Chapter 2 The Isle of Skye

Introduction

Skye is one of the classic areas of Great Britain for the study of igneous geology. The sea cliffs and hills in the north of the island magnificently expose a thick succession of mainly basaltic lavas which overlie Mesozoic sediments intruded by a suite of dolerite sills. Basaltic dykes of the northwest-trending swarm cut all these rocks. The Cuillins and Red Hills of central Skye have been eroded from the roots of a major volcano; they form a central igneous complex consisting of numerous intrusions of granite, gabbro and peridotite (Figure 2.1). Suites of dolerite cone-sheets intrude the gabbros and peridotites and all members of the central igneous complex are also cut by at least some members of the dyke swarm. The island contains a long and complicated record of igneous extrusion and intrusion (Table 2.1) and is a particularly suitable area for the study of the field geology of extrusive and intrusive igneous rocks. Investigations throughout the nineteenth century elucidated and highlighted the diversity and abundance of igneous rocks present and firmly assigned the activity to the Tertiary (Geikie, 1888, 1894, 1897; Judd, 1874, 1878).

The geological importance of the island was acknowledged when, at the turn of the century, the Geological Survey of Great Britain commissioned Dr Alfred Harker to make a thorough examination of all aspects of the Tertiary igneous rocks. Harker's contributions on Skye include a set of extremely detailed (published) Six-Inch to One-Mile geological maps of the Cuillin and Red Hills centres together with surrounding rocks. These outstanding maps form the basis to the Survey's One-Inch scale geological maps (Minginish, Sheet 70 and Glenelg, Sheet 71) while Harker's detailed observations and deductions were published as the classic Memoir on *The Tertiary Igneous Rocks of Skye* (Harker, 1904).

The extensive literature on the Tertiary igneous geology of Skye has been summarized in several publications over the past decade or so (J.D. Bell, 1976; Emeleus, 1982, 1983; Bell and Harris, 1986). A considerable amount of this work has concentrated on the mineralogy, petrology and geochemistry of the igneous rocks, and it has included important contributions to the theory of the petrogenesis of both basaltic and granitic rocks (summarized by Thompson, 1982). Fourteen SSSIs have been selected to cover the Tertiary igneous geology of Skye (Figure 2.2).

Tertiary volcanic activity commenced in the Palaeocene, when extensive NW-trending fissures acted as feeders for several phases of extrusion of basaltic and related magmas which built up the plateau lavas of the northern and south-western parts of the island (Table 2.2). The lavas were predominantly extruded subaerially, with periods of deep erosion and laterite formation between successive flows. Although the majority of the lava flows are mildly alkaline to transitional olivine basalts, more olivine-rich picritic flows occur and fractionated flows of hawaiite, mugearite, benmoreite and trachyte are present, particularly in the higher parts of the succession. The north Skye lavas were extensively subdivided by the Geological Survey (Anderson and Dunham, 1966; (Table 2.2)); they are now collectively grouped as the Skye Main Lava Series (SMIS), Thompson *et al.,* 1972). A few distinctly different tholeiitic flows fill valleys eroded in the SMLS of south-west Skye; these are the Preshal More type basalts (Thompson *et al.,* 1972; see (Table 2.2)).

Thompson *et al.* (1972) noted a tendency for progressive compositional changes from hypersthene-normative basalts, upwards to nepheline-normative basalts, alkali hawaiites and mugearites in the Beinn Edra, Ramascaig and Totaig groups (Table 2.2). However, both nepheline-normative and hypersthene-normative basalts and associated lavas occur locally throughout the SMLS. To explain the absence of any obvious strong evolutionary trend, the authors envisaged a complex plumbing system beneath Skye during the eruption of the Palaeocene lavas: there was probably no major magma chamber, but rather a whole series of small reservoirs fed from the mantle where the primary magmas were generated by partial melting of upper-mantle garnet lherzolite. Magma was generated at this source throughout the accumulation of the SMLS, some batches travelled quickly to the surface, others resided in reservoirs within the crust for varying times. Thus, the magmas which formed 'the lava flows followed a variety of paths to the surface, allowing for different amounts of fractionation, and of contamination by reaction with reservoir walls. In this way the somewhat random distribution of basalt and other effusive rock could be accounted for. Studies on the distribution of strontium, lead and neodymium isotopes in the lavas strongly indicate contamination by crustal rocks (Moorbath and Thompson, 1980; Thirlwall and Jones, 1983), supporting the model described above; furthermore, Thirlwall and Jones found that contamination was most pronounced in the most primitive (hot) compositions, and least pronounced in the most evolved (cool) ones. Further investigations of lavas in Mull have shown similar distributions and the problem of magma plumbing has been examined using data from both islands ((Figure 5.3); Morrison *et al.,* 1985). The Skye, Mull and other BTVP magmas appear to have been derived from mantle sources already depleted by partial melting and magma extraction during the Permo-Carboniferous (for example, Thompson and Morrison, 1988).

After extrusion of the SMLS flows, activity became focused in the area of the present-day Cuillin Hills where mafic magmas intruded to high crustal levels to form coarse-grained gabbros, eucrites, allivalites and peridotites, suites of cone-sheets and some of the dense swarms of dolerite dykes. At, or towards the end of this mafic magmatism, there was widespread explosive volcanicity in the Strath na Creitheach area. Up to this stage, very little acid magma had been generated, except for the arcuate Coire Uaigneich granophyre.

Thereafter, the central igneous complex experienced changes in both the focus of activity and in magma composition. Three separate centres were established in succession:

1. the Strath na Creitheach centre;
2. the Western Red Hills centre;
3. the Eastern Red Hills centre.

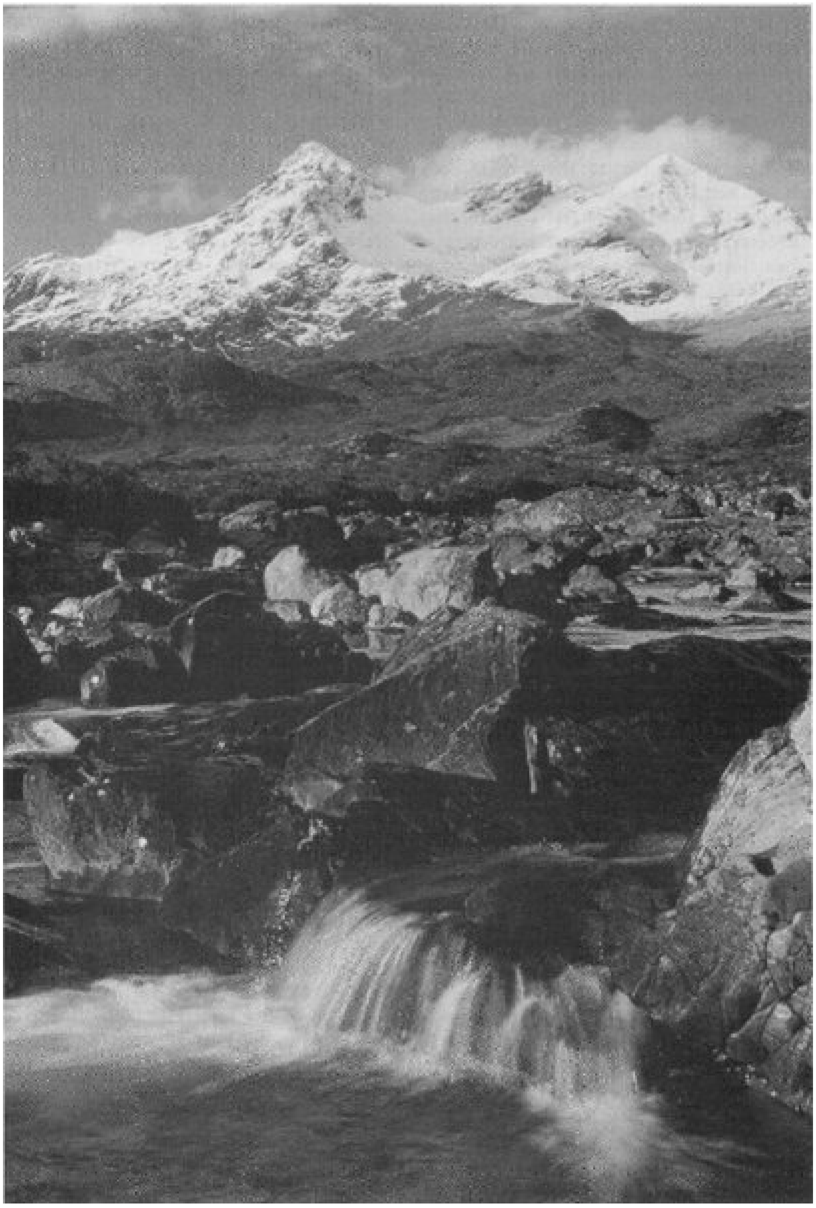
With time, activity moved progressively eastwards and granite became dominant at the present level of erosion, providing a particularly clear record of evolutionary changes taking place in the underlying magma chamber. However, despite the apparent dominance of granite in the later centres, basaltic magma was still clearly available and on occasions this mixed with acid magma to give distinctive hybrid bodies such as the marscoite suite, forming a ring-dyke in the Western Red Hills centre, and the Kilchrist Hybrids of the Eastern Red Hills centre. Further evidence of mixed magmas (acid–basic) comes from composite minor intrusions, such as the sills in the Broadford area. The final episode of igneous activity on Skye is represented by sparse NW-trending dolerite dykes.

Skye has been the site of notable geophysical experiments aimed at elucidating the deep structure of central intrusive complexes. Gravity surveys show that both the Cuillin Hills and the Red Hills are the site of a sharply defined, strong, positive Bouguer gravity anomaly. This is attributed to the presence of a large, steep-sided cylindrical or inverted cone-shaped mass of dense mafic rock extending to at least 15 km beneath all the central complexes (Bott and Tuson, 1973). An immediate implication of this is that the Red Hill granites are, despite their great areal extent, relatively superficial bodies probably not more than 2 km thick. Palaeomagnetic measurements made on the Cuillin gabbros and peridotites show that these rocks are reversely magnetized, as are the earlier SMIS lavas. However, some of the granites have normal polarities and magnetic investigations by Brown and Mussett (1976) indicate normal polarities over much of the area known, from the gravity studies, to be underlain by mafic rocks. Thus there must have been two periods when large quantities of mafic magmas were involved in the Skye centre; those producing the Cuillin centre were intruded when the Earth's magnetism was reversed, and those giving rise to the dense rocks under the granites were emplaced later when the polarity was normal. Radiometric studies indicate that the bulk of the igneous activity took place between about 60 Ma and 57 Ma ago, but that some intrusions were emplaced as recently as 53.5 Ma ago (Table 1.1).

Investigations of the oxygen isotope geochemistry of the rocks of the Skye central igneous complex and the surrounding lavas and sediments, show that there has been massive circulation of heated meteoric waters through and around the complex (Taylor and Forester, 1971; Forester and Taylor, 1977). This pervasive circulation, which was driven by heat from within the central complex, caused considerable metasomatic and hydrothermal alteration of both the igneous intrusions and adjoining basalts, frequently overprinting original igneous features in the intrusive rocks and the high-grade metamorphic effects in their surroundings. Thus doubts were cast on the igneous origins of some of the rock textures (for example, granophyric quartz-feldspar intergrowths in some of the granites) and on the validity of petrogenetic conclusions drawn from earlier geochemical and isotopic studies. Among the last were the isotopic investigations by Moorbath and Bell (1965) and Moorbath and Welke (1969) which had indicated that the granitic rocks of the Red Hills were largely derived from partial melting of Lewisian gneisses. As recounted in Chapter 1, these doubts and uncertainties were resolved by work on the Mull granites; subsequently isotopic data from Skye were refined and augmented by Dickin (1981) who demonstrated that both crustal and mantle sources have significantly contributed to the granite magmas of

Skye.

References



(Figure 2.1) Sgùrr nan Gillean and the Cuillin Mountains viewed from Sligachan, Isle of Skye. (Photo: David Noton Photography.)

Late dykes (dolerite, felsite and peridotite)

Eastern Red Hills Centre
- Composite acid/basic sheets
- Five granite intrusions
- Kilchrist hybrids (possibly post-date some of the granites)
- Broadford and Beinn nan Cro gabbros
- Acid lavas, ignimbrites, tuffs and agglomerates of Kilchrist vent (may pre-date this Centre by a considerable amount)

Dykes (dolerite, pitchstone)

Western Red Hills Centre
- Marsco and Meall Buidhe granites
- Marscoite suite of hybrids, etc.
- Nine granite and major felsite intrusions
- Marsco Summit Gabbro
- Belig vent

Dykes (dolerite)

Strath na Crèitheach Centre
- Three granite intrusions
- Loch na Crèitheach vent

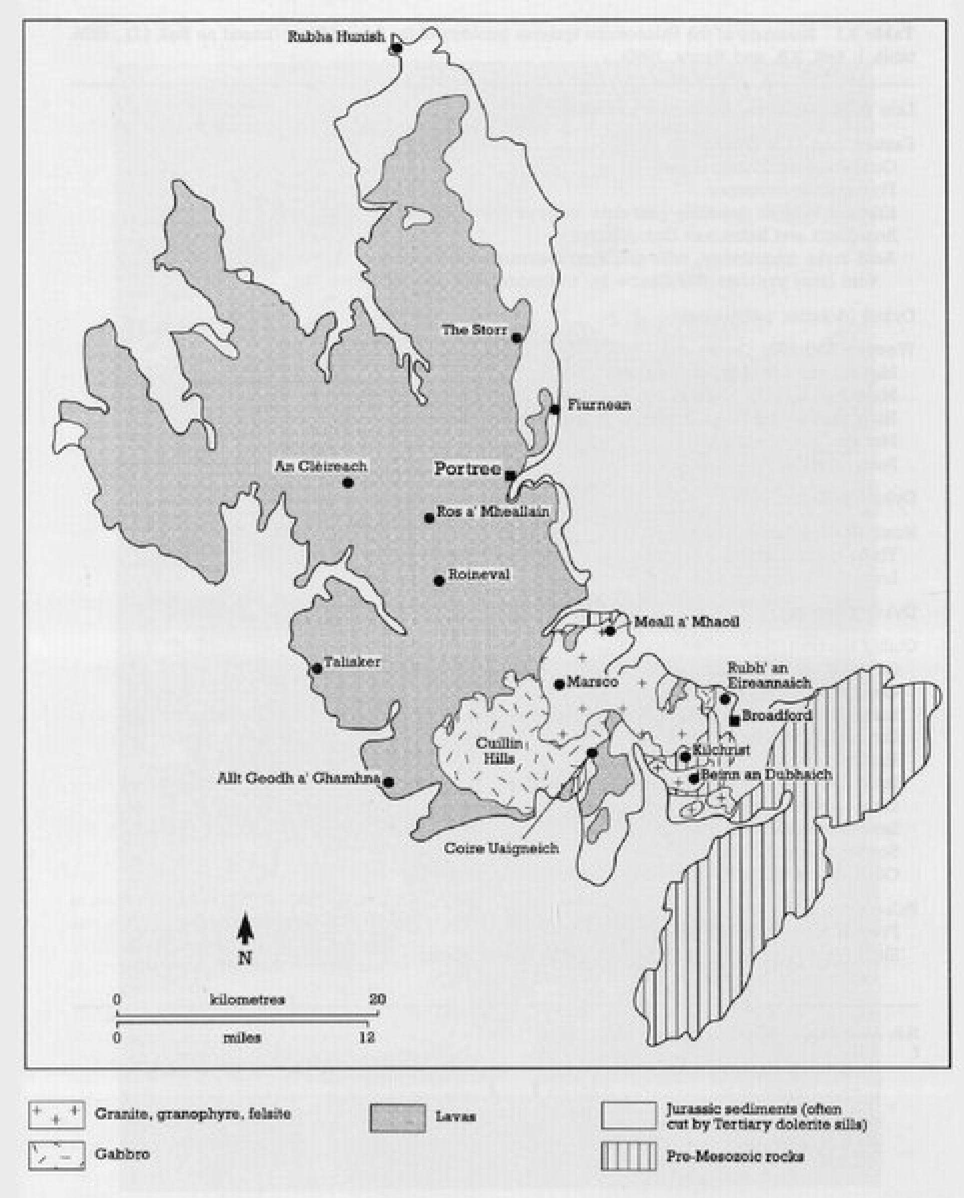
Dykes (dolerite)

Cuillin Centre
- Cone-sheets (dolerite)
- Coire Uaigneich Granophyre (but see text)
- Intrusive tholeiites
- Druim na Ramh Eucrite
- Explosive vents (of several ages)
- Inner Layered Series: allivalite, eucrite, gabbro
- Outer Layered Series: allivalite, eucrite, gabbro
- Layered Peridotite Series
- Border Group: gabbro, allivalite
- Cone-sheets and dykes (overlap with many of the above)

Palaeocene lavas
- Preshal More tholeiitic flows
- Skye Main Lava Series (SMLS) flows (with sparse clastic sedimentary horizons, and basal sediments and tuffs)

N.B. Additional details through text.

(Table 2.1) Summary of the Palaeocene igneous geology of the Isle of Skye (based on Bell, J.D., 1976, table 1; Bell, B.R. and Harris, 1986)



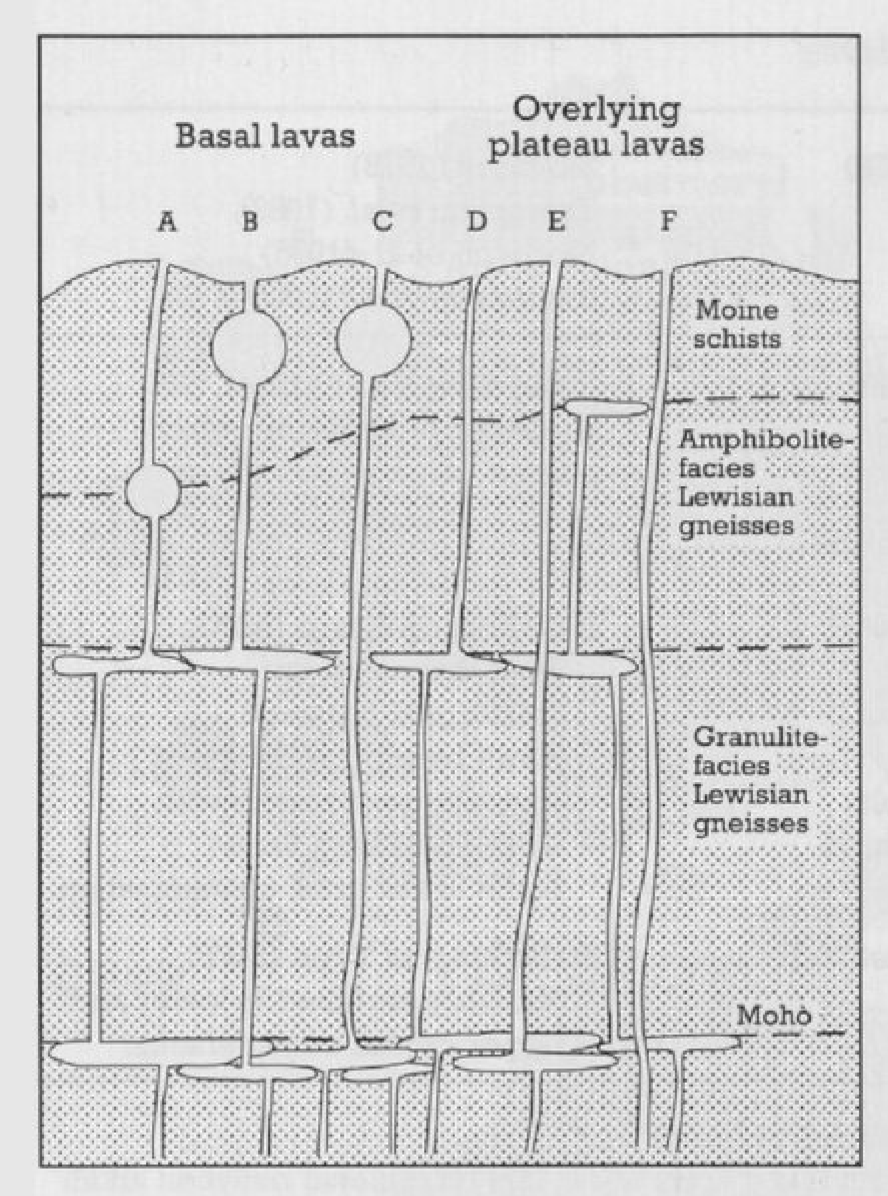
(Figure 2.2) Map of the Isle of Skye, showing localities mentioned in the text.

NORTHERN SKYE (1) Anderson and Dunham (1966)	WEST-CENTRAL SKYE (2) Williamson (1979)	Based mainly on NORTHERN SKYE (3) Thompson *et al.* (1972)
	7. Talisker Group	Preshal Mhor tholeiitic basalts
5. Osdale Group	6. Loch Dubh Group 5. Arnaval Group	
4. Bracadale Group	4. Tusdale Group	Skye Main Lava Series
3. Beinn Totaig Group	3. Cruachan Group*	Transitional and alkali-olivine basalts, hawaiites, mugearites, benmoreites and trachytes. More fractionated types are more common in the higher groups.
2. Ramascaig Group	2. Bualintur Group	
1. Beinn Edra Group	1. Meacnaish Group	

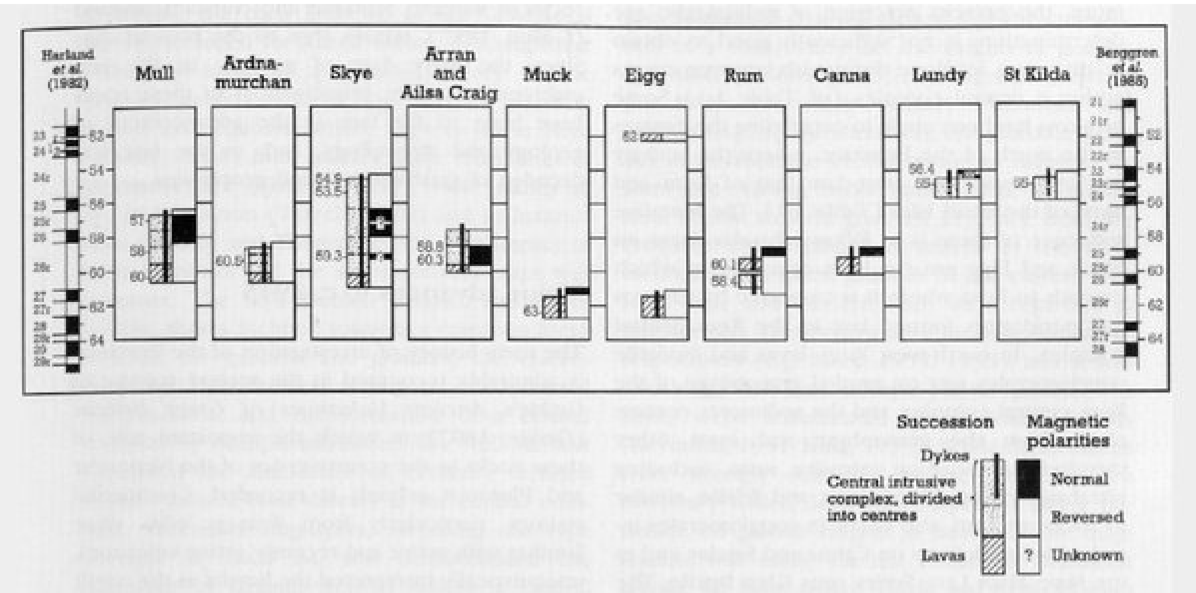
Individual groups are probably geographically restricted (see, for example, Anderson and Dunham, 1966, figure 13).

* The thick fluviatile conglomerates of the Allt Geodh a' Ghamhna site are at the base of this group.

(Table 2.2) Correlation of the divisions of the Palaeocene lavas of the Isle of Skye (mainly after Williamson, 1979, table 1).



(Figure 5.3) Sketch of the magmatic plumbing beneath south-west Mull during extrusion of the Palaeocene basaltic lavas (after Morrison et al., 1985, fig. 4). See text for explanation.



(Table 1.1) British Tertiary Volcanic Province: summary of the geological successions, radiometric ages and magnetic polarities (after Mussett et al., 1988, figure 2)