Balnakeil, Sutherland

[NC 390 700]

Introduction

The *c.* 3 km-long peninsula of An Fharaid encloses Balnakeil Bay and lies at the entrance to the Kyle of Durness, 15 km east of Cape Wrath on the extreme north-west tip of the Scottish mainland (see (Figure 9.1) for general location). It contains a magnificent and spectacular array of beach and dune erosional and depositional landforms ranging from undercut dune faces to large and active dune blowthroughs. Large blowthrough corridors and transgressive sand waves carry windblown sand across the An Fharaid peninsula from the beaches on the west coast to cascade over a prominent cliff on the east, a landform assemblage unique in Britain if not in Europe. The wide, steep-sided, blowthrough corridors are up to *c.* 25 m deep and up to *c.* 400 m long (Figure 9.21). Mature machair vegetation has stabilized much of the higher blown sand deposits in the north and east of the peninsula leading to a marked contrast between these stable machair slopes and the lower altitude, highly active dunes and blowthrough corridors. The dunes of Balnakeil are some of the most active in Scotland and display important interactions between wave erosion and undercutting of the dune-toe and the effect of high velocity winds in driving the eroded dune sand inland and uphill. However, in spite of the clear geomorphological interest and importance of this site, it has attracted only limited scientific research, and much of the following description and interpretation is drawn from Ritchie and Mather (1969) and Hansom (1998).

Description

Balnakeil beach occupies the west side of the isthmus that connects the An Fharaid headland with the mainland to the north of Dumess (Figure 9.21). The *c.* 3 km-long peninsula of An Fharaid consists of a block of gneiss tilted towards the south-west and connected at its southern margin to a similarly tilted block composed of schist beyond which the Durness limestones crop out (Ritchie and Mather, 1969). The blocks provide an inclined plane up which large quantities of sand are blown in a north-easterly direction from the beach and from frontal dunes undergoing erosion. The peninsula is up to 1.5 km wide dose to the headland in the north, but narrows to *c.* 400 m in its central section at [NC 390 700]. The west coast is cliffed from [NC 385 708] north to An Fharaid headland while the east coast is entirely cliffed with only a few small pocket beaches. The sand has a mean diameter of 0.292 mm with 52% of this being composed of calcium carbonate derived from shells (Ritchie and Mather, 1969). The spectacular assemblage of dig beach, dune and machair forms of the peninsula can best be described in two sections.

The southern section includes the wide intertidal sand beach of south Balnakeil Bay and the mature dune system that extends across the peninsula to cliffs on the east coast. A broad, *c.* 10–15 m-high, coast-parallel dune ridge backs the 220 m-wide sandy beach and is erosional over much of its length. Although there is evidence of past wave-undercutting and basal slumping of the dune toe, the erosional contact is often covered by a small ramp of windblown sand to give the appearance of relative stability (Hansom, 1998). Higher up, to the rear of the beach in the southern section, the dune face is well-vegetated with vigorous marram *Ammophila arenaria* growth, testifying to a healthy supply of fresh sand from the upper beach below. Several small blowthroughs occur in the coastal dune ridge, particularly around the stream outlet in the south close to Balnakeil Farm. Partial protection is afforded to the dune toe by the remnants of a tarmac roadway built in the 1950s along the approximate line of mean high-water springs, at the back of the beach.

To landward of the coastal dune ridge in the southern section, the undulating mature dunes are low in the west but increase in height as the system extends eastwards across the peninsula to climb An Fharaid headland as a thin machair cover. Damp dune slacks are common within the lower parts of the dune system and support wet machair vegetation communities. The bedrock surface is low in the west where it is veneered by sand but rises in the east to substantial cliffs of *c.* 30 m OD. The dune ridges trend in a north-easterly direction and reach heights of up to *c.* 20 m in places. They are mainly stable at present and support a mature vegetation cover, although there are several small blowthroughs and erosional scrapes probably initiated by sheep-rubbing and subsequently enlarged by wind. The highest dune in the

southern section has a large circular blowthrough eroded into its north-west face. The windward face of the blowthrough is cut into bare sand and is highly active with wind eddy and scour of the lee face. This has led to undercutting and an impressive series of individual turf-block terraces in the process of sliding down the steep sand face of the blowthrough.

The northern section is the narrowest part of the peninsula and extends from Flirum on the east and the rock protuberance on the west coast, which separates Balnakeil Bay beach into a southern and northern section, to the rocky slopes north-east of the intertidal skerry of A'Chléit (Figure 9.21). The geological structure of this section consists of a low rocky slope rising from sea level in the west to up to 50 m-high cliffs near Flirum in the east. The skerry of A'Chléit is connected to the mainland by an intertidal sand tombolo, and acts as an intertidal pinning point for the 200 m-wide beach. To the north and south the beach width is restricted to less than 50 m. In spite of the volume of sand that has accumulated in the shelter of A'Chléit, the upper beach is erosional in this central section, with only a narrow beach at high tide. Exposure to north-westerly waves has resulted in undercutting and destabilization of the *c.* 15 m-high mature dunes that back the narrow beach, linear erosion of the dune toe-upper beach interface and the development of steep erosional faces in the bare sand of the dunes. The associated removal of dune-face vegetation has resulted in blowthrough activity in two main areas. One of these, centred on [NC 390 702], continues through the peninsula east to Flirum and comprises large, steep-sided, linear blowthrough corridors that rise from sea level on the west shore to *c.* 30 m OD on the east shore (Figure 9.22). The presently unvegetated blowthrough feeds sands directly from Balnakeil Bay into a large transgressive sand wave that in the north inundates machair pasture and a small sheep enclosure and in the east cascades over the cliff. Dunes occur on the cliff edge in the east but sand is removed by waves at the foot. The active blowthrough corridor on the west is also flanked by a series of linear north-easterly orientated ridges capped by vigorous marram growth. The second blowthrough zone is centred on [NC 387 704] where a vehicle access track is under threat of undermining by frontal erosion of the dunes on the west side. Emergency maintenance work has resulted in assorted rubble being tipped to protect the track, and sand repeatedly being cleared and bulldozed into the blowthrough. To the south of this point a large, wide blowthrough extends from mean high-water springs (at the wrecked hull of a boat) eastwards to *c.* 30 m OD. This large wide area of bare sand is punctuated at the western end by the upstanding remnants of old fixed dunes, complete with vegetation cap that are now eroded on all sides to produce pinnacles ranging in height from 3 m to 15 m. Landwards of the blowthrough vigorous marram growth has led to stabilization of the dune surfaces. A distinct boundary exists between the lower surfaces stabilized by marram *Ammophila arenaria* and the higher surfaces to the east charcterized by machair grassland. This boundary is likely to be mobile with rapid sand inundation favouring marram encroachment of machair.

Interpretation

In spite of the wealth of active dune processes at Balnakeil, with large blowthroughs feeding transgressive sand waves that allow sand to travel from the beaches on the west coast across the peninsula to cascade down the high cliffs on the east coast, the site has attracted surprisingly limited geomorphological research. Ritchie and Mather (1969) and Hansom (1998) described the geomorphology of the site and highlighted the importance of aeolian processes in both the past and present geomorphological development and evolution of the site, particularly in the central section. However, further geomorphological research at this spectacular and highly active site is clearly warranted.

Based on both theoretical considerations and field observations, Ritchie and Mather (1969) suggested a clockwise rotation of the beach over time with the erosion in the north being balanced by accretion in the south. In common with many Scottish beaches and particularly those in the north and west of Scotland, it is likely that Balnakeil Bay now has a much-reduced supply of sand from the offshore than previously (Mather and Ritchie, 1977; Hansom, 1999). This is associated with the reductions in offshore glaciogenic supply following the slowdown in the rate of Holocene sea-level rise in mid-Holocene times (Hansom, 1999). This theoretical argument is supported at Balnakeil by data that show the offshore seabed to be characterized by bedrock rather than sediment (BGS, 1991), the sediment that once rested within this zone having been transported onshore earlier in the Holocene Epoch. With limited sand supply from the offshore and no sources of river-borne sand nearby, the quantity of sediment within Balnakeil Bay is more or less finite and its distribution mainly the result of wave- and current-transport processes within the bay. The field observations that support the above view relate to the predominantly unidirectional waves that impinge on the beaches from the north-west and produce a southwards transport of sand. Some 20 years after the beach rotation suggestion of Mather and Ritchie

(1977), similar landforms and processes were recorded by Hansom (1998) and so are clearly long-lived.

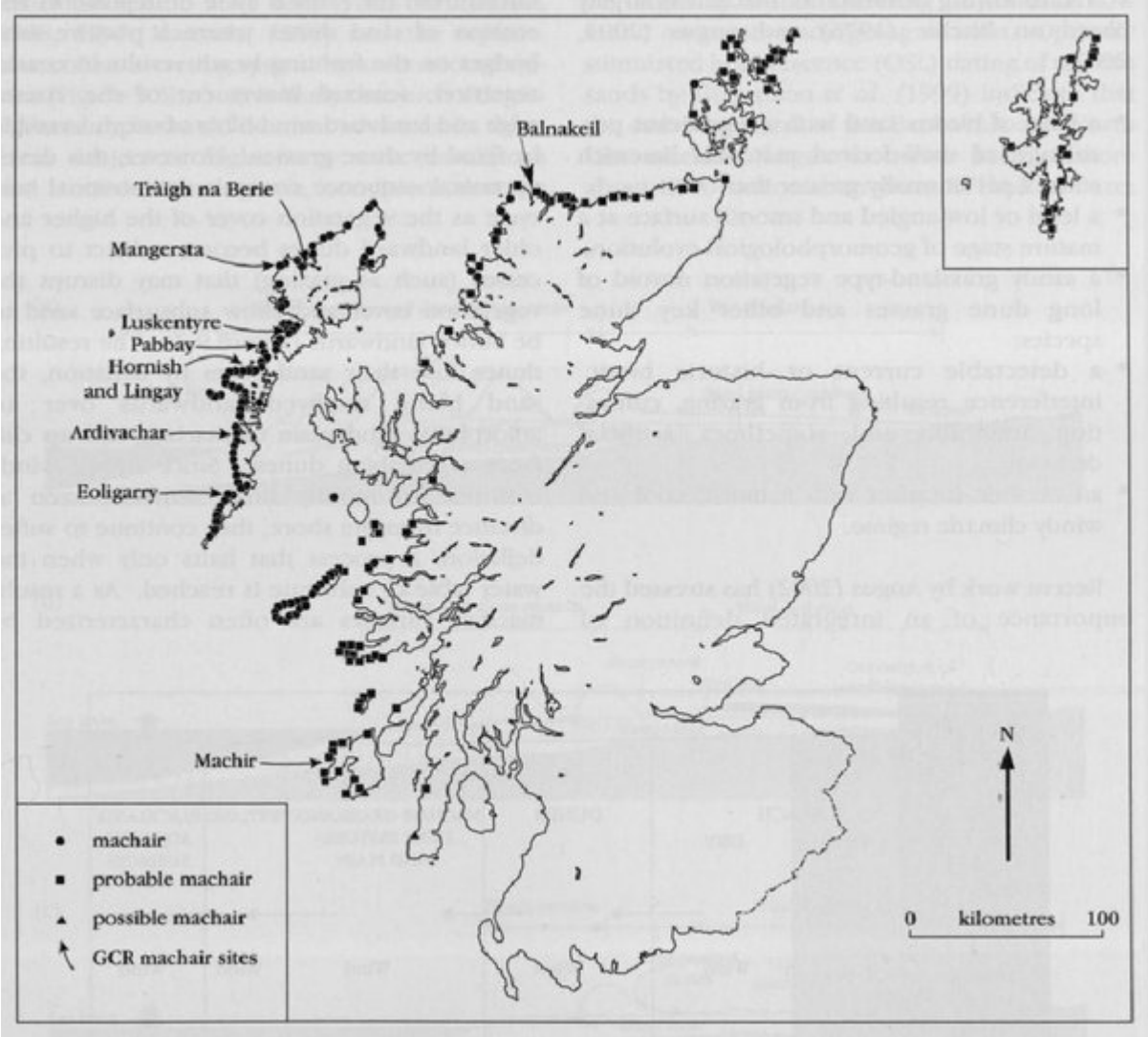
The northern beach remains narrow and waves access the base of the dunes regularly giving rise to chronic frontal erosion and slumping of the dunes above. Given the wave refraction patterns within Balnakeil Bay, much of the sand-loss is to the south but significant amounts of sand are also lost by wind-blow to the backing dunes via blowthrough corridors. The northern part of Balnakeil Bay is likely to operate at a budgetary loss in terms of sand input and output. However, in spite of an apparently rapid rate of erosion and dune-toe recession in the north, there is also some evidence suggesting that wave attack of the dune face may not be as rapid as supposed. In-situ timbers from the hull of a boat wrecked on the northern beach over 100 years ago are still exposed at MHWS, although the dune toe has receded a few metres beyond this (K. MacRea, pers. comm., 1996.).

In contrast, Mather and Ritchie (1977) noted accretion in the southern part of Balnakell Bay, where both the intertidal zone and the upper beach are wider. Refracted waves break on the shore more or less simultaneously, and although longshore transport out of Balnakeil Bay into the Kyle of Durness to the south occurs, it is probably limited. This may not have been the case earlier in the Holocene Epoch, and there is evidence that the sand budget in the south of the Kyle of Durness was sufficient to feed windblown sand to South Bahlakell via the now-stabilized sand sheets on top of the intervening peninsula to the west of Balnakeil Farm. As a result, it is likely that the southern part of Balnakeil Bay is a partial sediment-trap, although the amount of sand transported to and from the southern part of the bay is unknown. Storm wave activity on the south beach probably results in onshore-offshore sediment exchanges, and this is the likely reason why there is evidence of not only accretion but also erosion on the south beach. The eroded remnants of a tarmac access road built by the Ministry of Defence in the 1950s runs along the back of the beach. Within a year of construction, the roadway was undermined by wave erosion and abandoned (K. MacRea, pers. comm., 1996). Since then, rather than being buried by sand accretion, its foundations remain exposed and in places subject to minor undermining by waves. The presence of the foundations now provide protection to the dune toe from wave undercutting, although vigorous marram growth on the seaward faces of the well-vegetated dunes above indicate a healthy blown-sand supply from the beach below (Hansom, 1998).

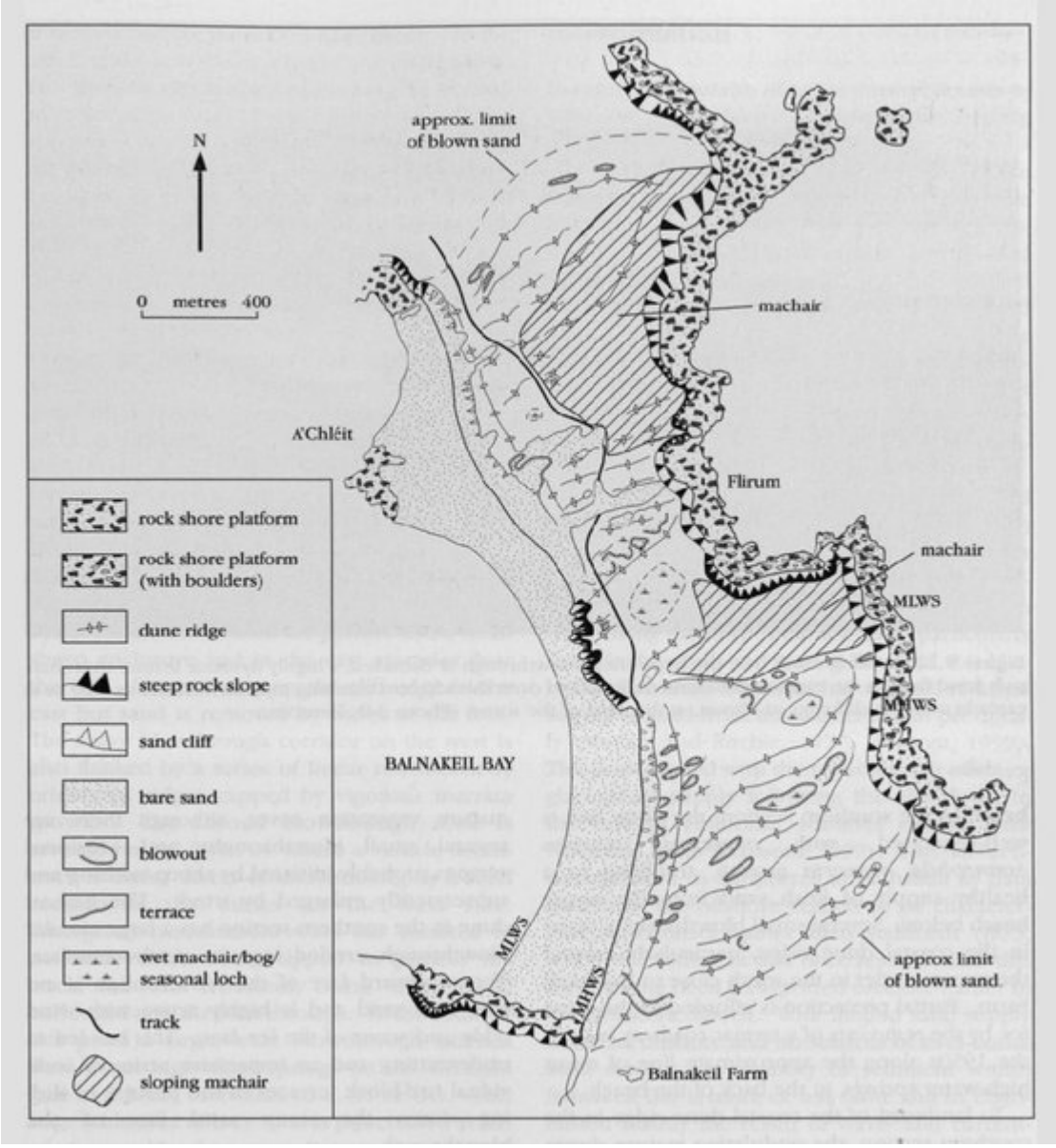
Wave-induced frontal erosion of the dune toe creates the conditions for wind-induced point erosion and blowthrough activity, since wave undercutting of the mature dunes backing the northern beach removes vegetation and allows unrestricted wind access to the bare sand surfaces. Wind deflation and sand transport has resulted in large areas of bare sand and massive blowthrough corridors that extend over *c.* 400 m from the west coast of the peninsula to cascade in sandfalls over the eastern cliffs. The range of large- and small-scale wind erosional and re-depositional features within this system is spectacular and of immense scientific interest. The stabilized linear dune-ridges that flank the active, steep-sided blowthroughs provide evidence that until recently the ridges were the sides of large active blowthrough corridors which are now naturally stabilized by vegetation. This suggests a long-lived process that undergoes small shifts in location leading to time-transgressive zones of alternating erosional activity and vegetational stability.

Conclusions

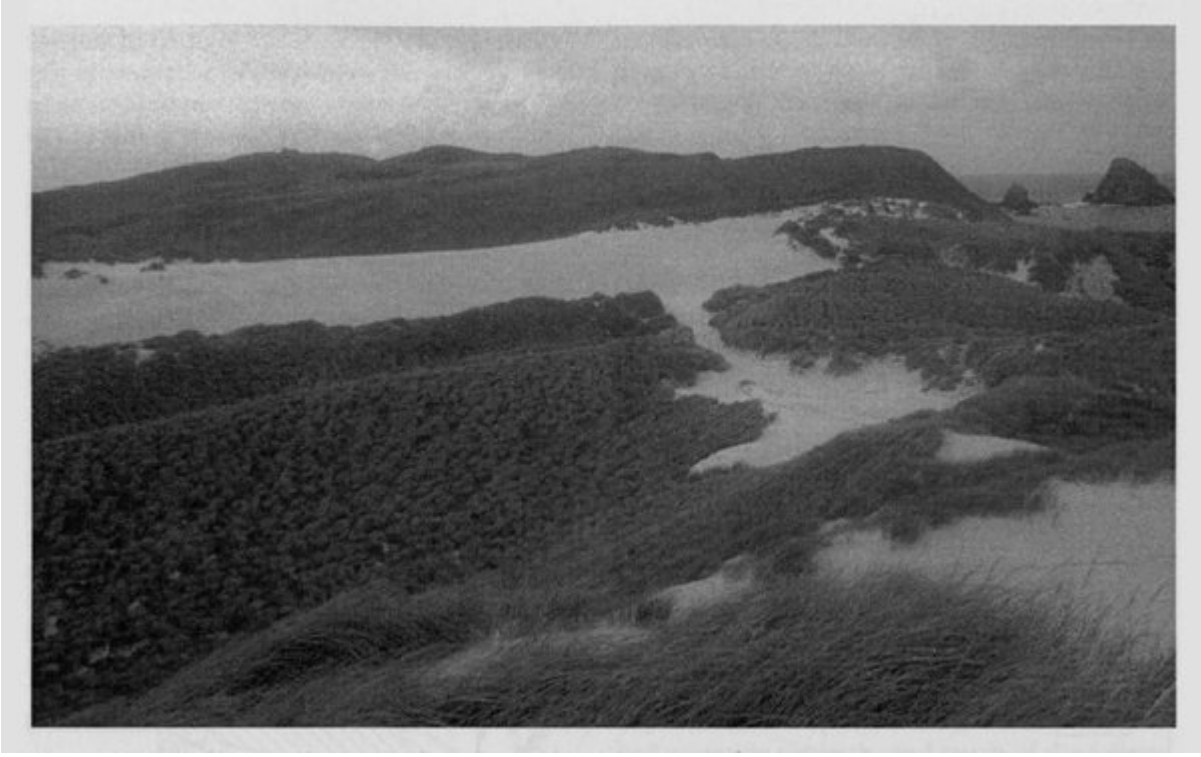
Balnakeil Bay contains some of the most dynamic dune forms in Scotland. The rock-floored peninsula tilts towards the south-west, providing an inclined plane up which large quantities of blown sand progress in a north-easterly direction. Large, steep-sided and highly active blowthrough corridors feed transgressive sand waves that transport sand across the peninsula from the beaches on the west to cliffs on the east. It is possible that an earlier transgressive sand- wave system operated on the rocky peninsula between the Kyle of Durness and southern Balnakeil Bay. Sand cascades down the eastern cliffs and is effectively lost from the Balnakeil system. Mature machair vegetation has stabilized the blown sand veneer at higher altitudes, and the juxtaposition between this and the marram-dominated highly active ridges associated with the blowthrough corridors is striking and of great geomorphological interest. Balnakeil Bay is characterized by the juxtaposition of a range of dune erosional processes and landforms within a setting that is unparalleled in Britain, if not in Europe.



(Figure 9.1) Distribution of machair in Scotland. Other than Sandwood, Torrisdale and Balta (see Chapter 7), all the sites included in the GCR fulfil both the geomorphological and vegetational definition of machair. Small vegetational differences in the above sites have resulted in the label 'probable machair'. Ongoing work that interprets the geomorphology and botany of machair aims to provide a definitive machair diagnostic test in the future and so the above classification will be subject to slight modification (Angus, 2003, pers. comm.). (After Hansom and Angus, 2001.)



(Figure 9.21) The geomorphology of Balnakeil–An Fharaid is dominated by the easterly transport of blown sand from the beaches of Balnakeil Bay into dune and machair surfaces that climb the slopes of the An Fharaid peninsula. Some of the larger linear blowthroughs channel sand to cascade over the cliff on the eastern edge of the peninsula. (After Hansom, 1998.)



(Figure 9.22) Looking north over the large linear blowthrough at Balnakeil, a highly dynamic feature that channels wind flow to the east to allow sand to be blown onto the adjacent climbing machair surfaces as well as to cascade over the cliff edge at Flirum, at the right of the scene. (Photo: J.D. Hansom.)