Askival–Hallival

Highlights

The site contains the thickest, unbroken succession of layered ultrabasic rocks in Great Britain. The large- and small-scale layered structures, the petrography and geochemistry of the layered rocks and their emplacement mechanisms have been studied in great detail and have contributed significantly to theories relating to the origins of igneous layering. The site is of international importance for these reasons.

Introduction

The Askival–Hallival site is a unique, internationally significant location for large-scale, cyclic layering in igneous rocks (Figure 3.1). The site provides excellent exposure of repeated layered units comprising alternating olivine- and plagioclase-rich rocks which are type examples of igneous cumulates. A total thickness of about 700 m of layered rocks is exposed between *c.* 160 m OD and the summits of Askival and Hallival, which belong to the Eastern Layered Series in the core to the Rum central complex.

The earliest systematic investigation of the Rum Central Complex was carried out by Harker (1908), who interpreted the layering as multiple sill-like injections of contrasting magma types. In subsequent work, Brown (1956) favoured a genetic model which combined repeated magmatic replenishment of tholeiitic basalt magma and crystal accumulation processes, a model which is broadly accepted today, although the parental magmas are now argued to have been of a picritic composition (evidence summarized by Emeleus, 1987 and Young *et al.,* 1988).

Description

The rocks of the Eastern Layered Series in the Askival–Hallival site (Figure 3.8) comprise a repeated succession of large-scale layered ultrabasic units. Each unit is composed of a basal feldspathic peridotite rich in cumulus olivine (and sometimes pyroxene) which is overlain by, and sometimes gradational into, a plagioclase-rich, troctolitic cumulate termed allivalite. Less commonly, extreme plagioclase cumulates, or anorthosites, may occur at the very top of a unit. Brown (1956) distinguished fifteen such units in the Askival–Hallival area ranging in thickness from under 10 m to over 80 m. The units are generally considered to be an upward-younging stratigraphic sequence with a primary easterly dip of about 20°. The terraced topography which characterizes the slopes of Askival and Hallival (Figure 3.1) results from the contrasting weathering properties of peridotite and allivalite; the allivalites form prominent, resistant escarpments, while the peridotites erode more easily forming the grass-covered terraces which provide the nesting sites for Rum's manx shearwater colony.

The allivalites and peridotites are mineralogi-cally simple, containing variable proportions of Mg-rich olivine, diopsidic pyroxene, calcic plagioclase and chrome-spinel. The petrographic textures reflect cumulate piocesses (Wager *et al.,* 1960) and all minerals occur as cumulus phases; plagioclase in particular defines a strong lamination parallel to layering in allivalites. Plagioclase, pyroxene and, very occasionally, olivine are also intercumulus phases forming large poikilitic crystals up to 20 mm in diameter enclosing the cumulus phases. The resistance to weathering of plagioclase poikilocrysts is responsible for the characteristic honeycombed weathering surface of peridotite. Cumulus chrome-spinel, commonly an accessory mineral in peridotite, is frequently concentrated in seams several millimetres thick at the very base of peridotite layers marking the abrupt unit boundaries. Weak harrisitic textures are sometimes exhibited by olivine crystals in the peridotites, but they are not as well developed as those in the Harris Bay site (see below). While there is little overall cryptic variation through the layered units in eastern Rum, individual units show slight variability, becoming more fractionated upwards, with a return to less fractionated compositions in the basal feldspathic peridotite of the overlying unit (Dunham and Wadsworth, 1978). This corroborates the suggestion that each major unit in the Eastern Layered Series represents a fresh unit of unfractionated magma (Brown, 1956).

Allivalites commonly are rhythmically layered (Figure 3.9) and frequently contain zones of slump deformational structures; a particularly good example is exposed on the eastern face of Askival in Unit 14 (Brown, 1956; (Figure 3.10)). Such structures are of a similar nature to those observed in unlithified sediments and suggest the accumulation of considerable thicknesses of poorly consolidated crystal cumulates on, or near to, the floor of the magma chamber. Slumping of the unstable magmatic sediments may have been triggered by tectonic activity.

In addition to the layered peridotites and allivalites, distinctive, dark-grey, cumulate troctolitic gabbros are exposed as conformable sheets in the lower levels of the complex to the east and north-east of Hallival and on the Askival Plateau (Brown, 1956). These gabbro sheets have recently been interpreted to be an integral part of the Layered Series by Faithfull (1985). The gabbros often contain numerous subangular to rounded clasts of granular basic hornfels, probably derived from Tertiary basalts in the roof zone to the complex. Their presence suggests that fragments off the roof and upper wall country rocks were incorporated into the chamber and were sealed off as the intrusion solidified inwards and downwards from the walls and roof.

Interpretation

The spectacular large-scale cyclic layering exposed in this site has been subject to intensive investigation concerning its origins. Recently, interest has been focused on detailed petrographic and geochemical studies and the refinement of theories relating to the formation of such rocks. Consequently, the site has achieved significant petrological importance in the theory of layering in igneous rocks world-wide.

The layered rocks of eastern Rum are interpreted to be the result of successive pulses of magma injected into a shallow-level magma chamber (Wager and Brown, 1951; Brown, 1956; Wadsworth, 1961). This magma is currently argued to have been of a picritic composition (for example, Volker, 1983; Emeleus, 1987; Greenwood *et al.,* 1990). Each pulse, or replenishment of new magma, is envisaged to have produced a single unit by high-temperature crystal accumulation on the floor of the magma chamber (Wager and Brown, 1951). Successive pulses of new magma crystallized in this way to build up the Layered Series. Recent studies (Huppert and Sparks, 1980; Faithfull, 1985; Tait, 1985) have proposed that pulses of new picritic magma ponded at the base of the chamber beneath cooler, less-dense residual magma. Initial olivine crystallization in the picritic liquid lowered its density, and it was cooled against the older magma above. The resulting temperature and density differences are thought to have caused strong convection to develop in the picritic layer culminating in the mixing of the two magmas when their physical properties equilibrated following the fractionation of a peridotite layer. With further cooling, the resulting magmas formed allivalitic and other troctolitic gabbroic rocks until the next pulse of picritic magma was injected and the cycle repeated.

A wealth of new information has recently been published from detailed textural, mineralogical and geochemical studies on the Layered Series heralding a new era of current interest in the site. This work includes that of Faithfull (1985) who related cryptic variation in the lower Eastern Layered Series to post-cumulus effects; Tait (1985) produced detailed crystallization models from geochemical and isotope studies; Palacz and Tait (1985) investigated contamination of the magmas using isotope evidence; Butcher *et al.* (1985) described upwards-growing peridotite 'finger' structures and interpreted them as modal metasomatic replacement of allivalite by peridotite; Butcher (1985) discussed channelled metasomatism by intercumulus liquids within late-stage veins; and the cumulate rocks have been cited as examples exhibiting textural equilibrium (Hunter, 1987).

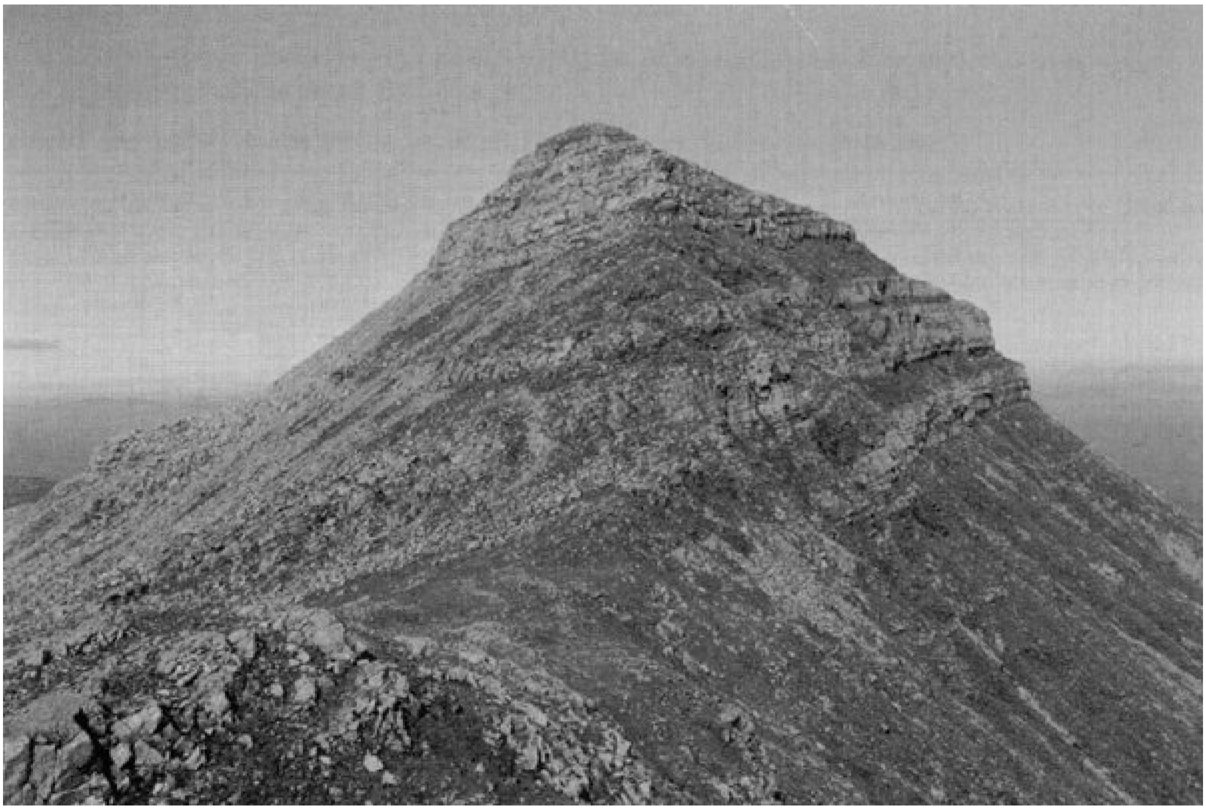
The Rum complex differs from other classic layered intrusions such as the Skaergaard (Wager and Brown, 1968) in that there is little or nothing of a marginal border group. Instead, the layered ultrabasic rocks are often bounded by rather variable gabbroic rocks which usually, but not always, separate them from the earlier Tertiary intrusions and Torridonian sediments. Marginal gabbros are exposed in the stream sections of Allt na h-Uamha [NM 409 968] and Allt Mor na h-Uamha [NM 405 973] in the east of the site. The gabbros have intruded along the line of the older Main Ring Fault near these streams and south to Allt nam Bà. Elsewhere, as on Beinn nan Stac and Cnapan Breaca, the relationships strongly suggest that the Marginal Gabbro and the layered ultra-basic rocks underlie earlier felsites and associated rocks which form an outward-dipping roof to the mafic rocks. In an investigation of the margin of the ultrabasic–gabbroic complex, Greenwood (1987) suggested, on the basis of detailed mineralogical and geochemical studies as well as a consideration of the field relations, that the Marginal Gabbro was probably not a distinct, separate body from the main succession of ultrabasic rocks but that it represented various degrees of modification of the more feldspathic ultrabasic rocks through reaction with country rocks. Extensive intrusion breccias are commonly developed at the contacts with earlier, more acid rocks (for example, Torridonian near Allt na Uamha); rheomorphic acid magmas generated at these contacts may well have reacted with partially crystallized mafic magmas to give the very variable gabbroic rocks that characterize the Marginal Gabbro zone of earlier workers.

Both Brown (1956) and Wadsworth (1961) postulated that the ultrabasic complex was emplaced as a solid mass along the Main Ring Fault lubricated by basaltic magma which subsequently formed the Marginal Gabbro. However, the lack of disturbance of layering right up to the edges of the intrusion and the roof-like contacts, give grounds for questioning this mode of emplacement. Recent publications argue that the layered rocks formed *in situ* from picritic magmas, with the possibility that some of the peridotites are in fact sill-like bodies intruded conformably into the layered allivalite rock (Emeleus, 1987; Renner and Palacz, 1987; Bédard *et al.,* 1988; Young *et al.,* 1988).

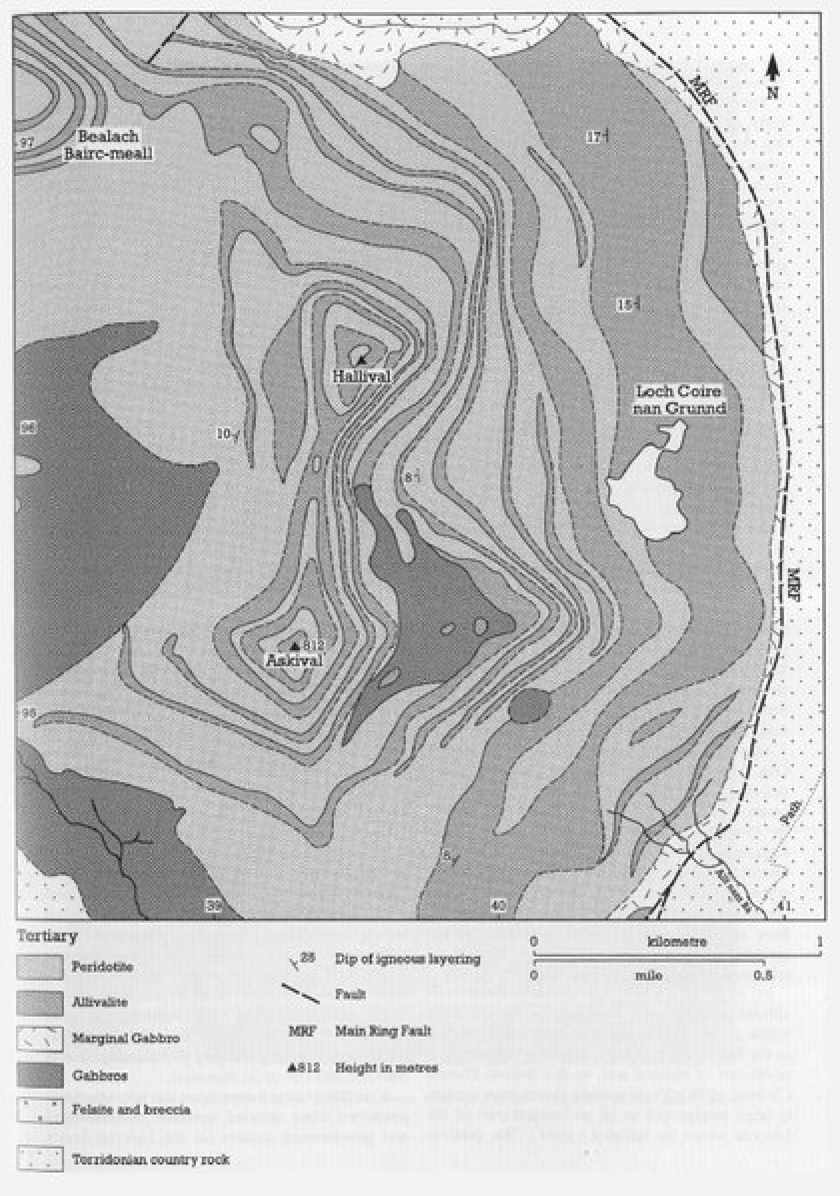
Conclusions

The excellent vertically and laterally extensive exposures of large-scale rhythmic layering in ultrabasic and gabbroic rocks on Hallival and Askival are unique within the British Isles. Unlike the other Tertiary centres of Mull and Skye, the Rum layered rocks formed as the last major event in the central complex and are thus virtually free from the overprinting effects of any subsequent igneous or tectonic events. Owing to this, they are particularly suited to the development of models concerning the origins of the layering, the accompanying rock textures and the variations found in their mineralogy and chemistry. The large- and small-scale structures and textures in the layered rocks are in many respects very similar to those developed in clastic sediments and invite interpretation in terms of the sedimentation from mafic magmas of successive crops of crystals of different densities. These features are common in peridotitic, gabbroic and other igneous rocks world-wide and, because of the exceptional clarity of the Rum examples, the theories developed here have strongly influenced petrogenetic thought regarding the crystallization of high-level magma chambers (for example, Wager and Brown, 1968; various articles in Parsons, 1987; Renner and Palacz, 1987; Bédard *et al.,* 1988).

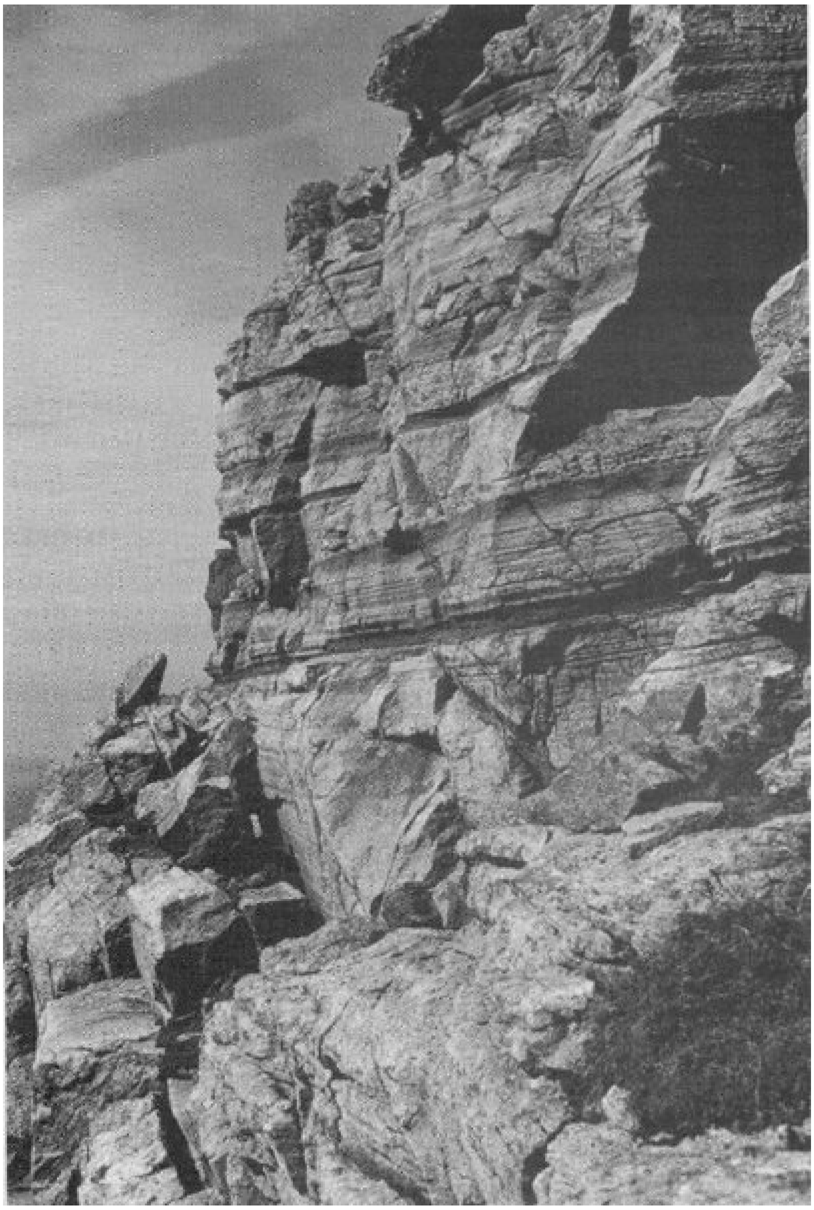
References



(Figure 3.1) Layered allivalite (light) and peridotite (dark) high in the Eastern Layered Series ultrabasic rocks, Hallival. Askival–Hallival site, Rum. (Photo: C.H. Emeleus.)



(Figure 3.8) Geological map of the Askival–Hallival site, Rum (after Emeleus, 1980).



(Figure 3.9) Fine-scale layering in allivalite, west side of Hallival. Askival–Hallival site, Rum. (Photo: A.P. McKirdy.)

(Figure 3.10) Slumped folding in allivalite, near Askival summit, Rum. Askival–Hallival site, Rum. (Photo: A.P. McKirdy.)