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RECENT PROGRADATION OF THE MAGILLIGAN FORELAND, CO. LONDONDERRY, NORTHERN IRELAND

by

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A B S T R A C T

– Since c. 1950 the shoreline at Magilligan Point has prograded by almost 200 m. Sequences of beach ridge and dune development are directly related to erosion of the adjoining coastline and the efficiency of the sediment transport system. Sand moving along the shore becomes captured by two overlapping and counteractive drift cells near the Point. Given the present conditions of sediment scarcity it is thought that this recent progradation is only a short-lived stage in the progressive destruction of the foreland.–

R E S U M E

–Depuis 1950, la côte de la pointe de Magilligan a progressé de près de 200 m. Une série de crêtes de plage et de dunes s'est développée, liée directement à l'érosion du littoral adjacent et à l'efficacité du système de transport de sédiment. Le sable transporté le long du littoral est capté par deux cellules de dérive, qui se chevauchent et se neutralisent près de la pointe. Vu les conditions actuelles de déficit sédimentaire, il semble que cette récente progradation ne soit qu'une étape éphémère dans la destruction progressive du promontoire. –

K E Y W O R D S : Spit, beach ridges, dunes, longshore drift, sediment cells.

M O T S - C L E S : Flèche, levées de plage, dunes, transport littoral, cellules de dérive.

INTRODUCTION

Magilligan Foreland (Fig. 1) is the largest coastal accumulation feature in Northern Ireland comprising c. 1100 ha of NE-facing, swash aligned beach ridges overlain in places by ombrogenous peats, calcareous freshwater marls, allogenic shell deposits and eolian dunes. In common with most of the exposed Atlantic beaches in Ireland the seawardmost dunes are either

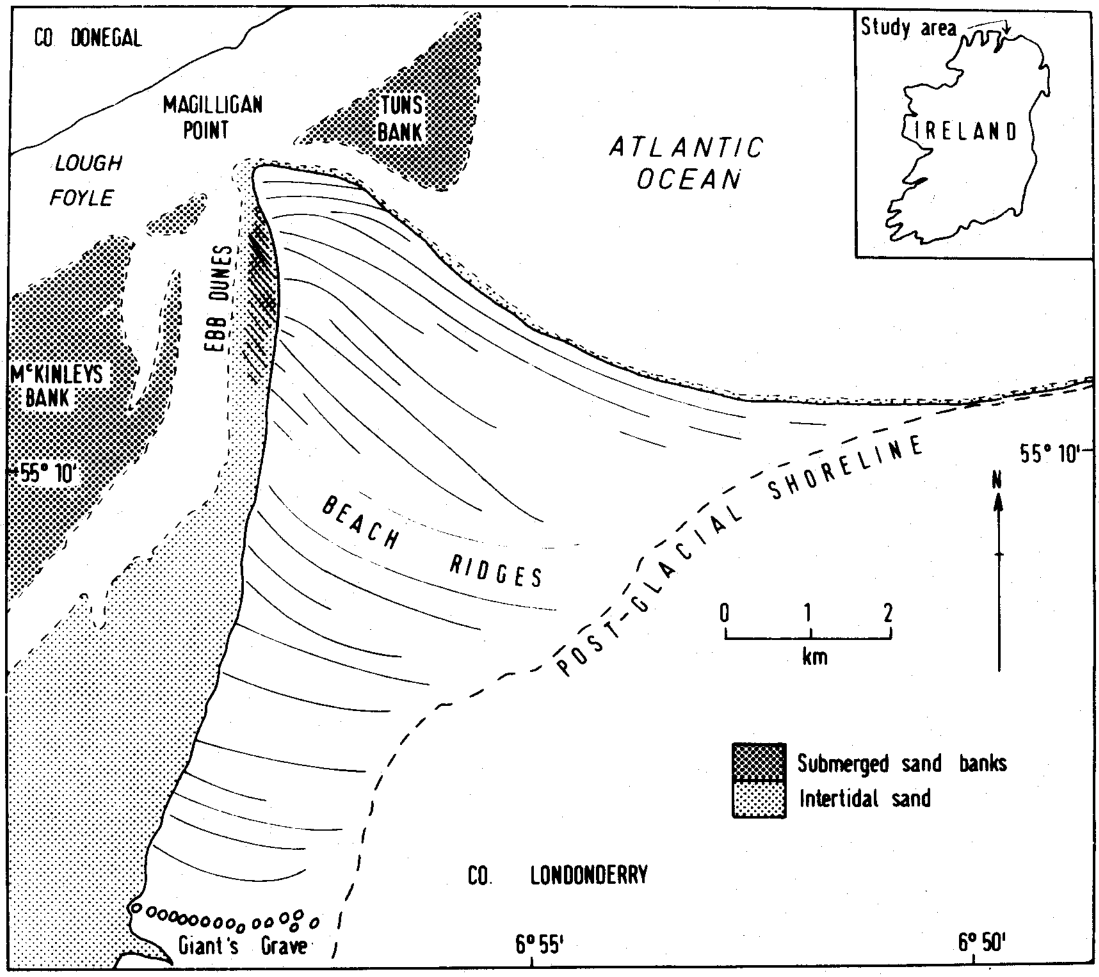

Figure 1. Location and morphological features of Magilligan Foreland.

stable or slowly retreating under marine erosion. There are a number of reasons that might account for this trend - net long term sediment loss, a slight rise in sea-level, secular variations in wave or wind climate, or deleterious human activities. However shoreline progradation is taking place along a 1.5 km stretch of coast near Magilligan Point. The processes responsible for, and the significance of, this somewhat anomalous trend form the subject of this paper.

GEOLOGICAL SETTING

CARTER (1975) concluded that the main body of the foreland was formed between 6000 and 1500 years BP. The beach ridges appear to have developed from the nucleus provided by a gravel storm beach (The Giant's Grave) to the SW, and were progressively constructed towards the NE, parallel to the present-day Atlantic shoreline, possibly aided by a slowly falling local sea-level and a surplus of available sediment. The bulk of the sediment is quartz sand derived from local glacial or fluvio-glacial deposits, while the remainder is largely biogenic carbonate of recent marine origin. To some extent the modern process environments may be discriminated between through analysis of sediment textures (Table 1), providing some criteria for recognition of older deposits.

Shoreline processes are dominated by two wave regimes which intersect in the region of Magilligan Point (CARTER 1975, 1979). To the NE Atlantic swell waves break parallel to a wide, low angle ($1-2^{\circ}$) beach, while to the SW locally generated wind waves dominate the intertidal flats and the steep ($6-10^{\circ}$), narrow high water beach in Lough Foyle. Using TANNER'S (1960) scheme

TABLE 1 Summary of textural characteristics of Magilligan foreland sediments

Process Zone	No. Samples	Average Grain size moments $\phi\bar{x}$	$\phi\sigma$	Skewness	Grain Shape Angular %	Rounded %
Offshore	10	2.28	0.55	-1.05	30	70
Breaker	31	2.10	0.85	-1.42	55	45
Beach:						
mid-tide	94	2.43	0.35	-0.03	10	90
berm	31	2.31	0.42	0.02	25	75
Dune:						
foredune	18	2.47	0.30	-0.09	15	85
inland	46	2.55	0.36	-0.16	15	85

the Atlantic shoreline may be classified as 'high energy' and the estuary shoreline as 'low to zero'. Tidal range in the area varies from 1.9 m at neaps to 3.2 m at springs. Dominant winds are from the SW.

COASTAL CHANGES AND SEDIMENT TRANSPORT

Since the first reliable map was published in 1830 most of the significant changes in the plan form of the shoreline have occurred near Magilligan Point (CARTER 1975), where alternating phases of advance and retreat have been repeated at about 40 year intervals involving a total area of around 30 ha. Elsewhere the coast has been either stationary or eroding; on the Atlantic side CARTER (1978) has described a pattern of non-uniform dune erosion apparently orginating through wave focusing during storms, so that some sections of the cliff may retreat at rates of 5-6 m/year, while adjacent ones remain stable. It would seem, that for a variety of reasons, this coast is currently incapable of progradation (CARTER 1977). Almost all the Lough Foyle coast is undergoing progressive erosion at a rate around 0.5 m/year although assessment of the true rate is not easy. The wind waves which approach the shore at all angles depending on wind direction are truncating the old beach ridges originally formed by the Atlantic swell.

Coastal changes rely on movement of sediment along and across the shore, and as there is only a limited supply of fresh sand, progradation must be at the expense of erosion elsewhere. Two mechanisms, air and water currents, are responsible for sediment transport. The importance of the former is largely in the gross, rather than the net, relocation of sand, while most unidirectional movements are due to nearshore water currents generated by a variety of stresses - oblique breaking waves, tides, indirect wind action and gravitational flows between laterally varying waves.

Along the Lough Foyle coast of the foreland material is transported towards the Point (Fig. 2); this is shown by progressive northerly rounding and abrasion of peat and marl clasts eroded from cliff face exposures, asymmetrical north-facing ebb tide bedforms, and persistent northward deflection of stream outlets. It is estimated that between 4000 and 10000 m^3/year of sand reaches the Point from this source. On the Atlantic coast the longshore transport system is less efficient due to a lack of a dominant drift direction. However autumn

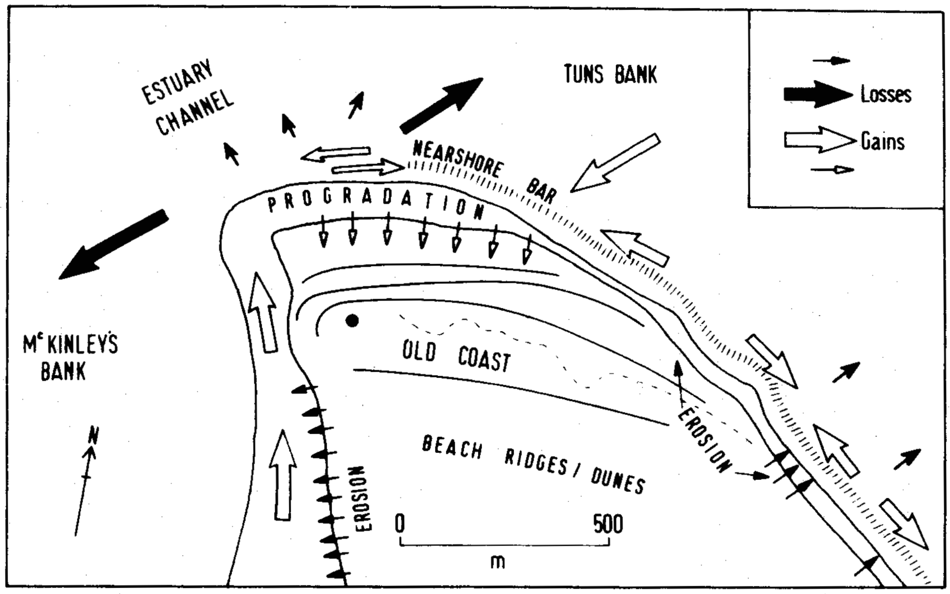

Figure 2. A simplified representation of the sediment transport directions at Magilligan Point.

and winter beach and dune erosion involves 150000 to 250000 m^3/year in shore-normal transfers, and although the beach tends to recover rapidly only a small proportion is returned to the dunes. Excess sand either moves offshore, onshore and inland (via dune blowouts) or longshore if wave conditions are suitable. Due to the non-uniform nature of the dune erosion, sand masses may migrate in both directions along the shore occasionally entering the drift systems near Magilligan Point. Additionally some sand may pass along the single, continuous nearshore bar (CARTER AND KITCHER 1979), which, at periods when water depth is low relative to wave height, has a profound influence on nearshore wave activity.

Near the Point the transport system becomes somewhat complicated due to the superimposition of two independent longshore drift cells (STAPOR 1974), derived from the wind and swell wave regimes. The interaction of these cells leads to rapid and eccentric beach changes in the vicinity of the Point (CARTER 1975, 1979). Figure 3 illustrates the "average" (average values are somewhat meaningless in this context) distribution of the longshore component of wave power (P_L) (KOMAR 1971) and

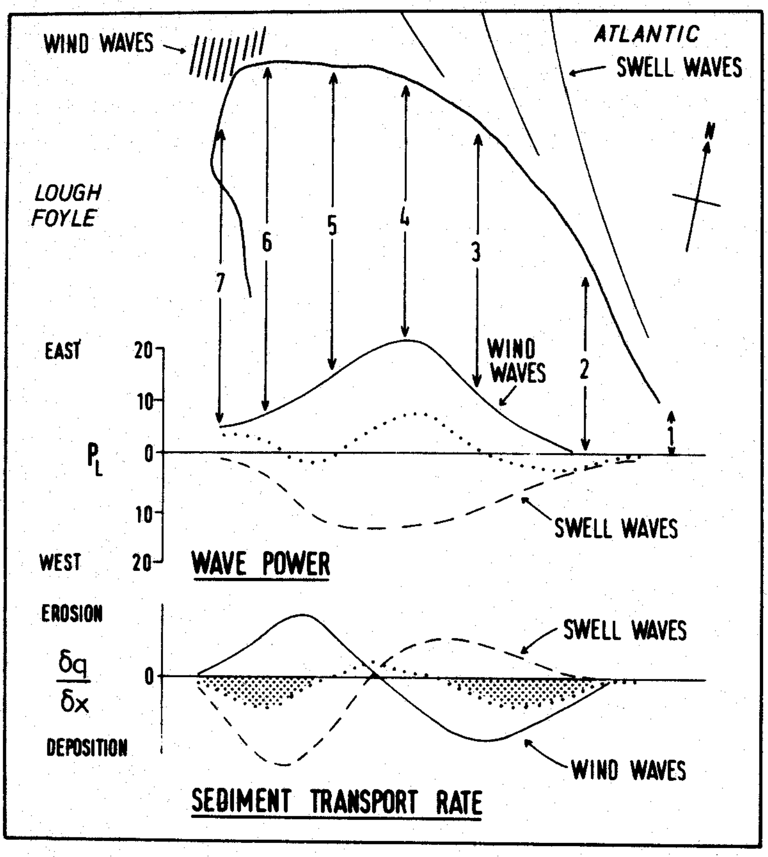

Figure 3. Interaction of coastal cells near Magilligan Point is reflected in both the longshore wave power flux (P_L - in joules/s/m shoreline) and in the sediment deposition rate ($\partial q/\partial x$). Numbers 1 to 7 indicate field observation points. Note that the patterns shown represent long-term average and not instantaneous conditions.

associated changes in the longshore sediment transport rate ($\partial Q/\partial x$) (MAY and TANNER 1973, p. 47), indicating the interaction of the two cells (dotted lines on Fig. 3) leading to pervasive depositional conditions. (Note that Fig. 3 shows two hypothetical depositional zones which due to constant variations in wave conditions tend to merge into a single zone on the actual beach).

Undoubtably some sediment is swept into deeper water and may eventually be deposited on offshore shoals. CARTER (1975) has suggested that some long-term recycling of sediment may occur between the Tuns Bank and Magilligan Point.

SHORELINE PROGRADATION

Sediment transport from both sides of the foreland becomes "trapped" within the two drift cells that exist near Magilligan Point. Most sediment contributes to the prograding beach/dune system, although a proportion may move into deeper water. It does appear however that progradation may at times give way to severe general erosion. For example a dramatic phase of progradation in the 1930's and 1940's culminated in widespread shoreline retreat in the early 1950's, possibly connected to severe storms in January 1953. Since then a series of beach ridges and dunes have developed (Fig. 4) most of which can be

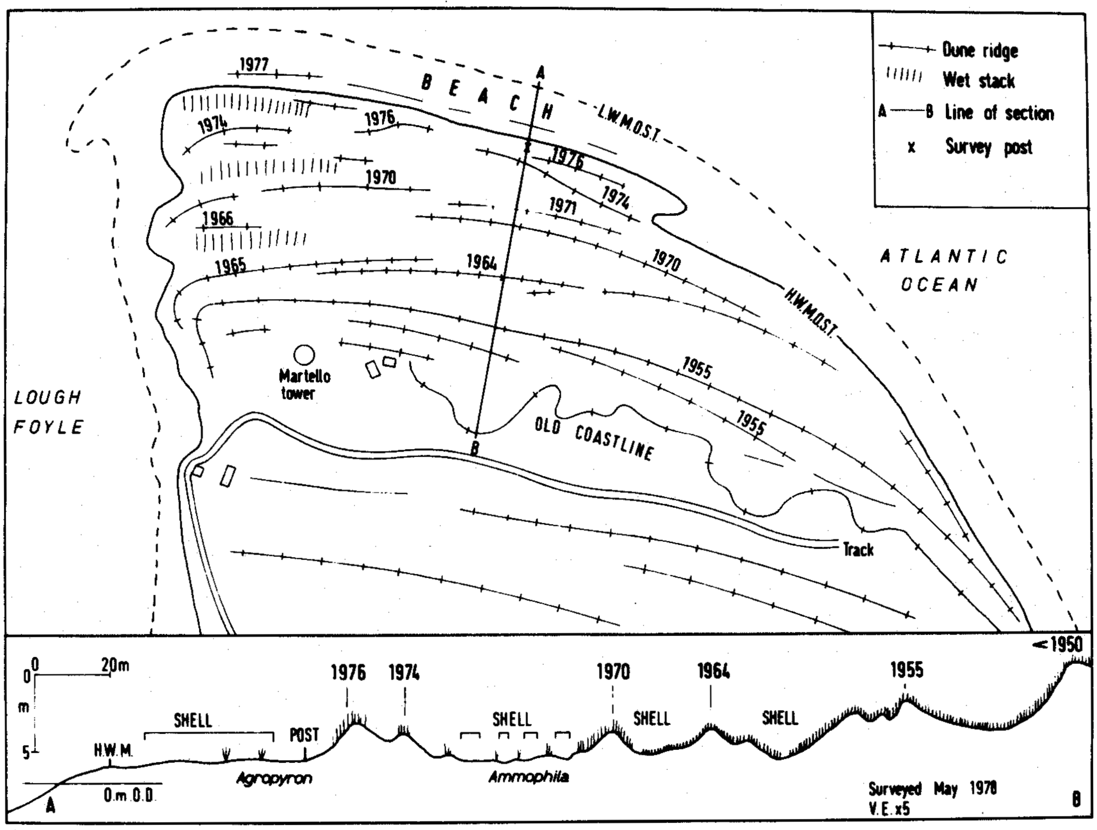

Figure 4. The recent beach ridge/dune progradation of Magilligan Point.

dated to within 2 years by examination of air photographs. The beach ridges are large-scale beach accumulation features that weld onto the beach face at intermittent intervals. Since 1962 ridges have formed in 1963/64, 1967, 1969/70 and 1974/75. Figure 5 shows the formation of the 1969 ridge during late summer and autumn under moderate wave action (breaker heights 0.3 to 0.6 m, periods 8 to 11s). The ridge was modified by a storm in February 1970 after which further accretion took place. Some interesting points emerge from Fig. 5: (i) the ridge did not move onshore as a coherent sand body, but passed through the surf zone on a grain-by-grain basis. (ii) the single nearshore bar underwent severe depletion during the ridge welding process but was never completely dissipated. (iii) the onshore movement of the ridge followed a flattening of the intertidal beach profile in late August. (iv) at first the ridge moved rapidly up the beach and was overtopped at each high tide. Later the over-

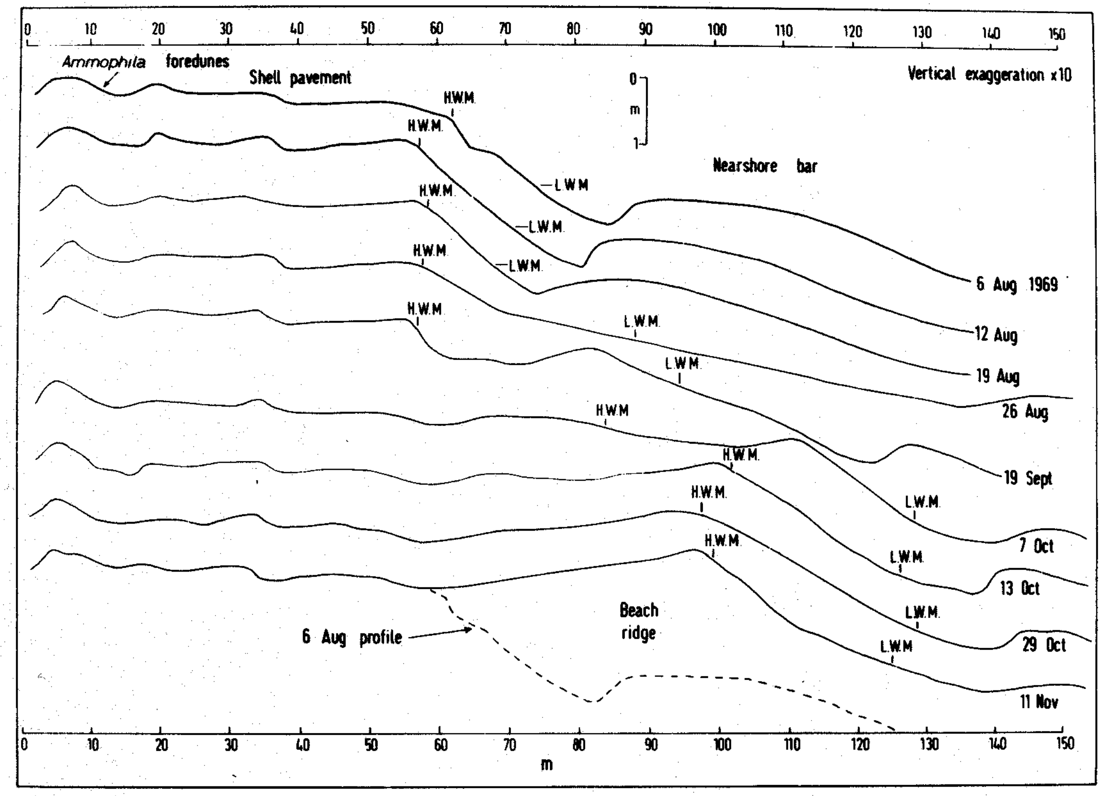

Figure 5. Beach ridge development at Magilligan Point between August and November 1969.

topping process was replaced by occasional, discrete overwashing through low points on the ridge crest, and the runnel was filled in. Surveys showed that the ridge contained 52000 m^3 of sand, compared to the 1955-1978 average of c. 59000 m^3. As well as major beach ridges, small swash bars regularly form on the beach face slope, and during fair-weather conditions several swash bars may coalesce into a substantial ridge involving several thousand m^3 of sediment. However these swash ridges are usually removed when wave activity increases.

Deflation of beach ridges provides material for foredune formation, although the process is complicated by the rapid development of a shell lag (pavement) over the sub-aerial beach (CARTER 1976, 1977) which cuts off the sand supply. In these circumstances dune growth is intermittent (CARTER in preparation) and linked to either periods when the beach surface is reworked by marine action, or when a new ridge or swash bar is forming. Over periods of 1-2 months when sediment is freely available foredunes may increase in height at rates of up to 20 mm/day, but through 3 to 5 years the rate falls exponentially so that total dune crest heights rarely exceed +5 m O.D. (about 3 m above HWM). This growth pattern (Fig. 6) is basically a reflection of the amount of sand that can be supplied from one beach ridge.

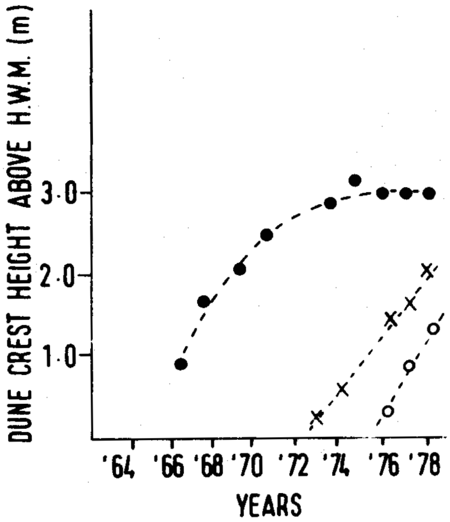

Figure 6. Annual incremental dune crest heights at Magilligan Point (●, x and o denote individual dune ridges, trend lines drawn by eye.)

Internal structures of these prograding deposits are similar to those described by other authors (e.g. PSUTY 1965, REINECK and SINGH 1973).

DISCUSSION

Discussion of recent progradation at Magilligan Point must be placed in both a short- and a long-term geomorphological perspective. Over short periods of a few years, progradation, manifest through beach ridge and dune formation, is very striking. Since the mid-1950's the shoreline has advanced over 200 m in places, involving over 250000 m^3 of sand. However this should not be regarded as a continuing trend; periods of severe shoreline retreat are indicated by air photographs and maps (CARTER 1975), and it is unlikely that seaward accumulation can continue indefinitely, particularly without a major re-arrangement of the estuary/river discharge pattern. The deep-water (over 60 m) estuary channel acts as a buffer, and also, probably, as a sand sink.

Progradation therefore is simply a response to the entrapment of longshore drift material between two counteractive cell systems. However mode and frequency of the delivery of this material varies according to the nature of the incident wave regimes. Short period estuary waves coupled to ebb-tide currents move sediment from Lough Foyle towards Magilligan Point on a fairly continuous basis, while the Atlantic swell waves, with only a limited ability for net transport, supply sand only at irregular intervals following non-uniform beach and dune erosion during storms. The respective roles of storm and fair weather conditions cannot be overstressed as it is the spectacular storm stripping and erosion of the beach and dunes which initially provide material for redistribution during intervening fairweather. Such post-storm recovery (HAYES 1972) may take the form of shore-normal accretion of bars, berms and dunes over only a few weeks, or a longer 3-dimensional (shore normal plus shore parallel) adjustment (CARTER 1977). The latter would include the recent formation of beach ridges at Magilligan.

Once sediment is arrested within the cells it appears to pass through several phases of redistribution and resorting. From observations and measurements in 1969/70 and again in 1974 material eroded from the dune cliffs gradually passes longshore and recharges the permanent nearshore bar. Eventually as the bar dimensions increase, nearshore wave conditions change, and at a critical, but as yet undefined stage, large quantities of sediment migrate grain-by-grain onto the beach face, to form a beach ridge. These ridges form during relatively calm conditions in late summer and early autumn, confirming the observations of DAVIS (1957), but contradicting those of PSUTY (1965) and REINECK and SINGH (1973 p. 391), who indicate development during storms.

At first ridge preservation is not accomplished by dune development, but by the formation of shell pavements (CARTER 1976). Foredunes grow intermittently depending upon not only the presence of exposed ridges, but also ipso facto on wave activity, longshore transport and dune/beach erosion.

DAVIS (1957) stressed the importance of annual patterns of cut and fill in sequential production of beach ridges. At Magilligan somewhat similar patterns are most likely responsible for occasional phases of retrogradation. For instance, if over a period of years longshore sediment supply is below the amount needed for ridge building, the seawardmost ridge will gradually be reworked by shoreface marine activity followed by eolian deflation, so that ultimately the ridge will dissipate completely. This will leave the seaward dune exposed to wave attack, and slow landward migration may continue, perhaps culminating in severe recession by an extreme storm, which would automatically provide material to trigger renewed progradation. Several small, but no large, examples of this process have been observed in the last few years (1975-1978).

To summarize, the overall picture is one of a gradually evolving coastal accumulation feature to which there is negligible fresh sediment input. Continual re-incorporation of sediment into the active process zone is leading to slow changes, but the long-term geological trend appears to indicate eventual destruction. Sediment transfers occur between dune, beach, nearshore and offshore, and residence times for sand range from several thousand years in the inland beach ridges to only a few hours on the beach foreshore. In conclusion it is apparent that present progradation is only a ephemeral episode in the history of Magilligan Foreland.

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