Cnapan Breaca–Long Loch and Dibidil–Southern Mountains

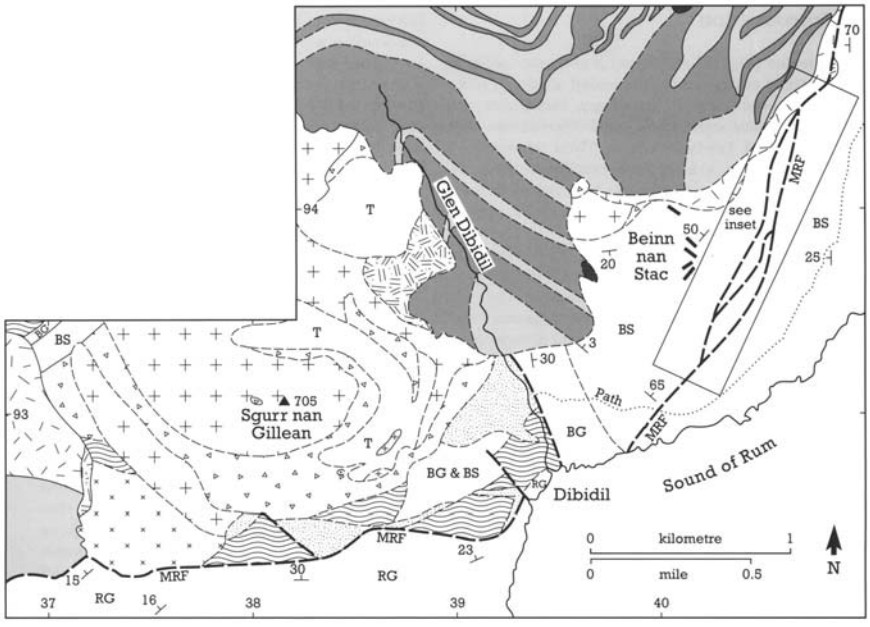
OS Grid Reference: NM383987

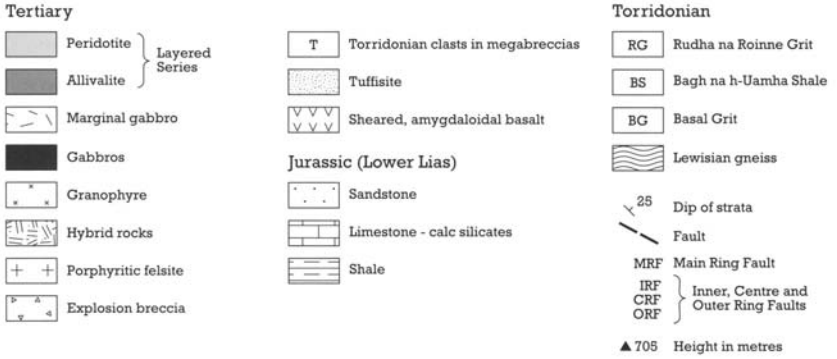
Highlights

These sites contain clear evidence for substantial uplift along the Main Ring Fault of Rum. The well-developed, felsite-explosion, breccia-tuffisite association is now known to be a combination of subaerial ignimbrites, tuffs and caldera breccias. At the roof-like contacts with the gabbros and ultrabasic rocks, there is excellent evidence for hybridization between the gabbroic rocks and remelted felsite.

Introduction

The Cnapan Breaca–Long Loch and Dibidil–Southern Mountainssites (Figs 3.7 and 3.13) demonstrate the earlier Tertiary igneous rocks in the northern and southern margins of the Rum Central Complex respectively. Both sites contain closely related felsite, granophyre, explosion breccia, tuffisite and bedded tuff in association with the Main Ring Fault. They record an early acidic phase in the evolution of the Rum complex. The Dibidil–Southern Mountains site (Figs 3.7) is of special significance in this respect because of the size and excellent exposure of the acid igneous bodies. The relationships between these early intrusives and Lewisian/Torridonian basement and the later Cenozoic ultrabasic and basic intrusives are well exposed in both sites. Together, the sites provide crucial information in the study of the magmatic and tectonic evolution of the Rum complex.





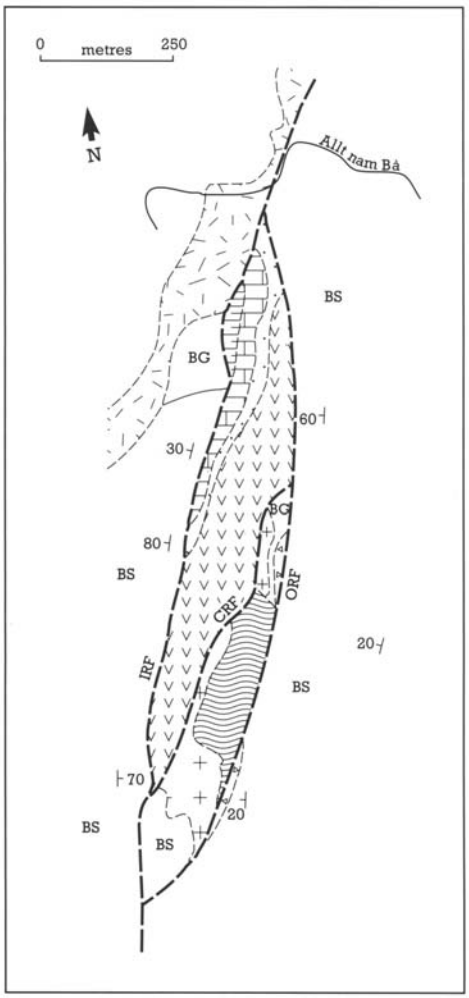


Figure 3.7: Geological map of the Dibidil-Southern Mountains and Allt nam Bà-Beinn nan Stac sites, Rum. Inset (on opposite page) shows detail to the south of Allt nam Bà. Main figure after Emeleus (1980) with subsequent modifications (Greenwood, 1987). Inset after Smith (1985, fig. l)

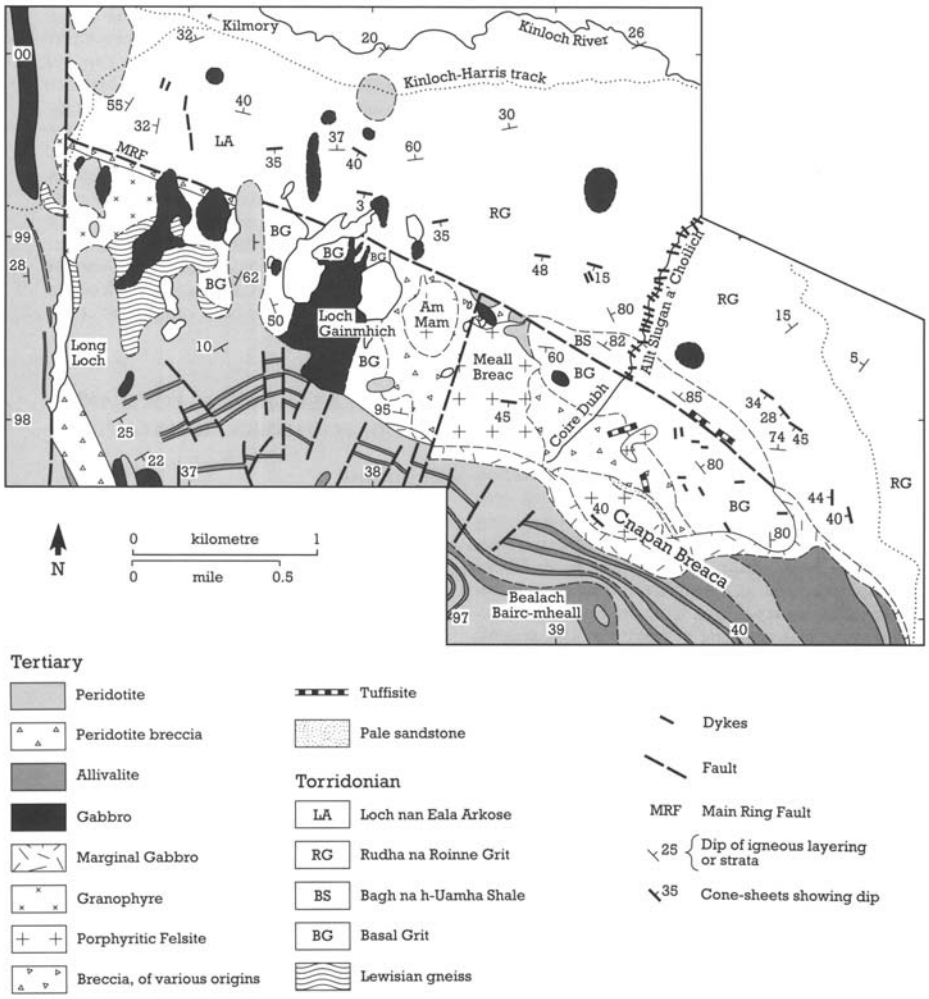


Figure 3.13: Geological map of the Cnapan Breaca-Long Loch site, Rum (after Emeleus, 1980)

Dunham (1962, 1964, 1965a, 1968) carried out the first comprehensive investigation of the felsites and associated rocks in the Cnapan Breaca–Long Loch site. The felsites and granophyres were related to a common parent magma generated by the fusion of Lewisian country rock. The degassing of this magma was considered to be responsible for the occurrence of explosion breccia and tuffisite. However,Williams (1985) reinterpreted some of the felsites to be of subaerial, pyroclastic origin. The Dibidil–Southern Mountains area was first mapped in detail by Hughes (1960a), who termed it the Southern Mountains Igneous Complex. Hughes regarded the complex as being bounded by a minor ring fracture, within and partly coincident with the Main Ring Fault. Current ideas, however, suggest a rather different structural setting; the Main Ring Fault clearly bounds the acidic Tertiary igneous rocks, but elsewhere they terminate against intrusions belonging to the later phase of emplacement of the ultrabasic and associated basic rocks.

Cnapan Breaca–Long Loch

The northern part of the site (Fig. 3.13) is underlain by Torridonian arkoses and shales to the north of the Main Ring Fault of eastern Rum which bounds the plutonic complex. Away from the complex, the Torridonian strata have a fairly uniform dip of 10°–20° to the north-west but become progressively disturbed towards the Ring Fault near which they strike east–west and dip north at angle up to 70° and more. The lowermost Torridonian sediments, the Basal Grit and Bagh na h-Uamha Shale groups (Black and Welsh, 1961), occur within the Ring Fault and are well exposed in the area between Cnapan Breaca and the northern end of Meall Breac. They have been highly disturbed by movement along the fault and are intricately folded.

Patches of granodioritic, dioritic, amphibolitic and feldspathic Lewisian gneisses are exposed in a wide area around the Priomh Lochs (NM 368 986), either side of the Long Loch Fault and

adjacent to the Main Ring Fault north of Meall Breac (NM 386 988). The presence of these rocks within the Main Ring Fault was used by Bailey (1945) as key evidence for an uplift of at least a thousand metres of the central, fault-bounded block.

Contacts of Lewisian and Torridonian rocks are exposed to the east and north of the Priomh Lochs (NM 372 988). Originally virtually planar, they have been affected by later movements and now dip north-eastwards at between 30° and 85°. The junction is generally faulted, although movement on the fault may not be large. An apparently unconformable relationship is seen north of the lochs (at c. NM 369 990), where gneiss is overlain by a coarse sedimentary breccia which passes up into bedded, gritty, coarse sandstone.

In the Cnapan Breaca–Long Loch and Dibidil–Southern Mountains sites, large masses of porphyritic felsite are closely associated with highly brecciated country rock. A felsite sheet caps Cnapan Breaca, dipping 35° to the south-west; a pipe-like mass with steep contacts is found in the east of Coire Dubh; a partly sheet-like, steep-walled mass occurs in western Coire Dubh and on Meall Breac; and on Am Mam, a felsite body with steep northern margins becomes sheet-like in the south. Small lenses of felsite also occur in an east–west-trending mass of explosion breccia along the Main Ring Fault to the north of Long Loch; unlike the other felsites, these are demonstrably older than the breccia which also contains fragments of the felsite as well as gabbro and arkosic sandstone.

The grey, weathered felsites contain conspicuous glomeroporphyritic aggregates of plagioclase, augite and opaque oxides, together with separate phenocrysts of quartz set in a holocrystalline groundmass of quartz and alkali feldspar. In addition, Williams (1985) has recognized some of the felsites at the base of the Cnapan Breaca sheet to be of pyroclastic origin. Typical features of eutaxitic welded tuffs are described by Williams from lenses within the felsite, these are: a strong planar fabric, formed by collapsed, attenuated pumice fragments (*fiamme*) and Y-shaped flattened glass shards; rounded Torridonian clasts also occur. A subaerial origin, as opposed to a shallow intrusive origin as suggested by Dunham (1968), for at least some of the felsites is therefore invoked from such evidence. Similar features occur south-west of Meall Breac (NM 384 981). Some of the felsites are ignimbritic.

The felsites are closely associated with coarse breccias and tuffisites which occur almost wholly within the Main Ring Fault. Largely unbedded breccias have a wide outcrop north of Cnapan Breaca, in Coire Dubh around Meall Breac and around Three Lochs Hill (NM 373 987) and form an E–W-trending strip along the line of the Ring Fault to the north of Long Loch. The breccias contain predominantly angular Torridonian sedimentary rock clasts which range from a few centimetres up to several metres in size. Basic igneous and Lewisian gneiss fragments are also occasionally present. Dunham (1968) distinguished two main types of breccia, one made up almost entirely of subangular, rounded blocks derived from the basal Torridonian set in a matrix composed of finely comminuted Torridonian, and the other containing Lewisian and basic igneous fragments set in a very fine-grained matrix of Lewisian. The first type occurs in Coire Dubh and west of Meall Breac, while the second type is found to the north of both Meall Breac and Three Lochs Hill (Am Mam). The east–west strip of breccia to the north of Long Loch differs from the other outcrops in that it contains fragments of rounded basal Torridonian, gabbro, angular felsite and gneiss set in a dark, almost glassy, comminuted matrix derived from all rock types present as clasts except felsite; it is spatially closely associated with the Main Ring Fault and may have resulted from explosive activity localized along the fault.

The occurrence of blocks of coarse gabbro in the second type of breccia recognized by Dunham (1968) is important since it indicates that there were plutonic gabbroic intrusions in existence before emplacement of the felsites and other acidic bodies. This view is reinforced by the discovery of rare blocks of feldspathic peridotite in these breccias on the north end of Meall Breac (Emeleus, in preparation). Some of the coarse gabbros show the effects of crushing, possibly produced during movement of the Main Ring Fault; quite extensive areas of uncrushed gabbro crop out east of Loch Bealach Mhic Neill (NM 376 990) and plugs of petrographically similar gabbro occur on both sides of the Main Ring Fault, for example, north of Loch Gainmich (NM 380 988) and between Kinloch and Coire Dubh (see Emeleus, 1980).

Thin, intrusive tuffisite sheets crop out in the eastern part of the site in close association with felsite and explosion breccia. The petrography of this unusual rock type is described below in

the Dibidil–Southern Mountains description; there extensive sheets of tuffisite occur. On Cnapan Breaca, the tuffisites can be generally shown to be younger than the explosion breccia; however, they are also sometimes demonstrably older than the felsites. Dunham (1968) records several tuffisite bodies cutting the Torridonian, both within and outside the Ring Fault, which show no apparent association with either felsite or explosion breccia.

From the southern side of Meall Breac, an olivine gabbro lying between the explosion breccia/felsite and the layered ultrabasic rock extends south-eastwards with widening outcrop. The mass, which is generally poorly exposed, is dyke-like in form and identical to the gabbro which crosses Cnapan Breaca and extends to the Main Ring Fault further to the east. This gabbro is the Marginal Gabbro (Brown, 1956) which has been postulated to have provided a 'lubricant' during the solid emplacement of the layered ultrabasic rocks, although recent evidence questions this interpretation (Greenwood, 1987).

The emplacement of the later gabbro against the felsites to the south of Meall Breac and Cnapan Breaca caused partial fusion of the felsite, resulting in extensive back-veining of the basic rocks by acidic material. Dunham (1964) reported that the remelted felsite back-veined the solid chilled margin of the gabbro, caused some acidification of partially solidified gabbro and then mixed with the still-liquid gabbroic magma in the interior of the intrusion to produce hybrid rocks.

In the west of the site, three tongues of ultrabasic rock extend northward from the main ultrabasic body, cutting through Lewisian and Torridonian country rock, explosion breccias, granophyre and the Main Ring Fault. McClurg (1982) recorded several similarities in these peridotites with the Layered Series peridotites and the peridotite matrices of the ultrabasic breccias. Consequently, McClurg considered the emplacement of the tongues to be contemporaneous with the tectonic disturbances responsible for the formation of the intra-magmatic ultrabasic breccias found elsewhere in this site.

Small-scale (1–3 cm thick) banded structures occur in the tongue peridotites, and in small ultrabasic and gabbroic intrusions elsewhere in the Province (for example, Rubha Hunish, Skye and Camas Mor, Muck). On Rum, these structures reflect variation in the modal proportions of interstitial clinopyroxene and plagioclase, with the proportion of modal olivine varying very little; this has been termed 'matrix banding' by Dunham (1965b).

Superb examples of layered peridotites of the Central Series occur on the low ridge immediately west of Long Loch and south of the Kinloch–Harris road (NM 363 991; see Fig. 3.14). This is one of the most accessible localities for examination of the varied layered structures in allivalite and feldspathic peridotite: for example, small-scale phase layering, density-stratified layering, layers with size grading, erosional surfaces and a variety of structures due to slumping. Excellent examples of distorted allivalite layering adjacent to slumped peridotite blocks occur just north of the Harris track (NM 363 994), and spectacular peridotite breccias, with subsided blocks up to 3 m in diameter and highly distorted layering, are beautifully displayed 300 m SSE of the south end of Long Loch (McClurg, 1982; Emeleus, 1987, Fig. 11). Numerous basaltic cone-sheets are exposed in the Allt Slugain a'Choilich which dip either towards a centre in upper Glen Harris or to one somewhat further west. These tholeiitic sheets, which both cut and are cut by basaltic and doleritic dykes, have been studied by Forster (1980).

Figure 3.14: Gravity stratified rhythmic layering in allivalite, west of Long Loch, Rum. (Photo: C.H. Emeleus.)

The major north–south Long Loch Fault, one of the principal features of the geology of Rum, occurs at the western edge of the site. This fault has a considerable zone of crushing, up to 50 m wide in places, involving ultrabasic and earlier rocks. The other spectacular fault on Rum, the Main Ring Fault, is well exposed within the site in Coire Dubh near to the intake of the hydroelectric pipeline (NM 393 983) and close to the deer fence gate. To the east of Cnapan Breaca, the marginal gabbro joins but is unaffected by the Ring Fault and the two are coincident for some distance to the south. West of this point, recent mapping of the margin of this gabbro suggests an upper surface dipping north at a low to moderate angle. Thus, the pre-Marginal Gabbro rocks of this site, the felsites, breccias and associated Torridonian rocks of the northern marginal complex, probably form a roof to these later mafic rocks which may continue beneath this roof as far north as the Main Ring Fault.

Dibidil–Southern Mountains

Lewisian gneisses crop out in a series of elongated, partly fault-bounded blocks for about 2 km west from Dibidil Bay (Fig. 3.7). Here, as on the south-east flanks of Beinn nan Stac, the distribution of gneiss is obviously closely linked with the Main Ring Fault. Torridonian rocks are also present as isolated masses within the igneous rocks and as a more substantial mass in the lower east side of Dibidil within the ring fault. Torridonian country rock outside the ring fault shows signs of disturbance near to this structure on the southern edge of the site.

Extensive sheets of porphyritic felsite are closely associated with coarse breccias and Torridonian sediments at several levels on Sgurr nan Gillean. The felsites in this site have the same general characteristics as those described from Cnapan Breaca–Long Loch. The largest sheet covers the summit area of Sgurr nan Gillean and forms the high ridge extending north out of the site to Ainshval (NM 377 944). At a lower level, on the east side of the hill and about 600 m north-west of the bothy (NM 393 929), a steep-sided felsite intrusion appears to connect the uppermost and lower sheets extending down towards the Dibidil River. This felsite was regarded as a feeder for the felsite sheets (Hughes, 1960a).

The close relationship between the felsite and breccia is clearly demonstrated on Sgurr nan Gillean, where the felsite sheets are generally bordered by breccias. The breccia has the form of flat-lying sheets, sometimes sandwiched between undisturbed Torridonian sediments. This relationship suggests that the breccia formed well below the land surface, however, like some of the Cnapan Breaca felsites in the north, the felsites show evidence in places for a subaerial, ignimbritic origin.

This site is of particular note in that it contains the most extensive developments of tuffisite in any of the Hebridean Tertiary central complexes. Hughes (1960a) first described the rocks as intrusive tuffs, and they were later recognized to be tuffisites by Dunham (1968), following the terminology of Reynolds (1954). Several tuffisite masses have been mapped along the southern edge of the site, closely connected with the Main Ring Fault. Excellent exposures of tuffisite occur near the ford in lower Dibidil (NM 393 931), where slabs in the Dibidil River expose a network of veins and stringers of dark-coloured, fine-grained rock charged with crystals of feldspar and quartz and numerous fragments of Lewisian country rock. Inclusions of porphyritic felsite also occur within the tuffisites of lower Dibidil and, since there is evidence that felsite cuts tuffisite on the southern slopes of Sgurr nan Gillean, there must be a time overlap in felsite and tuffisite formation.

Coarse, acidified, hybrid gabbros are found in several places in the Rum central complex, usually around the periphery of the ultrabasic/gabbroic complex. Hybrid rocks containing conspicuous elongate plagioclase and amphibole (after orthopyroxene) crystals up to 30 mm in length are found in sharp contact with later gabbro to the west of the Dibidil River (NM 3398 9373); further extensive exposures of finer-grained hybrid rocks occur on slabs and rock surfaces for some distance west of this locality. These hybrid rocks appear to be of late formation as they are not cut by the numerous dykes and inclined sheets which are so abundant in the felsite immediately to the west (for example, NM 385 935). The gabbros in Glen Dibidil have recently been recognized to belong to the layered ultrabasic series and are not later intrusive bodies as previously thought (Greenwood, 1987).

The small area of granophyre to the east of Papadil (NM 374 924) is not well exposed. It probably cuts felsite and Lewisian gneiss to the east and north, being fault bounded to the south where it is crushed near to the Main Ring Fault. It is cut by the gabbro which margins Central Series ultrabasic rocks against which it has been recrystallized.

Interpretation

The exposures, within both sites, of porphyritic felsite, explosion breccia, tuffisite and granophyre along the margins of the central complex record an early phase of acidic magmatism and associated tectonism along the Main Ring Fault. Walker (1975) has proposed that acidic magmatism is a characteristic feature of all British Tertiary igneous centres and the record of this early event is particularly well seen on Rum.

The acidic magmatism on Rum was closely associated with the development of the Main Ring Fault (Bailey, 1945). Emeleus *et al*. (1985) have recently proposed that rising acidic magma caused initial doming of Lewisian and Torridonian country rock which ultimately led to ring fracturing. Basal Torridonian and Lewisian rocks were uplifted within the ring fault system. Subsequent relaxation of magmatic pressures caused the central uplifted block to subside along the ring fracture. This is attested by the presence of Mesozoic sediments and Cenozoic lavas (see Allt na Bà) juxtaposed against faulted slivers of basal Torridonian and Lewisian gneiss which had been elevated by the initial uplift and left stranded at high structural levels along the Main Ring Fault (Emeleus *et al*., 1985). Large masses of basal Torridonian and Lewisian gneiss on the southern lower slopes of Sgurr nan Gillean and in the Cnapan Breaca–Long Loch site, represent relict roof rocks to the central complex.

The caldera-like subsidence within the Main Ring Fault appears to have been clearly associated with a reduction of magmatic pressures caused by escaping magma and volatiles along fault systems. The explosion breccia provides evidence for violent release of volatiles from the acid magma which shattered the country rock along lines of weakness such as faults and bedding planes (Hughes, 1960a). However, Williams (1985) has argued that they may represent vent breccias in a deeply eroded edifice through which felsic magma rose resulting in either shallow, sill-like and steep-sided intrusions or subaerial pyroclastic extrusion; evidence for the latter occurs on Cnapan Breaca. Williams also postulated that the close association of breccias with felsites on the inner margin of the Main Ring Fault could indicate an origin for the breccias by caldera-wall collapse; evidence for this interpretation is good in Dibidil (M. Errington, pers. comm.).

Using petrographic and geochemical evidence, Hughes (1960a) demonstrated that the felsite

and granophyre crystallized from the same magma derived from the fusion of Lewisian basement. The granophyre probably represents a thick ring-dyke intruded along the line of the ring fault at deeper levels than the felsite and it thus did not suffer degassing and associated explosive activity. Contemporaneous emplacement of tuffisite along the ring fracture system also occurred, representing fluidized, high-pressure injections of shattered country rock (Hughes, 1960a) mixed with fragment porphyritic felsite magma.

The northern and southern sites provide valuable information as to the nature of the margin to the later ultrabasic/basic complex. The contact between the latter and the felsites and associated rocks has been shown to generally dip outwards at both sites at angles as low as 40°, representing a roof-like contact (Emeleus, 1987). The ultrabasic layering is undisturbed right up to these contacts and extends beneath the overlying rocks where hybridization of basic/ultrabasic intrusives with felsite is observed. It is probable that large parts of the northern marginal complex and Southern Mountains marginal complex are immediately underlain by the layered ultrabasic rocks and that the contact represents the original roof to the mafic complex. If the roof contacts are projected upwards to the centre of the complex, the vertical extent of the Eastern Layered Series is limited to a few hundred metres above the present-day peaks. The layered ultrabasic rocks are, therefore, not considered to have been emplaced as a solid, upfaulted block, as previously suggested. The ultrabasic magma may have intruded upwards, causing further uplift along the Main Ring Fault involving the felsites and associated rocks (see Emeleus, 1987 for discussion), the layered series crystallizing essentially *in situ* beneath them. The emplacement of the Layered Series, however, still presents many difficulties and work is currently in progress which will hopefully resolve these problems.

Conclusions

The Dibidil–Southern Mountains and Cnapan Breaca–Long Loch sites are important localities exposing the margin of the igneous complex and allow investigation of the early magmatic and tectonic evolution of the Rum centre. The felsite–granophyre explosion breccia–tuffisite association can be related to major caldera-like subsidence along the line of the Main Ring Fault, with contemporaneous acidic magmatism. The roof contacts between these rocks and the underlying layered series are of particular importance in these sites since they provide evidence that the ultrabasic/basic complex crystallized *in situ* in relation to these rocks, although further uplift along the Main Ring Fault may have occurred during the emplacement of the ultrabasic magmas/rocks.

The precise nature of the origin of the felsites and associated rocks, and the structural complexities of the sites, have received little attention since the work of Hughes (1960a). The areas merit reassessment in view of the reinterpretation of the Cnapan Breaca felsite–explosion breccia association (Emeleus *et al.*, 1985; Williams, 1985) and work is currently in progress. Early acidic magmatism and the presence of welded tuffaceous felsitic rocks, such as those observed on the northern margin of the Rum complex, are common to many Tertiary igneous centres. The opportunity for a comprehensive understanding of well exposed acidic rocks in these sites on Rum will provide valuable information on the early magmatic and tectonic evolution of the British Tertiary Igneous Province as a whole (cf. Bell and Emeleus, 1988).

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