Sea level changes, Palaeogene volcanic districts of Scotland

From Earthwise

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Introduction
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During the Quaternary glaciations, the weight of ice over Scotland caused isostatic depression of the land surface while sea levels were lowered as water became locked up in the major continental ice sheets. When the ice melted in Late-glacial and postglacial times these processes were reversed, but isostatic recovery of the land initially lagged behind the eustatic rise in sea level, with the result that beaches and features of marine erosion were formed well above the present sea level. As isostatic recovery continued (and relative sea level fell), these features were uplifted to become raised beaches and wave-cut platforms. The amount of isostatic recovery was greatest over those areas where the ice had been thickest, with the result that initially horizontal raised marine features have been tilted. Since older shorelines will also have been affected by later events, their gradients tend to be steeper than those of the younger shorelines. Tilting is directed away from the centre of uplift, and ice distribution, which was in the area of Rannoch Moor.

Several groups of features that can be attributed to changes in sea level are recognised in the district, although dating them is difficult, particularly in the Inner Hebrides and Arran where there are very few associated fossiliferous deposits. The amount of tilting provides a rough method of dating, but it does not furnish unequivocal results. For example, correlation of sections of rock platform may be difficult in areas where sedimentary rocks or lavas dip at low angles. Over short distances, platforms may show a gradual rise only to fall and rise again when another resistant layer takes over, a problem that is well illustrated by the lava benches around Treshnish Point, Mull (Walker et al., 1992). Furthermore, it may be difficult to differentiate between benches formed by marine erosion and those picked out by glacial action, as for example in the variably resistant, flat-lying sandstone beds of the Torridon Group at Bagh na h-Uamha, eastern Rum (S B McCann in Peacock, 1969).
High rock platforms

Remnants of high rock platforms are common in the Inner Hebrides on the west coasts of Skye, Mull and Ardnamurchan, and around Rum. Heights vary between 18 and 51 m OD, and tend to be higher towards the east. Some of the high rock platforms are ice-striated and covered by glacial deposits, suggesting a pre-Late Devensian age.

On the eastern coast of the Trotternish peninsula, Skye, there are several high rock platforms at between 17 and 30 m OD. At Staffin Bay, a 500 m-wide platform at 18 m OD is largely cut in till, but a short distance to the north marine gravels rest on a rock platform at the same level (Ballantyne et al., 1991). On Rum there are high coastal platforms between 18 and 38 m OD. The prominent platform eroded from granite on the south-west coast is partly covered by Late-glacial marine gravels and by till, and on the east coast a sandstone platform has smoothed, glacially striated surfaces. On Ardnamurchan, marine notches have been recognised at about 40 m OD west of Kilchoan and on the north coast near Achateny.

The distribution of the high rock platforms in the west has generally been attributed to advancing mainland ice eroding and removing platforms in those areas nearest to the centre of ice dispersal and, especially, those on east-facing coasts. An alternative suggestion by Sissons (1982) was that for much of the Mid and Late Devensian, the approximate western limit of mainland ice was along a north—south line from Skye to Mull. The high rock platforms would then have formed to the west of this line, in seas that were relatively high because of substantial glacio-isostatic depression of the land. Fluctuations in the position of the ice front would explain why some benches are glacially striated while others are not, and why some are cut in till.

Late-glacial shoreline deposits

The higher raised beach deposits in the area were formed during the retreat of the Main Late Devensian ice sheets, when there was much sand and gravel being transported by meltwater. These gravelly deposits occur up to about 30 m OD. Late-glacial raised beaches at lower levels have been identified on Skye where they are generally restricted to sheltered shorelines and the mouths of certain lochs. On the north side of Staffin Bay, near Digg, Late-glacial gravel deposits rest on a high rock platform at 18 m OD, and in southern Skye terraced raised beach deposits are well developed between Broadford and Kyleakin, where they are quarried (p. 174). The altitude of the higher raised beach deposits falls westwards from about 30 m OD at Kyleakin to about 15 m OD at Loch Harport, with a gradient of about 0.4 m. km-1. This shoreline, now tilted by variable isostatic recovery, reflects the maximum sea level in Skye during retreat of the Main Late Devensian ice sheet. High raised beaches (over 15 m OD) do not occur within the areas affected by glaciers of the Loch Lomond Stadial; for example, they are absent from Loch Ainort and from Loch Siligachan (P914159a). The contrast between Late-glacial and postglacial beach levels may be observed east of Strollamus, Skye. Late-glacial beach sands and gravels occur at over 23 m OD, close to the eastern margin of the former (Loch Lomond Stadial) Strath Beag Glacier, whereas postglacial beach gravels deposited against the moraines from this glacier are at 7 m OD.

Late-glacial raised beach deposits are present on all the Small Isles. Late-glacial storm-deposited shingle ridges rise to about 30 m OD at Harris on Rum. Storm beaches from this period are also present at similar heights above sea level at Tarbert on Canna (21 m), Camas Mór on Muck (30 m) and Camas Sgiotaig on Eigg (25 m).

Raised, marine-cut benches occur at several levels around Mull and on Morvern. On Mull, the
highest (at about 30 m OD) and one of intermediate level (at about 20 m above OD) are covered by deposits attributed to glaciers of the Loch Lomond Stadial and hence predate that event. This relationship can also be demonstrated at the lower ends of Glen Cannel (Loch Bà) and of Glen Forsa, where outwash deposits associated with glaciers from the Loch Lomond Stadial are not cut by, and hence postdate, marine notches that are present in adjacent coastal exposures.

Raised beaches were formed on Arran when ice from the Highlands covered the north of the island. The highest altitude, at about 33 m OD, occurs at Imichar on the west coast. Outwash deposits associated with a major glacier from this period in Glen Iorsa are cut by beaches at about 20 m OD (see below).

**Main Rock Platform**

The Main Rock Platform is a particularly striking example of a well-developed marine shoreline eroded in rock. The height of the platform varies from over 10 m OD in the sea lochs north-east of Oban and in the innermost lochs north of the Firth of Clyde, to below present sea level in the west of Mull and south of Kintyre (Gray, 1989; P914160). The clearest development of the platform is in the south-west Highlands, including eastern Mull and Arran, though farther north, rock platforms on Skye and in other areas have also been correlated with the Main Rock Platform. The platform is generally broad and in places is over 200 m wide. Raised sea stacks may be present on the platform, which is commonly backed by relict sea cliffs.

The age of the Main Rock Platform has been much debated (Walker et al., 1992). It was originally regarded as Holocene in age (e.g. Bailey et al., 1924), but subsequently it was pointed out that this would not allow enough time for cutting away of so much solid rock, and a preglacial or interglacial age was suggested (McCallien, 1937). Sissons (1974) argued that the platform was eroded mainly during the Loch Lomond Stadial under periglacial conditions. The evidence favouring a Loch Lomond Stadial age includes:

- the unglaciated character of the platform in many areas
- the surface defined by platform remnants is tilted at a gradient between that typical of the early Late-glacial shoreline and that of the early Holocene shoreline
- Postglacial shorelines
- erosion of the platform in some very resistant rocks in sheltered locations where frost riving could have been much more effective than normal coastal erosive processes

Evidence against formation during the Loch Lomond Stadial includes:

- undoubted marine coastal erosional landforms are commonly present, for example sea stacks, caves and undercut cliffs
- the preservation of delicate glacial features, such as striae and p-forms, would hardly be expected to have survived erosion during the Loch Lomond Stadial
- the lack of angular debris in the offshore sediments, which would be expected to be present if there had been rapid erosion to form the platform during the Loch Lomond Stadial
- a few pre-Holocene dates have been obtained that apparently constrain the age of the platform

Remnants of the Main Rock Platform are strikingly preserved on the coast around the Firth of Lorn (Walker et al., 1985). In eastern Mull, Duart Castle is built above the raised platform, at about 8 m OD, and both the platform and raised cliff, which is over 10 m in height in places, are present for several kilometres to the south. South of Loch Don, both the platform and the backing cliffs form
prominent features, for example at Port Donain. Remnants of the Main Rock Platform also occur in Ardmurchan, and in Moidart they extend eastwards up to the limits of the Loch Lomond Readvance (Dawson, 1988). The level of the platform in Ardmurchan falls from about 2 m OD near Oakle on the north coast, to just above sea level at Ardmurchan Point, a distance of about 15 km. There are several good examples of the wide (up to 500 m), ice-sculpted platforms backed by raised cliffs, for example south of Rubha Carrach on the north coast where raised sea caves, the ‘Glendrian Caves’, can also be seen. The Main Rock Platform is extensively developed on Arran but tends to merge with postglacial shoreline features to form a single low raised shoreline around most of the island (Gemmell, 1972, fig. 1; Plate 42), inaccurately termed the ‘25 foot raised beach’ by earlier workers (e.g. Tyrrell, 1928). Much of the coastal road has been built on the platform, for example north of Machrie, between Corrie and Brodick Bay, and west of Loch Ranza. North of Corrie, very large glacial erratics of granite derived from the North Arran Granite Pluton rest on the platform. In north-east Arran, the platform is at about 4.5 m OD, falling to about 2.1 m OD to the south-east of Brodick and at Tormore on the west coast; it drops to 1.4 m near Kildonnan in the south of the island.

Rock platforms below the level of the High Rock Platform are present in eastern Rum and possibly on Canna, but details are sparse. However, on Skye there are well-defined low rock platforms formed by marine erosion, for example for some distance north of Portree Harbour where the platform is at 2 to 7 m OD. The clearest examples, with geos, caves and stacks, occur on Sleat and on the Strathaird peninsula, where the low rock platforms are at 0 to 5 m OD. These occurrences may be the equivalents of the Main Rock Platform, which might be expected to be present at these levels in southern Skye (Ballantyne et al., 1991). The platforms appear to be absent from areas previously occupied by glaciers of the Loch Lomond Stadial, for example Loch Sligachan and Loch Ainort.

Postglacial shorelines

In the early Holocene (Table 17), isostatic rebound of the land initially outpaced the rising sea level, and in general the evidence from Scotland is of falling relative sea level. However, between about 8500 and 6500 years BP, a major rise in sea level occurred which is attributed to the final melting of the ice sheet that covered much of North America (Walker et al., 1992). The wide-spread Main Postglacial Shoreline dates from this transgression (P914160).

Postglacial beaches on Skye are associated with a variety of features, including fossil shingle ridges and raised tombolos. The Main Postglacial Shoreline on Skye is tilted gently towards the north-west (at about 0.07 m. km-1), falling from about 10 m OD at Kyleakin in the south-east to about 6 m OD on the Duirinish peninsula in the north-west. At Staffin Bay, the Main Postglacial Shoreline is marked by well-defined, vegetated shingle ridges at about 6 m OD; to the north, segments of this shoreline are found cut into landslipped material. At Braes, about 12 km south of Portree, a tombolo rising to about 7 m OD extends out to the granite islet of An Aird. At the head of Loch Brittle, there is a rare example of sand dunes that most likely formed during and subsequent to the Main Postglacial Transgression.

Pockets of postglacial raised beach gravels, up to about 6 m OD, are present on most of the Small Isles. On Rum, a thin covering of raised beach sand and gravel at the head of Loch Scresort underlies the made ground at Kinloch Castle. Postglacial raised beaches also occur, for example at the foot of the Late-glacial raised beach deposits at Harris, Guirdil and Kilmory. On northern Eigg, near Talm, a postglacial raised beach is cut into landslip deposits, and is partially covered by later landslip debris, and to the south at the Bay of Laig, Holocene blown sand partly covers a postglacial
raised beach.

Remnants of postglacial beaches are common on Mull where they occur as gravel and sand beach terraces, sloping banks and spits, or as notches in morainic deposits, for example in the 'Loch Don Sand Moraine' west of Gorten. At the seaward end of Glen Forsa, an extensive spread of postglacial raised beach deposits at about 9.5 m OD underlies the airstrip and raised shingle ridges, and remnants of terraces up to 11.2 m OD occur around the head of Loch na Keal. More than one beach level may be present, as at Carsaig Bay. At Fishnish, a beach at about 12 m OD, marking the Main Postglacial Shoreline, is accompanied by less well defined beaches at about 7 and 3.3 m OD. Raised beaches are sparsely represented on Ardnamurchan, but are present at Kilchoan Bay where some are regarded as postglacial in age.

Remnants of postglacial raised beach deposits occur at various localities around the coast of Arran (Gemmell, 1972). They are especially well developed where abundant detritus was available from the erosion of moraines; good examples occur at Brodick Bay and north of the mouth of the Sannox River. Postglacial shoreline deposits also occur on the Main Rock Platform (see above; Plate 42). The beach deposits contain shell fragments similar to those of present-day beaches.

References

Full reference list

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