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Morphological and Chemical Variations of a Buried Palaeocatena in Late Holocene Beach-ridge Sands at Magilligan Foreland, Northern Ireland

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ABSTRACT

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Vertical and horizontal variations in soil profile morphology and chemistry within a sequence of buried palaeosols developed in Late Holocene beach-ridge sands at Magilligan Foreland indicate the existence of a palaeocatena. A humus podzol occurs on the crest of the beach ridge and passes through a gleyic brown calcareous alluvial soil and a typical humic alluvial gley soil to a raw eu-fibrous peat soil in the inter-ridge depression. This sequence reflects different slope positions and soil water regimes. Water-table fluctuations, possibly associated with Late Holocene sea-level oscillations, have combined with pedogenic processes to produce the distinctive morphology and chemistry of the palaeocatena. All palaeosols have developed in texturally uniform sands and have been decalcified to depths of between at least 0.85 m to 1.6 m. Ferruginous concentrations, present in the lower horizons of each palaeosol, formed after the profiles were decalcified. Palaeocatena development was probably restricted to a time-span of *c.* 1,000 years to 1,500 years. Two aeolian sand units bury the palaeocatena; the older of these has been 'welded', in part, to the palaeocatena by pedogenic processes. Percolation of water through the younger calcareous aeolian sand unit can account for the present near-neutral pH values of the palaeocatena.

ADDITIONAL INDEX WORDS: *Palaeocatena, palaeosols, beach-ridges, pedogenesis, Holocene, Magilligan.*

INTRODUCTION

VALENTINE and DALRYMPLE (1975) defined the term 'palaeocatena' as "a group of palaeosols on the same buried landsurface whose original soil properties differ owing to their different original landscape position and soil-water regimes"; they also stated that "this is the one ubiquitous soil characteristic that sedimentation and diagenesis will not produce". Therefore, "the crucial test of a buried soil landscape must be the existence of a palaeocatena" (VALENTINE and DALRYMPLE, 1976). However, as noted by FENWICK (1985) exposures of buried palaeosols are rarely of sufficient lateral extent to demonstrate these palaeocatenary relationships and most interpretations have been based on restricted and isolated exposures.

At Magilligan Foreland, Northern Ireland, WILSON and BATEMAN (1986) identified a buried palaeocatena developed in beach-ridge sands and presented field and laboratory data relating to the freely-drained end member (humus podzol) of the sequence located on the beach-ridge crests. The poorly-drained end member (peat) of the sequence, situated in inter-ridge depressions, and the intermediate soil types were not studied in any detail due to limited availability of exposures in the unstable sand cliffs.

As a result of erosion by winter storms in 1993 the entire sequence of a beach-ridge palaeocatena was exposed in an area of shoreline where buried palaeosols had not been recorded previously. The palaeocatena extended for *c.* 50 m and displayed a series of soil types reflecting different original landscape positions and soil-water regimes. This paper describes some of the morphological and chemical variations within and between the palaeocatena soils, complements earlier work on palaeosols at Magilligan (WILSON and BATEMAN, 1986; 1987), and adds to the already considerable body of information documenting the Holocene evolution of this coastal landform.

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MAGILLIGAN FORELAND

Magilligan Foreland (Lat. 55° 7′–55° 12′ N., Long. 6° 51′–6° 59′ W.) is a triangular beach-ridge plain covering an area of *c.* 32 km^2 on the eastern side of Lough Foyle and is probably the most intensively researched coastal landform in Ireland (e.g. CARTER, 1972; 1975; 1979; 1986; CARTER and WILSON, 1990; CARTER *et al.*, 1982; MALLORY and WOODMAN, 1984; MALLORY and MCCORMICK, 1988; MCBRIDE and WILSON, 1991; WILSON and BATEMAN, 1986; 1987; WILSON and FARRINGTON, 1989). The Foreland developed as a consequence of Holocene land/sea level changes and comprises over 150 northeast-facing swash-aligned beach ridges that are overlain by localised aeolian, lacustrine and alluvial sediments (Figure 1).

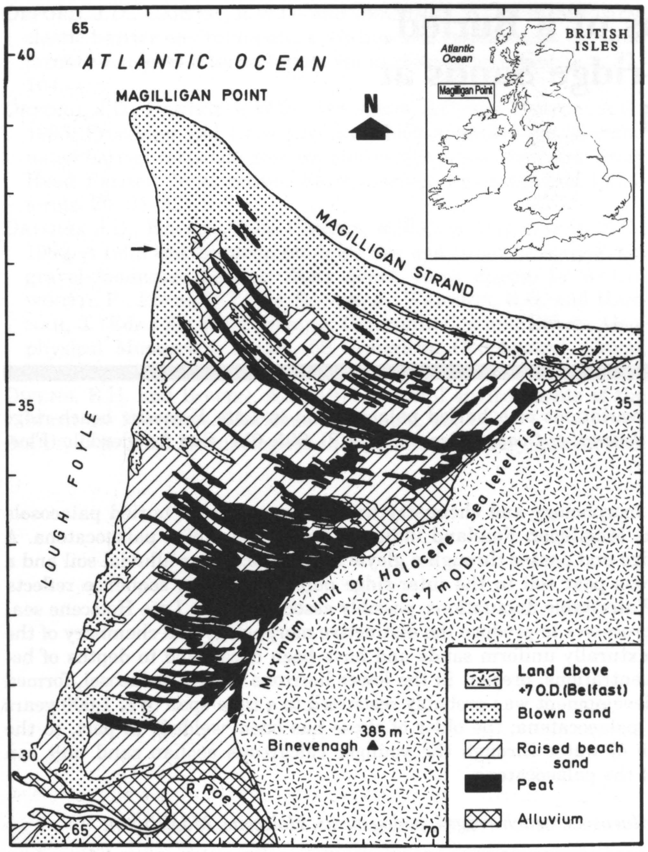

Figure 1. Holocene sediments of Magilligan Foreland (based on 1:50,000 Northern Ireland Geological Survey map). The horizontal arrow along the Lough Foyle shore indicates the location of the palaeocatena. The marginal grid is at intervals of 1 km.

Based on previously published interpretations of buried palaeosols (Wilson and Bateman, 1986; 1987), the palaeoecology of peat beds (McMillan, 1957; McMorris, 1979; Bradley, 1985), archaeological investigations (Mallory and Woodman, 1984), and radiocarbon dating, Wilson and Farrington (1989) were able to present a detailed reconstruction of the Late Holocene evolution of Magilligan. The earliest preserved palaeotopography is the gently-undulating beach-ridge plain. Ridge widths range from 100 m to 300 m (Carter, 1986) and ridge amplitudes are between 1 m and 2 m. This sequence of beach ridges accreted diachronously northwards between the local maximum of the Early Holocene eustatic transgression (*c.* 6,000 years B.P.) and the return to near present mean sea level (*c.* 2,000–1,500 years B.P.) (Carter, 1982). Pedogenesis affected the beach ridges, producing podzolic and brown soils on the ridge crests and flanks, and peat developed in the inter-ridge depressions. As accretion of the beach-ridge plain neared completion, prominent aeolian dunes formed along its seaward margins. Over much of Magilligan, agricultural activities during the last 2,000 years (Mallory and McCormick, 1988) have resulted in land levelling and the beach ridges are now difficult to identify on the ground. Only on aerial photographs and in cliff sections along the Lough Foyle shoreline, where the ridge system has been buried by aeolian dunes and subsequently truncated by wave erosion, can the original topography be traced. It was from exposures along the Lough Foyle shoreline that Wilson and Bateman (1986, 1987) identified buried palaeocatenas developed in calcareous beach-ridge and aeolian-dune sands and where the present buried palaeocatena occurs (Figure 1).

FIELD AND LABORATORY METHODS

Five visually distinctive palaeosols were recognised in the palaeocatena and each was described according to the system outlined by Hodgson (1976). Samples were collected from all horizons of the palaeosols and from the overlying aeolian sand. The heights of each palaeosol and the modern ground surface were surveyed with Electronic Distance Measuring equipment and related to Ordnance Datum (O.D.) Belfast.

In the laboratory, samples were air-dried and analyses performed on the fraction finer than -1ϕ (2 mm). All samples were tested for pH (1:2.5 w/v $CaCl_2$) and dithionite-extractable iron (Fe_d), and selected samples for pyrophosphate-extractable iron (Fe_p) and calcium carbonate equivalent ($CaCO_3$) following Avery and Bascomb (1974). (Because none of the palaeosol horizons gave an observable reaction when a few drops of dilute hydrochloric acid were applied, they were not subjected to calcimeter determination of $CaCO_3$) Organic matter content was estimated by loss-on-ignition at 430°C (Davies, 1974). Thirteen sand samples (three from the overlying aeolian sands and ten from the palaeocatena) were analysed for particle size distribution by dry-sieving at 0.25ϕ intervals; mean grain size and sorting were calculated using the measures suggested by McCammon (1962). Classification of the palaeosols was achieved using the system of the Soil Survey of England and Wales (Avery, 1980).

RESULTS

Geomorphology

The morphology of the beach ridge / aeolian dune exposure and the spatial arrangement of the buried palaeosols are depicted in Figure 2. Three sand units are present in the section, the lowermost of which is the beach-ridge sand containing the palaeocatena. The ridge declines in height from 4.0 m O.D. at its crest to 2.4 m O.D. at the lowest point of the inter-ridge depression, giving an amplitude of 1.6 m. The maximum gradient on the ridge is 5°, between palaeosols 1 and 3; elsewhere ridge gradients do not exceed 2°. The palaeocatena is overlain by two sand units which are considered to be aeolian rather than marine (beach) sands because they possess a strongly undulating topography adjacent to the exposure, contain abundant terrestrial snail shells, and lack large fragments of marine mollusc and gastropod shells, which are common in the beach sands. The aeolian sands probably originate from reworking of former beach-ridge sands in the area now occupied by the Lough Foyle inter-tidal sands. The older of these aeolian sand units is thin (<0.2 m) and is visually distinctive only between palaeosols 1 and 3

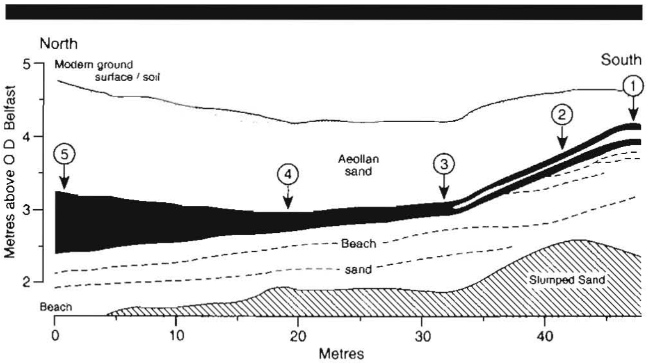

Figure 2 The buried beach-ridge palaeocatena at Magilligan Foreland The dense stipple represents the organic-rich horizon (bO and bA horizons) of the palaeocatena and the dashed lines mark horizon boundaries in the sub-soil Individual palaeosols are indicated by numbered arrows Detailed profiles for each palaeosol are shown in Figure 3.

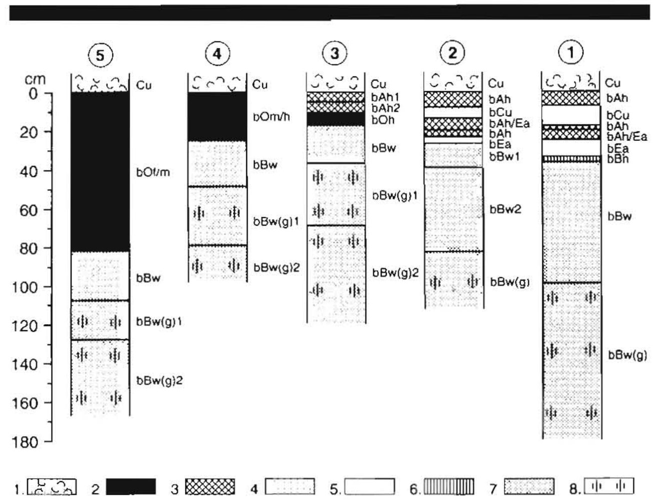

Figure 3 Profile morphology of the five palaeosols recognised in the beach-ridge palaeocatena and palaeosols in the older of the aeolian sand units Explanation of symbols: 1 $CaCO_3$-rich aeolian sand, 2 peat horizons, 3 mixed organic and mineral horizons, 4 decalcified aeolian sand, 5. eluvial horizons, 6 illuvial horizon, 7. decalcified beach-ridge sand, 8 ferruginous deposits.

where soil formation has occurred; subsequent burial has resulted in a parallel sequence of palaeosols (Figure 2). This sand unit also extends between palaeosols 3 and 5, but here pedogenic processes have 'welded' the sand to the underlying organic horizon (see below). The younger aeolian sand unit is thicker (0.5–1.5 m) and forms the undulating, modern ground surface at 4.2 m to 4.8 m O.D.

Particle Size Distribution

The dominant fraction in all samples is fine sand ($+2\phi$ to $+3\phi$) with between 83.4% and 95.2% by weight of the size distributions; this is followed by medium sand ($+1\phi$ to $+2\phi$, 2.3–14.7%) and very fine sand ($+3\phi$ to $+4\phi$, 0.7–5.8%). Very coarse sand (-1ϕ to 0ϕ, <0.1%) and coarse sand (0ϕ to $+1\phi$, <0.2%) are negligible components. Mean grain size ranges from $+2.38\phi$ to $+2.61\phi$ and sorting values are 0.25ϕ to 0.34ϕ, indicating very well sorted fine sand. Thus, strong textural uniformity exists within the sample set (*cf.* WILSON and BATEMAN, 1986, 1987); there are no significant particle size variations that can account for the visual contrasts between palaeosol horizons.

Soil Profile Morphology and Chemistry

Figure 3 shows the profile morphology for each of the five palaeosols recognised in the palaeocatena and Table 1 lists selected properties of these profiles. The most striking feature of the palaeocatena is the marked lateral variation in the altitude and thickness of the organic-rich horizon (Figures 2 and 3). Horizon altitude decreases and thickness increases from less than 0.1 m in palaeosol 1 (bAh and bAh/Ea horizons) to 0.82 m in palaeosol 5 (bOf/m horizon). Furthermore, the organic matter content increases, however, its degree of decomposition is noticeably less in the thicker horizons of the lower-altitude sites. In palaeosols 1 and 2 the organic-rich horizons are underlain respectively by light grey and light brownish grey (10YR7/2, 6/2) sands that are deficient in both organic matter and iron; these qualify as bEa horizons. A thin, yellowish brown (10YR5/4) horizon containing more organic matter and iron than the horizons immediately above and below occurs beneath the bEa horizon in palaeosol 1; this represents a bBh horizon but is of very limited lateral extent, being absent from palaeosol 2. The remaining horizons of palaeosols 1 and 2 are similar to those located beneath the organic-rich horizons of palaeosols 3, 4 and 5. They consist of brown, light brownish grey, pale brown, light yellowish brown, brownish yellow and very pale brown (10YR5/3, 6/2, 6/3, 6/4, 6/6, 7/3) sands that lack $CaCO_3$ and are deficient in organic matter. Some of these horizons possess vertically-aligned ferruginous deposits outlining the positions of former root channels; consequently the Fe_d content in these horizons is greater than in those without such features. All these zones qualify as either bBw or bBw(g) horizons, depending on the absence/presence of ferruginous concentrations.

Interestingly, the $CaCO_3$-rich sand (bCu horizon) of the beach ridges was lacking in all five palaeosols sampled. WILSON and BATEMAN (1986) showed that the Magilligan beach ridges contain *c.* 10% $CaCO_3$ and the depth to $CaCO_3$ in the palaeosols they examined was less than 0.9 m. In palaeosols 1 and 5 of the present sequence the profiles extend for depths of 1.6 m and 0.85 m respectively into the beach ridge without reaching $CaCO_3$-rich sand.

The palaeosols developed in the older of the aeolian sand units that bury the palaeocatena in profiles 1 and 2 which consist of two horizons only. Both soils possess a dark brown (10YR3/3, 4/3) bAh horizon, in which organic matter has accumulated, underlain by either a pale brown or light yellowish brown (10YR6/3, 6/4) bCu horizon. $CaCO_3$ is absent from each profile. In profiles 3, 4 and 5, pedogenic processes 'welded' the aeolian sand to the palaeosols of the beach-ridge palaeocatena such that it became an integral part of the palaeocatena prior to burial by the younger aeolian sand unit. Use of the term 'welded' follows RUHE and OLSON (1980) and SCHAETZL and

Table 1. *Properties of the palaeocatena soils.*

Profile and Soil Type	Horizon	Depth[a] (cm)	Dry Colour	pH	Loss-on-ignition %	Fe_p %	Fe_d %	$CaCO_3$ %
1								
	Cu		10YR5/6	6.9	0.7	0.02	0.26	3.3
Typical sand-ranker	bAh	0–7	10YR3/3	7.0	3.9	0.05	0.25	—
	bCu	7–17	10YR6/4	6.7	0.6	—	0.11	—
Humus podzol	bAh	17–20	10YR3/3	7.0	4.9	—	0.10	—
	bAh/Ea	20–24	10YR5/3	6.7	2.1	—	0.03	—
	bEa	24–33	10YR7/2	6.5	0.3	—	0.01	—
	bBh	33–36	10YR5/4	6.6	1.5	0.01	0.14	—
	bBw	36–99	10YR7/3	6.4	0.2	—	0.08	—
	bBw(g)	99–179+	10YR6/4	6.4	0.3	0.02	0.18	—
2								
	Cu		10YR6/6	7.6	0.5	—	0.26	4.6
Typical sand-ranker	bAh	0–8	10YR4/3	7.3	5.2	0.08	0.31	—
	bCu	8–13	10YR6/3	6.1	0.6	—	0.07	—
Gleyic brown calcareous alluvial soil	bAh/Ea	13–20	10YR4/2	6.7	2.6	—	0.04	—
	bAh	20–23	10YR3/2	7.1	12.2	0.12	0.27	—
	bEa	23–26	10YR6/2	6.8	0.4	—	0.01	—
	bBw1	26–39	10YR5/3	6.8	0.4	—	0.02	—
	bBw2	39–82	10YR6/2	6.6	0.2	—	0.06	—
	bBw(g)	82–112+	10YR6/3	6.5	0.3	0.01	0.16	—
3								
	Cu		10YR6/4	6.9	0.3	—	0.27	3.2
Typical humic-alluvial gley soil	bAh1	0–5	10YR4/4	6.8	5.5	0.14	0.50	—
	bAh2	5–11	10YR5/3	6.8	2.5	—	0.08	—
	bOh	11–17	10YR2/2	6.7	20.2	0.32	0.63	—
	bBw	17–37	10YR6/2	6.3	0.2	—	0.04	—
	bBw(g)1	37–69	10YR6/6	6.5	0.4	0.05	0.31	—
	bBw(g)2	69–119+	10YR6/4	6.2	0.2	—	0.14	—
4								
	Cu		10YR6/4	7.1	0.5	—	0.25	3.6
Typical humic-alluvial gley soil	bOm/h	0–25	10YR2/1, 3/1 & 3/2	6.4–6.8[b]	12.6–29.4[b]	—	—	—
	bBw	25–49	10YR6/3	6.3	0.3	—	0.05	—
	bBw(g)1	49–79	10YR6/4	6.2	0.3	—	0.18	—
	bBw(g)2	79–99+	10YR6/4	6.4	0.3	—	0.16	—
5								
	Cu		10YR6/4	6.8	0.4	—	0.18	3.7
Raw eu-fibrous peat soil	bOf/m	0–82	10YR2/1, 2/2 & 3/3	5.7–6.4[b]	32.1–91.9[b]	—	—	—
	bBw	82–107	10YR5/3	6.1	0.4	—	0.08	—
	bBw(g)1	107–127	10YR6/4	6.2	0.3	—	0.13	—
	bBw(g)2	127–167	10YR6/4	6.1	0.2	—	0.15	—

—not determined.
[a]Depths measured from buried soil surface
[b]Range of values for five samples from different depths

SORENSON (1987) and refers to situations where discernible C horizon material no longer exists between the solum of a ground soil and a buried solum. Soils buried by a thin layer of sediment are likely to become welded rapidly as the horizons of the ground soil develop and thicken downwards towards the buried soil. In the context of Magilligan, welding processes involved the accumulation and incorporation of organic matter and the leaching of $CaCO_3$. In profile 3, welding has created dark yellowish brown and brown (10YR4/4, 5/3) Ah horizons directly above the bOh horizon of the palaeocatena; in profiles 4 and 5 welding has been more severe and the sand has been totally incorporated into the bO horizons (Figure 3). Analyses of the relative proportions of sand and organic matter in the uppermost parts of these organic-rich horizons have confirmed the presence of significant quantities of sand.

All palaeosols are overlain by either yellowish brown, brownish yellow or light yellowish brown (10YR5/6, 6/6, 6/4) sand containing between 3.2% and 4.6% $CaCO_3$ and between 0.18% and 0.27% Fe_d. The surface zone of this sand unit is characterised by Ah horizons.

Throughout the palaeosols and modern soils pH values are within a limited range from slightly acidic to slightly alkaline (5.7–7.6) and, where measured, the Fe_p content is of negligible proportions.

Soil Classification

Palaeosol 1, on the beach-ridge crest, has the characteristics required for designation as a humus podzol (AVERY, 1980). It has an albic E horizon of high colour value and low chroma and an iron-deficient Bh horizon containing translocated organic matter. This palaeosol is identical to the humus podzols described by WILSON and BATEMAN (1986) from similar locations at Magilligan. A thin albic E horizon is also present in palaeosol 2 but is underlain by Bw and Bw(g) horizons rather than a podzolic B horizon. The soil may be an intergrade between a gleyic brown calcareous alluvial soil and a humus podzol but is best accommodated by the former sub-group because of the presence of weathered B horizons and gleyic features, (for the purposes of soil classification marine beach sand is regarded as a type of alluvium by AVERY (1980)); although calcareous material was not encountered in the profile it is believed to exist at greater depth. Soil profile morphology and chemistry were sufficiently similar in palaeosols 3 and 4 for them to be allocated to the same classification sub-group. They are typical humic alluvial gley soils possessing humose or peaty topsoils and gleyed sub-surface horizons. The bOf/m horizon in palaeosol 5 exceeds the thickness requirement of 0.4 m for classification as a peat soil. At the sub-group level it qualifies as a raw eu-fibrous peat soil consisting predominantly of fibrous and semi-fibrous peat thát accumulated in a poorly-drained site (the inter-ridge depression) under fen vegetation.

The two palaeosols that overlie the palaeocatena in Profiles 1 and 2 are designated as typical sand rankers and the modern ground soils are typical sand pararendzinas. These are lithomorphic soils associated with young ground surfaces or relatively short soil-forming intervals (AVERY, 1980).

DISCUSSION

The four buried palaeosols constitute a logical sequence downslope from the beach-ridge crest to the inter-ridge depression and comprise a palaeocatena (*sensu* VALENTINE and DALRYMPLE, 1975). The vertical and horizontal variations in soil profile morphology and chemistry reflect different slope positions and soil-water regimes. With the exception of pH (see below), the chemical analyses support the field data in that the palaeosols have the expected characteristics of the genetic soil types developed in very well sorted fine sand. Moreover, the particle size distributions show that the parent materials are texturally uniform both within and between sites; therefore, differential sedimentation cannot account for the visual and chemical contrasts between horizons.

Although the existence of a palaeocatena at Magilligan was first reported by WILSON and BATEMAN (1986) only the freely-drained end member (humus podzol) of the sequence was described in detail. Now, as a result of examining all palaeosols comprising the palaeocatena some refinements can be made to the Late Holocene evolution, stabilisation and pedogenesis of the Magilligan beach-ridge topography, originally outlined by WILSON and BATEMAN (1986) and WILSON and FARRINGTON (1989).

The major soil forming processes to have operated in the palaeocatena are organic matter accumulation and incorporation, decalcification, gleying and podzolisation. Furthermore, the first three of these are common to all palaeosols in various degrees, while podzolisation is restricted to palaeosol 1. WILSON and BATEMAN (1986) explained podzolisation on the beach-ridge crests in terms of a longer soil-forming interval resulting from their elevated and freely-drained locations relative to the inter-ridge depressions. They believed that the ridge crests would have been exposed first following relative sea-level fall and that vegetation colonisation and pedogenesis would have started here while the depressions were still subject to either permanent or tidal marine incursions. An equally likely scenario is that shoreline progradation led to isolation of the beach ridges, without any change in relative sea level. Whatever the cause of beach ridge stranding, the depressions remained wet due to either a high ground-water table or the establishment of shallow freshwater ponds; this is suggested by the occurrence of thin *Chara*-marl beds, containing freshwater shells, both below and within some inter-ridge peats, and basal peat layers that are rich in macrofossils of mosses such as *Drepanocladus aduncus*, *Calliergon cuspidatum*, *C. giganteum* and *Leptodictyum riparium*, and macro-and/or microfossils of *Phragmites*, *Filipendula*, *Carex*, *Menyanthes* and *Typha*, indicative of a brackish or freshwater nutrient-rich environment (MCMILLAN, 1957; MCMORRIS, 1979; BRADLEY, 1985; GODDARD, 1988). These species gave rise to fen and reedswamp peats. Later, conditions became less wet and fen woodland developed with *Alnus*, *Salix*, *Betula*, *Corylus* and *Taxus* all present. Drier conditions may have been a response to a fall in the water table during peat accumulation.

As peat formed in the depression, pedogenic processes on the flanks and crest of the ridge were dominated by organic matter accumulation and its incorporation into the sand, decalcification and podzolisation. These two latter processes indicate free-drainage, the development of relatively acidic soil conditions and the establishment of calcifuge vegetation communities, in contrast to the waterlogged and nutrient-rich conditions of the depression where calcicole species flourished. However, the presence of decalcified sand below the peat in palaeosol 5 is evidence for both acidic drainage at some stage during peat development and a fall in the water table to facilitate such drainage. This cannot have occurred after the palaeocatena was buried by the calcareous aeolian sand as percolation of water through this sand is likely to have raised pH to the present near-neutral values. Rather, it may correlate with the phase of drier conditions identified from pollen and macro-fossil analyses of the peat (GODDARD, 1988). A possible cause of water-table fall is a slight reduction in relative sea level. Such a fall and the consequent reduction in tide-controlled high water levels in Lough Foyle would have probably lowered the water table in the adjacent raised beach ridges, permitting decalcification to penetrate previously saturated sands. However, as yet there is no other evidence for minor changes of sea level. The sea-level curve for the north coast of Northern Ireland is acknowledged by CARTER (1982) as being based on very few index points, especially for the Late Holocene period, and is not sufficiently refined to show other than the general trend.

Decalcification in palaeosol 1 (humus podzol) extends for at least 1.6 m into the beach ridge and is significantly deeper than that reported by WILSON and BATEMAN (1986) for other beach-ridge humus podzols (<0.9 m). This anomaly cannot be explained by differences in the altitudes of the podzols; the humus podzol of the palaeocatena is at 4.0 m O.D. while those examined by WILSON and BATEMAN (1986) ranged from 3.75 m to 4.23 m O.D. A lower initial $CaCO_3$ content in the palaeocatena is also unlikely to account for the greater decalcification depth; analyses by WILSON and BATEMAN (1986) and WILSON (unpublished data) demonstrate a near-uniform $CaCO_3$ content of *c.* 10% throughout the beach-ridge system. In addition, there is no evidence of a significantly longer soil-forming interval for the humus podzol (see below). This depth of decalcification most probably exceeds that discussed by WILSON and BATEMAN (1987) for a buried aeolian-dune palaeocatena from elsewhere along the Lough Foyle shore of Magilligan; here the decalcification front was located 0.6 m below dune-slack peat and a maximum of 2.1 m below the slopes of the palaeodune. In palaeosol 5 of the palaeocatena, decalcification has penetrated for at least 0.85 m below the peat; horizontal projection of this decalcification level to palaeosol 1 suggests that at least 2.5 m of decalcified sand occurs below the crest of the beach-ridge palaeocatena. The patterns and depths of decalcification in both beach-ridge and aeolian-dune sands at Magilligan are unusual and demand further investigation.

Periods of temporary saturation due to water-table fluctuations are indicated by the vertically-aligned ferruginous concentrations outlining root channels in the lower horizons of all palaeosols. These channels, and, therefore, the ferruginous deposits, must have formed after decalcification as the internal reorganisation of sand grains following removal of $CaCO_3$ would have destroyed them (*cf.* KEMP, 1985). The ferruginous concentration features are considered to result from the establishment of anaerobic conditions following waterlogging and the reduction of ferric compounds to their more soluble and mobile ferrous forms. As the water table fell the larger soil voids (*e.g.* root channels) would have drained first causing the soil solution to diffuse towards these aerated zones where the ferrous ions were oxidised and precipitated as ferric oxide. Root channels have been stabilized and preserved by this process. The water-table fluctuations responsible for initiating these features may be associated with the recovery of sea level from slightly below present O.D. to its current level and the consequent increase in tide-controlled high water levels (presently 1–2 m O.D. during spring tides) in Lough Foyle (CARTER, 1982).

As no ^{14}C dates are available for the organic-rich horizon of the palaeocatena the time-span over which it developed is not known with certainty. ^{14}C dates from the base and top of other inter-ridge peats and from within peats, given by WILSON and BATEMAN (1986), MALLORY and MCCORMICK (1988) and WILSON and FARRINGTON (1989), reveal that peat growth was initiated at different times between *c.* 2,500 years and *c.* 1,000 years B.P. and that growth was terminated at different times between *c.* 1,100 years and *c.* 600 years B.P. The maximum age for an individual peat bed is 1,400 years. Although the peat in palaeosol 5 is slightly thicker (0.82 m) than the maximum thickness previously reported (0.79 m) there is no reason to suspect a significantly longer peat-forming interval at this site than elsewhere. This also is supported by the morphological and chemical properties (except for decalcification depth) of the humus podzol which are not any more strongly developed than in podzols at other sites. Thus, the palaeocatena is considered to have acquired its characteristics over a time-span similar to that for other peat-podzol sequences.

CONCLUSIONS

Detailed investigations of all genetic soil types present in the beach-ridge palaeocatena have provided a clearer understanding of the relationship between the factors and processes of soil formation at Magilligan prior to burial of this landscape by aeolian sands. The morphological and chemical characteristics of the palaeosols reflect their different original landscape positions and soil-water regimes. More elevated and freely-drained locations display relatively thin organic-rich horizons, deep decalcification and podzolisation. Low-lying sites are characterised by thicker organic accumulations, indicative of a high water table and/or the existence of a shallow pond. Water-table fluctuations (perhaps related to oscillations of relative sea level) allowed the decalcification of sand below low-lying peat soils and also caused ferruginous concentrations to develop in the lower horizons of all palaeosols.

The morphological and chemical properties recorded in the palaeocatena demonstrate that pedogenesis on low-amplitude raised beach ridges is capable of producing marked small-scale spatial variations in soil characteristics that are sufficient to create distinctive (genetic) soil types. Beach-ridge soil sequences are a neglected component of both coastal and pedological research; the results reported above suggest that similar studies on buried and unburied beach ridges elsewhere may yield valuable information concerning several aspects of coastal landform evolution.

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