Sand Dune Machair 3

Institute of Terrestrial Ecology

Natural Environment Research Council

Frontispiece Photo. Machair Group Meeting, Outer Hebrides, July 1978 (Photo: D.S. Ranwell).

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Report on meeting in the
Outer Hebrides
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Cover Drawing by Sid Lewis

The Institute of Terrestrial Ecology (ITE) was established in 1973, from the former Nature Conservancy's research stations and staff, joined later by the Institute of Tree Biology and the Culture Centre of Algae and Protozoa. ITE contributes to and draws upon the collective knowledge of the fourteen sister institutes which make up the Natural Environment Research Council, spanning all the environmental sciences.

The Institute studies the factors determining the structure, composition and processes of land and fresh-water systems, and of individual plant and animal species. It is developing a sounder scientific basis for predicting and modelling environmental trends arising from natural or man-made change. The results of this research are available to those responsible for the protection, management and wise use of our natural resources.

Nearly half of ITE's work is research commissioned by customers, such as the Nature Conservancy Council who require information for wildlife conservation, the Department of Energy, the Department of the Environment and the EEC. The remainder is fundamental research supported by NERC.

ITE's expertise is widely used by international organisations in overseas projects and programmes of research.

Contents

Introduction

A third meeting of the Machair Group was held at Lochmaddy, North Uist, Outer Hebrides from 14th-16th July 1978. The purpose of this meeting was to bring together people from different disciplines, but with a common interest in sand dunes and associated sandy plains (known as machair in Scotland), to exchange views both in the field and in lecture contributions. The latter are reproduced here together with an up-dated Bibliography of Machair compiled by Professor W. Ritchie and Mr. R.J. Ardern. Any opinions expressed in the following papers are solely attributable to the authors concerned.

The location was chosen for two reasons. It gave easy access to the 2600 ha of dunes and machair in South Uist, the second largest continuous sand complex in Britain. Also it lies close to machair archaeological sites up to 4000 years old which have been under intensive investigation for more than a decade.

Altogether, 20 people attended the meeting for part or all of the time. Field visits were made to Baleshare and Leathann (N. Uist), Borve and Rosinish (Benbecula), and Grogarry and Bornish (S. Uist). Lectures and discussions were held at the Lochmaddy Hotel, and a short recording on the meeting was made by the writer. This was subsequently broadcast by the B.B.C. The Machair Group was set up in 1973, "to improve communications between workers in the field of machair studies, to encourage complementary research studies and research in areas where it is most needed". There was a general feeling in the discussion at the end of the Lochmaddy meeting that the first of these objectives had been effectively achieved, but that little progress had been made beyond this improvement in communication between scientists. Some felt that the Machair Group had done its job in bringing people together and that it was now up to individuals to seek funds for specific areas of work and collaboration. However, the Machair Group has continued to survive, has held another meeting at Tarradale (Ross and Cromarty) in September 1979, and is planning a further meeting in Denmark in 1981. So long as it does survive, it would seem sensible for members to try to reach agreement on priority areas for research, and for the Group to lend its support to best qualified applicants seeking funds to work in them.

D.S. RANWELL

ACKNOWLEDGEMENTS

Thanks are due to all contributors for their participation. The Machair Group is especially grateful to Dr. R. Randall for helping to organize the meeting, to Dr. I. Crawford for demonstrating the remarkable excavations at The Udal, to Mr. I. Shepherd for guiding us round the Rosinish site, to Mr. E. Dunn and Mr. C. Brown for field discussions on agricultural use and widlife protection, to Professor W. Ritchie and Dr. S. Mather for demonstrating inter-tidal peat deposits and humus-rich soil horizons at Borve and to Ms. E. McQuhae for describing the sequence of events associated with the development and control of the Bornish blow-out. Mrs. A. Evans and Mr. R. Storeton-West gave much help in the preparation of this report. The Group is grateful to the manager of the Lochmaddy Hotel for providing a room for meetings.

Machairs for Recreation

W.T. Band

The author is Beach Management Project Officer for the Countryside Commission for Scotland. The project operates on the west and north coasts of Ross-shire and Sutherland. It has an overall aim of developing an understanding of how to restore eroded machairs. It also aims to make provision for summer visitors by taking practical action, where local interests are willing, in managing machair for recreation. The project follows on from a major scheme of this kind implemented at Achmelvich, near Lochinver, Sutherland, by the Highland Regional Council and assisted by grant under the Countryside (Scotland) Act. The range of management measures so far implemented includes: planting and reseeding works; experiments concerned with the control of grazing; sand fencing; path improvement; sign posting, and car parks (Plates 1 and 2). The work arises from ideas on machair conservation developed by Dr. W. Ritchie and Dr. A.S. Mather of Aberdeen University Geography Department in the course of compiling beach resource surveys. Further information on the project is given in Countryside Commission for Scotland (1978).

Many of the small bay-head machairs on the north-west mainland, particularly those lacking a line of protective foredunes, appear to be undergoing a phase of large-scale erosion. Climatic changes over the years no doubt play a part in this, but visitor pressure, rabbit populations, and over-grazing by stock have all apparently contributed. Thus, it is often difficult or impossible to identify a single root cause of damage. The beaches most subject to erosion are often those most visited by the public, and it is tempting to assume that therein lies the cause. However, aerial photographs show that erosion was well underway at many sites before visitor numbers became significant. More likely, the factors leading to damage from other causes are also the factors leading to heavy visitor use. For example, machairs close to crofting townships, and in communal use for grazing, frequently feature heavy stocking rates and lack of supervision. These machair common grazings often lack fencing and are readily accessible to vehicles via roads to nearby crofts.

Plate 1. Marram planting, sand fencing and a boardwalk — an attempt to stop further erosion of a heavily used route through the dunes. Big Sands, Ross-shire, (Photo: W.T. Band).

Close-cropped, well-drained machair turf is relatively resilient to trampling. Visitor trampling effects are most noticeable in the damage which occurs to dune vegetation in mature dune systems and in those erosion scars in machair which are at a pioneer stage in revegetation. The modern pneumatic tyre may well be less damaging to the grass sward than the iron-rimmed cart wheels previously used by crofters collecting seaweed, but damage that is initiated by vehicle tracking is often developed further by the burrowing of rabbits. Rabbits were slow to reach the north-west coast of Scotland and populations may well only have reached a maximum immediately prior to the myxomatosis epidemic in 1955. Burrowing activity is a primary initiator of machair erosion, but, once major erosion has occurred, rabbits rarely interfere significantly with the process of revegetation. The ultimate base of erosion scars is set by the water table, a level below which rabbits cannot burrow, and, even at the most heavily infested sites, results from experimental exclosures suggest that the overall grazing effect of rabbits is often minimal. However, rabbit populations might expand if overall grazing by stock was reduced. Most machairs in the north-west of Scotland are continuously grazed by sheep through all seasons, there being no fence to separate them from the hill portion of the common grazings. Typical leaf heights above the ground surface in mid-summer are 2-3 cm, while, in winter (at sites without the protection of a dune ridge), blown sand fills up the vegetation from the leaf bases to leave only withered leaf ends protruding from the sand.

Two questions arise; first, is the present level of grazing damaging or not to the sward, and, second, what level of sand deposition can a machair sward tolerate without damage? While grazing during the summer season may not be so severe as to cause actual plant death from defoliation and lack of photosynthesis, the size and growth of root systems often becomes reduced by grazing. Attempts at re-seeding erosion scars have shown that rooting depth is a crucial factor in allowing turf grasses to persist through the mid-summer drought conditions. Defoliation normally promotes tillering in grass plants, but the sward density in machair may be limited by the availability of nutrients which are under continual uptake as a result of the yearly export of grown lambs to pastures further south. In addition, heavy grazing eliminates the sheltering effect of foliage and this shelter may have an important role both in controlling sand blow and in allowing seedlings to establish. The cycle whereby sand overwhelms and damages a sward, thereby making available more sand for blowing, is well enough known. The rate at which this cycle pro-

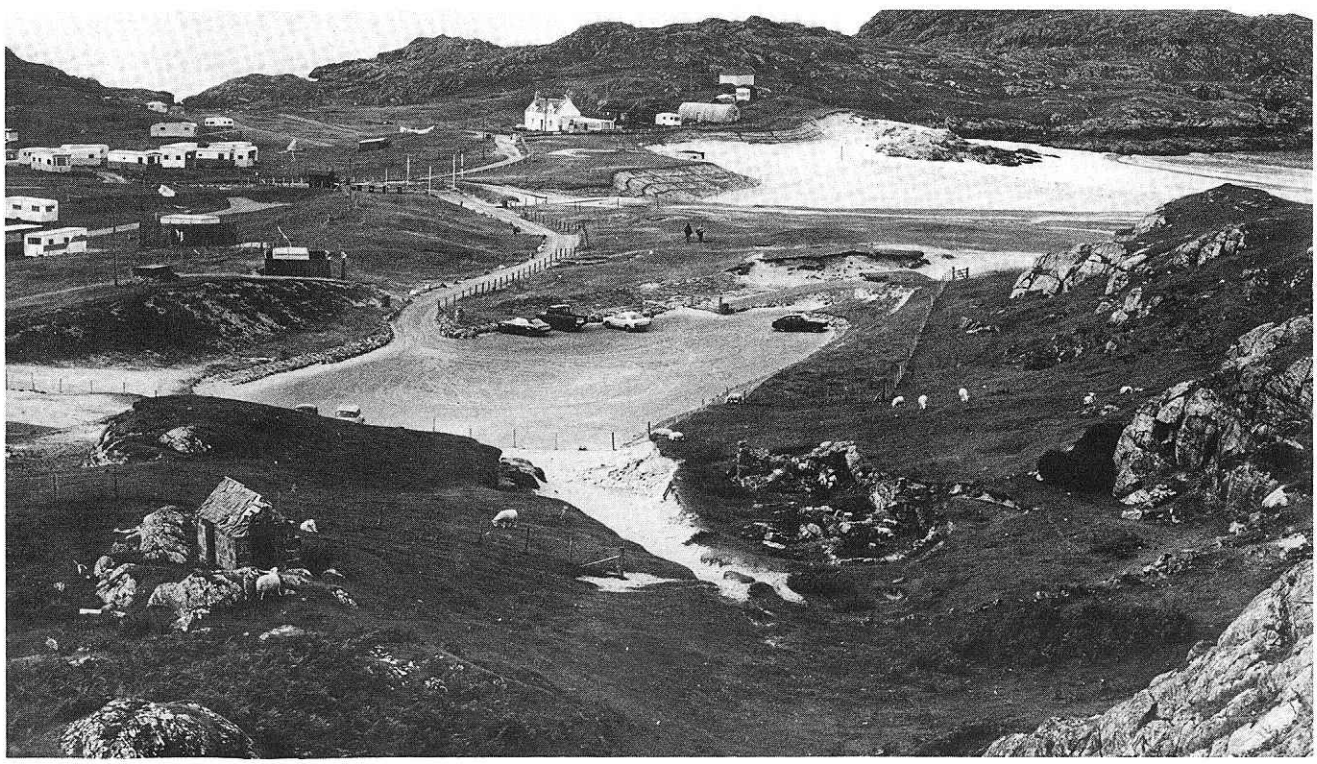

Plate 2. A machair recently reprieved from the wear of uncontrolled camping and caravanning. Achmelvich, Sutherland, (Photo: W.T. Band).

gresses may depend critically on the shelter afforded by the foliage. Thus, grazing could be an important and controllable factor in determining the progress of erosion. Preliminary observations suggest that a machair sward may grow up through and survive up to 10 cm of sand accumulation per year, but the typical levels of deposition and the levels of accumulation which red fescue (*Festuca rubra*) and other machair species will tolerate regularly are unknown.

Dunes appear to be less sensitive to grazing than machair, although the relatively high palatability of sea-lyme grass (*Elymus arenarius*) may be responsible for the comparative rarity of this species in the north-west of Scotland. Although marram grass (*Ammophila arenaria*) is not normally palatable to sheep, in the lean months of autumn, cattle graze marram to a few centimetres above the sand surface. This seasonal grazing appears to cause little damage to the marram growth, the effect being similar to that of burning, in that the old yellow growth is removed so that the new growth appears greener. However, the ability of the leaves to trap sand is reduced and the extent to which the development of embryo dunes is retarded by such grazing is an important question.

To try to answer these questions in a practical way, several simple experiments have been set up (Plate 3). At Achmelvich (Sutherland) and Opinan (Ross-shire), the first a machair lacking protective foredunes, the second a very varied dune/machair complex, complete beach perimeter fences have been installed and the grazing on these sites is now being controlled. The first year of stock exclosure at Achmelvich in 1977 showed a danger in undergrazing; the fescue-rich machair flowered in late June and thereafter the vegetation became dry and stemmy with slow growth and offered little surface shelter. In 1978 and 1979, both sites are being grazed only in the period from early May till mid-July, and results compared with plots where there is no grazing, or where the grazing occurs all the year round. In conjunction with re-seeding trials at Mellon Udrigle (Ross-shire) and at Achmelvich and Clachtoll (Sutherland), sheep and pedestrian exclosures have been set up

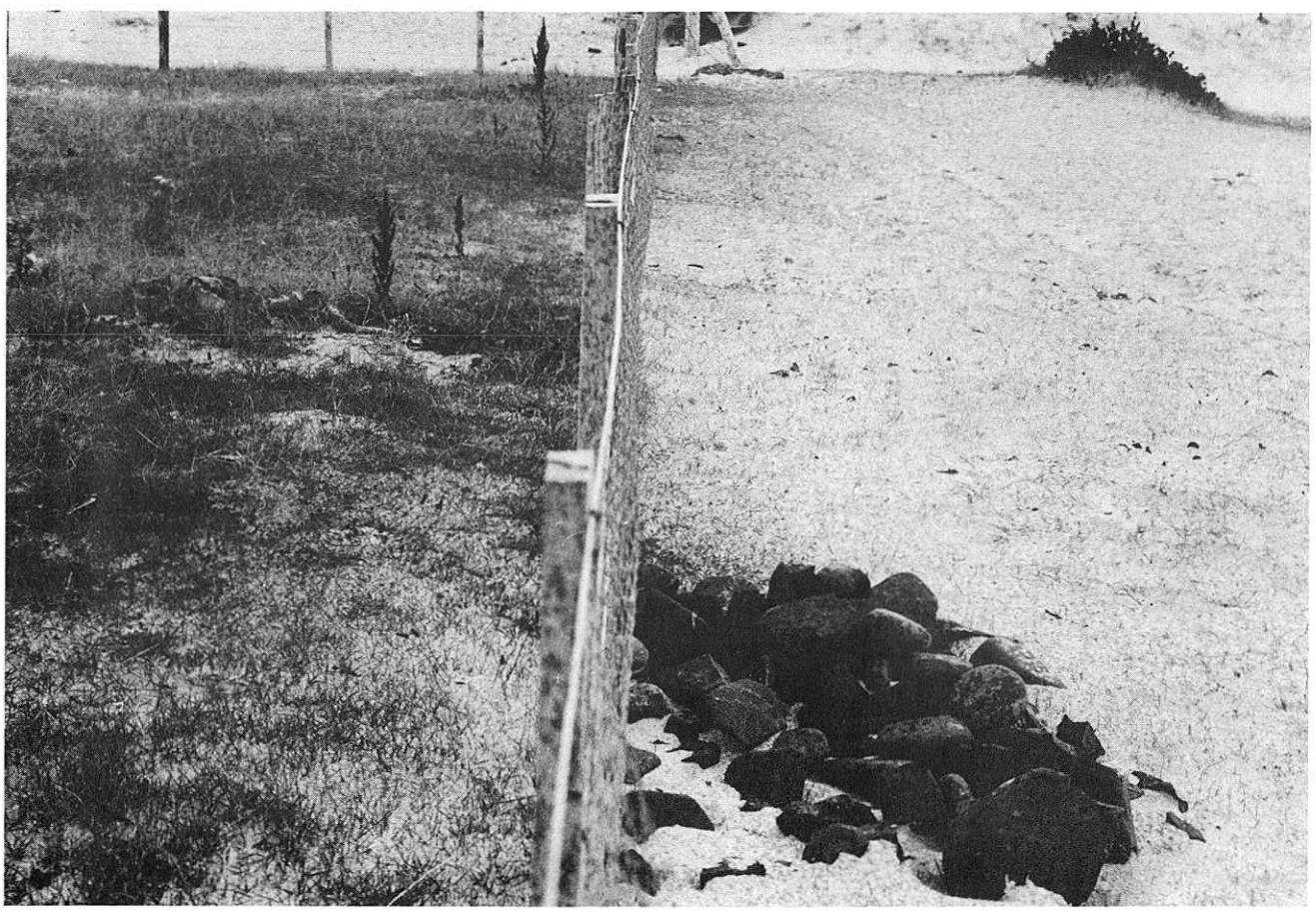

Plate 3. The combined effect of grazing and trampling only 3 months after construction of the fence. Clachtoll, Sutherland (Photo: W.T. Band).

These demonstrate the rapid spreading of pioneer vegetation types when freed from grazing and trampling. The effect of sand deposition on machair species is being studied in a pot experiment on machair samples, while actual rates of deposition are being measured over the winter along transects at Achmelvich machair. Lastly, the vegetation on a representative dune within the controlled grazing area at Opinan is being harvested with shears to study the effect of grazing on embryo dune development. It is hoped that these experiments will lead to a better understanding of whether or not there is a need to limit grazing at beach sites.

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Cropping the Machair

E.E. Dunn

The main uses of machair in the Uists are for wintering stock and for the production of winter keep primarily in the form of small oats (***Avena strigosa***) or a mixture of small oats and indigenous rye (***Secale cereale***), this last species used particularly on the drier areas. The presence of the machair therefore gives the Uists an advantage over other crofting areas in the north west of Scotland because they have a comparatively large ratio of arable to rough hill grazings and this arable can be used for the production of winter feed. This winter feed of course allows more stock to be carried throughout the year and thus allows for greater stocking and better utilization of the hill grazings during the summer. In more recent times, it has also provided the stimulus to increase the stock carrying capacity of the hill by improvements such as surface seeding and fencing. An additional advantage is that the machair, particularly if dunes are present, provides a dry and sheltered environment for stock during the winter, thereby saving the crofter the expense of providing winter housing.

Agriculturally speaking, machair soils are of very low fertility and very prone to drought. To grow worthwhile crops, rainfall must be frequent and any prolonged dry spell is fatal. The use of modern varieties of grain and up to date machinery is strictly limited. The large awns on the small oat prevent it from being sown by drill and it has to be broadcast by hand. Small oats and rye are the only two cereals known to tolerate the high pH, and other cereals suffer severly from manganese deficiency. There are problems in harvesting the crop. Binders and binder spares are becoming harder and harder to come by and there is no real alternative to these machines. Modern varieties of grain can be grown, but involve spraying twice with manganese sulphate, a time consuming operation as few crofters have, or can justify, buying a tractor mounted sprayer (or most other modern machinery), for the acreages involved. Most major and trace elements are deficient, or there is an induced deficiency due to the high pH. Of the major nutrients, phosphate is low and potash moderately low, the higher level of potash perhaps being due to decades of seaweed application. Excess of calcium and shortage of most other elements make cattle and sheep prone to deficiency diseases, notably pine in both cattle and sheep caused by a lack of cobalt, and sway back in sheep caused by shortage of copper. Undoubtedly, sub-clinical deficiencies of these and other trace elements occur, causing poor growth rate and also breeding problems.

Rotation on the machair is generally 2-3 years cereals, and then in many cases 2-3 years fallow when the land gradually becomes repopulated with natural grass (mainly fescues), legumes, and "weeds". The only other crop normally grown is potatoes in relatively small areas.

North of Scotland College of Agriculture, Benbecula, Outer Hebrides is trying to find an alternative to cereals, and the only viable one appears to be increased grass production, this being conserved as hay or silage. To make grass production a viable proposition, several problems have to be overcome. First, there is the problem of the "common" nature of much of the machair land, particularly in South Uist and Benbecula. This land is open to all township stock throughout the winter, and, unless every crofter reseeds and fertilizes his land, the cattle and sheep graze out any areas that have been reseeded and therefore make individual efforts to improve the grass fruitless. Reseeded areas also need to be fenced off to allow proper establishment and management. Then, the porous nature and low

organic matter content of the soil makes establishment of good grass difficult. We have had encouraging results by drilling the seed below the surface immediately after ploughing, and then giving a heavy rolling to conserve the available moisture. Seeding directly into uncultivated land previously sprayed with a complete herbicide might be another alternative. There is also the problem of competition from deep-rooting weeds, for example silver weed (*Potentilla anserina*) corn marigold (*Chrysanthemum segetum*), and couch grass (*Agropyron repens*). All of these are difficult and expensive to control.

Once the grass is established, no amount of fertilizer or fencing will guarantee a reasonable yield without frequent rainfall. In this respect, small oats and rye are more reliable crops. Given adequate and frequent rainfall, reasonable management and fertilizer usage, the productivity of the machair could be increased by incorporating sown grass into the rotation. Over the years, this would have the effect of raising the fertility of the machair soil, mainly through build-up of organic matter, and it could also give a return on land which is at the moment left fallow.

Effects of Grazing on the Machair of the Monach Isles

R.E. Randall

The effects of grazing and the species composition of ungrazed machair were central to the discussion arising from Randall (1974). Therefore, in 1976, the author led a party of students from the Brathay Exploration Group to erect a series of grazing exclosure quadrats on Ceann Ear, Monach Isles National Nature Reserve.

Five sets of exclosure quadrats were located as shown on Fig. 1. These were set up in the following habitats: –

1. Coastal *Armeria* turf near Haemaravagh Bay
2. *Eleocharis* marsh near Loch nam Buadh
3. *Carex nigra* turf near Port Roy schoolhouse
4. Herb-rich *Festuca* grassland near Port Roy schoolhouse
5. Stable **Ammophila** dunes in the north of Ceann Ear.

Fur further details of these habitats, see Perring and Randall (1972) and Randall (1976). Each exclosure was 5 m square, one half being enclosed by sheep netting and the other half by rabbit netting. Corner posts were 4" (10 cm) diameter pine poles dug into a depth of 0.75 m. Internal posts were 3" (7.6 cm) square oak poles similarly dug in. The rabbit netting was turned out and buried for 20 cm below the surrounding turf. The whole enclosure was encircled by round wire which was attached to strainer posts at the corners. Percentage cover of the vegetation was estimated by point quadrat using a frame of pins.

The exclosures were not re-examined until July 1978, when they were visited by Mr. N. Brown, working for the Nature Conservancy Council. The following report is based upon this visit. A further visit to record the status of the vegetation will be carried out in 1979 by Miss L. Farrell, a member of the original 1976 party.

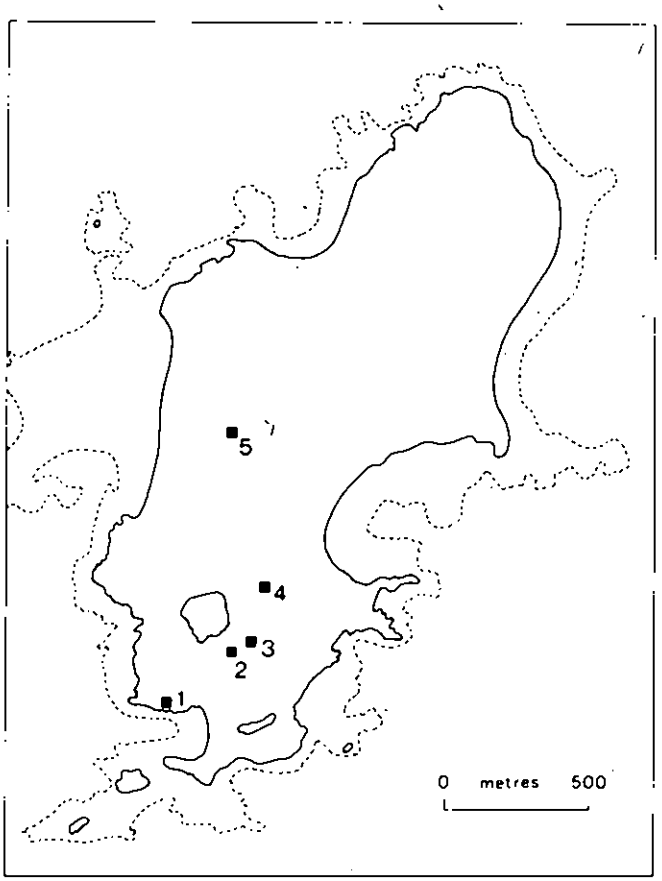

Fig. 1. Location of exclosure quadrats set up on Ceann Ear, Monach Isles, Outer Hebrides in 1976.

Quadrat 1. Coastal *Armeria* turf (Plate 4)
Outer quadrat still intact, but central division torn. Slightly greater growth of vegetation recorded within the whole quadrat area, especially on the North side away from the sea. No visual difference in species, or increase in flowering, within and outside the quadrat area.

Quadrat. 2. *Eleocharis* marsh (Plate 5).
Quadrat undamaged. A small, but probably significant, difference in biomass was noted inside compared with outside the quadrat. There is a more obvious difference in vegetation composition. The vegetation inside the quadrat has become much more herb-rich and many more species have succeeded in flowering than outside the quadrat. This is epecially true in the compartment which excludes both rabbits and sheep. The orchids *Dactylorchis incarnata* and *D. purpurella* showed especially vigorous growth within the quadrat.

Quadrat 3. *Carex nigra* turf (Plate 6).
The rabbit and sheep exclosure was destroyed (? by sheep), but the sheep exclosure remained intact. The vegetation inside this exclosure appeared to have much greater biomass than the vegetation outside the exclosure and it was also much more herb-rich. The main species to increase its abundance was *Heracleum sphondylium,* known to be common in ungrazed areas of Balranald, N. Uist and Breckin, Yell, Shetland. This species also showed a notable increase in height, from 4 cm outside the exclosure to 50 cm within it. Other species that had increased in the absence of sheep grazing were *Plantago lanceolata, Potentilla anserina, Rhinanthus minor* and *Trifolium repens.*

Plate 4. Grazing exclosure (2 years old) in coastal Armeria *turf, July 1978. Haemaravagh, view from east looking west towards the coast, Ceann Ear, Monach Isles. Note, left half designed to exclude sheep, right half to exclude rabbits and sheep, (Photo: R.E. Randall).*

Plate 5. Ungrazed (left) and grazed (right) Eleocharis *marsh, July 1978. Schoolhouse bog, Ceann Ear, Monach Isles. Note increase in herbs and flowering in ungrazed area, two years after exclosure, (Photo: R.E. Randall).*

Quadrat 4. Herb-rich ***Festuca*** grassland.
Quadrat destroyed. Sheep have access to both compartments and vegetation was similar inside and out. The rabbit mesh was broken, but the sheep netting still standing, suggesting that physical breakage by sheep was the likely cause of damage.

Quadrat 5. ***Ammophila*** dunes (Plate 7).
Rabbit netting compartment destroyed, but sheep netting compartment intact. No visual difference between vegetation inside and outside exclosure after 2 years.

In some ways these results are disappointing because it shows that, despite the effort taken with their construction, the quadrats were, in most cases, not strong enough for their job. However, there is enough left of the project to suggest certain trends: –

1. Different communities are affected in different ways by reduction of grazing. This difference is most clearly seen by contrasting the sheep exclosure in ***Carex nigra*** turf with that in stable ***Ammophila*** dunes (Plates 6 and 7).
2. There was some evidence that rabbits contributed to reduction in vegetation biomass in a heavily sheep-grazed community. As only the ***Eleocharis*** marsh had both sheep and rabbit and sheep exclosures still intact, this conclusion cannot be substantiated further.
3. ***Heracleum sphondylium*** seems to be a highly palatable species that is virtually grazed out of machair. As most machairs are overgrazed 5-10 fold in winter (see Randall 1974, p. 17), this severe reduction or elimination of one of the most palatable

species must reduce the economic value of the machair.

It will be interesting to see if the trends visually recorded after 2 years will be continued when the 1979 quantitative survey is carried out.

ACKNOWLEDGEMENTS

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Plate-6. Ungrazed (left) and grazed (right) Carex nigra *turf, July 1978. Near schoolhouse, Ceann Ear, Monach Isles. Note increase in* Heracleum sphondylium *in sheep exclosure compared with surrounding sheep and rabbit grazed turf, two years after exclosure, (Photo: R.E. Randall).*

Plate 7. Sheep exclosure in sheep and rabbit grazed stable Ammophila *dune, Ceann Ear, Monach Isles, July 1978. Note no visual difference in the vegetation within and outside the exclosure after two years, (Photo: R.E. Randall).*

Man and the Machair in the Nineteenth Century

A.S. Mather

Contemporary documentary evidence on the condition of machairs and on the use to which they were put by man is very much fuller in the nineteenth century than in preceding centuries. Prior to this period, such evidence as is available was confined to archaeological sources, and to occasional references in estate papers and accounts by travellers. In the 1790's and 1840's respectively, however, the Old and New Statistical Accounts (OSA and NSA) were composed, providing a description of each parish in Scotland, organised under headings such as topography, agriculture, economy and population. These accounts contain frequent mention of sand blow; this phenomenon was noted by the parish ministers, who composed the accounts, in locations as diverse as Islay, Coll and Tiree, the whole length of the Outer Hebrides from Barra to Ness, the mainland, and the Northern Isles (Sinclair 1794a and Anon 1845a). It is doubtful if local ministers describing these same areas at the present day would regard contemporary sand blow as a significant feature of their parishes, and it may be that sand blow and wind erosion were more widespread at the time of the OSA than at present.

The late eighteenth and nineteenth centuries were a period of socio-economic change in the Highlands and Islands. The population was growing and land tenure was being re-organised. A feature of the period around 1800 was the growth of the kelp industry. This involved collecting and harvesting of seaweed from beaches and shores for processing into a chemical raw material. Previously, seaweed had been widely used as a mulch and fertiliser in the cultivation of machair land. The kelp boom resulted in a reduction of the use of seaweed for this purpose (Sinclair 1794b), thereby perhaps reducing the stability of cultivated machair areas. At the same time, the pressures of foot and cart traffic crossing the machair to the seaweed gathering areas may have left their own imprints.

While the general trend in the Highlands and Islands in the nineteenth century was towards larger populations, some areas were cleared of their long-established, mainly subsistence cultivators, and converted into large, commercially-organised sheep farms. Part of the cleared population was resettled locally, frequently in coastal locations. Thus, the combination of a growing population and social dislocation resulted in severe population pressures building up in some areas. In such areas, the traditional machair cultivation practices which had evolved over the centuries became no longer tenable. Previously, a form of shifting cultivation had been practised on the machair; plots were cultivated for perhaps two or three years and then left to revegetate and recover (Carmichael 1884). Furthermore, peat ash, domestic refuse, and manure were probably applied in addition to seaweed. With increasing population pressure, fallow periods had to be shortened. Cultivation became more continuous, and, in relative terms, less organic material was available for applying to the cultivated patches. By the time of the inquiries of the Crofters Commission in the 1880's, cultivation on some machairs (for example on the Island of Boreray, Her Majesty's Commissioners of Inquiry 1884a), had become almost continuous and crop yields were very low.

As the population grew, and cereal crops became poorer, Marram grass was substituted for straw as a thatching material (Her Majesty's Commissioners of Inquiry 1884b). The rotations which were employed in the cutting of Marram were shortened. This practice in turn might possibly have reduced the stability of the sand dunes.

In addition to these indirect influences on the stability of dunes and machair, population pressures in the nineteenth century also resulted in more direct modifications, at least in some areas. On the island of Berneray (Harris), for example, dunes were 'reclaimed' for cultivation (Congested District Board 1900). While details of such reclamation are not available, it seems probable that it involved the levelling of dune terrain into a machair-like plain.

While human effects on the machair may have been greatest on the areas on which the greatest population pressures were exerted, they were not confined to such areas. Some of the machairs which had been cleared and converted into sheep farms were drained (Ritchie 1966), with the indirect effect of increasing susceptibility to erosion. In contrast, the allocation to adjoining farms of formerly common (and over-grazed) links was followed, in the case of Dunnet Bay in Caithness, by the emergence and growth of a well-defined dune ridge (Anon 1845b). On some dunes and machairs, extensive areas were planted with marram in an effort to retard sandblow (Her Majesty's Commissioners of Inquiry 1884c), and dune erosional faces were graded and turfed in some localitive such as the Uists (Anon 1845c).

Many of the machair areas in the Highlands and Islands are of the same age as man himself in the region, and human influences have probably been exerted on the machair since the earliest time. More extensive documentary evidence relating to the interaction between man and the machair is available for the nineteenth century than for any other period. The evidence is incomplete, but it is sufficient to generate certain hypotheses, for example, that machair instability was greater than at present, perhaps as a result of severe population pressure in some localities. It is hoped that this hypothesis can eventually be tested against the evi-

dence from estate papers and other more detailed records than can be provided by the statistical reports and minutes of evidence of the late nineteenth century commissions of inquiry.

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The Beach, Dunes and Machair Landforms of Pabbay, Sound of Harris

W. Ritchie

LOCATION AND GENERAL BACKGROUND

The regular, conical outline of Pabbay may be seen from Harris and North Uist. It lies 8 km north of North Uist, and 8 km west of Harris. It is situated on the open west part of the shallow, island-dotted Sound of Harris. The relatively deep waters of the Atlantic lie to the northwest; elsewhere the surrounding seas are extremely shallow with a varied sea bed topography (Fig. 2).

On closer inspection, the island is seen to have distinctive contrasting coastlines. To the north and east, there are steep cliffs with deeply indented fissures and narrow inlets. Most of the high ground is located in the north and northeast sectors of the island with the highest crest, Beinn and Charnain, reaching to 196 m in the northeast. Between this rounded summit and a lesser hill, Meahall (81 m) to the west, is a low pass or valley with two, small, permanent shallow lochs. In contrast, the south side of the island has a low, sand beach coastline consisting of a series of small crescentic beaches that have been constructed between low rocky reefs and platforms. These reefs, like the remainder of the island, have a strong northwest to southeast structural trend – a trend that may have been accentuated by the passage of glaciation. The beaches are composed of shell-rich, well-sorted, creamy-white sand, but towards the west on the southwest-facing coastline, the beaches are of shingle, and rock outcrops are more common.

Inland, three main landform surfaces can be identified: –

1. The northern half of the island which consists of ice-moulded and scoured hillsides and moorland. Almost all the former peat cover has been removed and much of the hillside consists of bare rock and boulders.
2. A central-west plateau at about 25 to 40 m above sea level which is covered unevenly by shallow bog and moorland in the west and north, but elsewhere lies beneath wind blown machair sand.
3. A series of south-facing slopes and shallow basins. These areas are sand-filled with various types of machair and sand dune landforms. To the east and northeast, the blown sand reaches over the flanks of Beinn a Charnain and extends as a

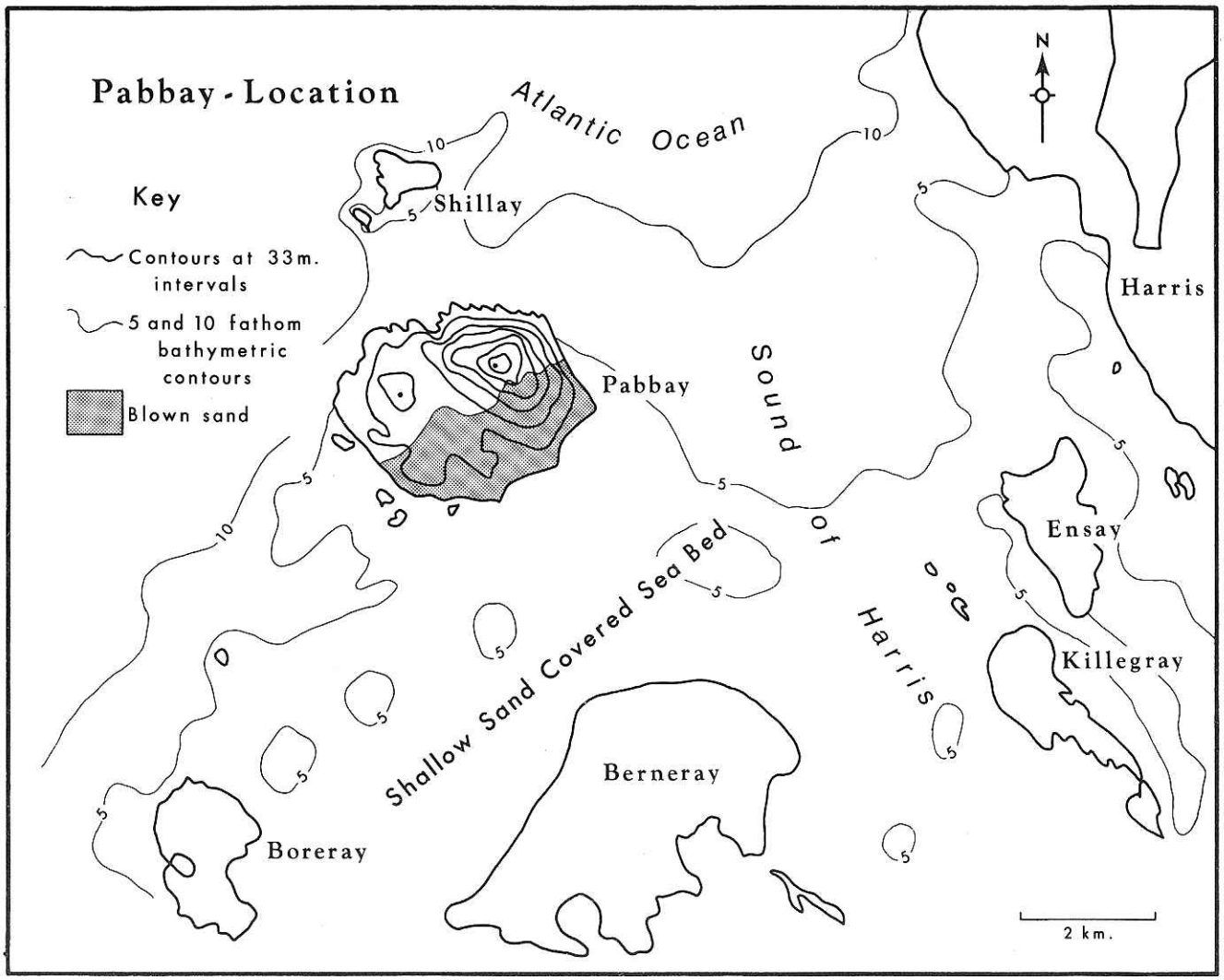

Fig. 2. Location of Pabbay in the Sound of Harris, Outer Hebrides.

discontinous, thin blanket almost as high as the summit.

It is this third zone, the area of dunes and machair along with the fringe of sand beach, that has been utilised by Man for settlement and agriculture.

The island has been totally uninhabited since the 1930's. Once there were three townships, and the boundary stone dykes are still clear on the landscape, as are the ruins of crofts, houses and other remains. The island is now grazed by sheep, cattle and deer (about 80 head). There is no record of rabbits. The land is well-watered and several streams run down through the machair and dunes to the coast. All but one of these streams dries-up in summer. In the stream beds, beneath the sand, it is possible to see variable thicknesses of stony, gritty glacial till which seems to cover the lower slopes, but disappears at higher altitudes where blown sand lies directly on bedrock.

Although Pabbay is only about 7.5km^2 in size, and only about half of the area appears to have any potential for basic cultivation, it is recorded as having been a fertile and populous island – described by Monro in 1549 as "... ane maist profitable Ile ... maist plentifull of beir, grising and fisching." In 1764, it had a population of 186, rising to a maximum of 338 in 1841. According to Moisley (1966), Pabbay was cleared shortly after to make a farm, and only 25 people were recorded in 1851; by 1881, only two were left. The evidence of this occupation is found not only in written records (where the writers normally emphasize the richness of Pabbay machair and the fame of the 'bere' (a type of barley used to make bread and local whisky), but also on the landscape where every hollow and patch of cultivable

soil carries the hatched pattern of lazybeds, tiny fields, and rudimentary ditching.

The only scientific paper of any substance relating to Pabbay is that by Elton (1938) who visited the island to make an ecological survey in 1935. In this paper, Elton quotes Sinclair (1794) who writes that "this island was once the granary of Harris but has lost much of its fertility by the encroachment of the sand drift, which now covers its S.E. side to the very top, exhibiting a most desolate appearance. The S.W. side is verdant and well cultivated. The N.W. side is exposed to the Atlantic and yields little or no vegetation." From additional evidence, Elton concluded that most of the sand drift took place before the end of the 18th century and there had been little change since that time, other than in increase in the height of the coastal dune ridge. Elton (1938) describes active erosion hollows on the upper slope near the old township of Baile-Lingay, features that exist today and are still trampled and rubbed by sheep. He also provides lists of plants, mammals, birds, and other natural features of the island. These lists do not appear to include any exceptional animal populations or other phenomena atypical of adjacent islands and machair areas.

Elton describes one site of inter-tidal organic deposits which he calls "submerged forest" and this is located on the south side of the isthmus at Quinish (Fig. 3). Elton inferred that these terrestrial organic deposits, including wood, provided proof of coastline submergence. These deposits, and another two sites on the south coast of the island, have been investigated in detail by the present author (see also Phillips, 1978). The constituent organic materials have been studied by pollen analysis, the stratigraphy has been recorded by levelling survey and related to tidal changes (average range is about 3 m), and selected samples have been dated by C^{14} methods. The discussion of the interpretation of these results requires more substantial treatment than can be given here, but, in summary, the deepest material is dated at 8330 ± 65 years b.p. and lies 2m below the seabed off Forthvath Reef (NF 909876) and another sample which appears to mark a major environmental change involving a major influx of machair-like sand is dated at 4366 ± 40 years b.p. This latter sample came from Quinish beach (NF 882865).

Although the subject of coastal change and machair evolution is not the prime concern of this paper, the existence of these submerged organic materials along the coast implies an ancient age for these machair areas (*not* necessarily their surface characteristics) and anticipates a complex sequence of geomorphological evolution over a long period of time.

MACHAIR AND RELATED LANDFORMS

The main types of machair and dune surfaces are outlined on Fig. 3. The machair system can be divided into six basic types of surfaces as given below. These areas are found only on the south and southeast parts of the island.

1. Beach

The main beach lies east of the Landing place (Fig. 3). The beach is about 200 m wide and high tides reach the base of the dune ridge. The gradient is low, 1-3°, and flattens towards low water mark. The beach is divided into two unequal parts by a sand ness, An Corran, which points southeast towards Berneray (Fig. 2). This sand feature appears to be produced by wave refraction patterns. Two small streams, which may run dry in summer, cross these beach areas.

Further east, there is a narrower beach, Traigh Baile Fo Thuath with similar surface characteristics. This beach ends in a low rock platform and boulder area, Rubh'a Bhaile Fo Thuath, which is the eastern point of the island. In both beach areas, there are only narrow zones of dry sand for onshore transport. The beaches are also sheltered and must be relatively low energy environments.

2. Dunes and other types of coastal edge

The main area of dunes lies behind the central beach. The dunes are up to 11 m high. They are undercut and appear to be retreating. The main ridge is irregular in height but, normally, sharp-crested. The highest dunes are opposite and west of An Corran. There are a few linear blowouts. The vigour of marram growth would suggest continuing upward accretion, and in some areas the backslope is encroaching over older, low machair areas.

On the east side of the south coast, the beach terminates against a low undercut machair edge some 2 to 4 m high. There are no significant dune landforms. Again, there is active undercutting and possible coast-line retreat. The sand supply which has been created by erosion is re-deposited on the edge and a low asymmetric ridge has been produced.

Elsewhere, the coastline consists of low rocky outcrops, pseudo-cliffs of varying height and slope and, on the southwest-facing coastline, a complex series of low plateau terrace edges, rock outcrops, and various types of shingle formations. Quinish (Fig. 3) is a small island where a low, irregular rock area has been partly covered in stones and shingle spreads. At low tide, it is con-

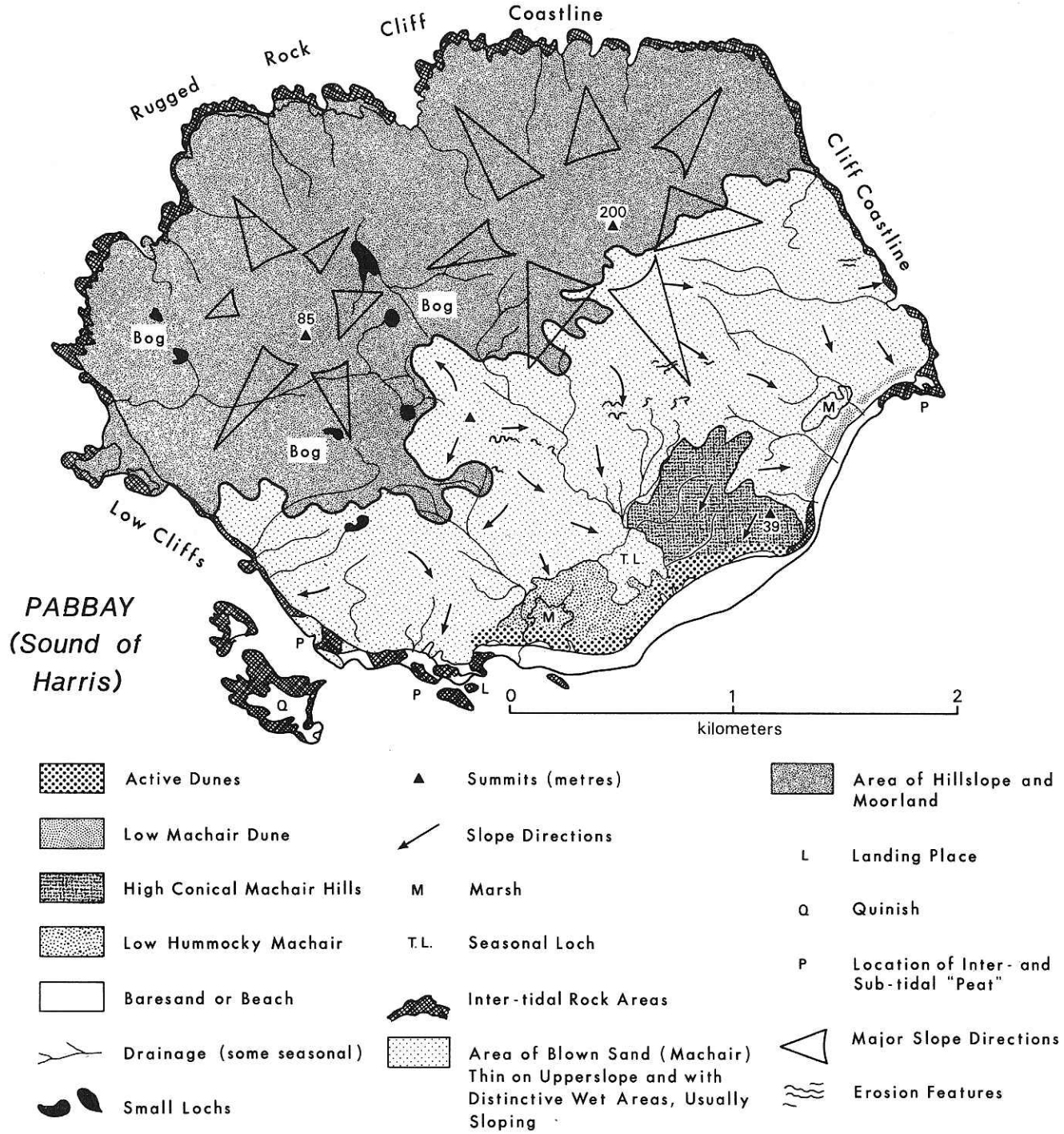

Fig. 3. Geomorphological map of Pabbay, Outer Hebrides.

nected to the main island by an isthmus of shingle and seaweed-covered stones.

There is also a small sand beach in the shelter of an offshore rock reef in the area known as the Landing place (marked by the letter "L" on Fig. 3) beside Haltosh Point, which is the most southerly point of the island. Beneath this tidal beach, there are other deposits of fresh-water organic materials.

3. Level or low angle machair plateau

This area lies inland and to the west of the Landing place. The machair is level or gently undulating. In a few places, there are ridges and hollows which could be

former erosional and redepositional features. The machair merges with the moorland plateau to the west. On aerial photographs, however, there appears to be a veneer of blown sand reaching even further west, but this cover is not discernible on the ground. Inland, towards the ruins of Teampull Mhoire, the ground slopes lower and the machair becomes marshy.

This surface is mature and obviously a site of preferred, close grazing by sheep and cattle. Remains of pens or stone-built fanks (rough enclosures used during sheep gathering and auctions) are common in this area. The vegetation is the normal machair grass sward.

4. Wet machair

There are several low machair areas with a tendency to marshiness associated with the drainage from a number of small stream courses that descend from the high ground. Perhaps 60% of the drainage of Pabbay passes through some form of machair surface. Most of these marshy areas are only seasonally wet, but this amount of wetness is sufficient to produce easily detectable patterns of vegetation. On the south east side of the island, the hill slopes are steeper and descend directly to a low machair axis inland of the coastal edge. About six minor seasonal streams flow into this sloping machair zone.

The pre-existing topography has produced a broad, basin-shaped depression into which surrounding drainage flows about 900 m east of the Landing place. The central area near the coast is so low that a seasonal winter-loch forms, and only during dry periods in summer does this emerge as a flat, partly vegetated plain. Small hummocky dunes stand as tiny islands in this marsh and loch depression.

Typical of the Hebridean landscape, even hillside areas have small zones and patches of marsh wherever there is a local depression in the bedrock or an irregularity in the till cover. Small wet machair areas are found widely distributed throughout the area, especially on the upper southeast-facing slope of Beinn a Charnain. Similar damp hollows are found on the other side of the island at the west margin of the machair plateau zone.

5. Hummocky and hilly machair (Plate 8)

These surfaces are the most distinctive elements of machair morphology on Pabbay. These sand hill forms occur around the side and on the floor of the main central depression (Fig. 3) on either side of the winter-loch feature. Hummocks lie between the coastal dune ridge and the slope of a spur running south from the hill massif. Smaller hillocks lie on the floor of the basin and to the west of the winter-loch.

The high, conical sandhills lie on the southwest-facing flank of the basin, i.e. northeast of the winter-loch. These are big features, 5 to 8 m high, with steep slopes. The vegetation is mature and more akin to machair than dunes (although there are patches of marram grass, especially on the crest). These conical sand hills reach as high as the 30 m contour. Between these conical hills, the machair is level or gently sloping towards the winter-loch in the floor of the basin. In spite of the mature appearance of the vegetation, the high relief of these sandhills implies a relatively recent origin. Perhaps this was the area of sand movement described by Sinclair at the end of the 18th century (Sinclair 1794).

6. Sloping and transitional machair (Plate 9)

The most extensive machair surface is composed of several forms of sloping machairs, including the margin of the plateau machair described under 3 above. Thick blown sand covers both the spurs and side slopes of Beinn a Charnain. The machair is normally smooth, but, in a few areas, there are deep erosion hollows with low scarp-like terrace edges. These are clearly maintained by sheep-rubbing and were mentioned in Elton's 1935 description. The locations of these erosion scars are shown on Fig. 3. They are normally above the 30 m contour and on the drier machair areas.

The machair thins out inland and uphill where it rests on top of moorland and bedrock. Partly as a result of ancient cultivation and partly due to small local changes in surface configuration, it is not possible to mark an exact boundary on any map or aerial photograph. There is nevertheless little doubt that some blown sand reaches more or less to the summit. There is also an impression that, although the general directions of drift was (or is) southeast to northwest, there was (or is) a marked tendency for some sand movement to have a net southwest to northeast direction. The sand appears to lie more thickly on southwest-facing slopes, and certainly reaches entirely across to the south part of the rocky east coast.

The distribution of blown sand as shown in Figs 2 and 3 was identified on black and white infra-red aerial photographs and shows a tendency for sand to be funnelled along the valley-like depression between the main hill masses and also to be carried up towards the summit of Beinn a Charnain and round onto the southeast-facing flank of the same hill

During the period of fieldwork (summer 1977) there was no evidence of continuing or active sand movements, but, in order to confirm that the machair is essentially stable and fixed by vegetation, it would be necessary to study the area under winter storm conditions. It is un-

Plate 8. General view of sloping machair on south side of Pabbay. Distinctive conical sandhills are easily distinguished by Marram Grass tussocks. In foreground is a typical eroding coastal section, (Photo: W. Ritchie).

likely that much sand movement can now occur as the surfaces (with the exception of the blowout and deflation areas) are completely vegetated and there would appear to be little or no exposed sand surfaces to nourish further sand migration. Moreover, the general level of grazing is moderate and there would appear to be no other disruptive factors.

CONCLUSION AND SUMMARY

The distinctive and important elements of this morphological study of Pabbay are considered to be as follows:-

1. Absence of rabbits — therefore it can be used as some sort of standard for comparison with rabbit-infested areas in the adjacent islands.
2. The presence of deer in the grazing stock.
3. The existence of distinctive high conical sand hills on the southwest-facing side of the main machair basin.
4. The fact that the beaches, dunes and machair face southeast to the Sound of Harris.
5. The known history of occupance and land use, including 19th century depopulation.
6. The existence of at least three inter- and sub-tidal terrestrial organic deposits with a stratigraphy that includes beach and windblown sand layers.
7. The general location of Pabbay in the Sound of Harris, facing Berneray and lying midway between Harris and North Uist.

All of these elements have considerable relevance to the general study of machair and related landforms. Pabbay provides a valuable area for comparative research. The importance of Pabbay in the wider study of coastal evolution in the Outer Hebrides (within which the study of machair is a basic element) rests on the existence of the inter- and sub-tidal terrestrial organic deposits and

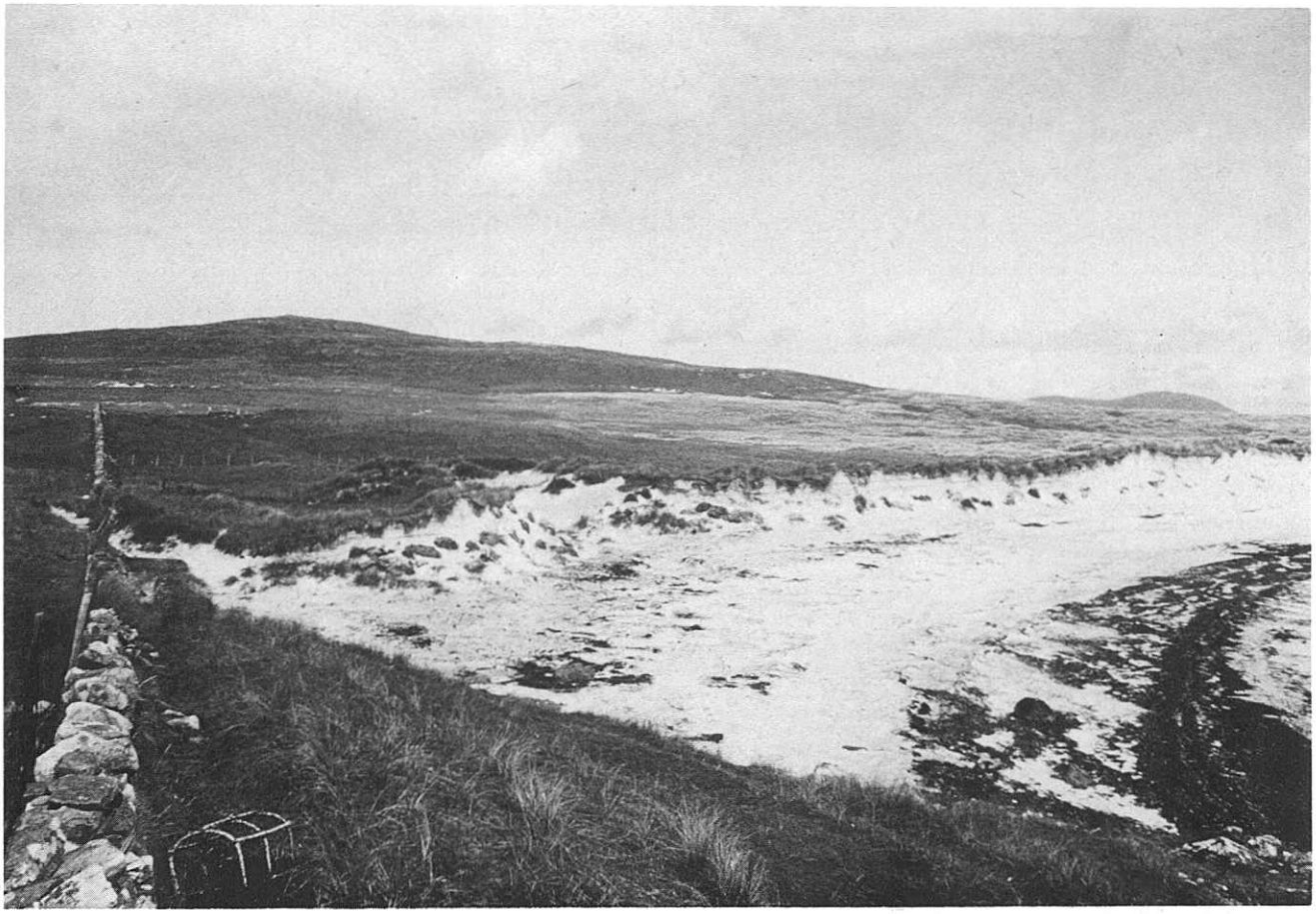

Plate 9. A general view of the south coast of Pabbay showing the eroding coastal edge, sloping and transitional machair and the zone of hillocks and conical sand hills to the right, (Photo: W. Ritchie).

also its critical location in a critical position between Harris, Berneray and the Uists.

ACKNOWLEDGEMENTS

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Towards an Integrated General Knowledge of Machair — the Need for Intimate Field Observation and the Real Demands of the Inter-Disciplinary Approach

I.A. Crawford

INTRODUCTION

This paper and the associated field visit were concerned with demonstrating the nature of the relevant archaeological, historical, linguistic, and oral tradition evidence, and the contribution these secondary fields (especially when closely scrutinised in primary sources) can make to environmental studies like those of the Machair Research Group. It is the stated purpose of the Group ' to improve communications between workers in the field of Machair studies, to encourage complementary' research studies ' (Ranwell 1977) and this objective is most desirable. However, it is becoming recognised that the trancendental virtues of holistic, interdisciplinary studies are frequently and piously extolled, but not so readily practised and especially, not with the depth, intensity and intimacy that significant research demands, difficult as this may be.

A recent work by the Nature Conservancy Council constitutes a case in point. This publication on the Outer Hebrides (Black 1977) seems likely to misguide future conservation policy in some fields. Certainly, the needs of geomorphology and geology were principally in mind, but an attempt was also made to incorporate information on land use and archaeology with the criteria associated with localities of Special Scientific Interest. Making all due concessions to the need to make haste before oil developments commence, these fields are so inadequately covered that they could lead to faulty appreciation of a site by a development authority. For example, the statement that 'there is a small amount of cultivation near Sollas but elsewhere the area is only used for cattle and sheep grazing' (Black 1977), is a travesty of the situation. This area is the summer outfield arable, winter grazing, and spring lambing ground for the Grenetote crofting township whose major single asset it is. Without it, the indifferent crofts of this area would not be viable. It has been farmed intensively and continously for centuries (at least twenty on the present writers evidence) and is the ***raison d'être*** for Grenetote.

As regards archaeology, the important Northton, Harris, deposits are not mentioned, it is stated that some field work takes place in summer at Udal (***sic***), N. Uist, and that at Rosinish, Benbecula, there is a 5000 year archaeological and geomorphological record making it a key site in the understanding of machair chronology and on which much more detailed work needs to be carried out.

Northton is badly damaged by erosion as are most if not all surviving machair sites, and has been the subject of Department of the Environment (Ancient Monuments Division) salvage excavation (Burleigh ***et al.*** 1973 and Simpson in press), but important deposits do remain ***in situ***. The Udal site referred to vaguely, contains the most important and extensive repository of archaeo — environmental and occupation levels presently known in Scotland and indeed further afield. Research excavation has been continuous since 1963 and much information is still awaiting retrieval (Crawford and Switsur 1977). It is a site of national interest and therefore worthy of protection.

At Rosinish, very much slighter evidence in both extent and chronological scope (Crawford 1977) has been severely eroded to the point where excavation was questionably worthwhile. This site has been the subject of a Department of Environment salvage excavation (Shepherd and Tuckwell 1977) now discontinued. The Machair Research Group's own papers show many instances of the limitations of fast survey techniques. For example, the adaptation of the fulmar to machair erosion-face nesting is termed 'almost certainly only possible on the Monachs' (Hepburn 1977), but eggs and nesting females have been visible on the Traigh Iar, north of Sollas (North Uist) for some years.

The polemical opening to this paper is intended simply to draw attention to these shortcomings in machair studies. The rest of the paper seeks for rectification and the need for experience sharing to establish profitable fields of contact and to tap available and potential sources of information. These objects and aims were stimulated by the Machair Group's field trip on July 16th 1978 to the Udal deposits.

The fields of study indicated above; documentary research; linguistics (Gaelic and Norse); field archaeology; oral tradition, and contemporary observation offer information of direct relevance to the geomorphologist and the geographer, though only sparsely and indirectly (apart from archaeology), to the botanist and zoologist. Most commonly, this information consists of observation of aeolian and maritime restructuring and the chronology of such events.

DOCUMENTARY RESEARCH

Local documentary history is much more limited in Scotland (especially in the West Highlands) than in England. Resources and personnel have not been available and where estate records, the major source, have survived they are generally uncatalogued and difficult of access. Secondary sources such as the Statistical Accounts (Sinclair 1794 and Anon 1845) are informative but restricted in range and relevance. For the Western Isles machairs, the best potential sources are the Con-

tullich papers (MacLeod of Harris) and the Ostaig papers (MacDonald of Sleat) – the latter covering N. Uist. These papers have only been worked to a limited degree and certainly not for the purpsoses of recording the minutiae of environmental change. The Contullich papers for example (Crawford 1967) contain details of the ravages wrought by the devastating storm in the Sound of Harris in 1697 when many townships in Pabbay, Berneray, and probably the Udal in N. Uist, were wiped out. This example of course is in the context of the known climatic deterioration during the last decade of the 17th Century. The basic historical research has yet to be undertaken to make this information available to environmentalists.

In tradition and personal observation, however, much is available. Throughout the Hebridean machairs, there is very long-lived tradition extending encyclopaedically over the last six generations and often far beyond. Details of physical phenomena peripheral to the main corpus of historical narrative, and songs etc. are widespread. Close questioning at parish level can elicit closely observed accounts of sea cuttings, general coastal change, and the deflation of machair hills. Present observers can testify to the appearance at least of the mechanics and dynamics of change, even if they themselves cannot fully interpret what was seen.

LINGUISTICS

The Gaelic vocabulary and phraseology contains detail and diversity which has hardly been explored, but is readily accessible to the right approach. Institutes such as the School of Scottish Studies (Edinburgh University) exist to handle such matters and in the vernacular. The nub of the problem is that there is a distinct reluctance to ask questions locally or an ignorance of who or how to ask, leading to an unfortunate divorce between field researcher and an informed local population. The vocabulary that exists might well be technically usable (as the physiographic term geo or geobha (a narrow, coastal and tidal, rock cleft) Gae-Norse already is). Contrary to some opinion (Gimingham 1974), machair is a clear concept in Scots Gaelic. The general usage is as given by the term ***plain*** in English (the Lowlands of Scotland were so called until recent times). A more specialised meaning is coastal sand plain and this is at least Late Mediaeval in origin, as place names testify e.g. Machrihanish and the Makars of Galloway. The vocabulary includes coileag (the characteristically shell-shaped erosion bunker), siaban (light living-blown sand) and tolamhaich (sand that is becoming land). There are observations on heavy 'old' sand, referring to the heaviness of machair under ploughing (not the light easy tillage this writer once thought). A typical phrase recorded indicates both mechanics and a datable and locatable happening. Thus, the Aird A'Mhorrain (O.S. spelling) machair is said to have been a sandy strand in the early 19th Century – 'agus chaidh i na machaire's e sin machair Ghreinetobht an diugh, faisg air Aird A'Bhorrain' (and then became machair – literally went into its machair – that is the machair of Grenetote today near Aird A'Mhorrain). Again the field is under-researched, but the material is available. Place names too are available – many more than appear (not always accurately), on the 6 inch Ordnance Survey maps and they too indicate physical change and over a long period, up to 1,000 years. Thus, the machair island of Kirkibost, N. Uist was unlikely to have been an island in 800-850 A.D. when Norse migrants named it, though the adjacent island of Illeray (now usually Baleshare) must have been an island then with its 'ay' terminal. Baleshare itself the principal township on Illeray means Eastern township and this does imply the former existance of a Baleshiar (Western township) now vanished, if so, by erosion between the 12th and 16th Centuries A.D. after the reintroduction of Gaelic and before detailed documentation. The Place name survey (Gaelic) at Edinburgh University has a large archive which is available to research enquiry.

ARCHAEOLOGY

Finally, there is archaeology and this is the best equipped of the disciplines under discussion to answer environmental questions, and over the longest time span – theoretically 10,000 years in this region. Here, unfortunately, the battery of new dating and analysing techniques now available cannot overcome the vast deficiencies that, in addition to normal aerial deflation, have developed owing to rising sea levels and local redeposition. Field survey does suggest that, barring a few exceptionally favourable locations, almost all the evidence for past machair settlement has vanished. It is quite possible that, by the next century, nothing will be left. We are perhaps rather fortunate that the growth of 'scientific' archaeology should have anticipated this disappearance, though less fortunate it has done so by so small a margin. In this connection, an attempt is being made at the Udal site to conserve a small representative sector of midden deposits to be available for sampling by techniques yet undeveloped. Environmental information potential of machair archaeological sites has been dealt with elsewhere recently (Crawford 1978) and will not be further detailed here. Suffice it to say that much can still be done, and indeed must be done; for example, in calibration of dating of machair change, in estimating time of machair appearance (e.g. old 'high'

machair, modern 'low' machair), in separation of all carbonised seeds (not merely cereal) by flotation techniques from midden deposits, and in studying the preservation of faunal as well as floral remains to give really comprehensive results. The archaeologist is the only researcher who can provide tangible evidence of datable former environments by his attempts to replicate them. It is probably what he does much the best, though all too rarely, and not always to the highest scientific standards

SITE VISIT TO THE COILEAGAN AN UDAIL DEPOSITS (Plate 10)

The main interest developed on this visit, apart from the opportunity to view the landscape formations responsible for the retention of such a uniquely long collection of old environmental horizons (in West Highland terms at least), was the nature and interpretation of sand deposition evidence and associable human involvement. Here, it was salutary to discover that virtually no-one present, and this included the few archaeologists, had anything like a comprehensive knowledge or experience of phenomena observable in sections cut or natural. A few loaded questions and naive answers confirmed this fact The geomorphologists were of course the strongest in this field and especially on 'natural' evidence. Marks in eroded sand surfaces and profiles caused by human interference such as ploughing were clearly a novelty to most members, though they can be observed widely on the machair Some excitement was occasioned by the inspection of a 1970's blow out which has exposed ploughing of probably 50-100 years in plan; and in characteristic dash dash section (///) easily visible when a dark organic horizon (not necessarily that of the ploughing period itself) is cut and sandwiched between layers of white sand. Much less easily observed (and clearly no field worker has done so, the opportunities being scarce) are old 'invisible' ground surfaces. These were a revelation to the present writer some years ago – like invisible ink they become manifest only in the right conditions of temperature and light such as hardly ever prevail in summer when most field work takes place. Especially under a moderate dry blow (say force 5 Beaufort scale), and on a gently inclined surface (say 1:50), exposed old sand deposits will begin to strip preferentially to slightly harder crusts. Sometimes, two or three successive individual ones will be visible simultaneously (but only for a few hours) giving the general effect of wood graining as seen in oblique plan. Apart from their slightly greater durability, these horizons are not visible in colour or texture, only their ***effect*** is visible. They are only rarely detectable in vertical sections – usually as a result of tracing surface forms thereto. It might be questioned if these observations are significant, whether these ***are*** old surface horizons, or, if so, whether they are of any more consequence than the myriad black siliceous horizons that indicate probably one day's severe blow. Fortunately, by close continuous observation, it has been possible to trace a number of such levels across the Udal site for distances up to 25 metres, to a point where they start to colour up faintly with occupation enrichment and become visible ground horizons, sometimes pronouncedly so Furthermore, an experiment carried out on the site of burying a good substantial turf line (no occupation material incorporated), for some fifteen years and then re-exposing showed this had become virtually undetectable after even so short a time The points that emerge are: how little we yet know of machair micro-physical phenomena; how easily evidence can be missed; how superficial an emergency field survey must inevitably be and, certainly at archaeological level, what a long apprenticeship needs to be served before such a matrix can be reliably interpreted.

The Udal site No. 6 (Crawford and Switsur 1977) provided considerable inter-disciplinary discussion. Here, a Bronze Age cairn system lies in the shore face, resting on a fine shingle spread which in turn covers earlier Bronze Age levels A section was cut through this complex by the exceptional tide of January 1974 and some urgent salvage excavation was carried out (Crawford, ***in press***) The original interpretation was that this was an artifical, human-laid platform. However, further consideration of the facts: that it spread beyond the cairn complex; had cists cut through it; lay at a level conformable with the observable high tide wash of 1974, and had no comparative corroboration in archaeology (not the most convincing argument given the paucity of evidence), suggested it may have resulted from tidal overwash on an exceptional tide. Geomorphologists and archaeologists divided on this issue on the lines indicated above, but neither side communicated sufficiently to convince the other. It would be very instructive in principle to have an issue like this argued to a conclusion in appropriate circumstances. Another feature of the Udal deposits is that the 15 levels visible on the Udal North (Late Iron Age to 17th Century) could often be distinguished in colour, even where convenient white sand 'spacer' levels were not present. The reasons for this, and anaerobic conditions were certainly one, would be most interesting to establish.

CONCLUSIONS

In the writer's view, if the Machair Research Group's efforts are to earn the plaudits its approach clearly

Plate 10. The Udal, North Uist, Outer Hebrides. The 'fossil' landscape of high machair at the Udal retained by two tells of occupation deposits, the Udal North on the right, the Udal South on the left, and by the rock headland Rubha an Udail centre background. In the foreground; low contemporary machair under cultivation, (Photo: I.A. Crawford).

deserves, and make good the idea that 'solutions to present problems will only be found by co-operative effort and by the application of conservation in the fullest sense ..' (Dickinson 1977), then it must encourage positive results. Finite points of direct interdisciplinary contact must be established and problems thereat solved, even if it be at the tidal wash versus archaeological waste level mentioned above. Scientific rescue survey has much in common with archaeological salvage: it is necessary, hasty, superficial, and tends to be unproductive in terms of coherent research. Perhaps now that machair studies are actually on the map some precise foci of mutual concern might be actively developed beyond the evanescent distraction of annual conferences and passing field trip voyeurism The criticisms offered here are that recent emergency survey on the Western Isles machairs has been cursory (though perhaps necessarily), that sources readily available have not been tapped, and that insufficient cross-disciplinary collusion has yet taken place. As a result, information has been published which could well cause conserving authorities to mis-assess priorities. All this, if true, can readily be rectified at this stage – hence this paper.

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The Archaeology of the Rosinish Machair

I.A.G. Shepherd

INTRODUCTION

The Rosinish machair, located on the north-east coast of Benbecula, comprises a relict area of machair hills rising to 16 m + O.D. (Newlyn). Its archaeological potential was recognised in 1964 during the salvage excavation of a Bronze Age burial structure (Crawford 1977). Excavation by the writer and Alexandra N. Tuckwell (now Mrs. I.A.G. Shepherd) between 1975 and 1977 on behalf of the Inspectorate of Ancient Monuments of the Department of the Environment, concentrated on the earliest features present, namely two areas of Beaker-period (*c.* 4000 B.P.) middens and underlying ploughsoil (Shepherd 1975, 1976, 1977; Shepherd and Tuckwell 1974, 1977, 1979, Tuckwell and Shepherd 1976)

The general morphology of the Rosinish area is illustrated in Fig 4. The sand supply for the Rosinish machair hillocks comes from a parent beach lying to the north, and this is the easterly extension of the sand floor

of the North Ford which separates Benbecula from the island of Grimsay.

The direction of sand accumulation at Rosinish appears to have been from north west to south east, subject always to the control exercised by the north west/south east grain of the underlying ridges of Lewisian gneiss. Textural analyses of sand samples from four widely separated locations gave no indication of differences in the sand supply. This result suggests a single, main shell sand source, and frequent redeposition in a series of closed cycles (after the initial influx of sand in pre-Beaker times). A complex series of shell sand accretion and deflation interludes has been inferred from the exposed hillock faces. Augering revealed that the Beaker site, Area II (North Hillock), was established on over 2 m of blown sand in which were two or three organic layers, indicating that machair evolution at Rosinish was well underway by 4000 years B.P. The other Beaker site, Area I, is more low-lying and would have consisted Initially of low grassy slopes on the banks of a tidal inlet (Fig. 4). At the south end of the area shown in Fig. 4, several periods of sand-blow and traces of former surface stability could be discerned between the Beaker and the upper Iron Age (*c.* 2000 B.P.) deposits. The evidence for the post-Iron Age development of the Rosinish machair is varied. There is over 2 m of sand build-up over the Iron Age levels at the north end, but much less in attenuated deposits on a truncated Iron Age surface at the south end.

AREA I

When first seen in 1974, during the preliminary survey, this area consisted of over 300 square metres of midden deposit, or organically-bonded sand and cultural material (pottery fragments, quartzite flakes, pumice lumps etc.). This deposit formed a bench, *c.* 35 m by 13 m and up to 1.3 m thick, lying seaward from the base of the main hillock-ridge. Wind action was truncating the deposits vertically and laterally, the former process producing on the midden surface an enriched scatter of (principally) shell, pottery, and quartzite.

The first main season of excavation was carried out in 1975 on a ten per cent random sample of one meter squares. This excavation was designed to distinguish important activity areas, and to produce a viable sample of cultural and environmental material (Shepherd 1976, see page 212 fig. 11.2). The principal result of this campaign was the recognition of cultivation evidence in the forms of ard (early plough) marks in 44% of the sample squares and the recovery of carbonised cereal remains from 50% of the squares

The 1975 sampling was followed by two seasons in which *c.* 100 square metres of cultivation evidence were examined by area excavation. The ard marks appeared in plan as dark lines of sandy humic material *c.* 70 mm wide and up to 70 mm deep. In section, they were often assymetrically V-shaped, with one side vertical and the other curved (Shepherd 1976, see page 214 figs 11.4, 11.5), reflecting the angle at which the plough stilt has been held. They occurred in a humic horizon *c.* 100 mm thick and were most visible when the upper parts of this layer had been stripped-off and the bases of the furrows revealed as dark lines against the white sand subsoil (Plate 11). Analysis of the land snail fauna from this ploughsoil revealed a very limited range of species compared with other old land surfaces. This evidence suggests that the humic content of the ploughsoil may well be derived from manuring, rather than from natural processes of soil development (Dr J.G. Evans and M. Vaughan, ***pers. comm.***).

Several interludes of ploughing could be discerned from the orientations and intersections of the ard marks in the 'ploughsoil' and in a 100 mm thick sand-blow which overlay the humic surface. This sand-blow was itself covered by midden material, at the base of which were further ard marks. Midden material, pitched stones, and pottery sherds compacted into furrows demonstrated that ploughing had continued through the base of the primary midden, which may have originally been deposited in an attempt to consolidate the sand-blow. A shallow ditch dividing two lots of cultivation was revealed in one area. It was *c.* 4.5 m long, from 0.5 to 0.7 m wide, and 0.3 m deep (Shepherd and Tuckwell 1979, see fig. 2 and page 112).

The ploughing through the base of the primary midden was abandoned and a dense, dark sandy midden was then laid down over much of the site. This deposit was subject to erosion from the north west which produced a cigar-shaped blow-out *c.* 25 m long. Deposition of a lighter-textured midden, partially interrupted by further erosion then took place. This secondary midden was laid down during a period of considerable sand instability, indicated by a high proportion of sand to organic debris in the deposit.

This cultivation evidence from Rosinish is among the earliest and most extensive from Scotland: it is dated by two samples of ***Patella vulgata*** (limpets) from the primary midden and the ploughsoil to 3850 ± 75 b.p. Glasgow University (GU), Radiocarbon laboratory reference number, (GU 1064) and to 3920 ± 60 b.p. (GU 1065) respectively. It is possible that the use of shell for dating (dictated by the lack of bone material), and the presence of peat charcoal in the middens, renders

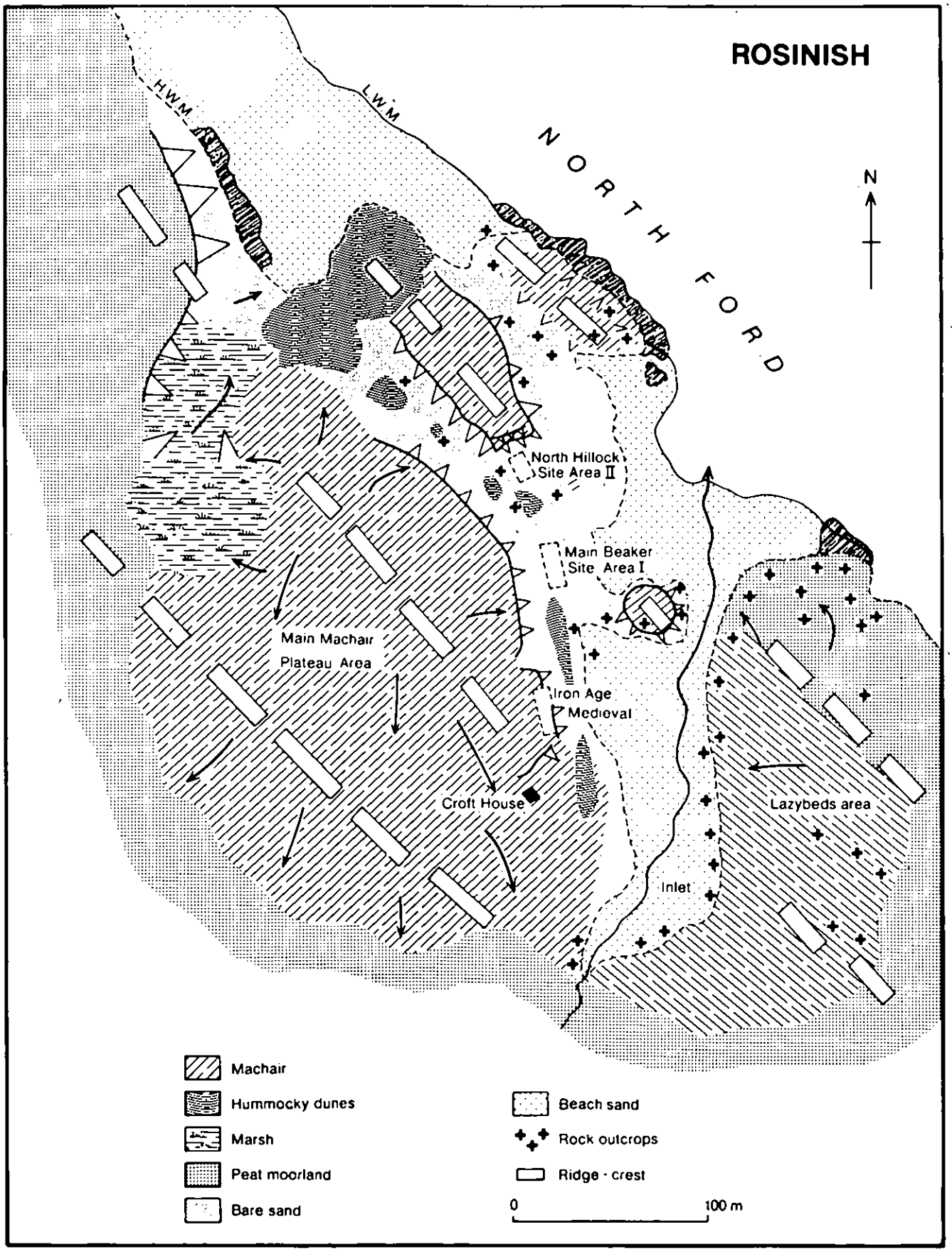

Fig. 4. The geomorphology of the Rosinish machair (courtesy Dr. W. Ritchie).

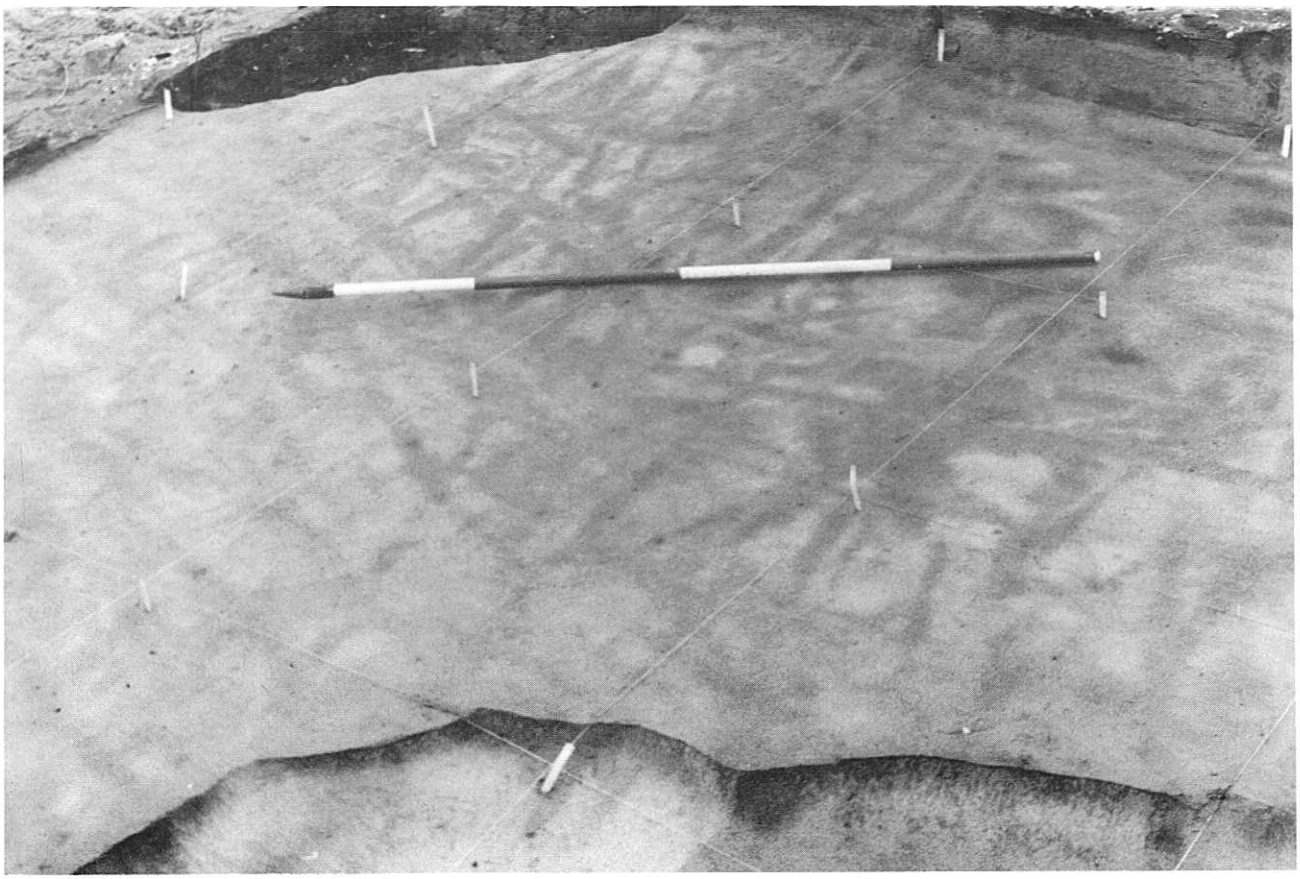

Plate 11. Basal early plough (ard) marks c. 4000 B.P., Rosinish, Benbecula, Outer Hebrides. The ranging pole (2 m long) gives the scale, (Photo: I.A.G. Shepherd).

these determinations some 300 years too early (Dr. M. Stenhouse, ***pers. comm.***).

Wet sieving of at least 15 kg of material from each layer of each one metre square opened in 1975 recovered carbonised cereal grains. The 170 grains examined to date consist of 95.3% raked six-rowed barley; 1.8% hulled six-rowed barley and 2.9% emmer (C. Maclean and P. Rowley-Conwy, ***pers. comm.***). A small amount of animal and some fish bone was also recovered. Cultural material found in Area I included many hundreds of sherds of Beaker pottery showing a wide range of fabrics and forms. They are largely characteristic of Clarke's Early Northern series (Clarke 1970, see pages 153-75), although some sherds from the primary midden are closer to Neolithic decorative techniques (e.g. Shepherd 1976, see page 212 fig. 11.3). The upper midden produced large shouldered jars similar to those from the Bronze Age machair site at Kilellan, Islay (Burgess 1976, see page 196 fig. 10.6). The lithic assemblage at Rosinish is dominated by locally available quartzite flakes (cf. the use of banded mylonite at Northton, Harris (Simpson 1976, page 224), and they are currently the subject of micro-examination for edge-damage. A few beach pebble flint tools such as thumbnail and end scrapers were also recovered.

Activity areas recognised included patches of fire-marked sand, small pits, a stone-walled shelter, a burial area, and a large multi-period shell dump consisting of layers with varying proportions of limpets, winkles and mussels, possibly reflecting (? seasonal) choices in line-baiting. In summary, this part of the Rosinish machair was put to a variety of uses over a period of possibly as much as several hundred years: these uses included cereal cultivation, rubbish disposal, line-baiting, and burial.

AREA II

This area lies *c.* 40 m north of Area I (Fig. 4) and deposits consisted of a partially-eroded stump of midden *c.* 6 m by 6 m and up to 0.35 m thick, overlying a layer of burnt clayey-sand, which in turn covered an unconsolidated sand surface. Traces of five possible stake holes were found beneath the midden near its centre. These, together with several small fire pits, suggest some kind of temporary shelter. One large pit, 1.2 m in diameter and 0.9 m deep, was found to contain large quantities of food refuse in the form of marine mollusca (limpets, razor, and oyster shells), crustacea (crab), some fish bone, and the bones of sheep, cattle, deer, and dog as well as some fragments of egg shell. Early Northern Beaker sherds and a thumbnail flint scraper were also recovered from this area.

AREA III

This site lies 70 m to the south of Area I (Fig. 4, site marked as Iron Age - Medieval), 1 m below the present surface level of the machair hill and *c.* 8 m above Area I.

A light sandy midden 0.2 m thick, containing some sherds of 9th to 11th century A.D. Viking Age type (A. Lane, ***pers. comm.***), gave onto a highly humic midden, 0.2 m thick, containing Wheelhouse pottery of 2nd and 3rd centuries A.D. The surface of this Wheelhouse-period layer had been eroded in antiquity.

OTHER EVIDENCE

Radiocarbon C14 determinations for a sample from the base of a layer of peat from the opposite (east) side of the tidal inlet to Area I of 4350 ± 60 b.p. (GU 1132); and one of 995 ± 50 b.p. (GU 1133) for a layer of peat overlying *c.* 1.7 m of blown sand on a 30° slope on the side of a small bay *c.* 400 m to the SE of Area 1, have been received recently. GU 1132 indicates a comparatively early start to the growth of blanket peat in this area and emphasises the primary role of machair in early Hebridean agriculture and settlement. The sample GU 1133 is also interesting as, in conjunction with the scoured surface of the Iron Age midden found to have ninth to eleventh century A.D. material sitting directly on it, it may indicate a period of marked climatic deterioration at the end of the first millennium A.D. (Dr. G. Whittington, ***pers. comm.***).

Sites comparable to Rosinish in the machairs of the Western Isles are rare. Pre-Wheelhouse (*c.* 1750 B.P.) settlement areas appear to be limited to such Beaker sites as Northton, Harris (Simpson 1976); Isle of Ensay (Evans 1979, page 24); Coileagan an Udail, North Uist (Crawford & Switsur 1977); Paible, North Uist (Maclean ***et al.*** 1978), Rosinish, Benbecula; and Gortan South Uist (Shepherd ***et al.*** 1978). However, the relative ease with which Beaker pottery can be recognised, compared with the absence of diagnostic features in pottery collections from other Hebridean non-Wheelhouse machair sites may represent an important bias in the data. The Rosinish cultivation evidence is perhaps best paralleled at the multi-period site at Sumburgh, Shetland (Lamb 1974, see pages 87-8). Work on the final publication of the excavations at Rosinish, summarised here, is now in hand.

ACKNOWLEDGEMENTS

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Biological Influences in some Units of Sand Dune Landscapes

D.S. Ranwell

INTRODUCTION

Vegetated dune landscapes can be subdivided into distinctive topographic units created or modified by biological activity. For example, we can distinguish dunes, and damp hollows (slacks), salt-affected zones, lime-rich and lime-deficient zones, and easily distinguishable hummocks, warrens; or gulleries intimately associated with individual species of plants or animals. There are also cultivation units like grazing paddocks, arable fields and forest plantations, associated with human activities.

Study concentrated on particular types of unit can help us to understand processes and time scales at work in dune landscapes and gain information of practical use for their management. Units considered briefly here include: the strandline; the dune mound; the dune ridge; the rabbit warren, and machair old field.

STRANDLINE

The strandline is a linear unit formed of sand and tidal litter cast up by the sea. Where blown sand accumulates on it, the level may be raised free of wave disturbance. If this occurs for a sufficient period of time for annual plants to complete a cycle of growth, they may trap enough blown sand to raise the level permanently above sea level. It is therefore the critical level where plants have an opportunity to gain mastery over a salt-affected, potentially mobile, and immature soil.

Strandlines are essentially ephemeral in space and in time. A vigorous strandline flora is unlikely to persist on a particular shoreline for more than a few decades because it either gets washed away, shifts gradually with cyclic chordal adjustments of bay deposits, or becomes engulfed in the coast dune it helps to create. There is little information about how long strandline floras actually do persist at sites. The vigorous strandline vegetation at Morfa Harlech (Merioneth) illustrated in Salisbury (1952, see Plate 22) was converted to dune in little more than a decade or so. Elsewhere, at Ferry Links (East Sutherland) for example, vigorous strandline vegetation may not be associated with dune formation, and may be more persistant. Mather (***pers. comm.***) suggests, "that one of the variables influencing strandline vegetation is the role of the beach unit as a debris catchment area — with strandline vegetation tailing off with too little or too much debris." This role may be much less important in dune building, where blown sand supply is a key variable.

Most Hebridean shores are accessible to stock which graze and trample strandline vegetation; most southern shores are heavily trampled by people. It is possible to find quite vigorous growths of ***Cakile maritima*** on some of the most heavily used recreational shores in Britain, for example at Caister in Norfolk. People tend to avoid an established strandline growth, but cattle do not, and they actively graze and damage such dominant strandline species as ***Cakile***. Some of the best current strandline growths seem to occur on shores adjoining golf courses (e.g. Ferry Links) or aerodromes (e.g. Macrihanish, Argyll) where grazing is controlled. The harmful effects of trampling and grazing on strandline vegetation could be significantly delaying dune formation and therefore increasing coastal erosion risks in the Outer Hebrides, so this would be a useful line of study

DUNE MOUNDS

Many plants in different parts of the world are capable of building dune mounds. They are one of the most characteristic and universal small scale units of the dune landscape. Such mounds are built in South Africa by sea wheat (***Agropyron distichum***). On the eastern North American seaboard they are built by American beachgrass (***Ammophila breviligulata***), while sea oats (***Uniola paniculata***) and ***Panicum amarum*** take over further south on the Gulf Coast. ***Sand spinifex*** (***Spinifex hirsutus***) builds mounds in Australia and New Zealand, and in Europe so do marram (***Ammophila arenaria***), sea lyme grass (***Elymus arenarius***) and sand couch grass (***Agropyron junceiforme***). It is the last of these that is discussed here because it is believed it has particular significance in helping us to interpret the origin of certain types of machair landscape.

There are rather few dune systems in Britain where isolated actively-growing sand couch grass mounds can be seen at the present time. In Scotland, they occur well to landward of a sand flat behind the storm beach at Europie in Lewis, on the high level sand flat near Northton in Harris, and on sandflats of prograding systems like Morrich More, Easter Ross and Tentsmuir, Fife. These very different situations have the following characteristics in common: they are damp to dry sand flats near high water mark spring tides not long isolated from (or even still liable to) occasional tidal flooding, and they occur near the seaward limit of dune systems. In this latter respect, they differ from the more landward, secondary damp slack sand surfaces with a fresh water table recently exposed by the passage of wind eroded parabolic dunes or dune ridges within a dune system. Sand couch grass captures wind blown sand and raises the level locally in very characteristic low circular mounds, 5 m or more in diameter, which stand out of the sand plain. A rare sedge (***Carex maritima***) is a characteristic colonist of the open damp sand between the mounds in North Scotland, and forms a very ephemeral plant community (like strandline vegetation). Once the sea is excluded by a natural barrier (or by isostatic adjustment), the damp sand between the sand couch mounds becomes very rapidly colonised by typical damp slack species like creeping bent (***Agrostis stolonifera***). These lock the dune mounds into a landscape highly reminiscent of hummocky machair superimposed on a flat plain. If this interpretation is correct, we might consider that the extensive hummocky machair we see at places like Baleshare could indicate sites of former sea overwash and subsequent rapid recolonization. Whether these resulted from unusually severe storms, or whether from isostatic adjustment and relative uplift of former foreshore areas, or both, are intriguing questions. They seem to indicate conditions of origin in the past that are not commonly found in the Hebrides today. Possibly recognizable buried fruits or rhizome fragments of the now rare ***Carex maritima*** might be recoverable from the peaty deposits in the damp slacks between mounds in this type of hummocky machair – it might be worth looking. One consequence of this hypothesis is that the mounds, which must have formed in a short time in conditions of limited sand feed, are likely to be little older in time of colonisation than the sand flat between them (cf. Ranwell 1975 p. 384).

DUNE RIDGE

Three perennial grasses are the main builders of coast dunes in Britain. Two of them, sand couch and sea lyme grass, can build dunes at a vertical rate of about 0.5 m per year; the third, marram, can do so twice as fast, up to 1 m per year. However, conditions of sand supply and wind erosion rarely allow the maximum rate of dune building to be expressed. Unlike the sand couch grass mound, which probably takes less than a decade to build, and strandline vegetation which rarely persists in one location for more than a decade or two, growth to maximum height of a coast dune ridge can take between half a century to a century on British coasts.

Once the dune-building grasses colonise the embryo dune formed by strandline vegetation, and providing there is adequate sand feed, strandline vegetation will be engulfed by the increasing basal width of the growing dune. It may not reappear (except as sporadic plants) for a very long period of time. The initial colonisation by these dune grasses on the East Anglian coast seems to be very largely by regeneration from fragments, but seedlings of sand couch grass have been seen in the first week of July locally on Scottish strandlines (e.g. at Tentsmuir, Fife). Marram is much less tolerant of salt than the other two grasses so only gets a hold when the level has built up above high water mark. Tidal flooding does not necessarily kill sand couch grass. After the tide had ripped off surface growth at Holkham (Norfolk) in January 1978, sand couch grass grew again strongly from shoot bases and rhizomes still ***in situ*** in shore sand (Harris, D. – ***pers. comm.***)

No one, so far as I know, has attempted to calculate the sand feed from the shore and compare it with the sand catch of a growing marram dune. Nor do we have measurements to tell us how it happens that dunes reach different maximum heights at different places within and between sites. Mather (***pers. comm.***) comments, "The relationship between exposure and dune

height is a very complex one. It seems that where wind direction is consistent, or where strong exposure is in one direction only, dunes tend to be low (e.g. Oldshoremore, Sutherland), and, conversely, that where there is exposure to two or more strong wind directions (e.g. Sinclair's Bay, Caithness or Feall Bay, Isle of Coll), dune height and dune steepness increase."

The time inevitably comes when marram at the crest of the ridge no longer traps as much sand as it loses in the wind conditions that prevail at the critical elevation. Then; the ridge (or a parabola of it) can begin to move inland at horizontal rates up to 10 m per year in Britain, smothering slacks to leeward and creating new slack surfaces to windward. The base of the lee slope of the coast dune characteristically develops another type of hummocky machair, this time formed on an inclined plane. It may result from the rejuvenated growth of dune slack shrubs like ***Salix repens,*** growth of ***Ammophila*** from seedlings, or renewed growth of the small 'counter dune' ***Ammophila*** patches left by variable parabola passage in the floor of the slack. The landward movement of whole ridges in a large exposed dune system like Newborough Warren in Anglesey may continue for several centuries under the influence of south west prevailing winds on an exposed shore. Ultimately, the ridge comes to rest in more sheltered landward regions and the vegetated dune is levelled by the slow natural processes of aerial weathering which may continue for thousands of years. Similar long term ridge movement inland is thought to occur on the South Uist machairs (Ritchie – ***pers. comm.***), and the ridge finally becomes dissipated into the line of lochs at the landward limit of the machair, as parts of the Newborough Warren dunes have done at Penlon lake.

WARREN

Not all parts of dune and machair systems are suitable for rabbit warrens. Mobile dunes are too unstable and burrows cave in. There has to be at least 1.5 m of sand above the maximum height of the winter water table level for warrens to persist. Much of the Bettyhill (Sutherland) machair is too thin over rock for burrowing, and the greater part of the Loch Bee (South Uist) machair is too wet for effective development of warrens.

Parts of Barvas (Lewis) and Melvich (Sutherland), however, had some of the most intensively burrowed warrens seen in any of 72 dune systems visited in Scotland in the period 1975-77. At both sites, burrow collapse, wind erosion, and eat out of palatable species seemed likely to lead to such warrens becoming uninhabitable. Rabbits are essentially back-door gardeners and do not normally graze far from warrens, so grazing intensities are likely to be closely related to radial distance from warrens. Results from rabbit exclosures studies can be very misleading if this effect is not taken into account. Rabbits do range more widely in cold weather when the nutrient-rich shoot bases of strandline grasses like sand couch may be a vital food resource. At the present time, rabbit populations on dunes are fluctuating rapidly from year to year as a result of recurrent myxomatosis. I believe we are likely to get more meaningful estimates of rabbit influences on dunes by deducing potential population maxima from censuses of potentially warrenable ground and burrow densities than from difficult and time-consuming direct measurements of rabbit populations at any one time.

The efficiency of traditional methods of rabbit control was clearly demonstrated at Macrihanish (Argyll), where it was estimated that some 10,000 rabbits infested the site prior to 1954 when myxomatosis became active in Britain (Colville and Gibson 1974). A pair of adjoining air photographs of almost identical warrenable hummocky machair taken on the same day in 1951 (Plate 12) show intense burrowing activity seaward of the aerodrome (where rabbits were not controlled), side by side with almost burrowless ground opposite the golf course, where they were regularly controlled by Campbell town trappers.

Once rabbit activity has created sand cliffs in machair, these continue to erode and can lead to blow-outs 10 m or more deep, as at Oldshore More (Sutherland). Studies on the sequence of physiographic and vegetation changes associated with dune warrens, and on desirable rabbit population levels and how to achieve them, would be of particular value to dune managers.

OLD FIELD

In many parts of North America (e.g. South Carolina) one can see all stages of old field recovery from former cultivation. Succession starts with herb-rich swards and leads on to secondary forest. There is a whole school of ecological studies on these North American old field successions.

The Hebrides is one of the few areas where old field successions (up to a century or more old) can still be seen in the British Isles. Few areas are more richly endowed with colourful flowering plants than these old field sites in Hebridean machair and they attract tourists from many parts of the world.

Plate 12a. Hummocky machair intensively rabbit-warrened where rabbits were left uncontrolled opposite aerodrome, Macrihanish, Argyll, June 1951, (Crown Copyright).

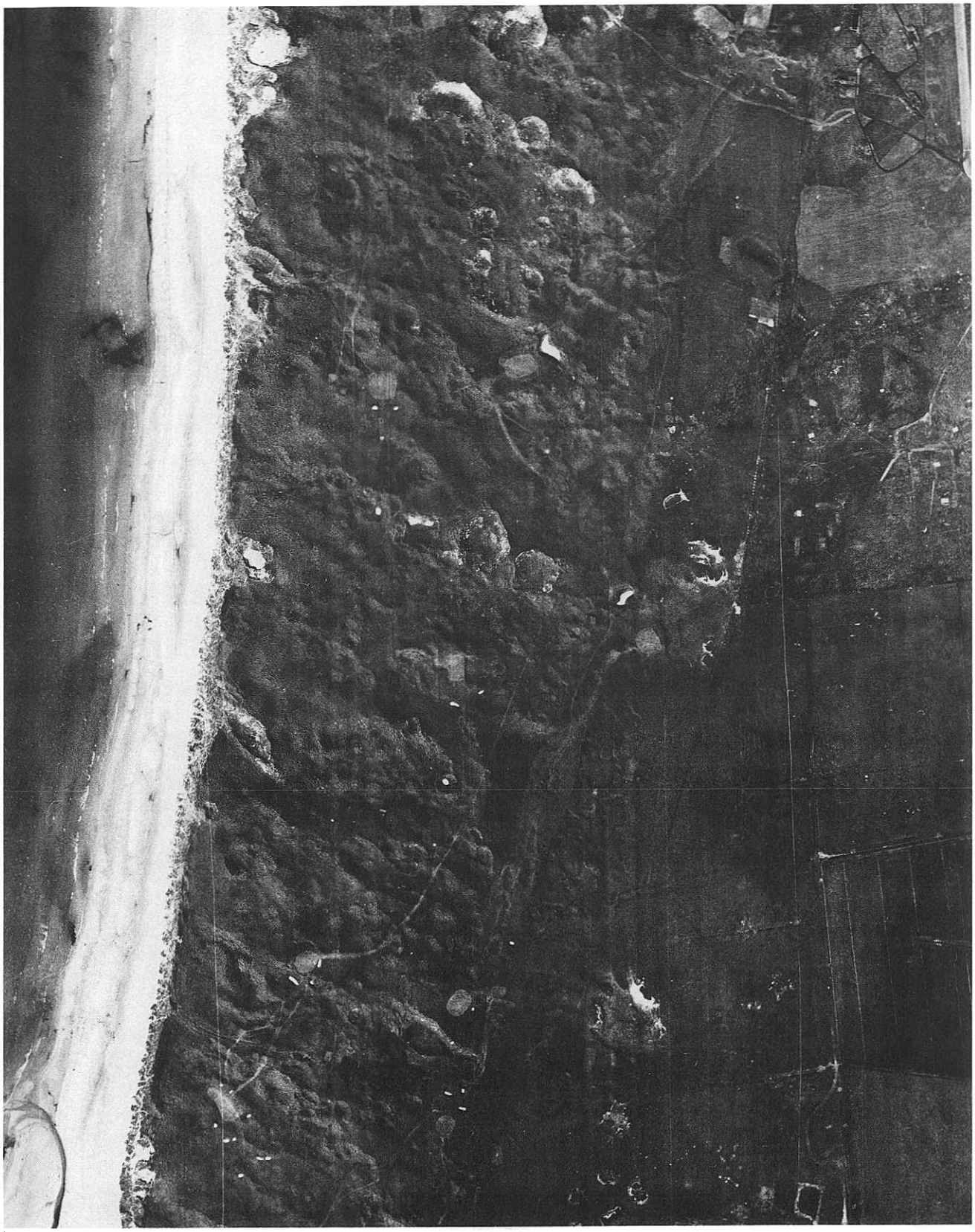

Plate 12b. Adjoining hummocky machair almost free of rabbit warrens where rabbits were regularly trapped to protect golf course, Macrihanish, Argyll, June 1951, (Crown Copyright).

Available evidence suggests it takes about 30 years for the commoner marsh orchids to establish in formerly cultivated machair and about 100 years for almost the full uncultivated machair flora to return.

Study of succession and soil development in these old field sites would provide valuable information for the management of nature reserves on machair, for the dating of buried soil horizons in Scottish dune systems, and for studies on the origin and development of one of our most ancient weed floras.

CONCLUSIONS

Five dune landscapes units, and problems of practical interest associated with them, are discussed. The following priority areas of study are identified: –

1. Rabbit warren distribution and evolution in relation to rabbit density and dune vegetation.
2. Influences of cultivation on the development of machair soil and vegetation.
3. The role of stock trampling on strandline vegetation and its impact on coast erosion.
4. The interpretation of historical dune landscapes, from a study of vegetated dune mound development.
5. Factors controlling the growth of vegetated dunes to maximum height.

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A Bibliography of Machair

W. Ritchie and R.J. Ardern

In November 1973, the Machair Study Group came into existence, and, since that date, three seminar and field meetings have taken place. During the second meeting in Aberdeen in 1975, it was agreed that a useful contribution to machair research would be a multi-disciplinary bibliography. Members of the Study Group agreed to send references to a central collation point. This has been done and although there are omissions and some fields of study appear under represented, the following list of references has been divided into broad categories, viz. –

GEOLOGY AND GEOMORPHOLOGY
ARCHAEOLOGY
HISTORICAL DESCRIPTIONS
AGRICULTURE AND GENERAL LAND USE
BOTANY
ZOOLOGY

The criterion for inclusion is that the paper should refer directly to machair land, or that part of its content should have some regional, systematic or descriptive element that is related to the study of machair.

Although many members of the Study Group made contributions, the bulk of submissions came from Dr. R.E. Randall, Prof. W. Ritchie, Mr. R.J. Ardern and Mr. I.A.G. Shepherd.

With continuing research in machair land this bibliography will soon become out-of-date, and it is hoped that a further revision might take place in two or three years time and be presented in a similar form. Accordingly, the compilers would be grateful if readers might note omissions and errors, and, if any new items come to hand, send them to one of the following addresses:

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NOTE: Valuable references are also contained in estate papers, especially the Clan Ranald Papers and the Harris Estate Papers.

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