St Kilda, Western Isles

[NA 100 000]

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Introduction

The islands of the St Kilda archipelago rise out of the Atlantic Ocean 66 km WNW of Griminish Point on North Uist (see (Figure 3.1) for general location). The four main islands of Hirta, Dan, Soay and Boreray, together with their adjacent stacks of Stac an Armin, Stac Lee and Levenish have a coastline that is *c.* 35 km long in total. The coast is rugged and almost entirely cliff-bound, with Conachair (430 m) on the main island of Hirta forming the highest British sea dig and Stac an Armin (191 m) the highest stack. A variety of spectacular cliffs and cliff-related forms, including geos, arches, stacks, caves, blowholes and vertical cliffs characterize the coastline of the archipelago. Partly because of the dramatic sea cliffs, the entire archipelago was selected as Scotland's first natural World Heritage Site in 1987.

St Kilda is all that remains above sea level of a large ring volcano, thought to have been active about 60 million years BP (Steers, 1973; Miller, 1979; NCC, 1987). Although few fragments remain of the St Kilda volcanic complex, its geological history has been pieced together by com paring the precipitous remnants with the more complete and accessible igneous complexes of Mull and Ardnamurchan (Cockburn, 1935) and absolute dating based on the radioactive decay of minerals (Miller and Mohr, 1965). St Kilda is mainly composed of Tertiary intrusive igneous rocks, with coarse-grained gabbro in the southwest of Hirta and Dùn. Extensive exposures of igneous breccia intruded by dolerite occur on the north coast of Hirta, on Soay, Boreray and on the two large stacks (Figure 3.2). Granitic intrusions occur in the cliffs of Conachair and Oiseval. A late intrusive phase of sheets and dykes of dolerite and felsite has indirectly influenced the formation of arches, caves and ledges in the cliffs.

Unsheltered coasts in the western isles are exposed to high mean wind speeds and for 75% of the time, wind speeds exceed 4 m s^{-1} mainly from between west and south (BGS, 1977a) and so St Kilda experiences extreme weather conditions with high wave-energy levels that probably exceed any other site in the British Isles. The predicted 50-year wave height of 35 m for this area is significantly higher than for other parts of the UK (BGS, 1977a). Significant wave heights exceed 5 in and 1 m for 10% and 75% of the year respectively (UKDMAF: 1998) and although a maximum significant wave of 9 m was recorded 15 km west of South Uist (BGS, 1977a), individual storm waves regularly exceed this. For example, to the west of Shetland storm waves reached 15.13 m at 60°N, 4°W in January 1974 (Marex, 1975), and 24.4 m at 59°N, 19°W (Draper and Squire, 1967). Since the seabed around St Kilda lies at about 120 m depth and the islands rise from a plateau at a depth of about 40 m, the coastline is very exposed to large, high-energy Atlantic waves and this has resulted in some of the most dramatic and spectacular coastal geomorphology in the British Isles. In keeping with its oceanic location, spring tidal range at St Kilda is limited to 3 m and maximum tidal streams on spring tides are low at 0.25 m s^{-1} (BGS, 1977a).

The archipelago's present isolation dates from the end of the Devensian glaciation when sea levels rose to flood the intervening land surface. As a result of this isolation, little research has been carried out on forms and processes operating on St Kilda. To date, only descriptive works of the coastal geomorphology of St Kilda are available (e.g. Mathieson, 1928; Steers, 1973; Miller, 1979), although more exists concerning the Quaternary history of the islands (e.g. Sutherland, 1984; Sutherland *et al.,* 1984; Peacock *et al.*, 1992).

Description

The complex and varied coastal outline of the St Kilda archipelago (Figure 3.2) is composed of a variety of cliffs, caves and geos, arches, tunnels, stacks and blowholes; since it would be over-exhaustive to describe the entire 35 km coastline in detail, the following account focuses on those features that are especially significant in the selection of this site for the GCR. Geos are deep inlets of the sea, often narrow with steep precipitous sides and often excavated along the line of a structural fault or less-resistant lithology. 'Geo' is derived from the Norse*, gja,* meaning a crack or cleft, and so the name mainly occurs in those areas where Norse influence was most marked in the past, such as in the Northern and Western Isles and in the north of Scotland.

The southern coast of Hirta (from Village Bay to Caolas an Dun), together with the north coast of Dùn, comprises low cliffs that are characterized by a profile that is relatively unusual in the British Isles. The steeper upper section of the cliff is cut in unstratified Quaternary till, whereas the lower-angled slope beneath the drift is cut in solid rock. The angles of the lower slopes match the dip angles of the underlying sheets and shelves of dolerite and microgranite. These lower slopes have been stripped of their till cover by wave action, yet they continue to afford some protection to the upper slopes from waves. Nevertheless, the upper slopes remain unstable and produce high-angled failures and an unusual profile. The overall regularity of this stretch of coastline is broken by several small geos and caverns that are related to wave-quarrying of small-scale faults and intrusions.

The relative homogeneity of the cliff forms on the north coast of Dùn is in stark contrast to the south coast, where the vertical lower face continues below the water level and plunges directly into deep water. The characteristic profile of the cliffs is a smooth and vertical face at the base, often with an overhang. This is surmounted beyond the reach of wave impact by a 70° face that is very rugged and broken (Figure 3.3)a. The detail of the coastline is extremely irregular and the only recognizable trend is related to wave-exploitation of the three major NE–SW fault lines that cross Dùn. The detail of the plunging cliff at sea level consists of a variety of stacks, caverns, arches, blowholes and narrow inlets at all stages of formation. Shore platforms are absent. Several deep geos pass into caverns that penetrate through the narrow island, an impressive example being the natural arch near Gob an Dùn, which is almost 50 m long and 24 m high. These caves and geos have generally been eroded along the line of dykes or thin, inclined, sheet intrusions where they crop out at sea level.

The south-west coast of Hirta (from Ruaival to The Cambir) displays local variants of the forms found on the south coast of Dun, according to geological differentiation and differences in altitude. On the southern stretch of this coastline, the Mullach Sgar complex crops out and the many dykes and sheets of microdolerite and granite result in irregular notched and stepped cliff profiles, with remarkable colour contrasts. Farther north, towards The Cambir, the cliffs reach higher altitudes (up to 350 m at Mullach Bi) and are generally more uniform, although at water level the diversity of wave erosional forms resemble those of the south coast of Dùn. Free faces have developed in the high cliffs with massive scree deposits or block fields beneath, close to the angle of repose. Below these screes, the lower cliffs are vertical. Along most of this coast dose to sea level, wave impact has excavated smoothed and shallow concavities into the gabbro and everywhere large columnar stacks, eroded stacks and arches are prominent. At the narrow neck of The Cambir, glacial till, consisting of large and angular boulders set within a sand and day matrix, is being actively eroded by waves on both sides, together with wind-stripping of the surface soil and turf cover. In 1970, the neck measured 60 m from west scar to east scar but, by 1998, it had narrowed to 45 m, a rate of retreat of 0.26 m a^{-1} on each side.

The north-east coast of Hirta contains the highest and most impressive cliffs in the archipelago. The coarse dolerites cropping out between Gob na h-Airde and Mullach Mòr, result in an irregular and stepped cliff profile, with many small protuberances. At the western end of this cliff, the natural arch at Gob na h-Airde is more than 91 m long and over 30 m high. The rectangular shape of the geo leading to this arch reflects the strong lithological control on this stretch of coastline. Farther east, the cliffs of Conachair and Oiseval are cut in granite and granophyre, intruded by dolerite sheets and dykes, creating a characteristic profile with short, near-vertical, free faces interspersed with longer, high-angled, grassed slopes and occasional screes. In places, horizontal sheets of dolerite have created pronounced ledges in the cliffs and preferential erosion of dykes has left several high altitude pinnacles. The continuous and very steep cliff of Conachair, the highest sea cliff in Britain, reaches a height of 430 m. This entire north-east coast is characterized by numerous stacks, caves, and overhangs with small horizontal cliff ledges at a variety of altitudes that appear to be related mainly to structure. Stripping of soil and turf by high winds occurs at a variety of altitudes east of Gob an h-Airde and reaches 400 m OD at Conachair.

The island of Soay to the north-west of Hirta is best defined as a complex and large stack (Steers, 1973) with no level ground. The coastline of Soay displays a similar sequence of features to the adjacent coast of Hirta, with the cliffs of north Soay reaching heights of 305 m. The arch in Soay Stac, together with the dog-tooth profile of Stac Biorach, in the narrow sound between Hirta and Soay, represent successive phases of coastal erosion. The island of Boreray, north-east of Hirta, has also been described by Steers (1973) as a large stack, and the steeply cuffed coastline of the island is again honeycombed with caves and geos. The adjacent stacks of Stac an Armin and Stac Lee, tower 191 m and 166 m above sea level and are characterized by vertical faces plunging into deep water. The former is the highest stack in the British Isles (Figure 3.3)b; Steers, 1973).

If the St Kildan landforms above sea level are impressive, then submerged beneath the waves is an equally spectacular suite of coastal landforms. (Figure 3.4) reveals two relatively level sea-floor platforms, the largest of which lies to the west as a virtually horizontal bedrock surface at –120 to –125 m depth with only a patchy sediment cover (Sutherland, 1984). This platform is backed by a 40 m-high submerged cliff in the west and a series of 20–30 m-high benches in the south-east that separate the –120 m surface from a low-angled surface, which rises very gently from about –80 m in the north-west to –60 m in the south-east, although there is a fairly ubiquitous step in the profile at –70 m on most sides. The islands and sea stacks of the archipelago that rise steeply above sea level directly from this surface do so from a common depth of –40 m and the two valleys on Hirta can be traced down to its level. As a result there appear to be two platforms, one at –120 m and separated by a prominent submerged cliff from the second, which lies between –80 and –40 m. The second platform is itself backed by a prominent cliff that rises from –40 m to a maximum height of 430 m at Conachair. In spite of the extensive occurrence of submerged platforms and cliffs, at present sea level only a few low skerries exist, and shore platforms are largely absent from St Kilda.

Interpretation

Since the eruption of the ring volcano 60 million years BP the igneous complex has been affected by numerous processes: submergence; glaciation; marine erosion; and subaerial erosion, all of which have played a part in its physical breakdown. Active erosion of the islands continues today with: wave quarrying of notches, caves, inlets, and geos along much of the cliff foot; rockfalls and scree formation especially on the south-west coasts of Hirta and Soay; and vegetation and soil-stripping at high altitudes, for example, at the Cambir and on Conachair. Wave quarrying and abrasion are reducing the island of Dun to a series of stacks (Steers, 1973) and the stack of Levenish, to the south-east of Dùn, may be a former extension of the island. Miller (1979) states 'no-one knows how long these remote islands will resist the elements, but disappear they will in the fullness of 'geological time'.

It is the relationship between lithology, geological structure and the sheer range of erosional and mass movement processes that creates the distinctive and dramatic coastal scenery of present day St Kilda. The volcanic formation of the St Kilda igneous complex, the subsequent cauldron subsidence and the various intrusive stages that followed (see Miller (1979) for a fuller discussion) imparted a unique and complex geo logical structure. The gabbro that forms much of the Islands has been injected with numerous sheets and dykes of basalt, dolerite and granophyres, many of which were further shattered, faulted and altered during each intrusive stage. Erosion of the gabbros, distinguished by their very coarse grain and dark colour, is responsible for the most jagged cliffs and stacks of St Kilda (Miller, 1979), while the numerous sheets and dykes provide weaknesses for preferential erosion, creating the complex of caves and geos at the level of wave attack. The geomorphology of the high cliffs, which often have an irregular notched and stepped profile, reflects a strong lithological control, but could also be regarded as an example of 'multi-storied' cliff profiles. Elsewhere, these are thought to reflect repeated cycles of sea-level rise and fall and intervening periods of paraglacial modification of the slopes (Trenhalle, 1997). However, much of the paraglacial veneer of material that has survived on lesser slopes elsewhere in Scotland has been stripped off in St Kilda, and only erosional evidence survives. There may well be remnants of past higher sea levels in the cliff profiles, but the coincidence with lithology is too marked to ignore.

The archipelago of St Kilda is exposed to a large fetch from almost every direction and as a result experiences high wave-energy levels, probably exceeding any other site in the British Isles. Large, high-energy, relatively unimpeded Atlantic swell and storm waves impact directly onto the exposed cliffs. During storms a great plume of water and spray overtops the high cliffs of Dun and falls into Village Bay (Miller, 1979), indicating the nature and scale of wave attack. The effect is so persistent that halophytic swards with species more characteristic of saltmarsh environments, such as sea plantain *Plantago maritima* and sea milkwort *Glaux maritima,* dominate the cliff vegetation communities, clothing not only the exposed south-west-facing coast of Mullach Bi, but also the lee-slopes of the Ruival cliffs facing Village Bay (Walker, 1984). Subaerial erosion and mass-movement processes, such as frost action and soil creep, are active in St Kilda, largely a result of the combination of steep slopes, complex geology, thin drift cover and extreme weather conditions. The operation of these highly active erosional processes upon structure and lithology creates much of the site's scientific interest and coastal geomorphology.

However, in spite of the apparently high-energy St Kildan wave climate, the presence of extensive platforms at –120 m and –80 to –40 m, both backed by precipitous cliffs the upper one represented by islands and stacks abruptly rising from –40 m, represents something of a paradox. A highly erosional system might be expected to produce a marked platform at, or dose to, present sea level on the more gentle slopes, yet the final 40 m of Holocene sea-level rise seems to have accomplished relatively little by way of platform erosion (Sutherland, 1984), in spite of being close to its present level for about 6500 years. The suggestion clearly is that the planation of the two bedrock surfaces and of the cliffs that back them was achieved during two earlier periods of lower and stable sea-level conditions at –120 m and –80 to –40 m. Sutherland (1984) suggests the –120 m surface and its cliff which rises to –80 m, to represent a Late Devensian sea level (i.e. about 18 000 years BP) and the –80 to –40 m surface and its cliff behind to represent the Loch Lomond Stadial sea level (i.e. about 11 000 to 10 000 years BP). There is a measure of agreement for these age allocations from glacio-eustatic and glacio-isostatic modelling studies of the Hebrides area (Lambeck, 1992). The predicted sea levels for the St Kilda area at 18 000 years BP lie at –120 m and, although not specifically modelled by Lambeck (1992), a figure of –80 to –40 m appears to be realistic for the St Kilda area at 10 000 years BP However, whereas it is likely that the –120 m platform was indeed modified as recently as 18 000 years BP, it may date from glacial periods earlier in the Quaternary Period when sea levels were at similar lows. As a result, the shallower surface may also have been initiated much earlier than the 11 000–10 000 years BP date suggested above.

Since there are no shore platforms at present sea level in St Kilda, the interpretation that relates the development of the submerged St Kildan platforms to 18 000 years BP and 11 000 years BP carries with it the implication that erosional conditions were more severe during these times than during the final 40 m of sea-level rise of the Holocene Epoch (particularly for the Loch Lomond Stadial, because of the need to cut a substantial platform in only 1000 years). However, it may be that the severe erosional conditions experienced in these cold periods were more the result of ice-related processes than of wave-related processes. During both cold periods, low sea-temperatures, floating ice, and intertidal frost-shattering would have resulted in very efficient shore-platform development, similar to that experienced today on high-latitude shores (Hansom and Kirk, 1989) and also thought to have caused rapid shore-platform erosion in the Inner Hebrides during the Loch Lomond Stadial (Dawson, 1984). Research in high latitudes indicates that although such ice-affected shore platforms develop rapidly, the conditions for frost-shattering (which require standing water and low-gradient intertidal surfaces) are not favoured by high wave-energy environments (which produce intertidal erosional ramps). As a result, the platforms produced by ice-affected processes are progressively destroyed when the wave climate becomes more severe (Hansom, 1983). It is thus possible that a reduced St Kildan wave climate during the two cold periods was conducive to extensive platform development, but that the increasing wave energy of the Holocene Atlantic Ocean was not. The lack of St Kildan platforms at present sea level indicates only that present conditions are not well-suited to shore-platform development; it does not mean that no erosion occurs.

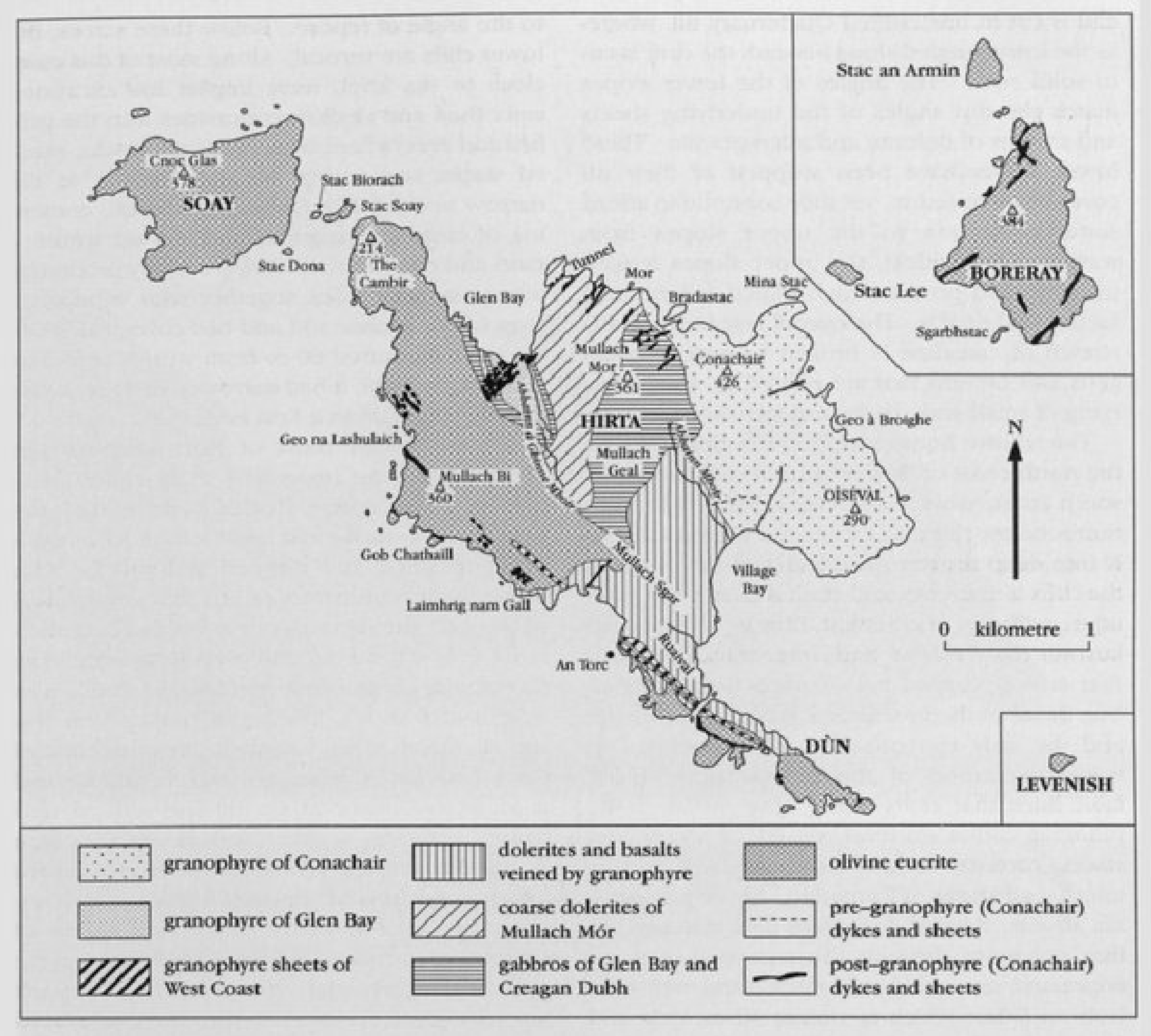
Conclusions

The geomorphological interest of the dramatic cliff coastline of the St Kilda archipelago lies in the height, scale and diversity of the cliffs and stacks, together with the wide range of erosional features that have formed in this high wave-energy environment, including numerous geos, caves, natural arches, blowholes and stacks at all stages of formation. A strong lithological and structural control of the coastal landforms adds further interest.

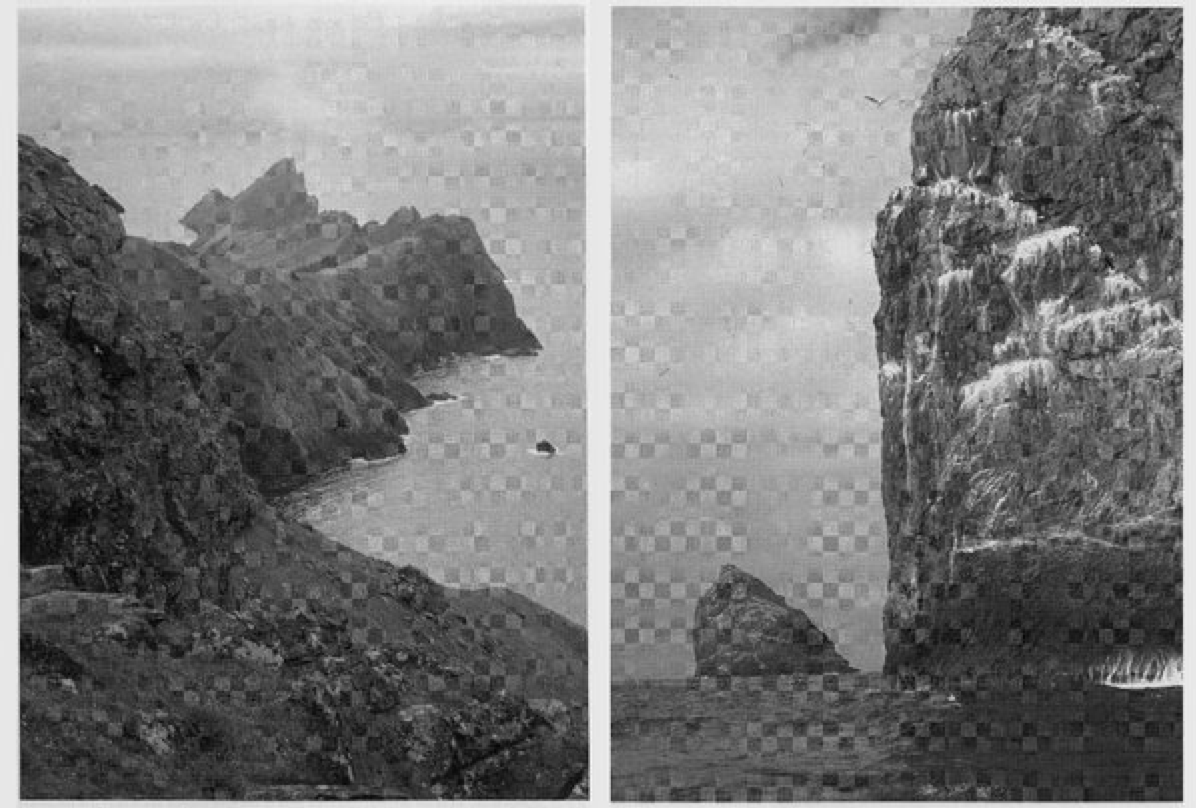
However, the present lack of knowledge concerning the detailed evolution of the St Kildan coast enhances the conservation value of the site, and more work needs to be done to unravel the story behind the existence of a spectacular suite of submerged cliffs and associated platforms, juxtaposed beside the present cliffs and the absence of any substantial shore platforms.

There is, of course, an additional historical, cultural and biological context to the cliffs of St Kilda that demands mention. The St Kildans maintained a 'hunting and gathering' economy on the islands up until the early 20th century, scaling the high cliffs to obtain seabirds for food. Clefts (store huts) still remain at various levels on the steep cliffs, such as Carn Mór and Aird Uachdarachd. However since the 1930s, this inhospitable, but geomorphologically spectacular, environment has been uninhabited and is managed by the National Trust for Scotland. The cliffs are also of great ornithological significance and St Kilda is recognized as one of the most important seabird sanctuaries in the North Atlantic Ocean. This assemblage of cliff geomorphology, seabirds and cultural and historical contexts set within a land-ownership and management environment of high standard led to the designation of St Kilda as Scotland's first natural World Heritage site.

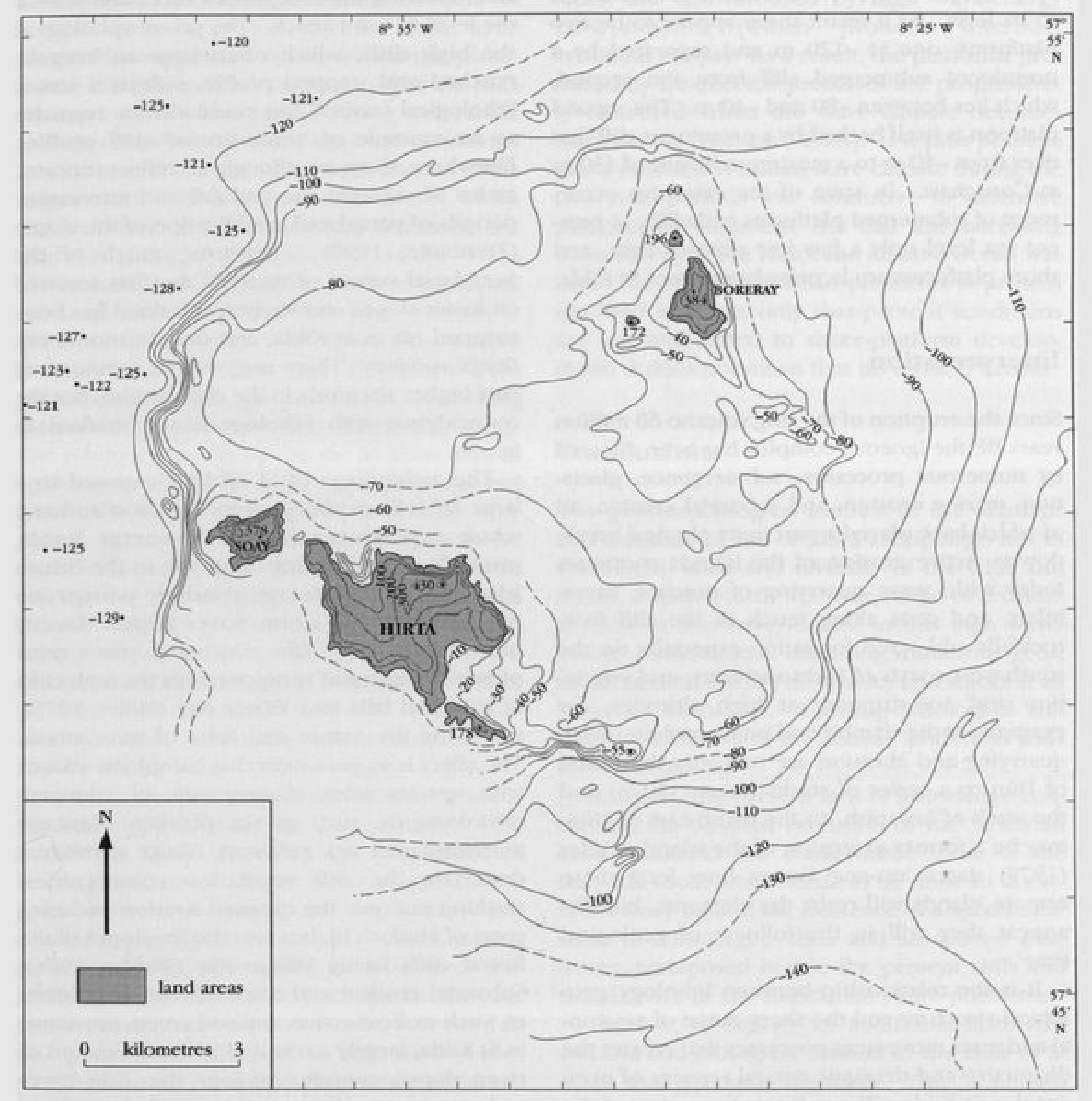
(Figure 3.1) High-cliffed coast of Great Britain, showing the location of the sites selected for the GCR specifically for coastal geomorphology features of hard-rock cliffs. Other coastal geomorphology GCR sites that include hard-rock cliffs in the assemblage are also indicated.



(Figure 3.2) Geological sketch map of the St Kilda archipelago showing the dominantly volcanic nature of the bedrock geology and the controlling effect of the granophyre sheets of the west in producing an approximately linear coastline. For relative geographical positions of the component islands of the archipelago, see Figures 3.1 and 3.4. (After Nature Conservancy Council, 1987.)



(Figure 3.3) a The west coast of Hirta, the main island of St Kilda, looking towards Dun, is characterized by stepped cliffs that steepen downwards to plunge steeply to well below sea level. (Photo J.D. Hansom.) Figure 3.3b Stac an Armin, seen here with the vertical plunging cliffs of Boreray (the second-largest island of St Kilda) in the foreground. This is the highest sea stack in Great Britain. (Photo J.D. Hansom.)



(Figure 3.4) Bathymetric map of the St Kilda archipelago. Depths are given in metres. Note the prominent break of slope where the roughly circular igneous complex stands proud of the otherwise low-gradient seabed. The seabed lies at c. −120 m and abruptly gives way to steep submarine cliffs that rise to a c. −60 m surface. In turn this surface abruptly gives way to submarine cliffs that may rise above sea level. Bathymetry is in metres below OD. (After Sutherland, 1984.)