Morfa Dinlle, Gwynedd

[SH 435 557]–[SH 450 612]

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Introduction

Morfa Dinlle, on the southern side of the western mouth of the Menai Strait (see (Figure 11.20)), comprises a complex coast undergoing erosion together with shingle ridges and dunes. At Dinas Dinlle, low cliffs about 25 m in height expose folded and faulted Devensian glaciogenic sediments that provide evidence for a possible advance of the Late Devensian ice-sheet (Campbell and Bowen, 1989). The sediments of the cliffs are also important in providing evidence that help elucidate the development of the western end of the Menai Strait (Bedlington, 1995; Harris *et al., 1996*). Marine erosion of glacial deposits south of Dinas Dinlle has supplied a heterogeneous mix of sediments to the mainly north-eastwards moving drift system along Pen Llyn (the Lleyn Peninsula) (Carter, 1990; Pethick, 1997). At the northern end of the cliffs, the coast has been reinforced to protect the Marine Hotel (Figure 11.20)a,b). A single shingle ridge extends northwards from Dinas Dinlle for about 2.5 km and has been protected, since 1976, by gabion mattresses along the ridge crest between Dinas Dinlle and an airfield. In places the lower seaward face of the ridge has been undermined leading to collapse of the gabions. The low-lying area between Dinas Dinlle and Morfa Dinlle village is believed to have been formed by deposition of gravel ridges, but these have been obliterated by the construction of the airfield. Morfa Dinlle itself comprises a series of shingle ridges capped in parts by low sand dunes. This area forms the GCR site.

There has been very little research into the character and dynamics of Morfa Dinlle. Steers (1946a) recorded that there was no physio-graphical description of the spit and noted that Morfa Dinlle is 'bordered by shingle which fans out in normal fashion at the distal end' (p. 120). He also regarded it as despoiled compared with the unspoilt Newborough Warren. Pethick (1997) also described and interpreted the site, upon which the following account is largely based. Both Carter (1990) and Pcthick (1997) believe that the shingle features have grown northwards from Dinas Dinlle probably since about 4000–5000 years BP

Description

Although the cliffs and shingle ridge to the south of Morfa Dinlle are not included in the present GCR site boundary, the geomorphological development of features within the boundary has depended upon their dynamics. The cliffs south of Dinas Dinlle are retreating irregularly, with occasional slumps and slippages across the face. Since 1875, the cliff at Dinas Dinlle has retreated by about 20 m, giving an annual rate of recession of less than 0.2 m a^{-1}. However, the rate of production of shingle-sized sediment from the erosion of the Dinas Dinlle cliff is considerably less than the rate of shingle accumulation on the north shore of Morfa Dinlle. Carter (1990) provided a first approximation for the rate of shingle input from the erosion of the Dinas Diane cliffs, suggesting that 1000 m^3 a^{-1} is released by erosion, of which only 15% is gravel (shingle). This total gravel input of 150 m^3 a^{-1} from the cliff would be insufficient to allow the observed rate of growth of the ridges, and it is concluded that erosion represents only a small proportion of the total input of gravel to the modern ridge system.

The modern shingle ridge system, in the north of Morfa Dinlle, is connected to the Dinas Dinlle cliffs by a shingle beach ridge running approximately north-south for approximately 2.5 km before the ridges curve along a SSW–NNE line. Although this beach ridge has been protected by coastal defences and received artificial sediment nourishment, several washover fans suggest a potential for landward movement. It is likely that the gabions (in place since 1976) have restricted the natural movement of the ridge leading to their ultimate destruction. The hard point at the Marine Hotel may now be beginning to impede down-drift sediment transport and so starve the ridge, but the field evidence for this is hard to assess without further study (Pethick, 1997).

Morfa Dinlle is characterized by a well-developed series of sub-parallel shingle ridges, partly obscured by wind-blown sand. The ridges in the northern region of Morfa Dinlle appear to be grouped into three sets.

1. Along the modern shoreline the shingle ridges run shore-parallel and are of recent origin. Nine distinct gravel ridges may be identified west of the relict dune field on Moth Dinlle.
2. North of Warren Farm the shingle ridges run south-west-north-east and merge with the deposits that form the peninsula south of Fort Belan.
3. South of Warren Farm, the ridges run almost north-south and may indicate a period when the tidal mouth of the Mon Gwyrfai was at the location of Warren Farm. One of the most distinctive features of Morfa Dinlle is its separation from the mainland by the tidal inlet Foryd Bay, the estuary of the Mon Gwyrfai. South of the line of high sand dunes, traces of shingle ridges extend up to and in some cases into Foryd Bay, two of these ridges appearing to merge with the unnamed peninsula south of Fort Belan.

Between 1980 and 1990 approximately 250 m of new ridge formed along the northern shoreline of Morfa Dinlle (Carter, 1990). Although much of this new ridge was formed during a single storm event, the average rate of its development was 25 m a^{-1} (Pethick, 1997). The average volume of shingle contained in 1 m length of the ridge is 60 m^3 (Carter, 1990) so that the modern rate of accumulation of shingle is 1500 m^3 a^{-1} (not 900 m^3 a^{-1}, as reported by Carter (1990) and Pethick (1997)), albeit probably deposited during a single event. Detailed surveys of the extreme landward and seaward ridges show that their crest elevation increases from east to west by 0.7 m (Pethick, 1997). They are partly obscured by sand dunes. High dunes form a single line some 300 m landward of and parallel to the present-day shoreline (trending approximately SSW–NNE). The maximum elevation of the dune crest is 14 m OD and average crest elevation is 10 m OD (Pethick, 1997). The dunes are formed over the shingle ridge basement, providing a highly permeable substrate so that the slacks are dry and deflation down to the underlying shingle is possible. As well as this line of high dunes, the area is characterized by extensive, low, sand dunes whose structure is again related to the underlying shingle ridges. These low dunes continue to form on the present-day shoreline as sand from the nearshore ebb delta ramparts is blown onshore. The wind carries sand over the unvegetated seaward shingle ridge to be deposited as new embryo dunes on the vegetated second dune ridge.

Interpretation

The interpretation of the features at Morfa Dinlle depends on evidence from present-day rates of change, the evidence of the shingle ridge patterns and the Holocene history of the wider area.

The volume of material entering the system from cliff erosion has not been determined accurately, but Carter's approximation (1990) indicates it could be around 800–1200 m^3 a^{-1}, of which about 15% is probably gravel. The receding cliff exercises an important control over the recession and planform of the gravel spit (particularly at its proximal end near Dinas Dinlle). Carter (1990) and Pethick (1997) estimate that the solitary barrier is retreating landwards at a long-term (over a timescale of several centuries) rate of about 0.2 ma^{-1}, probably by phased storm overwashing. Pethick suggests that this landward movement continued during most of the Holocene Epoch. As the beach ridge transgressed the western extremities of the ridge systems, they would have been exposed on the shore and their sediments reworked and incorporated into the beach ridge. Longshore movement would then carry this reworked sediment to the north to form new ridges. A small proportion of material entering the system may also come from the seabed adjacent to the beach.

Harris *et al.* (1996) propose that the Dinas Dinlle hills, south of Morfa Dinlle, formed part of a more extensive push-moraine complex that extended westwards into the nearshore. The Dinas Dinlle moraine is one of a number of morainic ridges, possibly four in total, cut by the present-day coastline. They are composed of till units lying below an upper sand and gravel facies that would act as an easily eroded sediment source as Holocene sea level rose. This source was, and to some extent still is, responsible for the sediments that constitute the Morfa Dinlle complex (Pethick, 1997). The large quantities of sand and gravels produced by erosion of the morainic ridges during Holocene sea-level rise (perhaps 7000–6000 years BP) were moved northwards by prevailing longshore drift to form a series of spits connected to the seaward end of each of the morainic ridges. The rockhead immediately seaward of the present-day Dinas Dinlle coastline lies at –35 m (Harris *et al.,*1996), suggesting a considerable depth of glaciogenic and Holocene

coastal deposition.

It is also possible that a further moraine extended across what is now the mouth of the Mon Gwyrfai and formed the peninsula immediately south of Fort Belan. Pethick (1997) suggests (based upon preliminary study of surficial deposits and morphology) that such a morainic ridge would explain the complex topography of both the north-eastern area of Morfa Dinlle and the tidal section of the Mon Gwyrfai.

Pethick (1997) argued that the gravel ridges and sand dunes of Morfa Dinlle are a late Holocene phenomenon, certainly dating from post-4000 BP and probably much later than this. Dating the ridges themselves has, however, not been possible. As sea level continued to rise in the period 6000–4000 years Bp, the coastline was forced eastwards and the continued erosion of the morainic ridges provided abundant sediment for the northward extension of the spits that consequently merged to form a single gravel beach between each of the morainic ridges to the south of Dinas Dinlle and extending to the north, perhaps as far as the present-day airport.

Peat deposits found in the intertidal area immediately west of Dinas Dinlle (Carter, 1990) are thought to date from 4000 years BP and confirm that a brackish-freshwater deltaic environment existed here at that time. This evidence, together with estimates of long-term cliff retreat, suggested to Carter that the coastline was then over 1 km west of its present-day position and that the gravel beach had already limited marine incursions to the east, although the Mon Gwyrfai would still have reached the open sea through a tidal inlet north of Dinas Dinlle (Figure 11.20)a.

Successive shingle ridges extend north and east from the cliffs at Dinas Dinlle across the low marshlands towards this tidal inlet. Pethick (1997) conjectured that between 6000 and 4000 years BP the Mon Gwyrfai tidal inlet was pushed gradually northwards as the gravel beach continued to extend from Dinas Dinlle. However, the Gwyrfai was prevented from flowing north on its present-day course by the presence of the moraine that extended across the mouth of the present-day tidal mouth of the Gwyrfai from the eastern shore of Foryd Bay to just south of Fort Belan.

As the gravel spit extended northwards and eastwards, so the tidal mouth of the Gwyrfai was increasingly confined between the distal ends of the gravel spit and the moraine. At some stage it appears from the topographical evidence that the northern end of the gravel spit joined the western end of the moraine and blocked the mouth of the Gwyrfai. An extensive brackish lagoon was initially formed in Foryd Bay, but the waters of the Mon Gwyrfai eventually breached the moraine and tidal flow into the bay was reestablished. Further detailed research is essential to test the validity or otherwise of the hypothesis. More recently, extensive land-claim of intertidal areas within Foryd Bay has reduced the tidal prism. The impact of these changes on the tidal entrance to the Bay may have been to reduce the overall dimensions of the tidal opening by northward extension of the shingle ridges. The impact of the changing tidal prism of Foryd Bay on the morphology of the Menai Strait is less obvious, owing to the relative discharges involved.

As the mouth of the Menai Strait narrowed, the coastal gravel beaches of Morfa Dinlle steadily advanced northwards and eastwards. The eastward movement of the coastline, which also resulted in the continued erosion of the morainic cliffs such as those at Dinas Dinlle, caused reworking of the gravel beach ridges as they were rolled landwards. Fresh sediments, eroded from the cliffs from Maen Dylan and Dinas Dinlle, were added to this reworked material. Today, however, the supply of new sediment from these sources is considerably less than the sediment inputs that were available from glacial debris present in early Holocene times.

As sediment moves north it falls more and more under the influence of the sediment circulation patterns of the Menai Strait. There is almost certainly a long-term exchange of material between the shoreline and the offshore area which, when understood, should explain the observed shoreline changes, including the supply of sand for the development of dunes above the gravel ridges. The evidence suggests that Morfa Dinlle is an active gravel–beach system, albeit with a relatively low rate of sediment input. This type of situation is increasingly unusual in England and Wales (especially on the west coast), since, over the past two centuries, human activities (notably shore protection) have acted to restrict sediment sources. Measurement of shingle characteristics over the northern sequence of shingle ridges shows a weak relationship between elevation and shingle mean diameter, and grain size increases towards the modem coastline. In general however, the shingle grain-size distribution seems to indicate a lack of pronounced structure suggesting that in-situ reworking of ridges has taken place, and lending support to the offshore seabed source hypothesis outlined above

(Pethick, 1997).

The outgrowth of the gravel ridges supports an extensive 'dry-core' dune system in which the water table is usually below the deflation level, so that standing water is rarely, if ever, found in the system. The dunes have a degree of natural instability associated with geomorphological changes, themselves associated with grazing, pedogenesis and impact of human activities (Carter, 1990; Pethick, 1997). The main line of dunes is a relict formation (Carter, 1990) which has no direct sand supply from the beaches at the present time. However, the occurrence of blowthroughs suggests that some redistribution of sand is occurring and an extensive marram *Ammophila* cover exists. The crestline of the relict dunes follows a distinctive rectilinear line (Figure 11.20)b that seems to be caused by the interaction between the dunes and the underlying shingle ridge structure. The dune crestline appears to be held in position by the underlying shingle structures but, because the orientation of dune crestline and shingle ridges is slightly offset, at intervals the dune crests 'jump' from one underlying shingle ridge to another so forming the characteristic rectilinear pattern (Pethick, 1997). Reasons for the offset between dune crest and shingle ridge crests may be due to the difference in the prevailing wind direction, responsible for the dune orientation, and the orientation of the shoreline on which the shingle ridges formed. Wind-waves approach the shore at an oblique angle, so driving longshore currents towards the north. Further research on these dune systems is needed to interpret the sequence of coastal changes and related climatic variation.

The shingle ridges of Morfa Dinlle, with their superficial dune fields, represent the morphological response to two major postglacial events: the drowning of the Menai Strait to form a tidal estuary and the erosion of a series of glacial moraines to the south. The chronology of events is difficult to determine but it is suggested that the development of a number of shingle ridges along the open coast pre-dated the formation of the Menai Strait. As tidal flow was ini tiated into the Strait, so these shingle features extended and coalesced to form, in conjunction with the Abermenai spit, the mouth of the Strait. The subsequent decrease in the tidal prism of the Menai Strait, owing to sedimentary deposition, led to the progressive decrease in the width of its tidal entrance and consequently to the northerly movement of the Morfa Dinlle shingle ridges. The spatial pattern of shingle ridges displayed in the area consequently provides a record of the complex Holocene history of this region.

Conclusions

In spite of artificial protection at the southern end, Morfa Dinlle is now one of the last active drift-aligned gravel-ridge systems in the west of England and Wales. The dunes and the gravel ridges are of international geomorphological interest, because the shingle ridges complex of Morfa Dinlle together with the integral Newborough-Abermenai shingle system and their superficial sand dunes represent an extremely important, but relatively rare, geomorphological feature. Although single gravel ridges are widely distributed along the UK coast, few multiple ridge systems exist. Of these, the Dungeness (see GCR site report in Chapter 6), Culbin and Morrich More (see site reports in the present chapter) systems are the most extensive and best-known.

The geomorphological importance of the Morfa Dinlle site also rests in the topographical record of Holocene development of the shoreline of north Wales and in particular the Holocene development of the Menai Strait. The present-day pattern of shingle ridges provide an important record of the development of the Menai Strait during the Holocene Epoch, since their morphologies are directly related to tidal and sedimentary conditions in the Strait.

As a consequence of the relationship between the geomorphology of the Menai Strait and its western tidal entrance, the Morfa Dinlle and Newborough-Abermenai dunes and gravel ridges must be seen as integral components of a single system, defining the mouth of the Strait and responding to past changes. The relationship between the Morfa Dinlle ridges and the tidal dynamics of the Menai Strait, recorded in the topographical features of this site and the adjoining Abermenai–Newborough Warren area that together form the mouth of the Strait, is of international importance. The relationship between the mouth area of an estuary and its tidal dynamics is central to an understanding of estuarine management and, owing to the loss or destruction of comparable sites elsewhere, the Morfa Dinlle–Abermenai sites provide a unique opportunity for research into this complex interaction of open coast and tidal geomorphology.

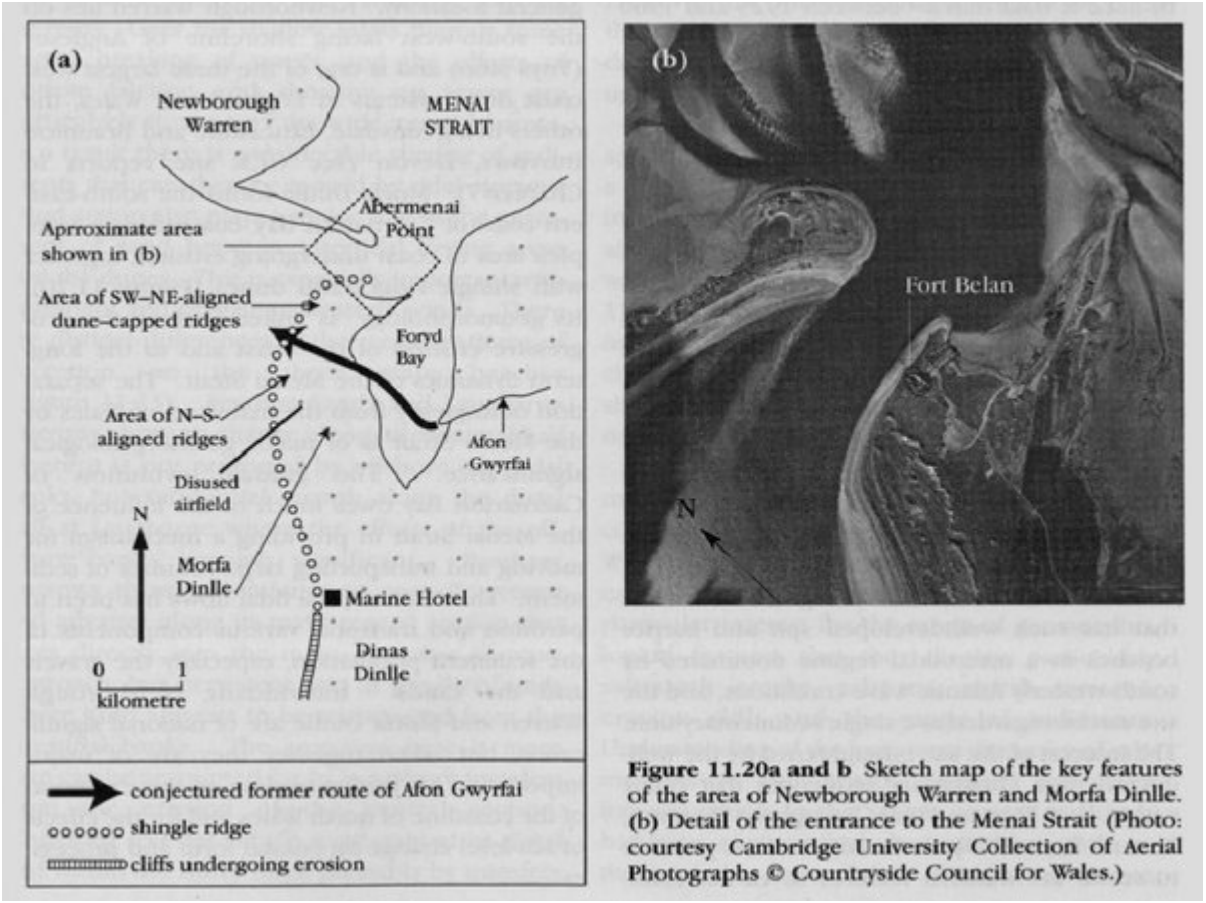

Figure 11.20a and b Sketch map of the key features of the area of Newborough Warren and Morfa Dinlle. (b) Detail of the entrance to the Menai Strait (Photo: courtesy Cambridge University Collection of Aerial Photographs © Countryside Council for Wales.)

(Figure 11.20) a and b Sketch map of the key features of the area of Newborough Warren and Moth Dinlle. (b) Detail of the entrance to the Menai Strait (Photo: courtesy Cambridge University Collection of Aerial Photographs Countryside Council for Wales.)