Ard Bheinn

OS Grid Reference: NR943335

Highlights

This site exposes some of the best evidence for the eroded remains of a caldera in the British Tertiary Volcanic Province. Collapsed blocks of basalt lavas and fossiliferous Mesozoic rocks have been preserved within the caldera; the mapping of lavas and volcaniclastic rocks has shown that several volcanic cones grew on the caldera floor.

Introduction

The Ard Bheinn site demonstrates the characteristic features of the Central Igneous Complex of Arran. A large variety of rocks is exposed in the complex which are of both intrusive and effusive origin; they are compositionally highly variable. These include agglomerates, gabbros, felsites and granites which crop out as arcuate masses. In addition, blocks of Mesozoic sediments and Tertiary lavas are preserved within the complex. Volcanic rocks of intermediate and acidic composition are associated with several eruptive centres which developed on the caldera floor.

The foundations for our understanding of the geology of this complex area can be attributed to the Geological Survey (Peach *et al*., 1901; Gunn, 1903; Tyrrell, 1928). These workers recognized the complex, volcanic nature of the area and demonstrated a Tertiary age by the identification of remanié blocks of Mesozoic sediments and similarities to ring intrusions found elsewhere in the BTVP. However, credit for our present detailed knowledge of the site is owed to King (1955) who mapped the area in considerable detail. King demonstrated that there were four, independent but overlapping, centres of volcanic activity in theArd Bheinn area situated within a subsidence caldera (1955, figs 1 and 2).

Description

The site contains part of the poorly exposed Central Igneous Complex of Arran which has the overall structure of a major caldera (Fig. 6.3). The evolution of the centre is discussed in detail by King (1955) and the rocks in the site can be grouped accordingly:

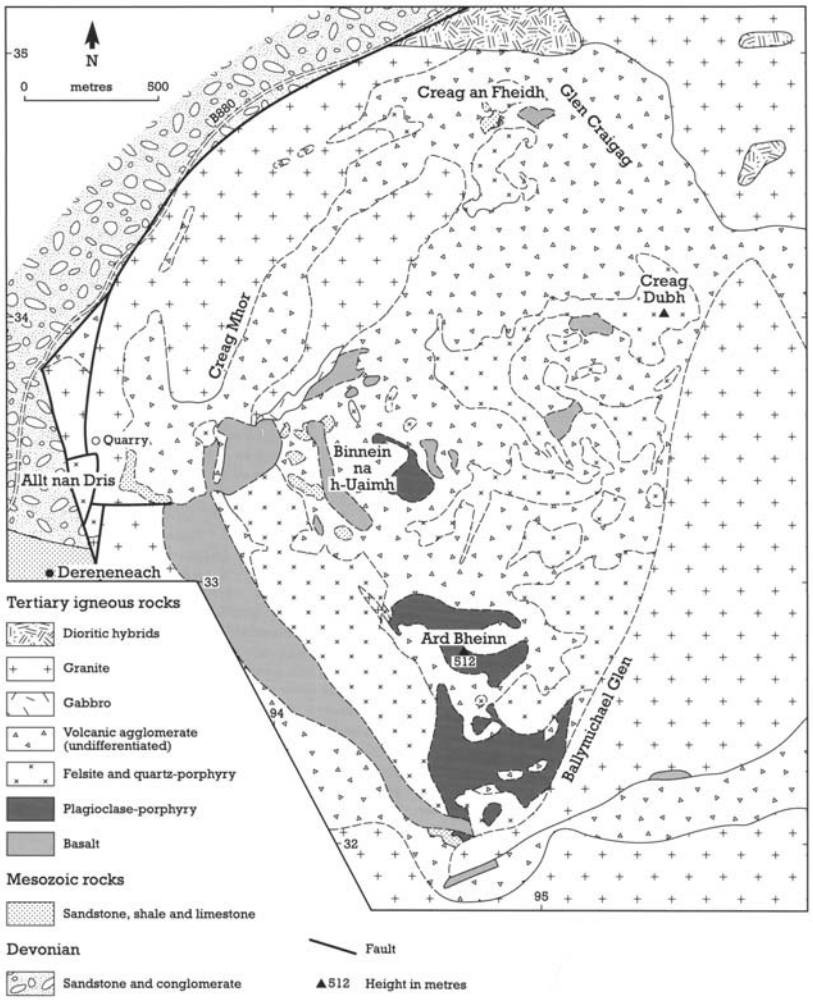

Figure 6.3: Geological map of the Ard Bheinn site (adapted from King, 1955, plate XVI)

(a) Pre-caldera rocks preserved as remanié blocks

Sedimentary and basaltic pre-caldera remanié masses occur at various localities within the complex. One of the key localities is in the Allt nan Dris (NR 935 333) where Rhaetian and other Upper Triassic strata crop out. Another is on the southern slopes ofArd Bheinn (NR 947 323) where small areas of fossiliferous Lower Lias sediments occur, as they also do close to the Permian and Triassic rocks in Allt nan Dris. Probable Upper Cretaceous limestones, now silicified and baked, are found in two localities, one forming a small cave marking the site of an old limestone quarry at Creag an Fheidh (NR 948 348), the other in a cave (Pigeon Cave) north-west of Binnean na h-Uaimh (NR 941 335). A large remanié mass of basaltic lava, about 100 m in thickness, occurs west of Binnein na h-Uaimh andArd Bheinn; at the northern end of this mass; the basalt is seen to overlie altered chalk at Pigeon Cave. Many smaller masses exist elsewhere throughout the complex.

(b) Arcuate masses of volcanic breccias, granites, gabbros and felsites formed during the early evolution of the complex

The principal members of the igneous complex are confocally arranged, arcuate masses within the caldera. These comprise large outer masses of vent agglomerate, a peripheral belt of granite, gabbroic strips north-west of Binnein na h-Uaimh (NR 943 335), a broad belt of felsite outcropping as arcuate masses with boss- and dyke-like characteristics and a lenticular granite mass.

The relative ages of the various pyroclastic formations within the complex are virtually impossible to determine. Distinct types occur in the peripheral zones and in the volcanic centres distinguished by King (1955). The peripheral caldera volcanic breccias are relatively uniform, the dominant inclusions being sedimentary and low-grade metamorphic fragments of

Dalradian rocks and include quartzite, schistose grit and quartz–mica schists and vein-quartz. They are frequently well-rounded pebbles and cobbles, and are almost certainly derived from Devonian conglomerates, since fragments of these conglomerates are also common. Post-Devonian sediments are much more sporadic in their occurrence. Igneous fragments are irregularly distributed, but seldom predominate over the sedimentary clasts, and include basaltic lavas and felsites. Basalt is ubiquitous, but mugearite and feldspar-phyric basalts are also found in marked contrast to their very minor occurrence in the remanié masses of early, pre-complex lavas. Rare andesitic, gabbro, dolerite and granite clasts are also present. Some of the basalt fragments are very well-rounded and up to several metres in diameter. They are possibly the result of prolonged attrition in a vent (cf.Richey and Thomas, 1930; Reynolds, 1954). This suggestion is supported by steeply inclined, ‘bedded' structures and intricate, sinuous, ‘intrusive' contacts between agglomerates of varying character.

The peripheral granites occur as an arcuate belt from Dereneneach and Creag Mhor to lower Glen Craigag and a mass terminating to the north of Ballymichael Burn (King, 1955). These are medium- to fine-grained, pinkish biotite granites containing abundant orthoclase (commonly perthitic), plagioclase, quartz and biotite with epidote as a common secondary mineral. The granites are in contact with the volcanic breccias against which they are found to be chilled, although the junction is often tectonized and the granite finely comminuted. A further lenticular mass of granite associated with the ring complex occurs to the north of Binnean na h-Uaimh. This is a more melanocratic rock characterized by strongly zoned plagioclases and green hornblende; it may be of hybrid origin. The thermal metamorphic effects caused by the emplacement of this granite are particularly pronounced along its north-eastern and south-eastern boundaries, where adjacent basalts and gabbros are acidified and have developed clouded feldspars. Hybrid, dioritic rocks occur in the stream at Glenloig Bridge (NR 946 351).

(c) Lavas and pyroclastics erupted from discrete volcanic centres developed within the confines of the caldera

The central, higher part of the area contains at least four separate volcanic centres superimposed upon the earlier steeply inclined, arcuate intrusions and volcanic breccias. Each volcanic centre is identified by groups of gently inclined lavas and pyroclastic accumulations. These centres are briefly summarized below (King, 1955).

Ard Bheinn Centre (NR 945 329)

This is the largest and least eroded of the centres and contains abundant basaltic andesite andesite and plagioclase porphyry lavas and pyroclastics. The andesites dip to the south and south-east at low angles, presenting a confocal pattern. They are truncated by later felsites and felsitic agglomerates.

Binnein na h–Uaimh Centre (NR 943 335)

Concentrically arranged basalts and andesitic pyroclastic deposits appear to be arranged about a single focus of activity. Agglomerates associated with the basalts are exceptionally varied and comprise a succession of layers with varying amounts of coarse sedimentary, basaltic, plagioclase porphyry and felsitic debris in the form of gently north-westerly inclined sheets.

Creag Dubh Centre (NR 952 338)

Basalts, andesites and associated breccias and porphyritic felsites are well represented at this centre as at Ard Bheinn. The arcuate form of the outcrops suggests several intersecting and overlapping lavas and pyroclastic layers attributable to a number of minor volcanic vents.

Creag an Fheidh Centre (NR 948 347)

The disruption of peripheral structures of the complex indicate that a volcanic centre was probably present here. The lithology is varied and similar to that encountered in the other centres with basalts, plagioclase porphyries and felsite being dominant, although no andesites have been found. Two foci are suggested by the arcuate disposition of the felsites.

(d) Late granite mass

The broad belt of granite extending from the source area of the Ballymichael Burn to mid-Glen Craigag is later than all of the other members of the complex. It is part of a late central granite intrusion located east of the Ring Complex and now occupying a large arcuate area mostly outside the limits of the Ard Bheinn site. The petrography of the granite is similar to that of the earlier peripheral granites. Small areas of fine-grained gabbro occur on the north-west margin of the Binnean na h-Uamha area. These are older than the granite and are comminuted where in contact with volcanic breccias. Well-developed flow layering in the gabbro has an arcuate pattern which conforms to the general structure of the complex (King, 1955, p. 331) but is cut across by the contacts; King suggested that this gabbro is a remnant of a much larger intrusion.

Interpretation

The Ard Bheinn area of the Central Igneous Complex contains probably some of the best-preserved evidence for an eroded caldera structure in the British Tertiary Volcanic Province. The arcuate outlines of the complex are clearly defined by later granitic intrusions and the evidence for central subsidence is unequivocal: the numerous, occasionally fossiliferous, remanié masses of Mesozoic sediments and closely associated lavas, similar to plateau lavas elsewhere in the BTVP, do not occur elsewhere on Arran, the country rocks adjoining the complex range from Devonian to Permian in age. Thus, King (1955) estimates that subsidence of c. 1000 m may have occurred. The nearest (on shore) exposures of similar fossiliferous rocks are on the North Antrim coast c. 60 km distant and even further afield in the Western Isles (cf. Peach *et al*., 1901). The inference drawn from their presence, together with the Tertiary lavas, is that Arran and the surrounding areas were covered by Rhaetian, Lower Jurassic and Cretaceous sediments and Palaeocene plateau basalts prior to post-Eocene and Pleistocene erosion. Despite their preservation within a caldera and the presence of numerous later intrusions, the sedimentary rocks generally show little alteration beyond induration, although skarn minerals have been recorded from the contact between metamorphosed chalk and agglomerates at Creagh an Fheidh (Cressey, 1987).

Ard Bheinn is a convincing example of a volcanic cone within the caldera postulated by King (1955). Here, and at Binnein na h-Uamha, there are well-defined flows of andesite and dacite, and associated pyroclastic rocks. The high proportion of rocks derived from magmas of intermediate compositions is unusual in the BTVP, where compositions are generally distinctly basaltic or granitic. From the evidence of hybrid dioritic rocks at Glenloig Bridge and of mixing of basic and acid magmas (as at "Hybrid Hill', c. NS 978 980–outside the site), a hybrid origin for these rocks is a possibility but this would imply very thorough homogenization of the contrasted, mixed magmas prior to eruption. The origin of these rocks must remain open, for no detailed geochemical work has been published on them since King's account (1955); they were not included in the radiochemical and geochemical investigations made by Dickin *et al*. (1981).

The coarser-grained granitic rocks of the complex appear to have been intruded along the margins of the caldera, possibly in association with the caldera collapse, although King's (1955) identification of crushing along the margins indicates post-consolidation movements. Emplacement of the granitic rocks may also have resulted in doming of the country rocks; this is particularly clear from the Survey's mapping to the south and south-east of the site, whereas the relationships along the northern and north-western margins of the complex suggest that the intrusions cut across the domed structure around the earlier Northern Granite.

The particular value of this site lies in the preservation of features of surface and near-surface volcanicity within a caldera collapse structure. Elsewhere in the BTVP, the present level of erosion is between 1–2 km (or even more) below what was the Palaeocene land surface, so that we are usually dealing with the eroded roots of the volcanoes. In this site much of the volcanic superstructure is preserved, and through the observations made here it is becoming increasingly recognized that some of the relicts of surface volcanism found in other central complexes (for example, Beinn na Caillich–Kilchrist on Skye) may also owe their preservation to subsidence within calderas. A positive gravity anomaly over the area indicates that it is underlain by mafic rocks at depth (McQuillin and Tuson, 1963).

The sequence of events within the Central Igneous Complex, and in particular this site, may be summarized as follows: after emplacement of the Northern Granite, a major igneous centre developed to the south. The initial activity involved formation of a caldera with central block subsidence of about 1 km and a diameter of at least 5 km. In the north-west, wall rocks collapsing into the caldera included olivine basalts from Tertiary lavas, which probably covered Arran and surrounding areas in the Palaeocene, and masses of fossiliferous Rhaetian and Lower Jurassic sedimentary rocks, together with Permian and Cretaceous rocks. At least four volcanic cones became established on the caldera floor and built up through the effusion of intermediate and acid lavas and pyroclastic deposits. Subsequently, granite and dioritic rocks were intruded along the ring fracture around the margins of the caldera. The status of gabbroic rocks in the north-west of the site, near Binnean na h-Uamha, is uncertain, but it may be a relict of a larger, pre-granite mass; the presence of the positive Bouguer gravity anomaly over the complex indicates that there are appreciable amounts of dense gabbroic rocks beneath the area.

Conclusions

The Ard Bheinn area contains a wide range of intrusive and extrusive igneous rocks with which are associated masses of fossiliferous and non-fossiliferous sediments, ranging in age from the Permian to the Cretaceous. This perplexing mixture of rock types is the result of surface and near-surface rocks being downfaulted within a major volcanic collapse structure, or caldera, which was subsequently intruded along its margins by granitic and other ring-dykes.

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