were recognized:

1. Talc-bearing, 350–425°C
2. Tremolite-bearing, 425–440°C
3. Diopside-bearing, 440–520°C
4. Forsterite-bearing, 520–600°C

At Kilchrist and Camas Malag, Tilley (1949) identified an alkali facies of the granite in contact with the skarn deposits. This rock is characterized by the presence of green alkali pyroxene (aegirine-hedenbergite) instead of the normal mafic minerals (biotite and hornblende) of the granite. At Kilchrist, the granite additionally contains metasomatized areas near the contact with veins of pyroxene (diopside-hedenbergite), plagioclase (oligoclase-andesine), fluorite, idocrase and garnet (grossular-andradite) with accessory epidote and orthite. Occasionally, phenocrysts of both microperthite alkali feldspar and plagioclase occur in the marginal facies.

At Camas Malag [NG 583 190], numerous basic and rare acidic sheets intrude near-vertical Cambro-Ordovician sediments which strike approximately parallel to the granite contact (Nicholson, 1985). Where concordant with the bedding, the sheets are clearly boudinaged and, where oblique, they are strongly folded. Individual boudins have chilled margins, even in the 'necked' portions, indicating that boudinage occurred during cooling (Longman and Coward, 1979). Nicholson (1970) considered these sheets to be of Tertiary age from their petrography; their deformation and that of the country rock is very localized and probably occurred during the initial stages of granite emplacement (Longman and Coward, 1979).

## Interpretation

The form of the Beinn an Dubhaich Granite has been the subject of much controversy. Harker (1904) mapped numerous vertical contacts between the granite and limestones and concluded that the intrusion is boss shaped. Broadly similar conclusions were reached by Stewart (1965), Raybould (1973) and Bell (1982). However, radically different interpretations were advanced by King (1960) and by Whitten (1961) who considered that the granite had a sheet-like form and that the complicated contacts at the east end of the intrusion were in part caused by erosion through the granite sheet into underlying sediments. These authors suggested that the granite had been emplaced along the Kishorn Thrust Plane which separates the Torridonian and Cambro-Ordovician rocks hereabouts. However, limited borehole evidence (Raybould, 1973) and geophysical studies (Hoersch, 1979) support the interpretation that the granite is a steep-sided boss which extends to depth.

The coincidence of the granite with the Broadford anticlinal structure in the Cambro-Ordovician sediments invites the view that the fold formed in response to the forcible intrusion of the granite. This is not, however, the case as it can be shown that Tertiary dykes, intruded after the sediments had been folded but before the granite was intruded, show no signs of granite-induced deformation. The dykes intruding sediments in the large 'rafts' within the eastern end of the granite show little strike deviation from those in the country rock and, in some instances, dykes in the country rocks are seen to have once been continuous with dykes within the marble rafts. This suggests that these 'rafts' are more likely to have been attached to the roof of the granite rather than to have been 'free-floating' enclaves within the intrusion. Despite the lack of evidence for large-scale deformation around the granite, limited, but locally intense deformation of sediments and dykes occurs at the western end of the intrusion, where both Cambro-Ordovician and Mesozoic sediments have been affected by granite emplacement (Nicholson, 1970; Longman and Coward, 1979).

The calc-silicate mineral assemblages and skarns produced in the cherty dolomitic limestones along the granite contacts and within the rafts are very spectacular and internationally renowned. However, they are strictly limited to within a few metres of the contacts although marmorization is more extensive. Similarly, the chemical and related mineralogical modifications of the granite caused by reaction with the carbonate rocks or carbonate-derived metasomatizing fluids are limited; an alkali-granite facies is present but there is no suggestion from these occurrences that any large bodies of, for example, syenitic compositions, could have formed. Thus, the exposures at this site support the general view that limestone syntexis is probably of limited petrogenetic importance in the genesis of the alkali rock.

The detailed investigations of the mineralogy of the granite by Tuttle and Keith (1954) and Tuttle and Bowen (1958) demonstrated that this high-level, unmetamorphosed intrusion has mineralogical characteristics which are intermediate between those of deep-seated batholithic granites and rhyolites. In the 1950s, there was considerable controversy about the origin of granitic rocks and one school of thought held the view that granites were largely the result of meta-somatic transformation of pre-existing rocks. These views were based essentially on observations made in high-grade metamorphic terranes and on large, deep-seated bodies of granite. Magmatists, who opposed this concept, maintained that granites resulted from the intrusion of granite magma and cited the evidence from small, high-level granite bodies and from rhyolite flows. Granitic rocks from these contrasted settings have different and distinct mineralogical features, which, it was argued, arose because of fundamental differences in their origins; the work by Tuttle and others on the Beinn an Dubhaich Granite, as well as other granites in the BTVP, demonstrated that some granites have mineralogical features supposedly characteristic of both settings which were, therefore, not separate and distinct but at the extremes of a series of continually varying mineralogies. Their work thus helped to pave the way for the present-day acceptance of the real existence of granite magma in the crust.

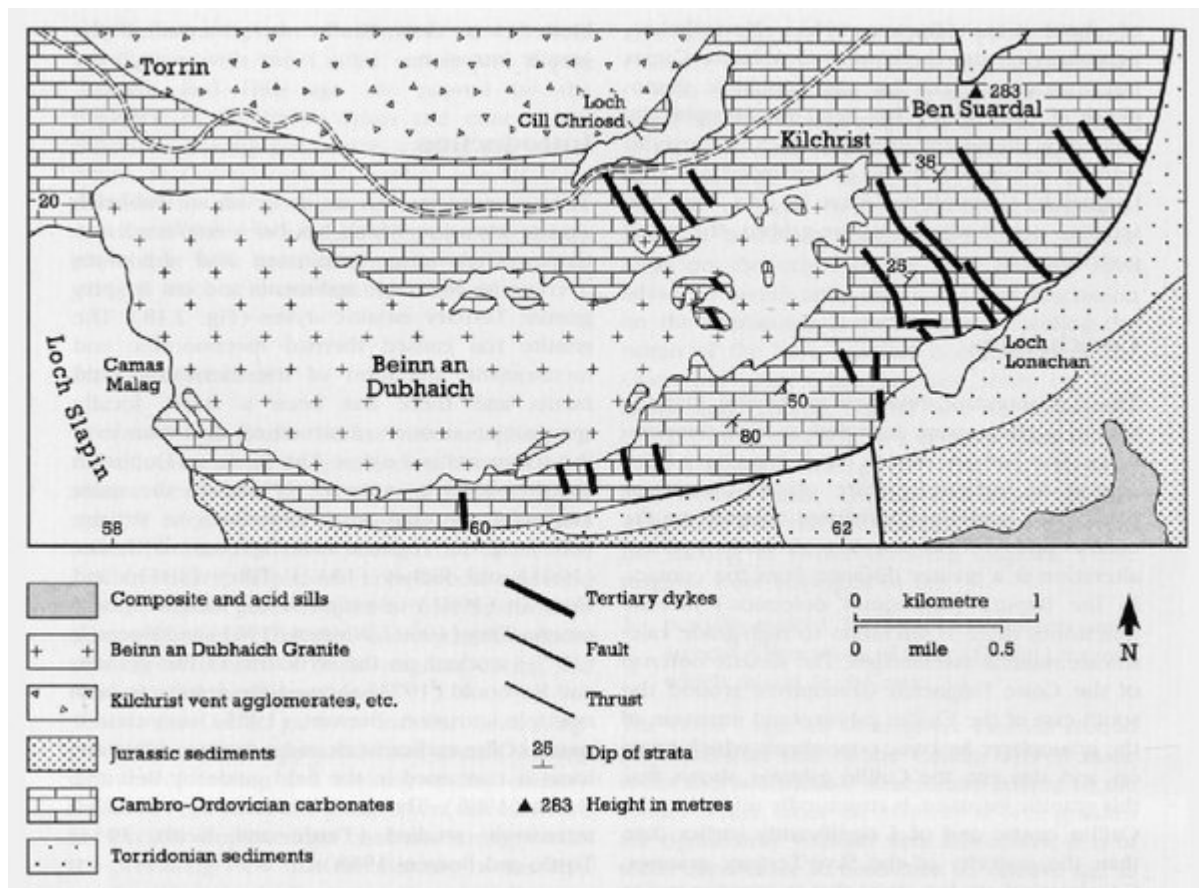
## Conclusions

The granite of Beinn an Dubhaich intrudes Lower Palaeozoic carbonate sediments with limited deformation of the sediments and a group of pre-granite, Tertiary basaltic dykes. Reaction between the granites and the country rocks resulted in the production of a distinctive calc-silicate mineral assemblage in the baked carbonate rocks at the contacts, and more widespread recrystallization to form extensive tracts of marble. In addition, there are thin magnetite-rich skarns at some of the contacts, and reaction between the granite and the carbonate rocks has produced small amounts of a marginal alkali granite.

The mineralogy of the granite shows features intermediate between those of extrusive rhyolites and plutonic granites. It thus provides a vital link between these compositionally similar rocks which were formerly considered, by some, to be of fundamentally different origins.

Although it has been proposed that the granite is a sheet-like intrusion injected along a Caledonian thrust plane, the general consensus argues that it is boss shaped. The complicated contact relationships at the eastern end are due to the present level of erosion being nearly coincident with a flat, roof contact which is highly irregular in detail. Evidence for several separate granite intrusions found towards the western end of the body may indicate the presence of small, nested ring-dykes.

## References



(Figure 2.18) Geological map of the Beinn an Dubhaich site (after Gass and Thorpe, 1976, figure 6).

Aureole beyond the skarn zones	Skarn zones		
	Group 1 Primary skarns	Group 2 Boron-fluorine ore skarns	
Talc	Grossular- andradite*	Magnetite*	Grossular- andradite
Tremolite		Tremolite	
Forsterite	Wollastonite	Forsterite*	Hydro
Diopside	solid solutions*	Diopside*	grossular
Periclase	Diopside- hedenbergite	Monticellite*	Idocrase
Wollastonite		Cuspidine*	Bornite
Spinel	Spinel	Fluorite	Chalcosite
Idocrase	Plagioclase	Chondrodite*	Covellite
Grossular	Idocrase	Humite	Chalcopyrite
Phlogopite	Xanthophyllite	Clinohumite	Pyrite
Brucite	Phlogopite	Ludwigite	Blende
Serpentine	Orthite	Fluoborite	Galena
Chlorite	Clinzoisite- epidote	Szailbelyite	Chessylite
Hydromagnesite	Prehnite	Datolite	Malachite
	Apophyllite	Harkerite	
	Pectolite		
	Xonotlite		

\* most abundant minerals

(Table 2.4) Minerals present in skarn zones (after Tilley, 1951, Table 1)