Hallaig, Isle of Raasay, Highland

[NG 588 387]

R.G. Cooper

Introduction

The Isle of Raasay lies between the Isle of Skye and the Applecross peninsula of the Scottish mainland. On its eastern side, at Hallaig, is a large landslip (Figure 6.14), which has moved in recent times (a slip was recorded in 1934). It is about 1.8 km long from north to south, and extends from the Cadha Carnach cliff on the east side of Dun Caan [NG 583 384] for 800 m to the coast. The landslip has been mapped in detail by Russell (1985, see (Figure 6.15)), and much of his work is utilized in this account.

Description

The Hallaig landslip lies on the eastern side of Raasay, immediately south-east of Dun Caan [NG 579 395], adjacent to the Inner Sound. The landslip forms a large crescent-shaped topographical feature extending from 290 m above OD to sea level. The main backslope to the slip is itself 150 m high in places (e.g. Cadha Carnach) and a major bench at *c.* 150 m above OD represents the top of the slipped mass. Loch a' Chada-charnaich infills a hollow on this bench. The landslipped material forms a steep slope from *c.* 150 m above OD to sea level, constituting a very large mass of failed material. The crags of Creag nan Cadhaig are prominent on this lower slope. They lie immediately to the north of the deserted village of Hallaig and are formed of Jurassic limestone, containing fissures (probably widened joints) of unknown depth, which are partly open to the surface. The fissures are up to 4 m wide at the surface, and appear to have opened in response to internal deformation of the slipped rock mass.

The most significant aspect of Russell's (1985) mapping of the landslide was the recognition, in the field, of the stratigraphical sequence on the backface of the landslip, and its repetition in the slipped mass. The critical sequence is:

Bearreraig Sandstone Formation

Raasay Ironstone Formation

Scalpa Sandstone Formation

In the field he mapped this sequence both along the backface and again across the landslip. Allied with measurements of dip, this provided data for five cross-sections (Figure 6.16). In the back-face, he found the in-situ bedding dipping between 12° and 15° west, while in the slipped mass the bedding strikes north–south with dips between 44° and 58° west.

In the vicinity of the sea cliffs he found that the Pabbay Shale, which underlies the Scalpa Sandstone, has exactly the changes in dip shown in (Figure 6.16). One small exposure of Pabbay Shale exhibits sheared surfaces and slickensided surfaces, the latter cutting one another. In the same area the underlying Broadford Beds have the normal tectonic dip, and hence were not involved in the slip at this location. Russell (1985) pointed out that near the foreshore the Pabbay Shale is raised, indicating an area of toe heave. The Admiralty Chart of the area (Chart No. 2480) shows tongue-like sea-floor features suggesting that this area of toe heave continues offshore.

Russell (1985) observed that open joints are a distinctive feature of the Raasay landslides, and accordingly made a study of them. In the area of the landslide itself, they are to be found only in the Bearreraig Sandstone Formation (here, a series of coarse-grained calcareous and non-calcareous sandstones). The joints generally have an east–west trend, with a few in the south of the landslide block trending north–south.

To the west of the southern part of the landslip block, widened joints in the Scalpa Sandstone have grassy bottoms and show no displacement across bedding units. On average they are 6.65 m wide, which Russell (1985) attributes in large part to subaerial erosion of their walls. On average they are 1.5 times as deep as they are wide. Their average weighted trend is 343°, approximately parallel to the slope trend. Many of the widened joints in the Bearreraig Sandstone Formation in the same area are narrower and deeper than those in the Scalpa Sandstone, being on average 5.4 times as deep as they are wide. Their average weighted trend is 349°, again running approximately parallel to the slope. Those close to the crest of the landslide's backface show some downward vertical displacement of their eastern walls (Russell, 1985, p. 59).

Interpretation

Despite the similarity of its east-facing position, the landslip at Hallaig on the Isle of Raasay differs greatly in its geological setting from the Trotternish Escarpment landslips on the Isle of Skye. Anderson and Dunham (1966) suggest that within the 145 m pile of sedimentary rocks exposed in the backface of the landslip, the first movement was that of the Portree Shale and Raasay Ironstone formations strata overlying the competent Scalpa Sandstone. This was followed by slipping of the Pabbay Shale with the Scalpa Sandstone acting as over-burden, and then by failure of the Great Estuarine Series and overlying Paleocene lavas.

Such a sequence of events may be necessary to explain the development of the entire slope eastwards from the summit of Dun Caan, which is the highest point of the island, but there is little evidence of it on the ground. Russell (1985) found no slipped lavas. He considers the large landslip block at Hallaig to have moved by rotational slip with the failure surface located in the Pabbay Shale. Its limit is controlled by the stronger Broadford Beds. He measured the strength of four samples of Pabbay Shale using a portable shear box, and carried out a stability analysis to assess the validity of the circular slip model depicted in the cross-sections in (Figure 6.16). The average peak shear-strength obtained was c = 590 k Nm^{-3}, $ø$= 35°. Taking the slope height (H) to be 300–350 m, and the rock density (γ) as 21.6 k Nm^{-3}, he used Hoek and Bray's (1981) circular failure charts and their ratio $c'/(\gamma H \tan ø)$ to find the factor of safety at various degrees of slope steepness (Table 6.1). The use of 21.6 k Nm^{-3} for the value of rock density is precisely the value of 137 lb/ft^3 used by Hoek and Bray (1981, p. 223) in their practical example of the method. It equates to a density of 2200 k Nm^{-3}, which converts to 2.2 g cm^{-3}. According to Farmer (1968, p. 15), this is a value typical of sandstones, mudstones and limestones; it is therefore a valid approximation to use. Russell (1985) concluded that failure could occur at an angle of 64° with a slope height of 300 m, and at an angle of 58° with a slope height of 350 m. This is in good agreement with slope gradient reconstructions shown on the cross-sections (Figure 6.16).

(Table 6.1) Factors of Safety (*F*) for the Hallaig landslip. After Russell (1985).

Slope height (m)	Slope angle (degrees)	F
300	80	0.75
300	70	0.90
300	60	1.06
350	80	0.69
350	70	0.84
350	60	0.97
350	50	1.12

The Hallaig landslip also differs in its geological setting from the Trotternish Escarpment landslips in that features in the immediate vicinity suggest that recent tectonic movements have taken place on the east side of Raasay. Such movements are likely to have had some effect on the landslip. The most apparent sign of such movement is a regular ridge of sandstone blocks running along the north-western side of Beinn na' Leac, a flat-topped hill of Bearreraig Sandstone (Aalenian and Bajocian, Mid-Jurassic, age) which rises to 319 m above OD, immediately south of the landslip. First described by Lee in 1920, the ridge is up to 4 m high along most of its length (Figure 6.17), and appears to mark the position of the fault which throws down this Jurassic outlier of Bearreraig Sandstone to the south-east. The fault is arcuate, and where it crosses the coast at the small bay south of Rudha na' Leac, the Jurassic succession from the Scalpa Sandstone (Upper Pliensbachian) to the Bearreraig Sandstone to the south is juxtaposed against the Broadford

Beds (Sinemurian and Hettangian) to the north; the throw of the fault is of the order of 300 m (Morton, 1969). Lee (1920) comments that the materials forming the ridge must be derived from the crags immediately upslope, and interprets the feature as scree accumulations now separated from the slope by movement on the fault. Since the ridge is too fragile to have survived glaciation, this movement must have been post-glacial, and the ridge is so fresh in appearance that the movement appears to have occurred recently. It may be a late expression of isostatic re-adjustment to the removal of the Devensian glaciers. Further evidence of recent movement is provided by features of Beinn na' Leac itself, and by reports quoted by Anderson and Dunham (1966). The east side of Beinn na' Leac is made up of landslips, to the extent that they greatly increase the apparent thickness of the Scalpa Sandstone that crops out there (Lee, 1920). Many vertical fissures of great depth occur on the surface of Beinn na' Leac. The latter are wide enough to be entered, and have been partly explored by cavers.

Evidence of recent movement, as adduced by Anderson and Dunham (1966), includes the local newspapers for 7 August 1934, which reported that twice within a period of six weeks a volcanic eruption had taken place in Raasay. Rising steam and smoke, showers of stones and a loud rumbling noise were reported by local inhabitants. They also reported that Professor A.D. Peacock, who visited Raasay shortly after the most recently reported occurrence, attributed these phenomena to stones falling down one of the very extensive fissures backing the latest slipped mass. Anderson and Dunham (1966) comment that it is 'more probable that such a spectacular disturbance was due to movement on a larger scale, i.e. to renewed slipping of the unstable mass'. It can be added that renewed movement on the fault could also give rise to such phenomena, and indeed to renewed slipping of the unstable mass.

It may be worthy of note that Musson *et al.* (1984) have traced evidence of an earthquake that took place on the nearby mainland on 16th August 1934, nine days after the newspaper reports noted by Anderson and Dunham (1966). They placed its epicentre in Strathconon Forest. In the light of additional evidence, Musson (1989) placed the epicentre farther west, in the Torridon area, although the position is still poorly determined. The earthquake was felt over a wide area, and Neilson and Burton (1985) list it as one of the larger British earthquakes of the 20th century, with an instrumental magnitude of 3.8 ML, which Musson (1989) regards as a rather small estimate considering the large area over which it was felt. Torridon village, assumed by Musson (1989) to be close to the epicentre, is 35 km from the Hallaig landslip on the Isle of Raasay. Anderson and Dunham (1966) note that in the mid-1950s many new fissures could be seen, as could evidence of 'considerable and recent movement', and Russell (1985) provides photographs of manifestly recent shallow slides (his plates 8 and 9). In this connection it is relevant to record that Ballantyne (1997) in a review of rock slope failures in the Scottish Highlands noted that Holmes (1984) found that most translational rockslides had taken place over failure planes inclined below the residual angle of friction, the lower threshold angle for rock masses to slide under their own weight. After considering and eliminating glacial over-steepening, progressive failure, and high cleft-water pressures as causes of rock slope failures under these conditions, Ballantyne (1997) concluded that seismic activity was a likely triggering factor.

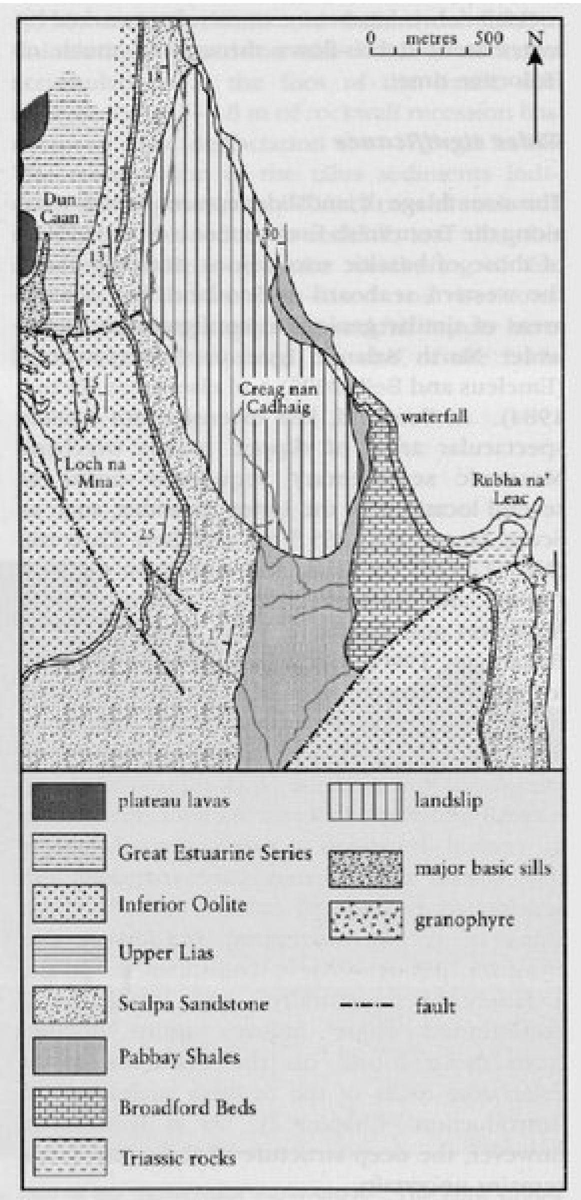
One further circumstance may be significant in relation to the Hallaig landslip. This is the remarkable depth of the sea-channels which flank Raasay. In particular, the Inner Sound, which lies between Raasay and the Applecross peninsula of mainland Scotland, has a channel which includes the deepest submarine hollows in the British sector of the continental shelf (Whittow, 1977). These extend down to more than 300 m below sea-level. The submarine slope is steep, with an average angle of about 19°, although the eastern side of the trench is seldom steeper than about 8° (Robinson, 1949; confirmed by the bathymetric survey of Chesher *et al.,* 1983). Thus the steeper side of the trench lies adjacent to the east coast of Raasay, and the Hallaig landslip. The asymmetry of the trench led Sissons (1967) to write: 'a fault control of this trench seems likely and it may well be that the fault has caused these relatively soft rocks [i.e. the Jurassic sedimentary rocks] to form the floor of part of the Inner Sound and so aid its excavation [to these great depths] by glacier ice', even though they have been strengthened by the injection of Paleocene igneous rocks, e.g. dolerite sills and dykes. Whittow (1977, p. 276) put forward the opinion that the presence of major faults on Raasay suggests that the entire chain of islands (Scalpay, Raasay, Rona) may be fault controlled: 'Their entire eastern shores may have been carved from faultline scarps, and the neighbouring ocean deeps excavated along the relatively soft rocks of the down-faulted [Jurassic] sedimentary basins'.

Conclusions

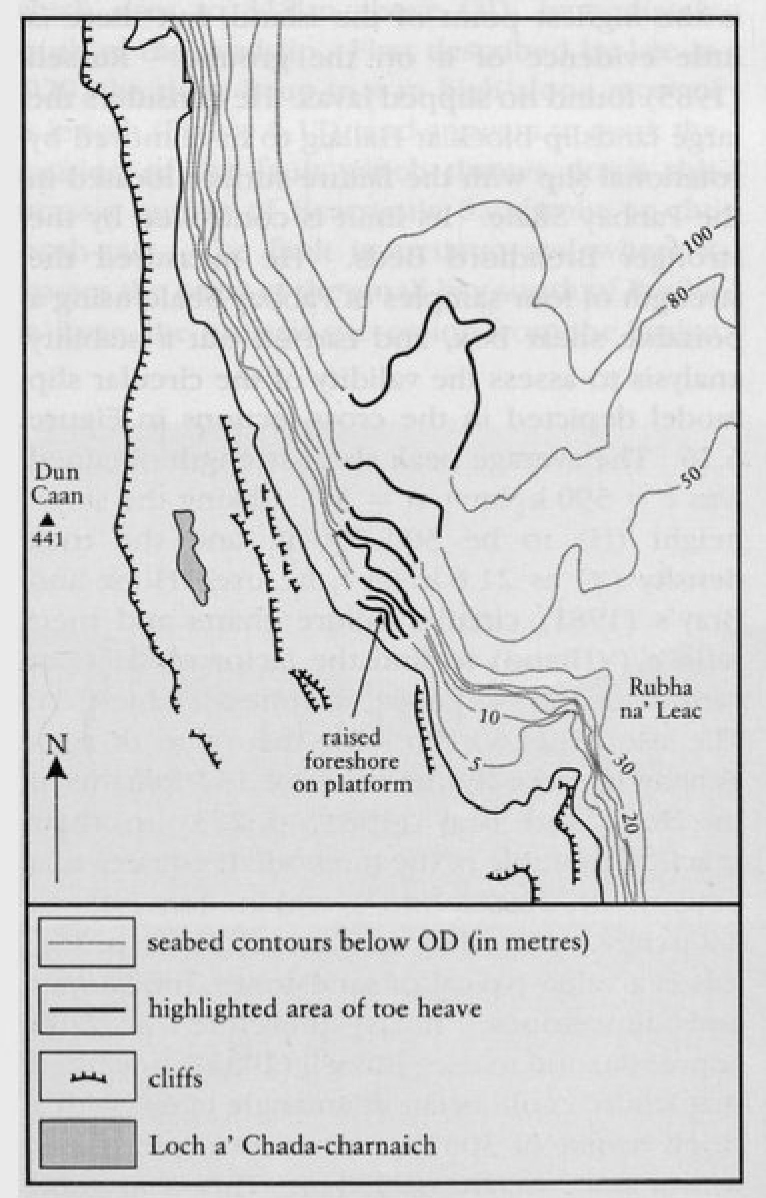
The Hallaig landslip on Raasay is a very large crescentic failure of Jurassic sedimentary rocks that shows evidence of a classic circular failure. Unlike the Trotternish Escarpment landslips of northern Skye, Paleocene lavas were not of importance here, at least in the first two of the landsliding stages postulated. The landslip is lent particular interest by the manifestly unusual events (for Great Britain) apparently taking place at Beinn na' Leac, immediately to the south. Here, inferred fault movement, detachment of scree, and widening of joints all seem to point to some kind of post-glacial flexure and faulting of the sandstones which make up Beinn na' Leac itself. These tectonic events may be related to the great depth of the Inner Sound, enhanced by glacial excavation. These factors and the various landslips of the area seem intimately related, in ways still to be evaluated in detail. However, the Hallaig landslip is the only British mass-movement site with good evidence for neotectonic activity.

Shocks accompanying submarine slumping on the 19° underwater slope might have been responsible for the phenomena observed in Raasay in 1934, and could also have acted as an episodic trigger of continued movements of the Hallaig landslip. Both subaerial movement of the landslip, and submarine slumping, could be triggered by fault movement, and it is known that the general area was seismically active in 1934.

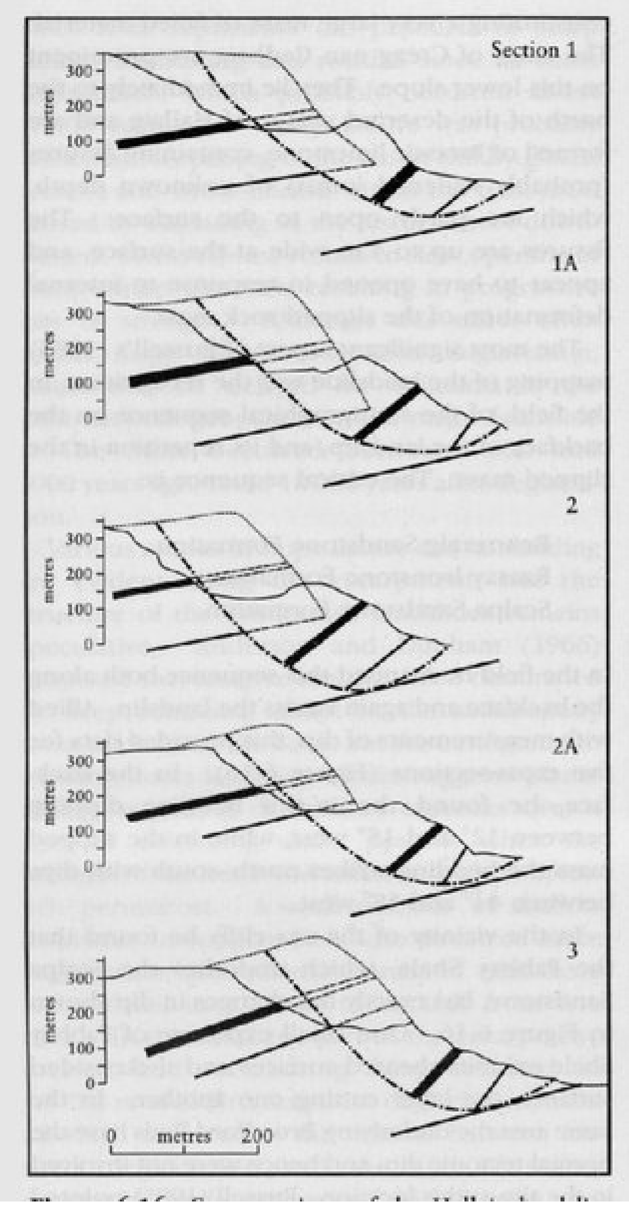
References



(Figure 6.14) The geological setting of the Hallaig landslide on the coast of the Isle of Raasay.



(Figure 6.15) Slipped masses of the Hallaig landslips and the offshore features. After Russell (1985).



(Figure 6.16) Cross-sections of the Hallaig landslip. After Russell (1985).

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(Table 6.1) Factors of Safety (F) for the Hallaig landslip. After Russell (1985).

(Figure 6.17) The Hallaig landslide — Beinn na' Leac ridge. (Photo: R.G. Cooper.)