Feature

Recent research developments on the Isle of Rum, NW Scotland

The appearance in 1997 of the British Geological Survey's memoir on Rum was followed by a period of intense research, leading to upwards of 35 papers, books and other articles. The scope of these publications, and the research progress over the last 15 years since publication of the memoir, is reviewed here. Igneous activity on Rum was short lived, possibly only ca. 500 ka, and, at about 60.5 Ma. The Rum central complex thus pre-dates the nearby Skye central complex. The earliest, acidic and mixed acidic/basic magmatism on Rum involved both shallow intrusions and ignimbrite eruptions into a collapsing caldera bound by the Main Ring Fault, a structure which probably also exercised a structural influence on subsequent mafic and ultrabasic magmatism. Subsequent emplacement of gabbros and ultrabasic rocks caused only limited thermal metamorphism of the surrounding Torridonian sandstones, contrasting markedly with the intense alteration of uplifted masses of Lewisian gneiss within the ring fault. Detailed textural studies on the gabbroic and ultrabasic rocks allow distinction between intrusive peridotites and peridotite that formed as part of the classic layered units of Rum and, furthermore, this work and that on the chromite seams and veins in these rocks shows that movements of trapped magma and magma derived from later intrusions, may produce textures and structures hitherto regarded as primary features of cumulate rocks. Rare picritic dykes provide an indication of likely parent magma for the mafic and ultrabasic rocks, but these and other magmatic rocks on Rum have all undergone varying degrees of crustal contamination, involving both Lewisian granulite and amphibolite crust but, notably, not Moine rocks as at Ardnamurchan. Sulphides in the chromite seams and ultrabasic rocks show possible influences from assimilated Jurassic sediments. From recent apatite fission track studies it seems likely that Rum, in common with other Palaeogene centres, underwent a brief, but significantly younger (Mesozoic) heating event.

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The glaciated peaks and glens and the rocky coast of the mountainous Isle of Rum National Nature Reserve on the west coast of Scotland expose a wide range of igneous, metamorphic and sedimentary rocks ranging in age from the Archaean to the Palaeogene (Figs 1, 2, 3). Although the island, together with the adjoining Small Isles of Eigg, Muck and Canna, has attracted geologists and mineralogists since before the nineteenth century, the first comprehensive account of the geology was the British Geological Survey's Small Isles memoir, published in 1908, by A. Harker. Subsequently, and especially since the 1940s, building on the pioneering work of J.W. Judd, A. Geikie, Harker and others, the island has been a focus for geological research. Several contributions from this period are of particular note. E.B. Bailey recognized

Fig. 1. Dibidil, south-west Rum. The mountains Ainshval (left) and Beinn nan Stac (right) are in the Southern Mountains Zone, Trallval (centre, distance) exposes layered ultrabasic rocks of the Eastern Layered Intrusion. The Main Ring Fault crosses the foreshore at Dibidil, Torridonian strata crop out on the lower slopes of Beinn nan Stac, outside the fault zone (from Emeleus & Troll, 2008).

the presence of the Main Ring Fault (MRF) system and discovered, together with C.E. Tilley, that Lewisian Gneiss had been significantly uplifted within the fault. In the 1950s G.P. Black demonstrated that unlike on Skye, Mull and Ardnamurchan, Paleocene lavas and conglomerates of north-west Rum (see Fig. 6) post date the central complex, and G.M. Brown described the layered rocks of Eastern Rum which became a cornerstone in the developing theory of cumulate rocks formalized by L.R. Wager, G.M. Brown and W.J. Wadsworth. In the 1960s C.J. Hughes demonstrated the importance of rheomorphic melting of felsic igneous and country rocks by later mafic intrusions (see Fig. 10), a conclusion, confirmed by A.C. Dunham, which overturned Harker's view that the acid intrusions on Rum post dated adjacent gabbros and peridotites, and R. McQuillin and J. Tuson discovered the pronounced gravity high over Rum, indicating the presence of a major body of dense mafic rocks underlying the central complex. In the 1980s N.J. Smith proved the Jurassic age of rocks caught up in the Main Ring Fault while P.J. Williams showed that rhyodacites hitherto regarded as wholly intrusive were probably of ignimbritic origin. Finally in the late 1980s, J. Bédard and others questioned accepted interpretations of the layered rocks, suggesting alternative radical origins for their emplacement. These, together with other investigations up to the mid-1990s, are considered in the 1997 second edition of the British Geological Survey's Rum memoir and in the general works listed at the end of this article.

Outline of the geology

Rum contains the deeply-dissected and well exposed remains of a Palaeocene central complex emplaced into late Proterozoic sandstones of the Torridon Group (Figs 2, 3). Younger sedimentary rocks once covered the area but these are now limited to Triassic sandstones overlying the Torridonian beds in north-west Rum and down-faulted Lower Jurassic strata preserved in the Main Ring Fault together with basaltic lava belonging to the Paleocene Eigg Lava Formation. The central complex developed in several phases largely controlled by, and restricted within the Main Ring Fault (Figs 2, 3). Initial igneous activity principally involved silicic magmatism (Phase 1). Ignimbritic porphyritic rhyodacite was intruded and extruded, accompanied by caldera subsidence and spectacular debris avalanche deposits which were closely followed by intrusion of rheomorphic breccias and microgranite intrusions. Microgranites are of slightly later date, but are compositionally similar to the slightly more evolved ignimbrites. Associated movements within the Main Ring Fault (MRF) caused uplift of Archaean Lewisian Gneiss and the lowermost members of the Torridon Group by as much as 2 km, with concomitant doming of the country rocks which, in turn, was accompanied by major landslips. Although the principal movements within the MRF involved uplift,

Fig. 2. Simplified geological map of Rum (compiled by G.R. Nicoll).

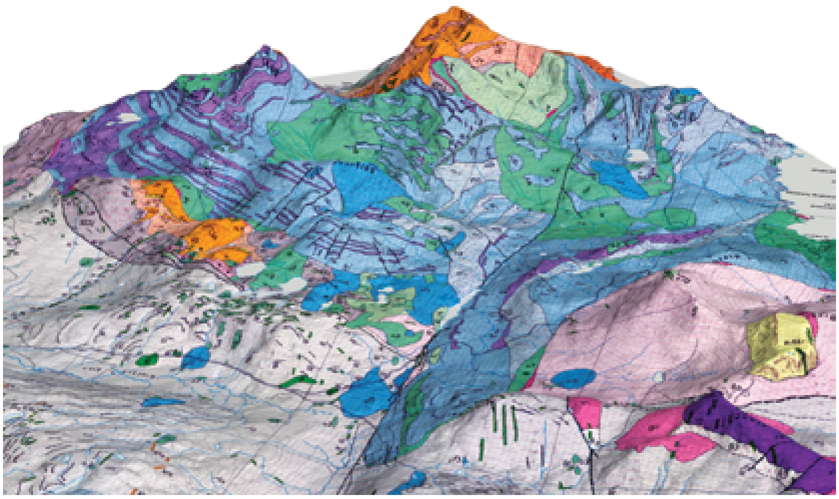

Fig. 3. Geological map of Rum draped map over topographic base, viewed from north (from Emeleus & Troll, 2008).

the fault-bound slivers of fossiliferous Lower Jurassic rocks and Palaeocene lavas found along parts of the fault system attest to significant subsidence, between the two main phases of uplift.

The onset of predominantly mafic magmatism defines the start of Phase 2. Initially this was limited to intrusion of a suite of thin basaltic cone-sheets and dykes. Ensuing pulses of picritic and basaltic magma were fed from sources along a central, north–south zone, possibly an early manifestation of the Long Loch Fault (Figs 2, 3), from where they were injected laterally, and probably ultimately limited by the Main Ring Fault. The resulting sequence of flat-lying, interlayered feldspathic peridotites, troctolites (locally termed 'allivalite'), thin chromite seams and gabbros formed the sixteen major sheets, or 'units', of the Eastern Layered Intrusion (ELI) in eastern Rum (Fig. 11), and the layered ultrabasic rocks and gabbros of the Western Layered Intrusion (WLI) (see Fig. 2). The intervening Central Intrusion (CI) consists of a chaotic assemblage of blocks and megablocks of layered ultramafic and ultrabasic rocks enclosed in feldspathic peridotite (Figs 4, 5) and is considered to be the feeder zone for the layered ultramafic and mafic rocks of the ELI and the WLI. The three intrusions are the visible part of Rum's geological core, which is a thick, steep-sided root of dense (mafic and ultrabasic) material revealed by the gravity measurements. Several tongues and numerous plugs of feldspathic peridotite and gabbro that belong to Phase 2 breach the Main Ring Fault and occur within the Torridonian sandstones.

Unroofing of the complex occurred during Phase 3 when deep valleys were excavated in the flanks of the Rum volcano, laying bare its plutonic core. Vigorous erosion of the plutonic rocks, together with the Torridon sandstone, Lewisian gneisses and contemporaneous lavas of the Canna Lava Formation gave rise to the thick valley-filling conglomerates of western Rum and beyond (Figs 6, 7, 13). These probably formed by mass flow during flash floods with shallow vegetation-bordered lakes occupying the valleys during calmer intervals. Rivers originating on the Rum volcano extended far afield to Canna, Sanday and Skye, where distinctive clasts of Rum-derived microgranite and rhyodacite are found in inter-lava pebble conglomerates. Contemporaneously with Phase 3, the Skye Lava Group (which includes the Canna Lava Formation) was erupted, ponding against the Rum volcano and becoming interbedded with the fluvial conglomerates from Rum. The Skye Central Complex (ca. 59–56 Ma) intrudes the Skye Lava Group and thus post dates the Rum Central Complex (60.5 Ma). Sparse basaltic dykes in the north-west of the island represent the final igneous activity on Rum, although most of these probably relate to the Skye centre, or

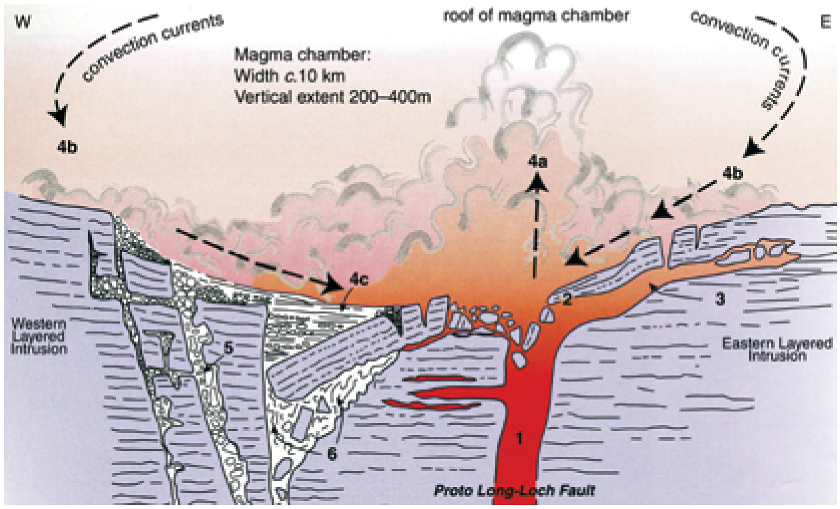

Fig. 4. Schematic reconstruction of the Central Intrusion illustrating periodic injections of picritic magma. Collapse of earlier cumulates (1) with 2, accompanying lateral injection of magma (2), (3) which fountained into the magma chamber (4a) subsequently flowing down the chamber walls as crystal laden currents (4b), dislodging crystal mushes and disturbing earlier cumulates 4c), as it flowed across the chamber floor Movement on faults was accompanied by magma injection and fragmentation of the walls, forming breccias (5) and large, coherent masses of cumulates slumped into the conduits (6), with further breccia formation (with kind permission of BGS, copyright NERC).

Fig. 5. Slumped block of layered bytownite troctolite in breccias of smaller blocks in a deformed crystal mush. Central Intrusion.

are of yet younger age. There then elapsed a considerable interval before Pleistocene glaciers fashioned the present mountainous topography, when the island was almost submerged beneath ice from the Scottish mainland and subsequently supported several local glaciers during the Loch Lomond stadial (11 000–10 000 BP). Man arrived shortly thereafter, at about 8500 BP, to use Rum as a resource for workable raw materials—bloodstone—an iron-pyrites flecked variety of chalcedony obtained from the lavas that makes sharp blades and tips.

Advances in the last fifteen years

Dating the Rum central complex

Radiometric determinations on alkaline veins in gabbro (Phase 2) and the Western Granite (Phase 1) provided ages of about 60 Ma and a hawaiite (Canna Lava Formation, Phase 3) on Rum also gave an Ar-Ar age of 60 Ma although plant remains in interbedded conglomerates indicated a somewhat younger age of 58.6 Ma. The new ages provide evidence that the Rum central complex is probably the earliest of the on-shore centres in the Scottish sector of the British Palaeogene Igneous Province (BPIP). Single crystal $^{40}Ar/^{39}Ar$ ages obtained by Troll and colleagues from plagioclase phenocrysts in rhyodacite (Phase 1) have a range of ages with a concentration at 60.33 ± 0.21 Ma and lesser peaks at ca. 61.4 Ma and 63 Ma. The 60.33 Ma age is interpreted to be that of rhyodacite eruption and emplacement while the older ages probably represent recycled and largely re-equilibrated feldspars from the Lewisian gneisses, for which there is also compelling petrographic evidence. These ages reinforce the view that phases 1 and 2 were essentially coeval and were soon followed by Phase 3. Emplacement, eruptive activity and initial unroofing of the Rum centre all occurred possibly within 500 ka, or less.

Phase 1—The early caldera

The older 'shallow-level intrusive events' now preserved in the Northern Marginal Zone (NMZ) and Southern Mountains Zone (SMZ) (Fig. 2), were further elucidated. In both zones, the Main Ring Fault (MRF) system exercised a controlling influence, defining a caldera's limits and at times providing a pathway for the explosive ascent of silicic magmas. Coarse, poorly-bedded deposits derived from the collapse of uplifted materials and unstable caldera walls in the NMZ spread over the caldera's floor and, as time progressed, these 'Coire Dubh type breccias' became interbedded with thin crystal tuffs. This succession eventually became buried by thick, mixed rhyodacite/basalt and rhyodacite ash flows also fed from sources on or near the MRF. The deeply dissected SMZ contains a similar, but more complex interbedded sequence of rhyodacite ignimbrite flows, lithic tuffs, and coarse Coire Dubh type breccias deposited in channels and streams and by mass flow. These are cut by steeply inclined intrusive ignimbritic rhyodacite bodies, at least two of which fed extrusive ignimbrites (Fig. 8), and the Rum central complex is notable for the clearly demonstrable links between intrusive and extrusive pyroclastic rocks. Evidence for a close association between rhyodacite and basaltic magmas is found in

Fig. 6. Lava flows of the Canna Lava Formation overlying Western Granite, with lavas overlying Torridon Group sandstones on Fionchra (middle distance). The gabbro mountains of the Skye Cuillin are in the distance (from Emeleus & Troll, 2008).

Fig. 7. Boulder conglomerate underlying lava of the Guirdil Member, Canna Lava Formation, Fionchra (with kind permission of BGS, copyright NERC).

Fig. 8. Fiamme in porphyritic rhyodacite, NMZ, Meall Breac (from Emeleus & Troll, 2008).

the distinctive intrusive Am Màm Breccias (Fig. 9b), of both the NMZ and SMZ described by Nicoll and colleagues. The breccias are characterized by abundant inclusions of coarse gabbro, gneiss and Torridonian sandstone, ranging in size from millimetres to tens of metres, together with rounded and lobate basaltic inclusions commonly with diffuse margins against the pervasive mid-grey dacitic matrix (Fig. 9a). Sheets and dykes of this breccia, some with thin rhyodacite margins, intrude Coire Dubh type breccias and occur along strands of the MRF.

The bare, steep-sided corries of the SMZ (Fig. 1) have facilitated a detailed reconstruction of the faulting, breccia formation, and extrusion and intrusion history where Holohan and colleagues have demonstrated that both uplift and subsidence demonstrably occurred along components of the MRF. These movements were accompanied by severe folding of the volcano-sedimentary sequence and intrusion of ash-flow—feeding rhyodacite along reverse faults, recording the extremely complex interplay between intrusion-related uplift, caldera subsidence, sedimentation and associated eruptive activity during this early stage of development of the central complex.

The Western Granite, using measurements of Anisotropy of Magnetic Susceptibility (AMS) as indicators of magmatic flow, has recently been suggested to be part of Phase 1 and to originate from a source, or sources, along a proto-Long Loch Fault. The granite is very similar in composition to the rhyodacite and intruded steeply along the fault and flowed westwards, spreading out beneath a roof of Lewisian gneiss and later rocks. Palaeomagnetic measurements by Petronis and co-workers showed that the Phase 1 microgranite was subsequently tilted westwards by 10° or more, probably as a consequence of the emplacement of the later basic and ultrabasic intrusions of Phase 2.

Despite the dominance of silicic magmatism during Phase 1, Troll and colleagues showed that basaltic magmas were contemporaneously available, the evidence being provided by composite dolerite–rhyodacite intrusions, the mixed-magma relationships of the Am Màm Breccias, and the blocks and megablocks of extremely coarse-grained gabbro and rare feldspathic peridotite within the Am Màm breccias, including one house-sized megablock which preserves a chilled contact between gabbro and thermally-altered amphibolite Lewisian gneiss. The underlying importance of mafic magmatism in the generation of all the Rum igneous rocks is thus strongly emphasized.

From trace element and isotopic analyses of the rhyodacites, Meyer and colleagues conclude that it is likely that they were largely derived from Lewisian amphibolite gneisses through partial melting caused by ascending mantle-derived mafic magmas. The rhyolites are unusually depleted in Cs and Rb, possibly indicating that the Lewisian protolith had undergone an earlier partial-melting event, perhaps of Caledonian age. The magmas responsible for the Paleocene melting are considered to have been of mafic MORB type, compositionally similar to the sparse, late picritic dykes of Rum described by Upton and co-workers.

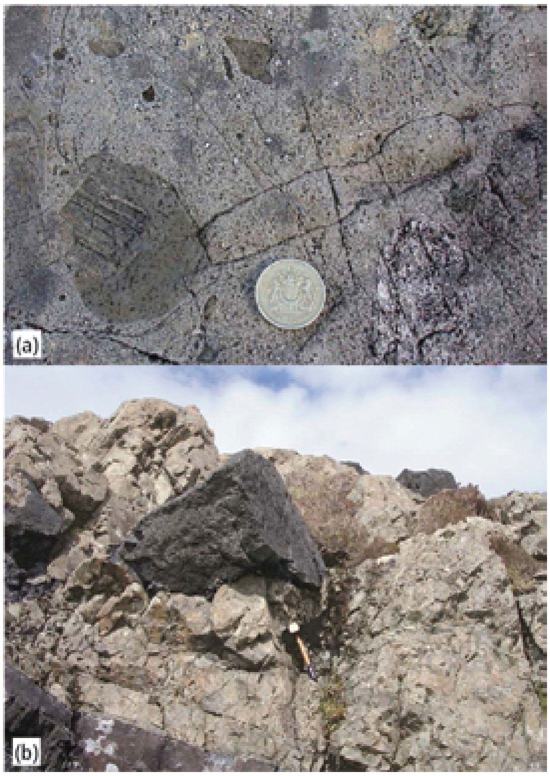

Fig. 9. a. Am Màm breccias matrix. Fragments included rounded basic area partly enclosing baked siltstone and (to right of coin) gneiss. Scale: coin 22 mm (from Emeleus & Troll, 2009). **b.** Am Màm Breccia with gabbro blocks in dacite matrix, NMZ. (Emeleus & Troll, 2008, photo: G.R. Nicoll)

Phase 2: The layered complex

The change to the almost exclusively mafic and ultramafic magmatism during Phase 2 came with the intrusion of a suite of thin basalt cone-sheets and numerous basic dykes. Although many of the dykes

Fig. 10. Intrusion breccia at the contact between gabbro of the Western Intrusion and the earlier Western Granite, Harris Bay (courtesy BGS, copyright NERC).

may belong to the regional NW-trending Rum dyke swarm, the presence of radial dykes centred on Rum had already been recognized by Harker who also considered the concentric inclined sheets (cone-sheets) to focus beneath the central complex, but little recent work has been done on these intrusions.

Emplacement of the main mafic and ultramafic central complex and its numerous associated gabbro and feldspathic peridotite plugs caused recognisable thermal metamorphism of the country rock Torridonian arkosic sandstones and Lewisian gneisses. Holness and Isherwood have reconstructed isograds outside and inside the MRF, which show that gneisses and sandstone within the fault system had undergone high-grade thermal alteration, locally reaching the stage of anatectic melting. Thermal alteration of the Torridonian country rocks (arkosic sandstones, shaley sandstones) was generally markedly less outside the ring fault and declined rapidly away from it. The surprisingly limited thermal alteration is considered to reflect the short time taken to emplace the mafic rocks of Phase 2, and vigorous cooling through circulating water along and outside the MRF (estimated at 700 000 years). An implication of these studies is that when the mafic rocks formed, the overburden was thin, possibly as little as 700 to 1000 m in thickness, although this will have varied as the volcanic superstructure evolved.

The superbly exposed layered rocks of the central complex (Fig. 11) are celebrated for the abundance of structures closely comparable with those found in clastic sedimentary rocks, including slumping, graded bedding and cross bedding, in addition to large and small scale layering (Figs 11, 12c-e, g). The layered rocks have generally been interpreted in terms of magmatic sedimentation and are classic examples of igneous cumulates. The somewhat wholesale application of this approach to these intriguing rocks has been questioned more recently, with the suggestion that: 1, many of the feldspathic peridotite layers were of intrusive origin, for example the peridotite of Unit 9 in the ELS, and 2, movement of high-temperature interstitial magmatic fluids may have caused a marked modification of the original textures and compositions. An approach by Holness to the problems of their origins has been made through detailed textural studies using a universal stage microscope to determine the degree of crystal equilibration of the layered rocks. Measurements on closely spaced samples from profiles through several layered units established that there is generally a high degree of textural equilibration in the troctolites and peridotites, which remains fairly uniform within a unit and thus argues for most layers to represent single magmatic events. However, troctolites immediately above and below the well-defined perdiotite of Unit 9 (ELS), exhibited a progressive decrease in textural equilibration at and adjacent to

Fig. 11. Layered units in the upper part of the Eastern Layered Intrusion, Hallival. Scale: ca. 120 m from col to summit.

the peridotite margins, consistent with textural resetting on peridotite intrusion. Furthermore, additional supporting evidence was obtained from gabbroic rocks at some distance above this peridotite, where a gabbroic component of Unit 9 is noted for an undulating, strongly laminated clinopyroxene-rich mafic layer that overlies troctolite and grades upwards to gabbro. This 'wavy horizon' (Fig. 12f) and similar structures in Unit 14 have been variously attributed to slumping and 'soft-sediment' deformation or the metasomatic transformation of troctolite overlying intrusive feldspathic peridotite. Holness and co-workers have suggested from studies on the textural relationships and mineral compositions of the troctolite and overlying gabbroic rocks that an evolved crystallized gabbroic raft subsided into intruding picrite, resulting in the complete replacement of interstitial liquid in the raft by through-flowing reactive liquid from the picrite, stripping out virtually all of the clinopyroxene. As the new liquid ascended, it mixed with interstitial liquid in the overlying cumulate, eventually producing a supercooled liquid oversaturated in pyroxene, which then precipitated in abundance but inheriting a pre-existing laminated texture. Such intra-cumulate metasomatic processes may have wider applications, and explain less spectacular pyroxene-rich layers in these and other layered rocks.

An investigation of the Anisotropy of Magnetic Susceptibility (AMS) in ELI troctolites demonstrated parallelism between magnetic foliations and ubiquitous feldspar lamination in the troctolites. Gently plunging magnetic lineations are usually oriented

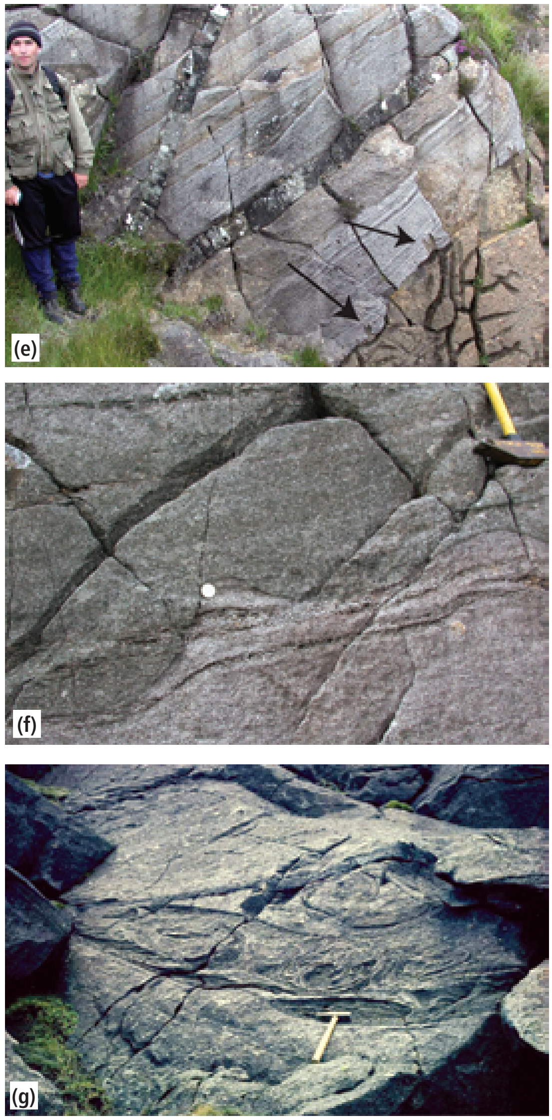

Fig. 12. a. Chromite seam, ELI. (photo: D. Pirrie). **b.** Harrisitic texture, feldspathic peridotite, CI. **c.** Small-scale layering with slumping, ELI. **d.** Peridotite 'dropstone' in troctolite, CI (from Emeleus & Troll, 2009). **e.** Graded layering and slumping in feldspathic peridotite. **f.** Replacement by peridotite seen at base, cut by later basalt sheets, CI. 'Wavy horizon' in troctolites of Unit 9, ELI (from Emeleus & Troll, 2009). **g.** Slumping in troctolite, Unit 14, Askival.

across the dip direction, although some were downdip. These weak linear fabrics are interpreted to reflect magmatic lineations, the majority developed during soft sediment deformation in response to central sagging, while the discordant lineations in Unit 10 are attributed to downdip slumping of crystal mushes.

The modifying role of migrating interstitial liquids has been further highlighted through studies by O'Driscoll and colleagues on the thin chromite-rich layers, or seams, commonly located between feldspathic peridotite layers and underlying anorthosites and bytownite troctolites (Fig. 12a). The seams at unit boundaries have been attributed to crystal settling, but many have features that are difficult to reconcile with magmatic sedimentation: chromite crystals coat irregular peridotite/troctolite boundaries, and they also occur in peridotites and within anorthositic troctolites beneath peridotites, also seams occasionally transgress lithological boundaries and there is, furthermore, some question as to whether such small crystals (commonly <0.01 mm) could sink in mafic magmas unless aggregated. Most common are the laterally extensive, 2–3 mm thick seams, or 'main seams', at macro-unit boundaries. From close examination of certain seams it was concluded that they had originated by *in situ* chromite crystallization from super-heated hybrid magma. This hybrid magma formed when plagioclase-rich cumulate was assimilated during picrite emplacement, where chromite also appeared to have been capable of remobilization, forming small-scale collapse and intrusive structures. Thin 'subsidiary' seams, some centimetres below main seams, were attributed to downward percolation of picritic magma into troctolite, with chromite forming at the tip of percolation, melting and hybridization. The Rum chrome spinels cover a wide compositional range, with significant differences between chromite from seams and those disseminated in peridotite or as detrital grains. This compositional range spans several fields in discriminant diagrams and, as noted by Power and colleagues, this casts doubt on their reliability as indicators in provenance studies or as aids to interpreting altered mafic suites.

The 'harrisitic' olivine crystals (Fig. 12b) found in the WLI and less commonly in the ELI, already noted by Harker, are generally thought to have grown rapidly. From crystal size distribution (CSD) studies, it was concluded that crystal growth times were short (days, or even hours) and that their distinctive skeletal, hopper olivines developed due to supersaturation of olivine in the magma. This occurred when thin picritic sheets, largely lacking suspended olivine, spread out on the magma chamber floor beneath pre-existing cooler magma. Once crystallization commenced, growth on the existing substrate was dominant, forming complex 'crystal gardens' at the floor of the magma chamber. This process was evidently repeated time and again and separated by periods of less pronounced undercooling when intervening granular-textured peridotite formed.

These investigations provide convincing evidence that igneous layering may be of rather diverse origins, of which gravitational sedimentation is but one. New textures and structures may develop as magmas cool and crystallize through the operation of processes somewhat analogous to diagenesis in sedimentary petrology. In addition, subsequent intrusion may cause radical overprinting of original features on a local scale. The survival of such detailed textural features, and hence their study, will generally be favoured in relatively small intrusions, such as Rum, where no large body of magma existed at any given time and cooling will have been relatively rapid.

Proposed parent magma compositions for the mafic rocks of the Rum centre range from basaltic to ultramafic, but convincing evidence is sparse. The high proportion of exposed rocks with abundant magnesian olivine, coupled with the pronounced positive gravity anomaly coincident with the centre, indicate that these magmas were most probably picritic, possibly represented by the rare ultramafic dykes with abundant highly magnesian olivine and only slight evidence of Pre-Cambrian crustal contamination. Contamination by Pre-Cambrian crustal rocks has widely occurred, however, especially of the troctolites by Lewisian amphibolite facies rocks. Geldmacher and co-workers have shown that this contrasts with the nearby Ardnamurchan central complex, where mafic magmas were contaminated by granulite facies Lewisian gneisses at moderate crustal levels and subsequently by supracrustal metasediments belonging to the Moine Supergroup. The major east-dipping Moine Thrust lies between Rum in the Hebridean Terrain and Ardnamurchan in the Northern Highlands Terrain, implying that Mesozoic or earlier erosion removed any over-thrust Moine metasediments from Rum prior to the Palaeogene.

Fig. 13. Western Granite forms Ard Nev (left) and occurs at the base of Orval (right), which is capped by flows of the Canna Lava Formation overlying an eroded granite surface (from Emeleus & Troll, 2008).

Indeed, the Rum mafic magma chamber was as an open system, and bulk rock isotopic investigations have shown that the magmas underwent varying degrees of contamination and successive recharges and Sr-isotope variation in plagioclase, which indicates that the degree of contamination varied within and between individual crystals, with larger crystals generally being isotopically heterogeneous whereas the smaller ones are more homogenous. This suggests that a primary magmatic composition was exposed to contamination as crystal growth proceeded, showing, for example, a clear increase in contaminated isotopic signatures up-section in Unit 9. Crystals are envisaged to form at the cooling roof of the chamber, becoming periodically detached and transported to the floor, providing opportunities for mixing between crystals with differing growth and contamination histories. Tepley and Davidson suggest that if their data do reflect primary magmatic isotopic variation, then cooling was sufficiently rapid to inhibit subsolidus equilibration over the short distances involved (1–2 mm). The implication is that the effective closure temperature (ca. 1000 °C) was reached in a few thousand years. This is in agreement with the pluton having grown through many small increments rather than by large injections of magma.

Rum contains little in the way of economic minerals although olivine and the chromite-rich sands off the south of the island have some potential. Their exploitation is unlikely, however, since they adjoin the National Nature Reserve and, furthermore, dredging would likely disturb fishing grounds. The manner of occurrence of platinum-group minerals (PGM) and chromite on Rum probably has implications for other, larger deposits since the small size of the pluton provides a better opportunity to investigate their origins. Following indications of Pt in the offshore deposits and subsequently in the Western Layered Intrusion, platinum-group minerals were identified in heavy mineral concentrates from streams and in many ultrabasic rock samples. These include Pt-Cu and Pt-Fe alloys, and possibly native Pt, commonly associated with and occasionally enclosed within sulphide minerals, the most abundant examples being found in the chromite seams. Although some of the platinum-group minerals show signs of limited hydrothermal alteration, the majority are little affected and the relatively unfractionated distribution of the platinum group elements is attributed by Power and colleagues to the primitive (picritic) character of the Rum magma. Disseminated sulphides (up to 5 modal per cent) were also discovered in a peridotite plug in north-west Rum in an irregular thin (< 5 m) marginal zone but are also abundantly present (up to 40 modal per cent) in thin dykes that cut the marginal peridotite. The isotopic characteristics of these sulphides in the marginal peridotite indicate that late carbonate contamination has probably played a role in their formation, possibly from a Jurassic source (now removed by erosion) as suggested for ELS Unit 1, rather than the adjoining Triassic cornstones, This raises the possibility that pyrite-rich Lower Jurassic shales had been assimilated.

Phase 3 marked the final Palaeogene events on Rum, with erosion of the central complex, accumulation of lavas and interbedded clastic sediments and, finally, intrusion of sparse basaltic dykes (Figs 6, 7, 13). However, from work by Dobson and colleagues on apatite fission tracks it appears that Rum, in common with other Hebridean Igneous Province central complexes, experienced a mid-Eocene (45–50 Ma) heating event possibly caused by an as yet unidentified small volume intrusions that had in part rejuvenated the hydrothermal systems.

Today, Rum is a National Nature Reserve, managed by Scottish Natural Heritage and formerly by the Nature Conservancy Council. For more than 60 years a succession of Chief Wardens and Reserve Managers and their staff have facilitated scientific research on the island and they are owed a considerable debt of gratitude for their help and encouragement, and not least for the support given to the many undergraduates who have undertaken thesis mapping on Rum, thereby adding greatly to our knowledge.

Acknowledgements

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Suggestions for further reading

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