Pyroclastic rocks of the Skye Central Complex

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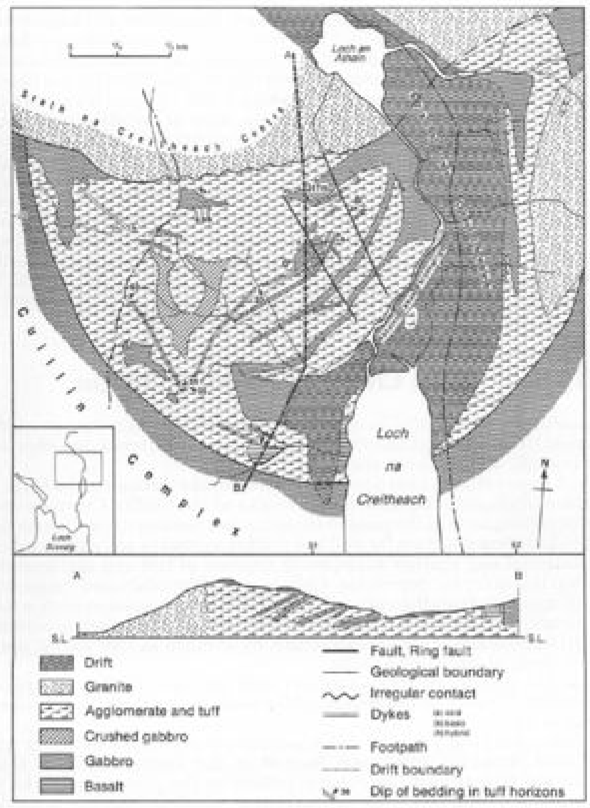

Figure 10 Geological sketch-map of the Srath na Creitheach pyroclastic deposits (modified from Jassim and Gass 1970)

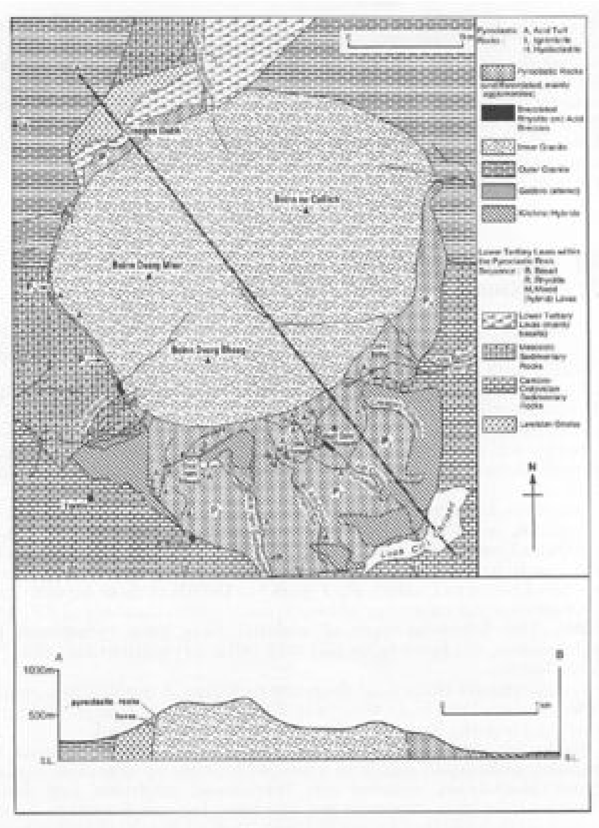

Figure 11 Geological sketch-map of the Creagan Dubh and Kilchrist pyroclastic deposits

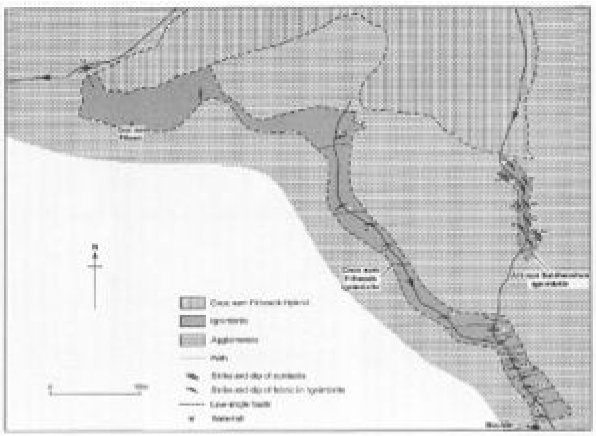

Figure 19b Excursion 5 Kilchrist. Ignimbrite outcrops, location map

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Contents

Chapter 8 Pyroclastic rocks of the Central Complex

(A) Introduction

Pyroclastic rocks are found throughout the Skye Centre, ranging from material which is unequivocally intrusive, to deposits which were clearly laid down under subaerial and subaqueous conditions (see Chapters 3, 4 and 6). Historically, there has been a tendency to link spatially-associated pyroclastic rocks and intrusive units. For example, the pyroclastic rocks of the Kilchrist area were considered by Harker (1904) to represent a vent infill, formed early in the evolution of the Eastern Red Hills Centre (see Chapter 7). However, if attention is paid to the contact relationships of such pyroclastic accumulations, it is clear that ring-faulting has, in many cases, played a vital role, causing subsidence of these annular-shaped masses to their present level within the Skye Centre. This is particularly evident in the case of the material preserved at Kilchrist and in Srath na Creitheach. With respect to timerelationsips, it is only possible to conclude that the pyroclastic deposits pre-date spatially-associated intrusions which disrupt and cut them.

The numerous pipes of volcaniclastic material located within the Cuillin Complex are closely associated with the layered sequence and are described in Section (N) of Chapter 4. Likewise, the agglomerates and breccias of the Western Red Hills Centre represent an early vent phase of volcanic activity pre-dating, but associated with, the granites of that centre. They are described in Section (6B) of Chapter 6.

Apart from these occurrences, there are two large accumulations of pyroclastic material which cannot easily be related to any of the four intrusive centres. These deposits may well represent relatively early pyroclastic volcanism, which occurred before the development of the intrusive centres. Their relative ages are not known. They are: (1) The Srath na Creitheach Deposits; and, (2) The Creagan Dubh and Kilchrist Deposits of the Eastern Red Hills district.

(B) The Srath na Creitheach deposits: description

The pyroclastic deposits which crop out at the northern end of Loch na Creitheach, in Srath na Creitheach, occupy an area of approximately 2km^2 and have an estimated thickness of at least 450m (Figure 10) (Jassim and Gass 1970). These rocks were originally described by Harker (1904), who concluded that they represent a lens of agglomerate caught up in the gabbros of the Cuillin Complex. In contrast, Jassim (1970) and Jassim and Gass (1970) suggest that this mass of pyroclastic material represents some form of vent infill which was deposited under subaerial and subaqueous conditions. At least twelve large slabs of gabbro, presumably derived from the Cuillin Complex, are intimately associated with these deposits. The descriptions presented below are largely taken from the studies of Jassim (1970) and Jassim and Gass (1970).

Along their western and southern margins, the pyroclastic rocks are in contact with layered rocks of the Cuillin Complex (see Section (4K) of Chapter 4). This boundary has been identified as a steeply-inclined, arcuate ring-fault. The northern and eastern margins are against granites of the younger Srath na Creitheach Centre (see Section (5B) of Chapter 5).

Pyroclastic material, ranging from coarse agglomerates through to fine-grained, well-bedded tuffs, has been preserved. Fragment sizes vary from several metres across, down to a few millimetres, with an average size around 4cm. The dominant fragment type is a fine-grained basalt (s.l.), together with lesser amounts of coarse-grained gabbro. Other block-types are comparatively rare, but include: peridotite, basaltic tuff, and a plagioclase-rich rock which exhibits a trachytic texture. The blocks of peridotite were most likely derived from either the Layered Peridotite Series, or the Outer Layered Eucrite Series (see Sections (4D) and (4F) of Chapter 4).

Jassim and Gass (1970) have classified the pyroclastic material into two distinct groups: (1) unsorted agglomerates and coarse-grained tuffs; and, (2) fine-grained, well-bedded tuffs. Material in the first category is the most common, consisting of abundant sub-angular fragments of both basalt and gabbro, set in a tuffaceous matrix. The well-bedded tuffs occur as two inclined horizons (Figure 10), which have completely different strikes. Both consist of alternating bands of fine- and coarse-grained material, containing abundant crystals of plagioclase (composition An_{60}), rare clinopyroxene and mica, together with comminuted rock-fragments and ash. Hydrothermal alteration has, however, severely modified this material.

The twelve large gabbro slabs, ranging in size between 40 and 900m long, tend to stand proud of the surrounding pyroclastic material and contacts are typically sharp and concordant. Brecciation and fragmentation of the slabs are common. Two types of gabbro textures have been identified: (1) a granular type, with rectangular plagioclase crystals; and, (2) an ophitic type, with elongate plagioclase crystals. Both crystal habits can be found within any one slab. Layering is only reported from one slab and is discordant to the margins. Strictly, most of the slabs should be called eucrites, and not gabbro, as cumulus plagioclase compositions are in the range $An_{70–75}$. Also present are plagioclases, of composition An84, which are very similar to the 'calcic-phase phenocrysts' reported from the Outer Layered Eucrite Series (see Section (4F) of Chapter 4) and the Inner Layered Gabbro Series (see Section (4K) of Chapter 4) of the Cuillin Complex. The next most abundant mineral is clinopyroxene, often cumulus, but also as an intercumulus phase (in an ophitic to subophitic arrangement with the plagioclase). Compositionally, this mineral is similar to the clinopyroxenes in the Outer Layered Eucrite Series. Olivine, where present, is typically chloritised.

(C) The Srath na Creitheach deposits: origin

Jassim and Gass (1970) have outlined the events which they consider explain the nature and distribution of the pyroclastic rocks described in Section (8B), above. These are:# A large volcanic vent developed, which broke through to the Earth's surface, disrupting the basic layered rocks of the Cuillin Complex and the overlying lavas of the plateau sequence (see Section (3D) of Chapter 3).

1. A caldera structure formed and further explosive activity gave rise to subaerial and shallow subaqueous deposits of tuff and agglomerate within this volcanic depression. Collapse of gabbro slabs and fragments of plateau lava from the vent walls caused their entrapment within the sequence. Surface reworking of previously formed tuffs then occurred.
2. Subsidence of the vent structure, by as much as 750–1000m, took place along marginal ring-faults.
3. The pyroclastic rocks, together with the older Cuillin Complex, were then intruded by the granites of the Srath na Creitheach Centre (see Chapter 5).

What is not clear from the above sequence of events is whether or not the vent structure, itself, was located in the immediate area. It is important to note that the outcrop pattern of the pyroclastic rocks is controlled by ring-faults, not intrusive contacts. It is therefore possible that the vent occupied a position which has subsequently been engulfed by later intrusions (for example, further north), and that the pyroclastic rocks were deposited on the flanks (or even further away) from any vent structure. This possibility would alleviate the problem of having to explain the presence and mode of formation of the bedded tuffs within the sequence. However, the mechanism by which the gabbro slabs were incorporated into these deposits is not easily explained. It is possible that the original vent-forming phase, in (i), above, transported fragments of these rock-types to the surface, where they were subsequently incorporated into subaerial deposits by gravitational slumping on an irregular topography.

(D) The Creagan Dubh and Kilchrist deposits: description

Pyroclastic rocks in the Eastern Red Hills district (Figure 11) crop out at Creagan Dubh (P_1, 0.5km^2), NW of Beinn Dearg Mhor, and in the Kilchrist area (P_2, 2km^2), south of Beinn Dearg Bheag.

The pyroclastic rocks in the Creagan Dubh area lie unconformably above subaerially-erupted basic lavas (see Section (3D) of Chapter 3). In the Kilchrist area the field relationships are less clear due to poor exposure and the effects of ring-faulting, ring-dyke intrusion, tilting and erosion. Nevertheless, these rocks are estimated to be at least 300m thick.

Other occurrences are: a thin screen of rhyolites (see Section (3E) of Chapter 3), polylithic agglomerates and ignimbrites between the Inner and Outer Granites (P_3, west and south of Beinn Dearg Mhor, (Figure 11)); and, poorly exposed and poorly preserved coarse, polylithic agglomerates SE of Beinn na Caillich (P_4, (Figure 11)). Details of these deposits and their distribution are presented below, mainly from the study of B.R. Bell (1985). The following types of material have been recognised: (i) agglomerates; (ii) basic tuffs; (iii) acid tuffs; (iv) ignimbrites; and, (v) hyaloclastites.

(i) Agglomerate is the most abundant rock-type. It is polylithic, poorly sorted, and has been hydrothermally-altered by the younger subvolcanic granites. Only the least-altered material will be described.

Blocks are randomly distributed, range from being sub-angular to rounded, and vary in size from a few millimetres up to several metres across. Block-types recorded are: Torridonian sandstone and shale, Cambro-Ordovician dolostone and quartzite, Jurassic limestone, sandstone and siltstone (see Chapter 2), Lower Tertiary basalt (and other basic types), dolerite, rhyolite, tuff (including ignimbrite), granite, pitchstone, gabbro, and pre-existing coarse- and fine-grained polygenetic pyroclastic material. Locally outcropping Lewisian Gneiss is not present as blocks in the agglomerates (Figure 11).

Generally, poor exposure limits the evidence of stratification, although subaqueous or subaerial deposition and reworking and erosion surfaces are clearly visible 100m east of the southern part of the Allt nan Suidheachan. Also, a 0.5m-thick lateritic horizon, within the agglomerates, is preserved north of Loch Cill Chriosd, in the Allt Coire Forsaidh. This horizon consists of lithic clasts of lapilli-size, set in a tuffaceous matrix, and is interpreted as a subaerial weathering surface (i.e. a palaeosoil).

Block-supported and matrix-supported macro-textures are found within the agglomerates, indicating that the contemporaneous reworking processes, which gave rise to the present-day distribution of the material, were variable, with respect to parameters such as transportation distance, slope-dependent flow rate, water/rock ratio and fragment-size distribution.

Whole-rock analysis of most of the blocks within the agglomerates is impracticable due to hydrothermal alteration, but the compositions of a few of the unaltered centres of the larger igneous fragments were determined by B.R. Bell (1985) in order to evaluate the volcanic rock-types preserved within the agglomerates.

Amongst the basic blocks, both the transitional Skye Main Lava Series and the high-calcium, low-alkali tholeiite groups defined by Thompson et al. (1972, 1980a) and Esson et al. (1975) are represented (see Section (3D) of Chapter 3), as well as big-feldspar basalts and mixed (acid-basic) lavas. One granite block was analysed and is typical of the Group (1) of Thompson (1982), which are compositionally "primitive", and usually feature early in the evolution of British Tertiary Volcanic Province centres (see Section (12D) of Chapter 12). The field and analytical evidence therefore indicates that all these igneous rock-types pre-date the formation of the agglomerates and were locally available for incorporation into the agglomerates during Lower Tertiary times.

(ii) Intercalated with the agglomerates are numerous horizons of basic tuffaceous material. Commonly, the agglomerates grade through lapillituffs into tuffs, over distances of between a few centimetres and several tens of centimetres. The tuffs are dull grey-green and contain a small proportion of lapilli-size (up to 10mm) lithic clasts. Other features include eroded tops and abrupt upward changes into much coarser agglomerates.

(iii) Closely associated with the agglomerates and basic tuffs are thin horizons of acid tuff. Twenty-five distinct exposures have been mapped (B.R. Bell 1985), although some may be lateral equivalents. Typically, they are less than 2.5m thick (and often less than 1m). Except for some of the deposits exposed on the crags south of Beinn Dearg Bheag (Figure 11), they are observed only where cut by the numerous streams which dissect the area.

The acid tuffs often have irregular, weathered tops, which in some cases are infilled with fine-grained basic tuff from the overlying formations. Bedding may be discerned in some instances (for example, the two deposits NE of Meall Coire Forsaidh, (Figure 11)), whilst in others very little vertical variation in grain-size is noted.

The acid character of these deposits is only readily identified in the least-altered units, where wispy fragments of rhyolitic material, up to 5mm long, with soft, curved margins, are found set in a fine-grained, fragmental groundmass. Angular crystals of quartz and, less commonly, alkali and plagioclase feldspar, are present, but because these deposits are pyroclastic it is difficult to determine whether or not these minerals are related to the primary acid component. Small xenoliths of various types of country-rock are dispersed throughout these tuffs.

(iv) Ignimbrites in the Eastern Red Hills district were first recorded by Ray (1960), who described material from two localities in the Allt nan Suidheachan-Cnoc nam Fitheach area (Figure 11). Both were considered to be intrusive, forming marginal facies of a 'microadamellite' intrusion. Subsequently, this intrusion has been interpreted as a mixed-magma rock (see Section (7B) of Chapter 7) and the ignimbrites are considered to be extrusive (see below). In addition to the ignimbrites noted by Ray (1960), three other occurrences from elsewhere within the district (Figure 19b) have been recorded by B.R. Bell (1985): (1) on top of a rhyolite lava, in the screen between the Inner and Outer Granites (west of Beinn Dearg Mhor); (2) east of Cnoc nam Fitheach, in a tributary of the Allt Cnoc nan Uan; and, (3) in Coire Forsaidh, in a tributary of the Allt Coire Forsaidh (Figure 11). These three deposits occur as thin-bedded units within the main sequence of pyroclastic rocks.

Within the Allt nan Suidheachan-Cnoc nam Fitheach area more detailed mapping by B.R. Bell (1985) identified three discrete outcrops of ignimbrite (Figure 19b). One of these outcrops consists of four distinct sheets, with a total thickness of 4.4m, and is exposed in a small gully which flows NW from Cnoc nam Fitheach into the main stream. This ignimbrite is relatively crystal-rich, has a strong eutaxitic texture, and dips at an angle of 35° to the NW.

The Allt nan Suidheachan ignimbrite is also inclined, but at a higher angle (60°), to the NE. Essentially, it is a large slab of material 120–130m in length and between 10 and 20m thick. The fiamme which define the fabric of this ignimbrite have very high aspect ratios (length:thickness), not uncommonly 25:1, or more. This suggests that extreme compaction and welding of very hot material was involved. This fabric abuts the contact at a shallow angle, suggesting that the mutual boundary is tectonic in origin.

The field relationships of the Cnoc nam Fitheach ignimbrite are complicated, but detailed mapping has led to the identification of several important features. First, the deposit has a distinct base, with bedding defined by an eutaxitic texture dipping at 4° to the north. This lower boundary is erosional, with the mixed lapilli-tuffs and agglomerates below showing a slight amount of Lower Tertiary lateritic weathering. Second, low-angle brittle faults cut the fabric of the ignimbrite and cause the dip of the fabric to increase as one proceeds up-section. These faults, of unknown displacements, have also acted as excellent hydrothermal fluid passageways, causing extensive alteration of the ignimbrite on either side for distances of a few centimetres. The resulting pale green, homogeneous rock has very few recognisable primary characteristics.

At the top of this deposit the fabric of the ignimbrite shows a high degree of distortion, with slumping and the formation of small detached folds and cusp-shaped masses. These upper surface features are similar to those found in acid pyroclastic rocks which have been deposited in shallow water. Directly above this deposit are coarse agglomerates and lapilli-tuffs.

All the ignimbrites in the Eastern Red Hills district are charged with xenoliths and xenocrysts/phenocrysts. Xenolith types include most of the pre-Tertiary and Lower Tertiary lithologies which crop out within the district. In the case of the crystals, there is abundant sanidine, perthitic alkali feldspar and quartz. The glass component of the ignimbrites is commonly dark brown (less often dark green) and is much altered and devitrified.

Because of their pyroclastic nature and xenolithic component, ignimbrites are not particularly suitable for chemical scrutiny. Nevertheless, by removing all recognisable xenoliths (by hand-picking, down to millimetre sizes), B.R. Bell (1985) showed that the Cnoc nam Fitheach ignimbrite is acidic, with a moderately high alkali-element content. Furthermore, the relatively high concentration of Zr (572ppm) and low CaO content (0.32wt.%), together with the fact that zircon is an uncommon mineral in these ignimbrites, suggests that the magma from which these deposits were derived may have been on a peralkaline trend (Watson 1979).

(v) The material identified as hyaloclastite is located north of Cnoc nam Fitheach (Figure 11) and has been extremely altered by hydrothermal fluids due to its close proximity to the Inner Granite (see Section (12F) of Chapter 12). Poorly exposed, it looks agglomeratic, but thin-section examination shows a matrix of pale green, hydrated, basaltic glass, without comminuted lithic clasts and tuffaceous material which characterise the true agglomerates.

Hyaloclastites and palagonite tuffs are present at the base of the volcanic sequence of north Skye (see Section (3A) of Chapter 3). Their mode of formation has been interpreted in terms of the eruption of basaltic magma into shallow lakes. At Cnoc nam Fitheach, the material has a significant and distinctive clast component, which suggests that reworking of coarse pyroclastic material has occurred in a subaqueous environment in close proximity to primary hyaloclastite deposits.

(E) The Creagan Dubh and Kilchrist deposits: origin

From the descriptions presented in Section (8D), above, it is evident that the volcanic products of the Eastern Red Hills district can be readily distinguished and that it is not appropriate to group such highly variable pyroclastic accumulations under the term 'agglomerate'. Furthermore, it has been concluded that the field relationships at Kilchrist can be better explained in terms of a ring-dyke intrusion (see Section (8D), above, and Section (7B) of Chapter 7), together with its central, down-dropped block of pyroclastic rocks (Figure 11). The evidence from the different types of material which have been described strongly suggests that surface processes—either subaqueous or subaerial—have dominated the mode of deposition of the pyroclastic rocks and that within-vent processes, as suggested by Harker (1904), were not involved.

The numerous acid tuffs, for example, together with the ignimbrites, are clearly extrusive in form. They were possibly erupted as a result of magma-mixing processes in subvolcanic chambers which developed during the evolution of the Skye Centre (see Section (6K) of Chapter 6). Deposition of these volcanic products would have been on relatively irregular surfaces, strongly controlled by the voluminous agglomerate accumulations. The aspect ratios of the fiamme in the ignimbrites and the wispy rhyolitic fragments in the tuffs also suggest large degrees of compaction. It has been shown by Wolff and Wright (1981) that rheomorphism, in the form of secondary mass flowage, can occur in such deposits, and that deposition on slopes is a critical aspect of features such as flow folds, cusps and slump structures. Magma of the peralkaline type appears to favour the formation of such structures.

Closely associated with these acid pyroclastic rocks are rhyolitic lavas (see Section (3E) of Chapter 3) which are compositionally very similar to the subvolcanic granites of the district. Presumably, the chambers which existed below the volcanic centres were, from time to time, tapped, resulting in the eruption of viscous, rhyolitic magmas which did not flow far from their point of emission.

According to Walker (1975), a significant feature in the positioning and development of individual centres throughout the British Tertiary Volcanic Province, including Skye (see Chapter 13), was the presence of acid diapirs high in the crust at an early stage. Such diapirs are important because they would considerably influence the development of pyroclastic material. Walker (1975) suggests that some of the so-called vent agglomerates may in fact be derived from shattered country-rock from roof-zones, together with chilled and disrupted material from the upper parts of these diapirs. Due to updoming this material would exist at an elevated position in the crust and through erosion could be readily subjected to surface reworking processes. Thus, the agglomerates may be essentially sedimentary, although occasional fragments of explosion breccia, possibly representing primary pyroclastic material which has not been broken down into individual clasts, have survived.

The eruption of basaltic magma into water, coupled with the input of coarse clasts of reworked, brecciated country-rock, provides a suitable mechanism for explaining the formation of the hyaloclastite deposit. Again, the new evidence agrees with the model of Walker (1975), who suggests that basalt eruptions developed after the intrusion of the acid diapir which caused brecciation of the country-rock.

The lack of Lewisian Gneiss fragments in the agglomerates possibly provides some evidence as to how high within the crust the top of the acid diapir rose. The absence of this rock-type suggests that the zone of brecciation above the diapir was above the gneiss-lava unconformity at its pre-granite intrusion level within the crust.

References

Appendix 1: Glossary of petrological names and terms

Appendix 2: Glossary of fossil names

Appendix 3: Glossary of place names and grid references

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