Glas Eilean–Mingary Pier

OS Grid Reference: NM493626

Highlights

One of the best sections through a cone-sheet swarm to be found in the British Tertiary Volcanic Province (BTVP) is exposed on the shore west of Mingary Pier. Numerous basic, rare acid and composite sheets enclose thin screens of country rock, some of which have developed distinctive thermal metamorphic minerals. A well exposed linear volcanic vent on Glas Eilean cuts the cone-sheets and is itself cut by a tuffisite dyke.

Introduction

The numerous cone-sheets of the Ardnamurchan complex are exceptional in their development and are of international importance. The 1.5 km stretch of coast between Glas Eilean on Kilchoan Bay and Mingary Pier provides a representative section through a large number of basic and less-abundant felsite sheets associated with Centre 2. Other features of interest within the site include remnants of the early lava plateau and deposits in a linear vent (Figure 4.4).

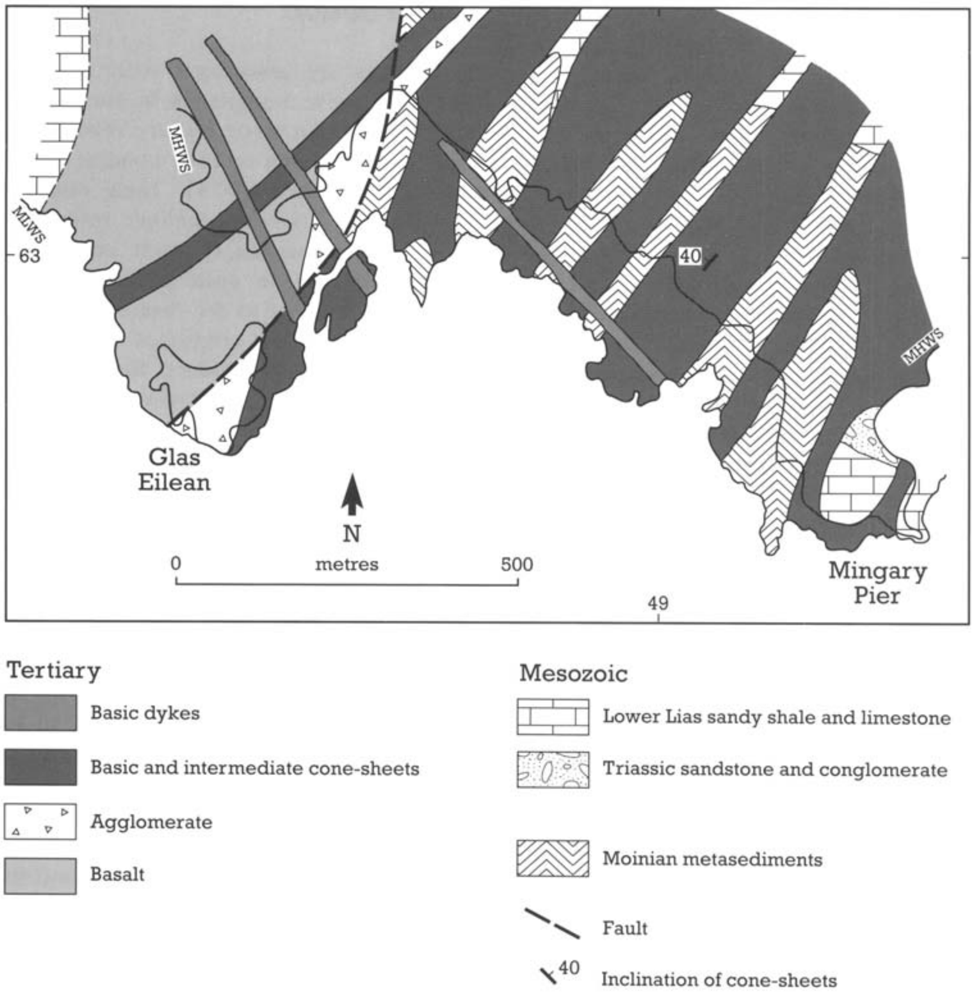

Figure 4.4: Geological map of the Glas Eilean-Mingary Pier site (after Gribble et al., 1976)

The cone-sheets of Ardnamurchan were originally mapped by the Survey (Richey and Thomas, 1930) which led to the recognition of several distinct sets related to each of the intrusive centres. The origin of the intrusions has been subject to continuing debate since the interpretations of Bailey *et al*. (1924) and Richey and Thomas (1930) for the cone-sheets of

Mull and Ardnamurchan respectively. These workers, and Anderson (1936), attributed the sheets to the updoming of the country rock by rising magma which resulted in conical fractures along which the cone-sheets were emplaced. Durrance (1967), Phillips (1974) and Walker (1975) have subsequently presented modified interpretations on the mechanisms of cone-sheet emplacement. The geochemical characteristics of these intrusions have been studied by Richey and Thomas (1930) and, more recently, by Holland and Brown (1972). Reynolds (1954) described and discussed features of the Glas Eilean linear vent.

Description

The predominantly intertidal exposures in the site (Figure 4.4) demonstrate a profusion of cone-sheet intrusions which are so frequent that the proportion of igneous rocks often exceeds that of the country rocks they intrude. They belong to the outer set of cone-sheets associated with Centre 2 and include some of the most silicic compositions in the complex (Richey and Thomas, 1930; Holland and Brown, 1972), although being mostly of non-porphyritic quartz-dolerite, porphyritic dolerite or basalt. Individual cone-sheets vary greatly in inclination (20° to 75°) and range in thickness, from 0.5 to 15 metres; however, most are inclined at 35° to 45° towards the Aodainn–Achosnich area and are between 0.5 and 2 metres thick. In general, they cannot be traced for any substantial distance along strike and in many places the sheets interdigitate and form anastomosing masses several metres thick. Country rocks are biotite-grade Moine psammites and phyllites, Triassic breccias and conglomerates, Lias limestone–shale rhythmic sequences and Tertiary lavas, against all of which the cone-sheets are conspicuously chilled. Contact-metamorphic effects involving the formation of idocrase, sphene, garnet, clinopyroxene, tremolite and prehnite are commonly observed in the adjoining Lias calcareous shale rocks. The sheets are cut by numerous WNW- to NW-trending basic dykes and themselves cut earlier dykes and sills. The country rocks occur as thin septa, or screens, between the cone-sheets.

South of Mingary Pier (NM 494 627), a composite sill of quartz dolerite and granophyre is exposed and, a few metres to the west, there is a composite cone-sheet. Such composite sheets have margins of basic quartz dolerite and central portions of felsite (often xenolithic), granophyre, craignurite or acidified quartz dolerite. The internal contacts between the acid and basic members may be sharply defined or gradational.

At Glas Eilean (NM 484 628) a small remnant mass of gently westerly dipping lavas is exposed. At least two amygdaloidal flows are present, intruded by numerous cone-sheets. The original hydrothermal assemblage of the rocks has been almost totally obliterated by pneumatolytic alteration similar to that found around the Mull central complex. The rocks are deeply weathered to an earthy-red and green colour and are traversed by anastomosing veins of chlorite, albite and epidote, often with prehnite. Similar mineral assemblages occupy the altered amygdales. No fresh olivine has survived, although pseudomorphs are common.

The small tidal island of Glas Eilean, and the foreshore to the north-east, expose a linear vent cutting the lavas, cone-sheets and Moine schists. It is broken into two outcrops by a fault which, in places, throws the lavas against the schists. Fragments of quartz dolerite and tholeiitic basalt derived from the cone-sheets occur within the vent agglomerate, which also contains fragments of Moine schist, basalt lava, Jurassic sandstone, limestone and shale. The clasts lie in a devitrified, chloritic matrix containing spherulites of quartz and alkali feldspar. The agglomerate is locally intricately veined by an acid tuff composed of devitrified acid glass enclosing bodies of basic devitrified glass (Paithankar, 1968). A tuffisite dyke with flow-textured margins cuts the agglomerate. The dyke matrix, which closely resembles the agglomerate matrix, contains a variety of clasts, of which basalt is the dominant type. The clasts increase in size from the margins of the dyke towards its centre, where the concentration of coarse fragments may make it difficult to distinguish the rock from the normal vent agglomerate.

Interpretation

Cone-sheets are associated with many of the central intrusive complexes in the British Tertiary Volcanic Province but are relatively scarce elsewhere, implying unusual conditions for their formation (Walker, 1975). Their outcrops are concentric and they are inclined inwards having an inverted cone shape, each cone sharing a common apex. The apex probably marks the position of the roof to the magma chamber from which the intrusions originated. Cone-sheets are important in understanding the tectonic processes, mechanisms of intrusion and the stress fields associated with the emplacement of the British Tertiary central complexes. In addition, their ubiquity makes them useful time markers dividing periods of intrusion.

The cone-sheet swarms of Ardnamurchan were first interpreted by Richey and Thomas (1930) who, in accordance with the structural and stress analysis studies previously applied to the Mull centre (Anderson in Bailey *et al*., 1924), concluded that upward pressure from the magma chamber produced conical fractures in its roof (cf. Anderson, 1936) and that the cone-sheets were intruded along these fractures. Two distinct sets of cone-sheets were recognized by Richey and Thomas, arranged around separate foci located east of Glendrain (Centre 1) and south of Achosnish (Centre 2). A partial set associated with Centre 3 was also recognized.

Durrance (1967) argued that the cone-sheets could not be divided into two independent suites but occupy one large conjugate spiral (as opposed to concentric) shear fracture system centred on Sanna. This focus is located at the periphery of the complex and corresponds closely with the gravity maximum of the Ardnamurchan complex (Bott and Tuson, 1973). This model postulated that a release of magma pressure and associated compressional stresses, coupled with a degree of torsion, resulted in the spiral fracture system along which the cone-sheets were subsequently injected when the magma pressure increased. Gribble *et al*. (1976) strengthened this model by noting that the cone-sheets originally attributed by Richey and Thomas (1930) to Centre 1, and to the outer set of Centre 2, occupy predominantly sinistral shear fractures. However, the inner set belonging to Centre 2 and the few Centre 3 cone-sheets, tend to have been intruded into dextral fractures. According to Durrance's model, the shear sense of these fractures would have been controlled by torsional stresses set up by the high-level emplacement of magma bodies.

Walker (1975), in presenting a new concept for the evolution of the Tertiary intrusive centres, suggested a radically different mechanism for cone-sheet formation. The cone-sheets in the British Tertiary Volcanic Province generally coincide with areas of updoming, presumed to have been caused by early uprising acid diapirs (but see Le Bas, 1971). Walker suggested that the sheets are emplaced passively along fractures produced by rising magma which tended to move in the direction of maximum hydrostatic pressure (the amount by which the fluid pressure of the magma exceeds the lithostatic pressure). Where basic magmas followed preferred pathways of increasing excess pressure, governed by the perturbations in the surfaces of equal excess fluid pressure near to a high-level acid diapir, cone-sheets instead of dykes were produced.

The Ardnamurchan cone-sheets vary considerably in lithology and texture, but chemically all of them appear to belong to a single tholeiitic lineage (Richey and Thomas, 1930; Holland and Brown, 1972). They range from plagioclase- and clinopyroxene-bearing quartz dolerites to felsites; composite examples are also known. Holland and Brown concluded that on the basis of ‘mean' chemical analyses, there is no easily distinguishable difference in magma type between Centre 1 and Centre 2 cone-sheet swarms, and no evidence to support or oppose the hypothesis of Durrance (1967). On total alkali–silica plots, the cone-sheets cluster around the Hawaiian alkali-basalt–tholeiite field boundary (MacDonald and Katsura, 1964) and appear to be quite different from the regional Hebridean alkaline trends (Bailey *et al*., 1924; Tilley and Muir, 1962; Thompson *et al*., 1972).

The variation in clast size within the tuffisite dyke intruding the Glas Eilean vent must reflect a marked increase in gas velocity towards the centre of the dyke, where the entrained fragments are as much as 100 mm across compared with the 2–4 mm sizes of the marginal fragments.

Conclusions

Magma intruding a series of fractures centred beneath Sanna gave rise to the dense outer cone-sheet swarm associated with Centre 2, and possibly also to the cone-sheets associated with Centre 1. Diapirs of acid magma may have caused uprising basaltic magma to be diverted in the direction of maximum excess hydrostatic pressure to form the cone-sheets. The cone-sheets intruded cold country rocks against which individual intrusions were chilled; thermal metamorphic effects were limited and distinctive mineral assemblages were confined to the compositionally favourable Jurassic calcareous shales. The Ardnamurchan cone-sheets have tholeiitic affinities and contrast with the regional alkaline basaltic lavas. The Glas Eilean linear vent, which cuts the cone-sheets, is the youngest major body of pyroclastic rocks in Ardnamurchan, the intrusive tuff, or tuffisite, cutting it demonstrates the ability of flowing gases to entrain and transport fragments of considerable size.

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