Chapter 3 The Small Isles — Rum, Eigg Muck Canna–Sanday

Introduction

The Isle of Rum (Figure 3.2) was the site of a major volcano which was active for a period of one or two million years in the Palaeocene, about 59 million years before the present. The volcano developed on a ridge of Precambrian rocks (Torridonian sandstones unconformably overlying Lewisian gneiss) which was covered by a veneer of Mesozoic sediments and Palaeocene lavas. The ridge was flanked by basin structures in the Minch to the west and the Sound of Rum to the east in which thick sequences of Mesozoic sediments accumulated. At the present time, the deeply eroded roots of the volcano are exposed, together with mainly Torridonian country rocks (Figure 3.2). The north-westerly dipping Torridonian rocks crop out over most of northern and eastern Rum and form the scarp and dip-slope topography north of Kinloch Glen; the Tertiary igneous rocks form the high, rugged mountains occupying most of the southern part of the island.

Rum abounds in features of geological interest but owes its special significance to the spectacular geology of the eroded remains of the Tertiary volcano. Excellent examples of layered ultrabasic rocks, unrivalled in the British Isles, are an outstanding feature of the complex (Figure 3.1). The ultrabasic Layered Series is of international importance in the development of theories relating to the origin of layering in igneous rocks (for example, Wager and Brown, 1968; Bédard *et al.,* 1988; Young *et al.,* 1988). The centre is also of significance because of its demonstration of the tectonics associated with its emplacement (for example, Bailey, 1945, 1956; Brown, 1956; Emeleus *et al.,* 1985). Spectacular examples of felsites, explosion breccias, and tuffisites related to the emplacement of the complex are well exposed (for example, Hughes, 1960a; Dunham, 1968). Good examples of contacts between mafic and acid rocks, with evidence for local generation of rheomorphic acid magmas, are also of special interest in the study of the Rum centre (Hughes, 1960a; Dunham and Emeleus, 1967; Greenwood, 1987).

Almost everywhere on Rum there is some significant feature of Tertiary igneous activity exposed. The sites selected cover most aspects, but the island is, in effect, a single site in its own right and it is fortunate that it is a National Nature Reserve. The geology of Rum has been summarized in the Reserve handbook (Black, 1974); an outline of the Palaeocene igneous sequence is given in (Table 3.1).

(Table 3.1) Summary of the Palaeocene igneous geology of Rum and the Small Isles (based on Emeleus and Forster, 1979, table 1, with later amendments)

Valley-filling pitchstone of the Sgurr of Eigg, and associated conglomerates Dolerite dykes
Lavas and fluviatile sediments of north-west Rum and Canna-Sanday, olivine basalts, hawaiites, mugearite (on Canna), including also tholeiitic basaltic andesite, icelandite (on Rum)
—Period of profound erosion during which the Rum central igneous complex was unroofed and eroded—
The Rum Layered Igneous Complex:
Central Series: feldspathic peridotites, including breccias and some layered allivalites and peridotites
Western Layered Series (WLS): feldspathic peridotites and gabbroic rocks at Harris
Eastern Layered Series (ELS): layered feldspathic peridotite and allivalite, also gabbroic and ultrabasic intrusive bodies
(The WLS and ELS above may be coeval)
Dolerite and basalt dykes (some also post-date the Layered Igneous Complex)
Dolerite and basalt cone-sheets on Rum
Early phase of acid igneous activity:
Western Granite, also granite at Papadil and Long Loch
Porphyritic felsite (ignimbrites, in caldera, and intrusions)
Tuffisites (some may post-date porphyritic felsite)
Volcaniclastic breccias — probably a mixture of explosion breccias and breccias formed by caldera wall collapse
Dolerite and basalt dykes (some intruded after breccias and prior to felsites)

Initiation of the Main Ring Fault System: movement on this system of arcuate faults probably continued at least until emplacement of the ELS/WIS and was a major tectonic feature during the early acid phase of igneous activity.
Lavas of Eigg and Muck, and those involved in the Main Ring Fault on Rum. Principally olivine basalts, feldspar-phyric olivine basalts and mugearites on Eigg. The dykes cutting these lavas belong to the main post-felsite and granite phase of dyke intrusion on Rum. Thin sedimentary layers occur in the Eigg and Muck successions.

The first comprehensive account of the geology of Rum is contained in the Geological Survey's Memoir on the Small Isles of Inverness-shire (Harker, 1908). Many of the views advanced by Harker were subsequently considerably amended in a key paper by Bailey (1945). These contributions, together with the results of investigations between about 1950 and 1966 have been reviewed by Dunham and Emeleus (1967).

The earliest Palaeocene igneous activity on Rum was the accumulation of basalt lavas, probably part of the Eigg and Muck lava fields. Initiation of the central igneous complex was probably preceded by intrusion of numerous gabbroic plugs followed by doming and the formation of an arcuate fault system. This faulting was recognized by Bailey (1945), who showed that gneisses and basal Torridonian sediments contained within it had been uplifted by possibly as much as 2000 m. Acid magmatism led to the formation of volcanic breccias, tuffisites, bodies of porphyritic felsite and granites. Initially, the breccias were attributed to explosive volcanism associated with the acid magmas which formed the felsites (Bailey, 1945; Hughes, 1960a; Dunham, 1968) and which were considered to be intrusive. Subsequently, Williams (1985) showed that the felsite frequently exhibited typical eutaxitic structures and some, at least, were probably formed as ignimbrites, possibly ponded within a caldera (Emeleus *et al.,* 1985). Recent work on the chaotic breccias of Dibidil and Coire Dubh strongly suggests that much of the fragmented material may be due to catastrophic collapse, from time to time, of the walls of a caldera formed during subsidence on the Main Ring Fault (M. Errington, private communication; observations of the authors and B.R. Bell). The argument for the presence of a caldera was strengthened when it was found that Lower Lias fossiliferous sediments and basalt lavas similar to those on Eigg occurred within the Main Ring Fault system (Smith, 1985), implying that there must have been significant subsidence (1–2 km?) along this fault system after the uplift demonstrated by Bailey. It was also shown that the period of subsidence was followed by further central uplift during which Torridonian strata were brought up over the Mesozoic sediments and later lavas (Smith, 1987; Emeleus *et al.,* 1985). Furthermore, the subsequent emplacement of at least the Eastern Layered Series peridotites and allivalites was clearly guided by these arcuate faults. The complex interplay between acid magmatism, major doming and ring-faulting, intrusion and the extrusion of pyroclastic flows, caldera formation and the development of chaotic breccias, are noteworthy features of the igneous geology of Rum.

The layered ultrabasic rocks and associated gabbros were considered in some detail by Wager and Brown (1968) in their classic work on layered igneous intrusions. Subsequently, these rocks have figured prominently in the development of theories concerning the compositions of the magmas responsible for mafic bodies such as the Rum Layered Series. The frequent close association between the layered ultrabasic rocks and gabbros makes basaltic magmas attractive parent material. However, there is a growing body of opinion which advocates high-temperature picritic basalt or magmas of feldspathic peridotite composition as being parental to the Rum layered ultrabasic rocks and other similar masses. The existence of these high-temperature magmas at high crustal levels was advanced by Dreyer and Johnston (1958) and Wyllie and Dreyer (1963) from examination of the minor ultrabasic intrusions about the Cuillin gabbros (Cuillin Hills) and on the Isle of Soay, south of Skye. The close similarities between the minor ultrabasic intrusions and layered ultrabasic rocks on both Skye and Rum suggested to Gibb (1976) that the ultrabasic rocks had been formed from parental magmas consisting of a suspension of olivine crystals in ultrabasic ('eucritic') liquid. Donaldson (1975) subsequently investigated the harrisites and ultrabasic breccias of south-west Rum (Harris Bay) and postulated that the rocks had formed from (possibly hydrous) feldspathic peridotite liquids. Further supporting evidence for the presence of intrusive ultrabasic magmas came from McClurg's (1982) discovery of quenched aphyric ultrabasic dykes intruding the layered rocks, the recognition that at least some of the feldspathic peridotites in the layered succession of ultrabasic rocks were intrusive, sill-like sheets (Renner and Palacz, 1987; Bédard *et al.,* 1988), and the presence of quenched ultra-basic margins to the layered rocks at Beinn nan Stac and Harris Bay (Greenwood, 1987; Greenwood *et al.*, 1990).It thus appears inescapable, from the evidence of the Rum sites (Allt nam Ba-Beinn nan Stac; Askival–Hallival; Harris Bay) and elsewhere (for example, Skye Cuillins), that conditions in the larger central complexes of the BTVP and their immediate surroundings sometimes favoured the rise of hot, dense, picritic liquids to within a short distance (*c.* 1 km?) of the Earth's surface.

Although not unique by any means, these examples are unusual and must have involved special conditions involving initial rapid, strongly localized throughput of hot basaltic magmas, thus providing preheated pathways along which the ultrabasic liquids were able to rise to high structural levels before crystallizing and congealing.

Brown (1956) and Wager and Brown (1968) attributed the prominent layering seen in the Rum Eastern Layered Series ultrabasic rocks to accumulation of early high-temperature crystals (mainly olivine, followed by plagioclase) from successive batches of fresh basaltic magma. The model of a frequently replenished magma chamber is generally accepted, but, as outlined earlier, many now consider that ultrabasic magmas, with or without contemporaneous basaltic liquids, were responsible for the large-scale layering.

Young *et al.* (1988) consider that there was a stratified picrite-basalt magma chamber in which both magmas were crystallizing simultaneously. Investigations of layers high in the Eastern Layered Series led Renner and Palacz (1987) to suggest that Unit 14 (Brown, 1956) records replenishments of the Rum magma chamber by fresh batches of both picritic and basaltic magmas, and their field observations show that some of the subsidiary peridotite layers are actually sill-like bodies, intruded into near solid or solid troctolitic (allivalitic) rocks. Bédard *et al.* (1988) also examined layers high in the Eastern Layered Series and concluded that it was highly likely that peridotite layers in this succession formed from thick sills of picrite magma intruded into partly consolidated troctolites, thus coming close to the original explanation of the layering put forward in the Memoir (Harker, 1908). The distinctive textures of the ultrabasic rocks provided type examples of cumulate textures (Wager *et al.,* 1960); early-formed olivine and/or plagioclase were thought to have been cemented by the crystallization of trapped, contemporaneous liquid to give well-formed (early) crystals enclosed by poikilitic (late) crystals. Subsequent studies on Rum and elsewhere (for example, Sparks *et al,* 1985; Irvine 1987) have shown that there may have been substantial migration of the trapped liquids, which modified the early 'cumulate' minerals; it has also been realized that many of the textures of igneous rocks hitherto considered to have formed when the rocks first consolidated may, in fact, have been considerably modified. The ultrabasic rocks of Rum have been extensively referred to in such studies (for example, Hunter, 1987).

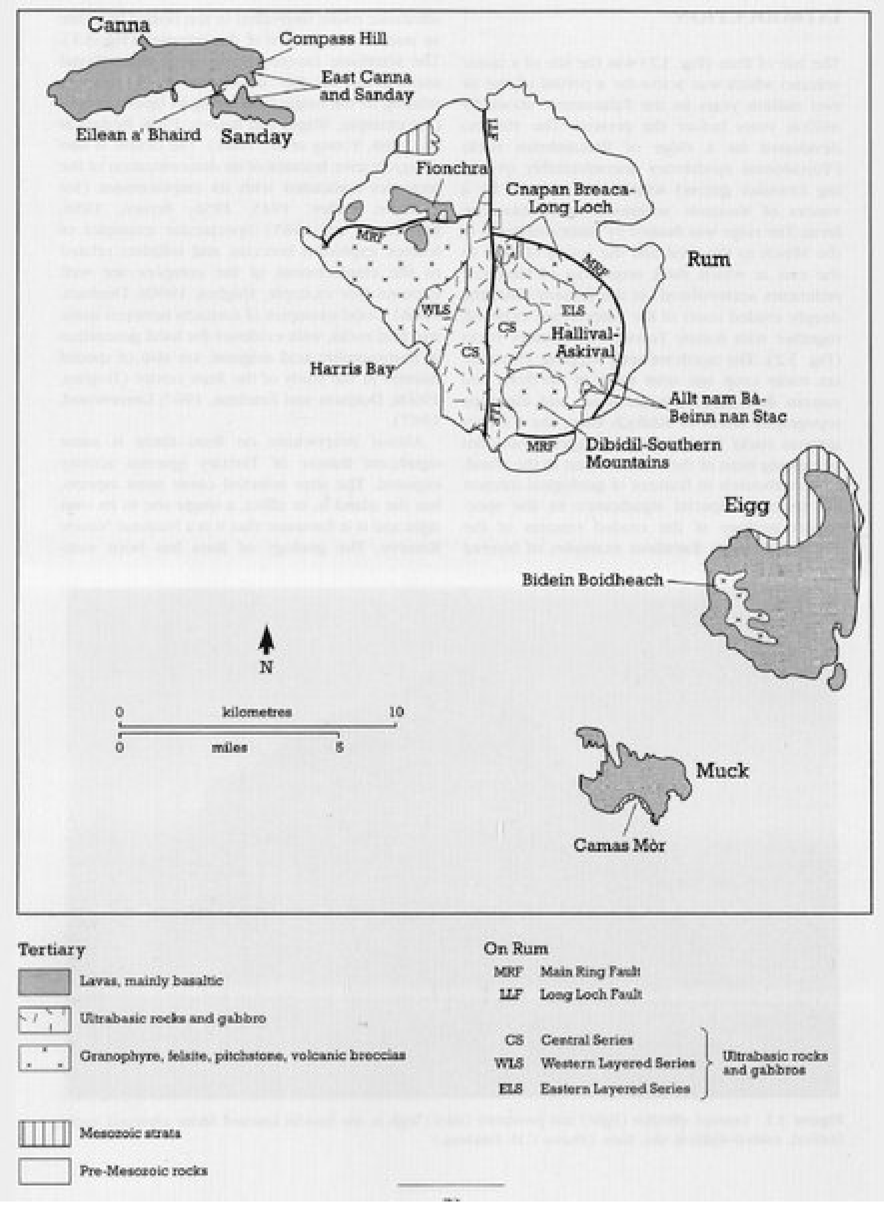
A field guide to the Tertiary igneous rocks of Rum has been published by the Nature Conservancy Council (Emeleus and Forster, 1979) and a compilation map of the solid geology has been published as one of the Nature Conservancy Council's 1:20 000 series on the island (Emeleus, 1980). A special issue of the *Geological Magazine* (Volume 122, Part 5, 1985) contains a wide variety of papers entirely devoted to the Tertiary igneous geology of Rum. Much of the recent research has concentrated on the layered ultrabasic rocks; this work has been reviewed and summarized by Emeleus (1987); the pre-layered rocks igneous geology has also been surveyed (Emeleus *et al.,* 1985).

Tertiary igneous rocks also crop out extensively on the islands of Eigg, Muck, Canna and Sanday which have been described by Harker (1908), Ridley (1971, 1973) and Allwright (1980).

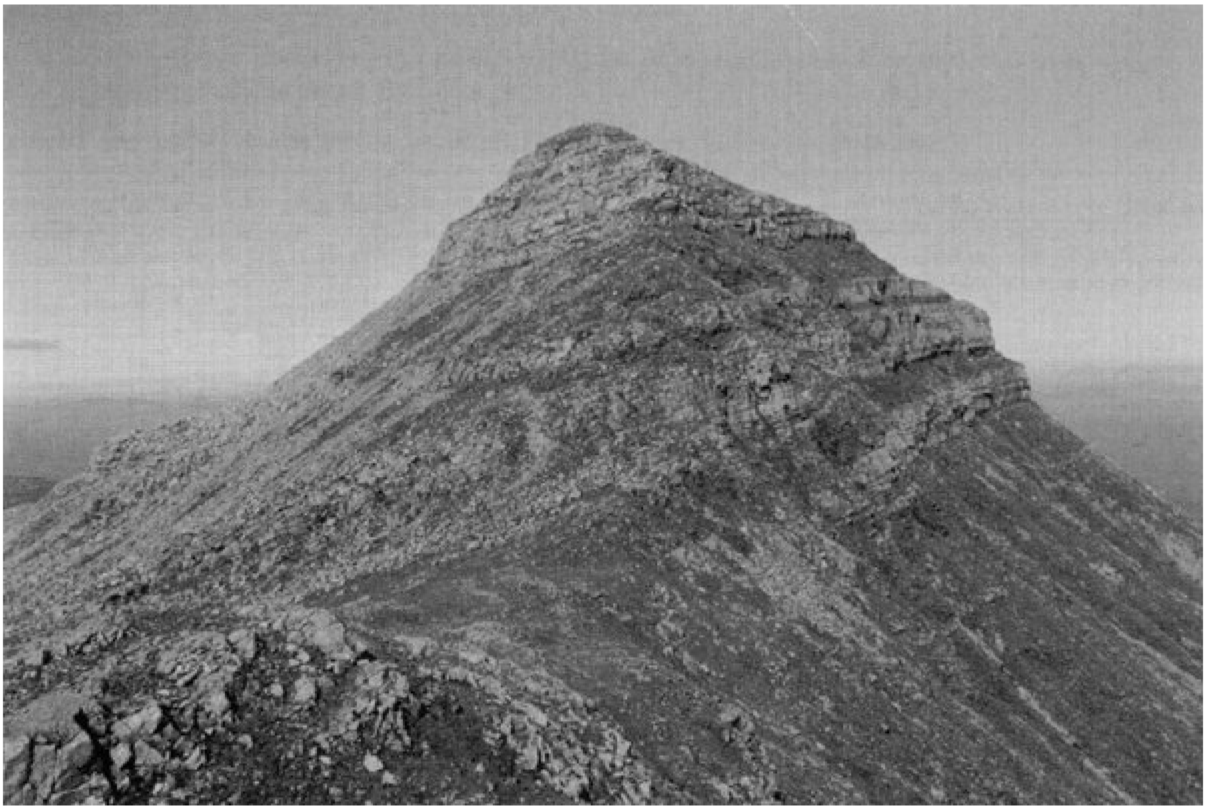
On Eigg and Muck, subaerial basaltic lava flows overlie Jurassic sediments and are cut by a dense NW–SE-trending basaltic dyke swarm which continues north-west to Rum where it is cut by layered ultrabasic rocks; the lavas on these two islands thus pre-date the Rum centre. The Sgurr of Eigg forms a conspicuous feature at the south end of Eigg formed by a pitchstone floor filling a valley system eroded into the basalt lavas and the dyke swarm (Figure 3.3). Radiometric dating of the pitchstone shows it to be one of the youngest igneous events in the British Tertiary Volcanic Province (52 Ma, Dickin and Jones, 1983).

The islands of Canna and Sanday consist entirely of Palaeocene lavas, volcaniclastic rocks and sediments. Fluviatile sediments are intimately associated with the products of the volcanic activity and clasts in inter-lava sediments provide evidence that the lavas on Canna and Sanday are closely linked with those of north-west Rum. Canna and Sanday are important links in a chain of sites that enable a relative dating of the Rum central complex and the later Skye Cuillin central complex in the study of the evolution of the British Tertiary Volcanic Province (Meighan *et al.,* 1981; Mussett, 1984).

References



(Figure 3.2) Map of the Small Isles showing localities mentioned in the text.



(Figure 3.1) Layered allivalite (light) and peridotite (dark) high in the Eastern Layered Series ultrabasic rocks, Hallival. Askival–Hallival site, Rum. (Photo: C.H. Emeleus.)

Valley-filling pitchstone of the Sgurr of Eigg, and associated conglomerates

Dolerite dykes

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Early phase of acid igneous activity:

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Lavas of Eigg and Muck, and those involved in the Main Ring Fault on Rum. Principally olivine basalts, feldspar-phyric olivine basalts and mugearites on Eigg. The dykes cutting these lavas belong to the main post-felsite and granite phase of dyke intrusion on Rum. Thin sedimentary layers occur in the Eigg and Muck successions.

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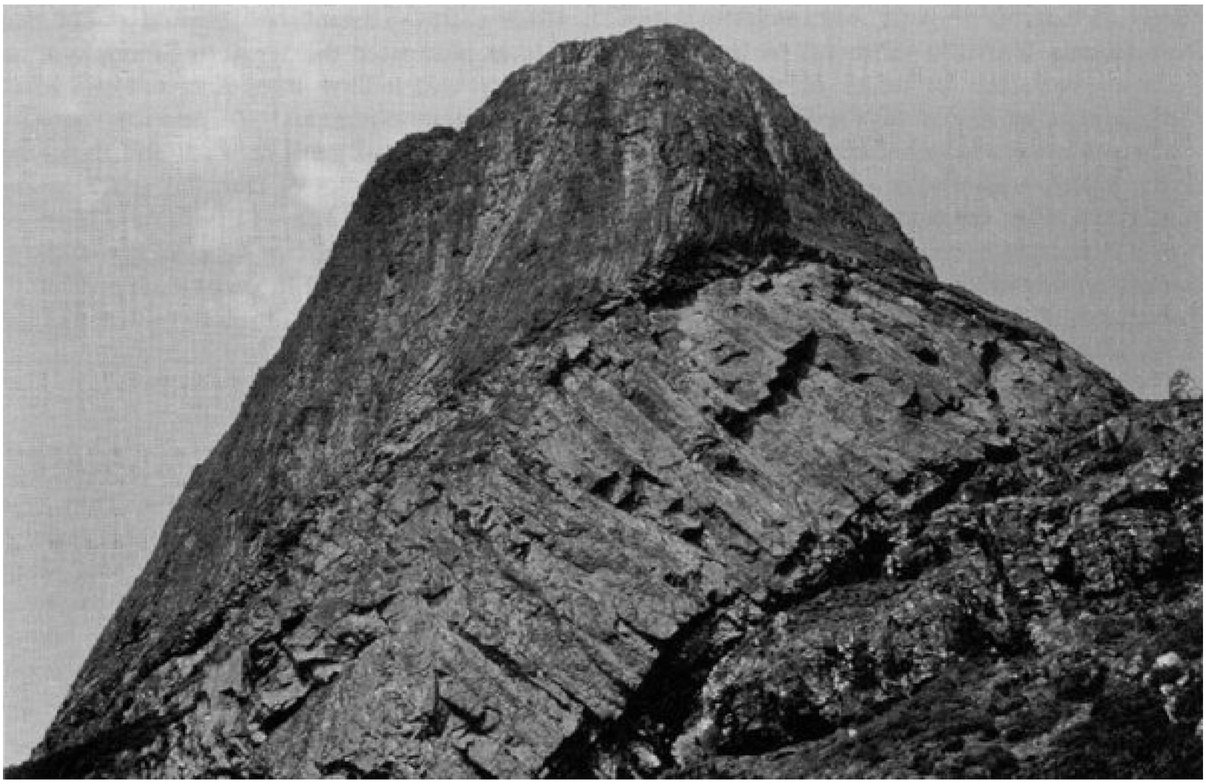

(Figure 3.3) The Nose, east end of Sgùrr of Eigg. Massive Eocene pitchstone flow overlies eroded Palaeocene basalt lavas. The pitchstone fills a steep-sided valley, columnar jointing is developed in the pitchstone perpendicular to the valley side (slopes top right to bottom left), but gives way to fine-scale, near-vertical jointing at higher levels. The individual lava flows cut out against base of pitchstone (bottom right side). South-west Eigg site. (Photo: A.P. McKirdy.)