ESHANESS COAST

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Introduction

The most extensive and thickest development of volcanic rocks in the Middle Old Red Sandstone of western Shetland is at Eshaness, where basaltic to andesitic lavas, andesitic pyroclastic rocks and a rhyolitic ignimbrite form a sequence some 500 m thick. The Eshaness Coast GCR site provides a section through most of this sequence, in spectacular sea cliffs that are renowned for their geomorphological features such as geos, blowholes, subterranean passages and cliff-top storm beaches (Figure 9.45). Volcanological highlights include well-preserved lava tops, textures due to contact with wet sediment, very coarse proximal pyroclastic breccias, a section through a welded ash-flow and a complex tuff with a variety of features suggestive of hydromagmatic eruption. The volcanic rocks were first described by Peach and Horne (1884) and subsequently in more detail by Finlay (1930). A succession modified from that established by Finlay forms the basis of the Geological Survey map by J. K. Allan (Wilson *et al*., 1935) and of the summary by Mykura (1976). Some petrographical and geochemical details are given by Flinn *et al*. (1968) and Thirlwall (1979).

Figure 9.45: The cliffs of Eshaness, looking NE from the lighthouse. The nearest headland (the North Head of Caldersgeo) comprises andesitic pyroclastic breccias of unit 6 resting on andesites of unit 4. Most of the cliffs of the middle distance are andesites of unit 4; and the prominent dip-surface of the Grind of the Navir ignimbrite is just visible in the distance above the prominent stack (Moo Stack). (Photo: BGS no. D1660.)

The Old Red Sandstone rocks of Shetland occur in three distinct structural blocks, differing in age, depositional and volcanological development, tectonic history and effects of igneous intrusion and low-grade metamorphism (Mykura, 1976). These blocks are separated by major N- to NNE-trending faults. The volcanic rocks of Eshaness, together with those of the island of Papa Stour and smaller outcrops at Melby on the western tip of the Walls Peninsula, all occur to the west of the Melby Fault (Figure 9.46) and hence are probably related temporally, if not magmatically (see Interpretation). The Eshaness outcrop, consisting almost entirely of volcanic rocks, is bound to the east by the probable northern extension of the Melby Fault, which juxtaposes the Northmaven plutonic complex. The rocks are folded into a shallow NNE-trending syncline, which plunges to the NNE in the northern part of the outcrop and to the SSW in the south. The GCR site (Figure 9.47) is entirely on the western limb of this syncline, which dips to the SE at 10–12°.

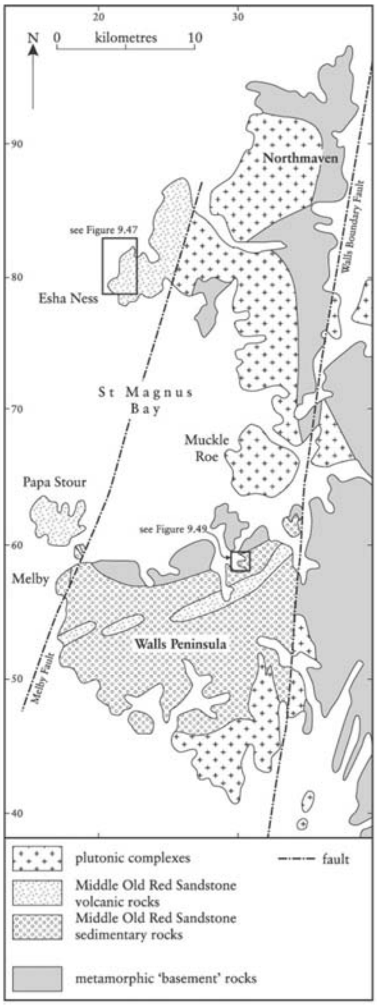

Figure 9.46: Location of Middle Old Red Sandstone volcanic rocks, major intrusions and major faults in western Shetland, after Mykura (1976).

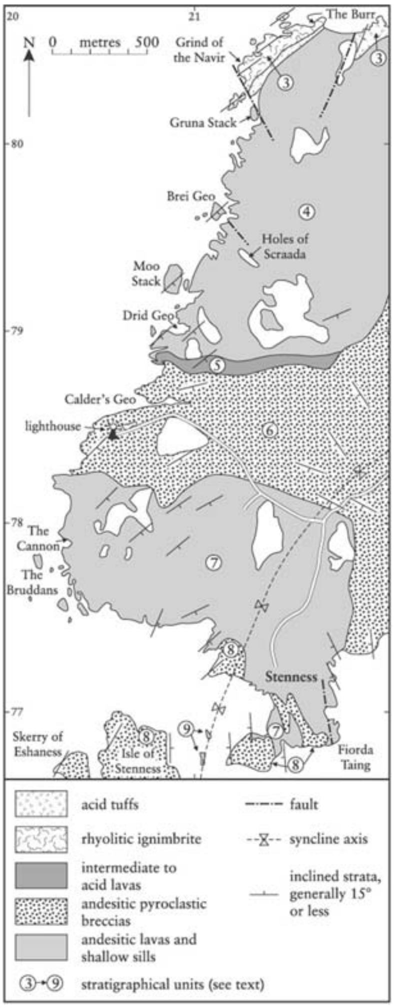

Figure 9.47: Map of the Eshaness coast, adapted from Geological Survey 1:10 560 sheets Shetland 19 and Shetland 23 (1959).

Description

The volcanic succession of Eshaness has been divided into nine units (Mykura, 1976), but the lowest two crop out only on the eastern limb of the syncline. Within the GCR site there is a continuous section from the ignimbrite of unit 3 in the north, to the pyroclastic rocks of unit 8 in the south (Figure 9.47).

1. and 2. The basal units, seen on the west side of Brae Wick (245 786) outside the GCR site, consist of reddish-purple micaceous sandstones and tuffaceous sandstones, overlain by olivine basalts and andesites with lenticular tuffaceous beds.

3. The well-jointed ignimbrite of unit 3 is responsible for the spectacular geomorphological feature of the Grind of the Navir (2127 8042). Here, large angular blocks have been, and still are being, excavated by the waves to form a natural passage and 'staircase' and then piled up on top of the cliff to form a high-level storm beach. Most of the outcrop consists of a relatively homogeneous pinkish-purple rhyolitic welded tuff with a well-developed eutaxitic fabric accentuated by flattening of the clasts. Broken and corroded crystals of pink alkali feldspar, commonly with a hollow core, are typically up to 10 mm long, but some are up to 150 mm; smaller fragments of collapsed pumice, shards of glass and rounded darker basic fragments are also abundant, with less common plagioclase, quartz and magnetite-rich aggregates that are presumably pseudomorphs after mafic minerals. All are etched out and well seen on weathered surfaces (Figure 9.48). The fine-grained grey matrix consists largely of devitrified glass with trails of opaque 'dust' and with elongate angular cavities. All parts of the rock are heavily altered, with the feldspars replaced by sericite and/or carbonate and pervasive secondary silicification throughout. The base of the ignimbrite is not exposed, but the top forms

an extensive flat surface that dips inland behind the Grind of the Navir. A very sharp junction is well exposed between ignimbrite with few clasts and a very fine-grained matrix and an overlying soft, yellow-brown-weathering tuff. The poorly sorted base of the tuff contains angular feldspar clasts up to 20 mm long similar to those of the ignimbrite, but it is generally fine grained above. Vesicles and cavities up to 20 mm long are flattened, but otherwise the tuff lacks the fabric of the underlying ignimbrite. Some of the cavities are filled by quartz, but others are hollow. The tuff is well bedded in parts and some beds have convolute flow structures with some brecciation. Coarser-grained beds up to 1 m thick contain large ragged fragments of very vesicular basic-looking rock.

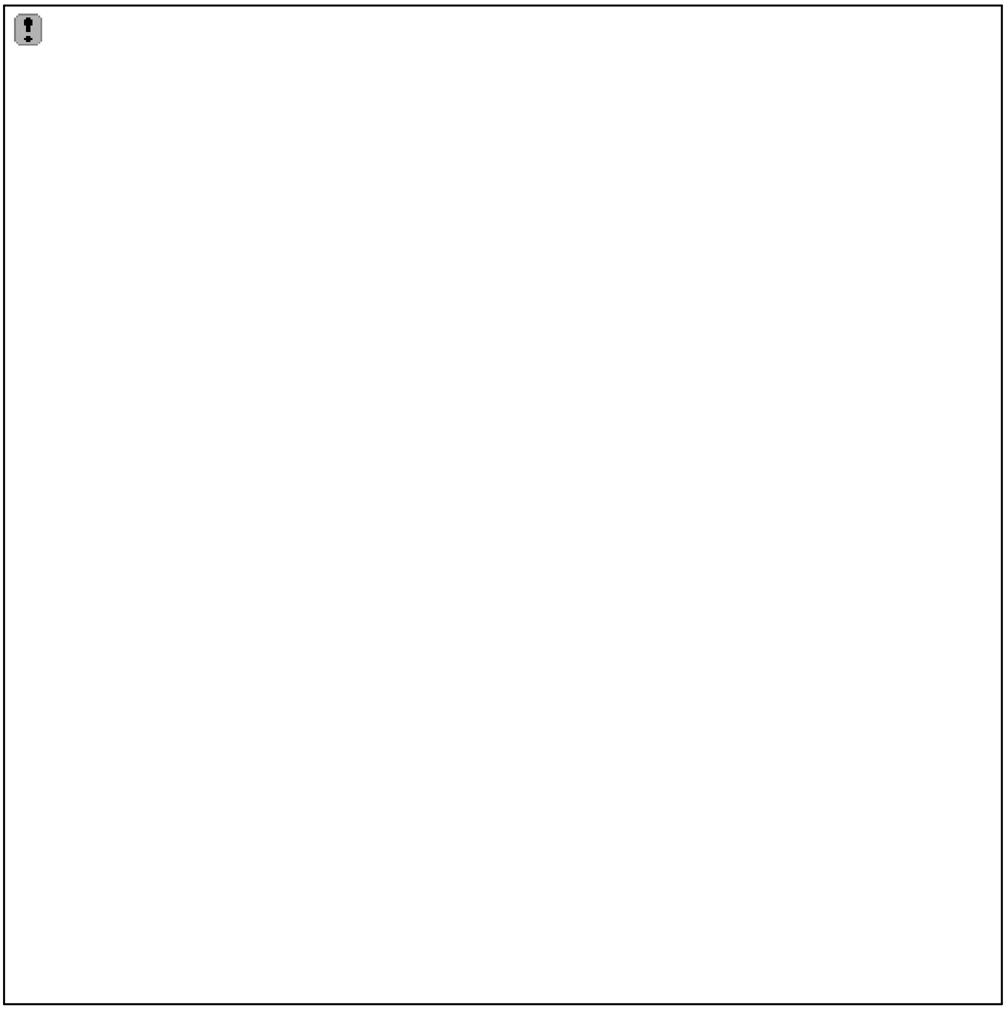

Figure 9.48: Ignimbrite of the Grind of the Navir, Eshaness coast. The larger clasts are of alkali feldspar, commonly with a hollow core; smaller clasts are mainly collapsed pumice, glass shards and basic fragments. (Photo: BGS no. D1662.)

4. Between Gruna Stack (213 802) and Drid Geo (209 790) are several sheets of aphyric andesite (Finlay recorded three), with distinctive vesicular, slaggy and autobrecciated tops. The vesicles are commonly elongated in the direction of flow. The central parts of the sheets have irregular to flaggy, flow-parallel jointing, commonly with a rather lenticular appearance. They are described as ‘mugearites' on the Geological Survey map and byMykura (1976), but the original designation as augite andesites is more appropriate for these essentially calc-alkaline rocks. Most are highly altered. At Brei Geo (2125 7975), the top surface of a sheet is spectacularly domed, the domes and hollows having an amplitude of 2–3 m. This surface can be examined in detail at the cliff top some 100 m to the north, where it is seen in contact with a remnant of bedded brown sandstone. Detached lobes and subangular patches of vesicular andesite, up to 20 cm across, cut across the bedding in the sandstone at a high angle and with a sharp contact (cf. peperite), suggesting intrusion of the magma into wet sediment. Undisturbed sandstone is not present between the sheets.

5. Andesites of unit 5 occur on the eastern limb of the syncline where they are highly silicified and oxidized. On the western limb they have been correlated on the map with a thin flow that rests upon green-, purple- and yellow-weathering clays developed on an amygdaloidal lava at the top of unit 4 (2083 7885). The thin flow, which is also yellow-brown weathering, is very flaggy at the base and has very strong flow-banding that is folded and convoluted in parts. Some layers are vesicular, with slightly elongate, lined vesicles 1–2 mm in diameter. Other layers contain angular pink fragments that could be silicified. The general impression is that this was a very viscous flow, more acid in composition than the underlying andesites.

6. Very coarse andesitic pyroclastic breccias, which are over 100 m thick in the GCR site, increase in thickness and overall clast size northwards (Finlay, 1930). Vertical sections are well seen around Calder's Geo (209 786) (Figure 9.45), but the breccias are best examined on the cliff top SW of the lighthouse (around 205 784), where all traces of soil and superficial deposits have been swept away by high-level wave action. The clasts are largely andesitic, but fragments of felsic rock, sandstone and metamorphic rocks are not uncommon. The larger blocks are up to 1 m in size and mostly angular. Some are slightly rounded, but there are no obvious bombs. The unit as a whole is very poorly sorted, but the relatively finer-grained beds are crudely bedded and crudely graded; more marked rounding of clasts suggests some reworking in parts.

7. The top surface of the pyroclastic breccias is remarkably planar and forms a prominent ledge around the north side of the headland 400 m SW of the lighthouse. It is overlain by a feldspar-phyric hypersthene andesite, which is homogeneous throughout most of its thickness with few vesicles and little development of rubble or visible hydrothermal alteration. For the most part it is massive and blocky, although the central part has spheroidal jointing, well seen at The Bruddans. At its base (2040 7825) it has a definite 5 cm chill. Its top surface forms the SE-dipping land surface on headlands to the north and south of The Cannon (a horizontal blowhole in the cliff). In contrast to the lower parts, the top of the flow has quite large elongate vesicles and some inclusions of sandstone, although it remains quite coarsely porphyritic, with no chill. There are abundant fissure fillings and some wider areas of poorly bedded yellowish-brown sandstone that seem to post-date the cooling of the lava. An overlying flow of pyroxene andesite, which crops out between the Bruddans and Stenness is less porphyritic and more scoriaceous with intense hydrothermal alteration in places. Finlay (1930) reported that this unit thickens towards the north where up to four flows occur.

8. A unit of very coarse andesitic pyroclastic breccias with subordinate interbedded sandstone and conglomerate crops out in the core of the syncline at Stenness and on islands just offshore. The junction with the underlying lava is irregular and fissures and hollows in the lava surface are filled by tuff and sandstone. Much of the unit is massive, with blocks up to 1 m in size, but bedding occurs in places.

9. The highest unit is a flow of vesicular fine-grained andesite, which forms two skerries, 500 m SW of Stenness, just outside the GCR site boundary.

Interpretation

Because of the lack of intercalated sedimentary rocks in the Eshaness succession, there is little direct evidence of the environment in which the volcanism took place. However, by analogy with successions west of the Melby Fault at Melby and on Foula (Mykura and Phemister, 1976; Mykura, 1976, 1991), it seems reasonable to assume an arid or semi-arid alluvial plain with temporary lakes. The sediment was derived from the W or WNW and the area was close to the NW margin of the main Orcadian Basin where alluvial fans may have been developed. According to Mykura, post Mid-Devonian dextral movement of 60–80 km on the Melby Fault has transposed these outcrops from much farther south than the other structural blocks of Shetland, and confident correlations have been made with successions on Orkney (see below).

The eruptions were almost entirely subaerial, and the lack of sedimentary intercalations at Eshaness could be interpreted as evidence that the volcanic rocks accumulated rapidly, with such sediment as did accumulate between eruptions being removed by subsequent flows. There is good evidence at Brei Geo for interaction of magma with wet sediment, suggesting that at least some magma was emplaced as high-level sills in thin unconsolidated sediments, possibly on a lake bed. However, it is difficult to imagine this as the dominant mechanism in view of the general lack of intercalated sediments. The lowest andesite of unit 7 has many sill-like features (planar base with preserved chill, homogeneity, lack of alteration and flow-brecciation, inclusions of sandstone near the top). If it was emplaced as a sill, its top surface must have been uncovered for the cooling cracks to be filled with sediment prior to the eruption of the next flow.

The very coarse pyroclastic breccias of units 6 and 8 are clearly the products of large-scale eruptions and are relatively proximal, although there is no indication of where the source may have been, apart from the observation that some units thicken and coarsen northwards (Finlay, 1930). In addition to juvenile material, the vents sampled both sandstones and metamorphic basement, which is consistent with a site close to the margin of the sedimentary basin. Some reworking is apparent within the pyroclastic units, but a lack of volcaniclastic sedimentary rocks within the sequence in general suggests that the volcanism did not result in a pronounced topography.

The rhyolitic rocks of the Grind of the Navir probably represent a number of distinct types of pyroclastic eruption. The ignimbrite exhibits classic features of a welded pyroclastic flow with broken crystals, collapsed pumice and a classic eutaxitic texture. Mixed lithofacies in the overlying, dominantly well-bedded tuffs suggest the involvment of several eruptive styles; the basal, very poorly sorted lapilli-tuff and the finer-grained vesicular tuffs are probably the result of hydromagmatic eruptions that may have included pyroclastic surges and ash-falls, whereas the beds with large, ragged vesicular clasts suggest a more dominantly magmatic, possibly strombolian type.

The complete succession at Eshaness includes a wide range of compositions and Thirlwall (1979) has identified basalts, andesites, dacites and rhyolites. Several geochemical and mineralogical features suggest that the rocks are best classified as transitional between calc-alkaline and tholeiitic, in marked contrast to the calc-alkaline suites that characterize the Old Red Sandstone volcanic province in general. Thirlwall (1979) also presented good evidence that the Eshaness sequence could have been derived by multistage low-pressure fractional crystallization from a parental magma close in composition to an olivine tholeiite and relatively low in incompatible elements, features which are also atypical of the province as a whole.

There is no direct evidence of the age of the Eshaness sequence, although Flinn *et al*. (1968) did obtain a Rb-Sr isochron age of 365 ± 2 Ma (recalculated from 373 Ma using new constants) from the Grind of the Navir ignimbrite; in view of the pervasive alteration, this age is probably a minimum (Thirlwall, 1983a). Several authors have proposed correlations on lithological grounds between the volcanic successions at Eshaness, Melby and Papa Stour (Finlay, 1930; Flinn *et al*., 1968; Mykura, 1976), but Thirlwall (1979) identified geochemical differences. Although the Papa Stour rocks seem to be significantly distinct to have formed from a separate centre, he did conclude that the Eshaness and Melby sequences could be related. The volcanic rocks of Melby occur above the Melby fish beds, which have been reliably correlated with the middle Eifelian Sandwick Fish Bed of Orkney and palynological evidence has confirmed the Papa Stour and Melby volcanic rocks as late Eifelian (Marshall, 1988; Rogers *et al*., 1989, fig. 2).

Despite their Mid-Devonian age, Thirlwall (1979, 1981a) attributed the Eshaness and other volcanic rocks of Shetland to the same late Caledonian, WNW-dipping subduction zone that was responsible for late Silurian and Early Devonian volcanic and plutonic activity in northern Britain. He pointed out that their geochemical characteristics are even closer to those of modern arcs than are those of the earlier volcanic rocks in the main part of the province, and attributed their transitional tholeiitic nature to a closer proximity to the surface trace of the subduction zone. Although the magmas do have features that could be related to a subducted slab of oceanic lithosphere, by Mid-Devonian time the tectonic environment was one of post-orogenic extensional basins. Indeed, most of the volcanic activity in Shetland and Orkney was coeval with, and hence was probably controlled by, extensional faulting in the Orcadian Basin (Astin, 1985, 1990; Enfield and Coward, 1987; McClay *et al*., 1986; Rogers *et al*., 1989).

Conclusions

The volcanic sequence at Eshaness is representative of several in the most westerly structural block of Old Red Sandstone outcrops in Shetland. Their late Eifelian age is significantly later than Old Red Sandstone volcanism elsewhere in northern Britain, but it is the earliest late Caledonian volcanism in Shetland and Orkney. Although the rocks have subduction-related characteristics, their eruption was probably related to a major phase of extensional faulting during the development of the Orcadian Basin.

The mainly andesitic and rhyolitic rocks of the GCR site have transitional calc-alkaline to tholeiitic petrological features and may be related by fractional crystallization. Proximal pyroclastic breccias are intercalated with subaerial lavas and some high-level sills intruded into wet sediment, although inter-volcanic sediments are rarely preserved in the sequence. The ignimbrite and overlying hydromagmatic tuffs at the Grind of the Navir constitute one of the best preserved records of continuous rhyolitic pyroclastic eruption in Britain, which would well merit further detailed study.

These and many other volcanological features, are well seen in magnificent sea cliffs that are also noted for their geomorphological structures.

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