Quaternary Research Association

Field Guide

Islay and Jura, Scottish Hebrides

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C O N T E N T S

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Frontispiece:- Raised marine features between Ruantallain and Loch a Mhile, Western Jura. Loch a Mhile is impounded by a staircase of unvegetated Lateglacial beach ridges. The Main Lateglacial Shoreline (Main Rock Platform) is in the foreground. Copyright, John Dewar Studios, Edinburgh.

Day 1: CENTRAL ISLAY

Introduction

In the western isles of Scotland, raised shoreline features are generally fragmentary (Sissons, 1976a). The islands of Islay, Jura and Scarba in the Scottish Inner Hebrides are important exceptions to this pattern (Fig. 1). In this area raised shore platforms, terraces and beach ridge staircases are striking features in the coastal landscape. Detailed investigations in Islay and Jura on the distribution and altitude variations of raised coastal terrace fragments and beach ridges have permitted the reconstruction of Lateglacial and Postglacial relative sea-level changes. The raised shoreline information has also been used in conjunction with ice-marginal landform evidence to establish the nature of regional deglaciation. During the field excursion the most important field relations pertinent to the Late-Quaternary history of the area will be examined.

Previous Research

Previous studies of Late-Quaternary environments in Islay and Jura have been undertaken by Charlesworth (1955), McCann (1961, 1964) and Synge and Stephens (1966). Charlesworth (1955) reported the occurrence during the Lateglacial of a major phase of valley glaciation (Stage M, the Highland Readvance which is generally considered equivalent to the Loch Lomond Readvance in the western Highlands (Sissons, 1974a)). However, the most detailed work was undertaken by McCann (1961, 1964) and Synge and Stephens (1966). McCann proposed that the deglacation of the last ice-sheet on Islay was interrupted by a readvance of ice over east Islay this being indicated by a fall in the marine limit. However, he did not present any morphological evidence for a readvance. McCann (1964) also suggested that the Highland Readvance was represented in NE Islay by a moraine at Coir Odhar (NR 400785)(Fig. 1). McCann also undertook detailed investigations on the raised beaches shingle complexes of western Jura (see pages 9-19).

Synge and Stephens (1966) proposed that a large end moraine complex is present in west Islay and suggested that it represented deposition at the edge of the last Scottish ice-sheet. Synge and Stephens depicted the ice-sheet limit as shown on Fig. 2. They also suggested that the contemporaneous sea-level in NW and NE Islay was at 95-100 feet (19.0-30.5 m) while the highest shoreline within the morainic area was said to be at 55 feet (16.8 m). McCann (1964) suggested that the general lowering of Lateglacial sea-level in the Islay-Jura region was interrupted by two periods of relative sea-level stability. He suggested that there was an initial rapid fall from 100 feet (30.5 m) to 75-80 feet (22.9-24.4 m) when there was a short halt. Thereafter relative sea-level fell at a slower rate and was interrupted by a second halt at 55-60 feet (16.8-18.3 m) in west Jura. McCann considered that additional evidence for the latter pause in sea-level lowering occurs in neighbouring Colonsay and that raised beaches at 75 feet (22.9 m) in Mull correlate with raised beaches at similar altitudes in Jura and Islay.

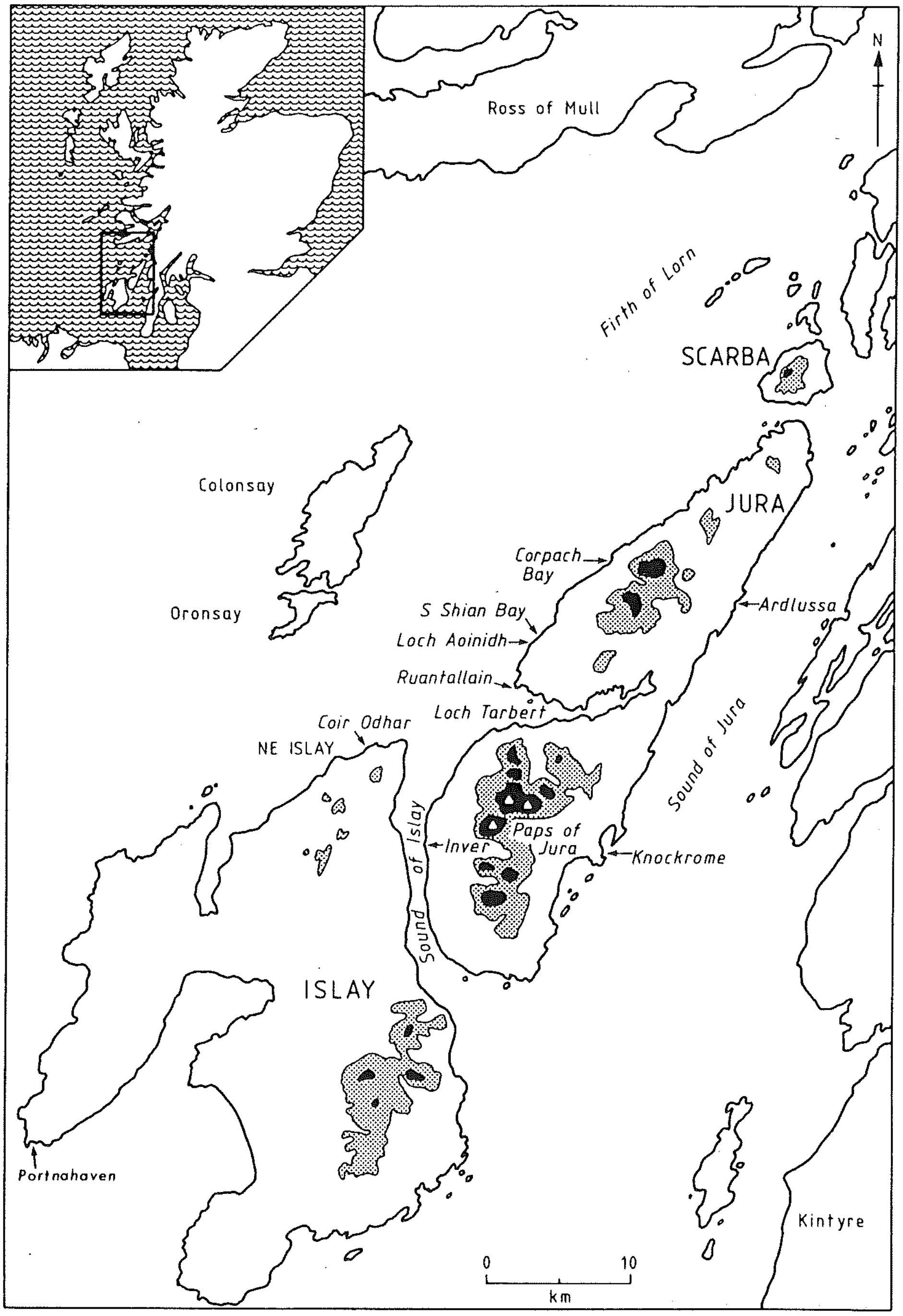

Fig.1 Location of Islay, Jura and Scarba. Ground areas over 200 m (shaded) and 400 m (black) are also shown.

GLACIAL AND FLUVIOGLACIAL LANDFORMS AND FORMER SEA-LEVEL

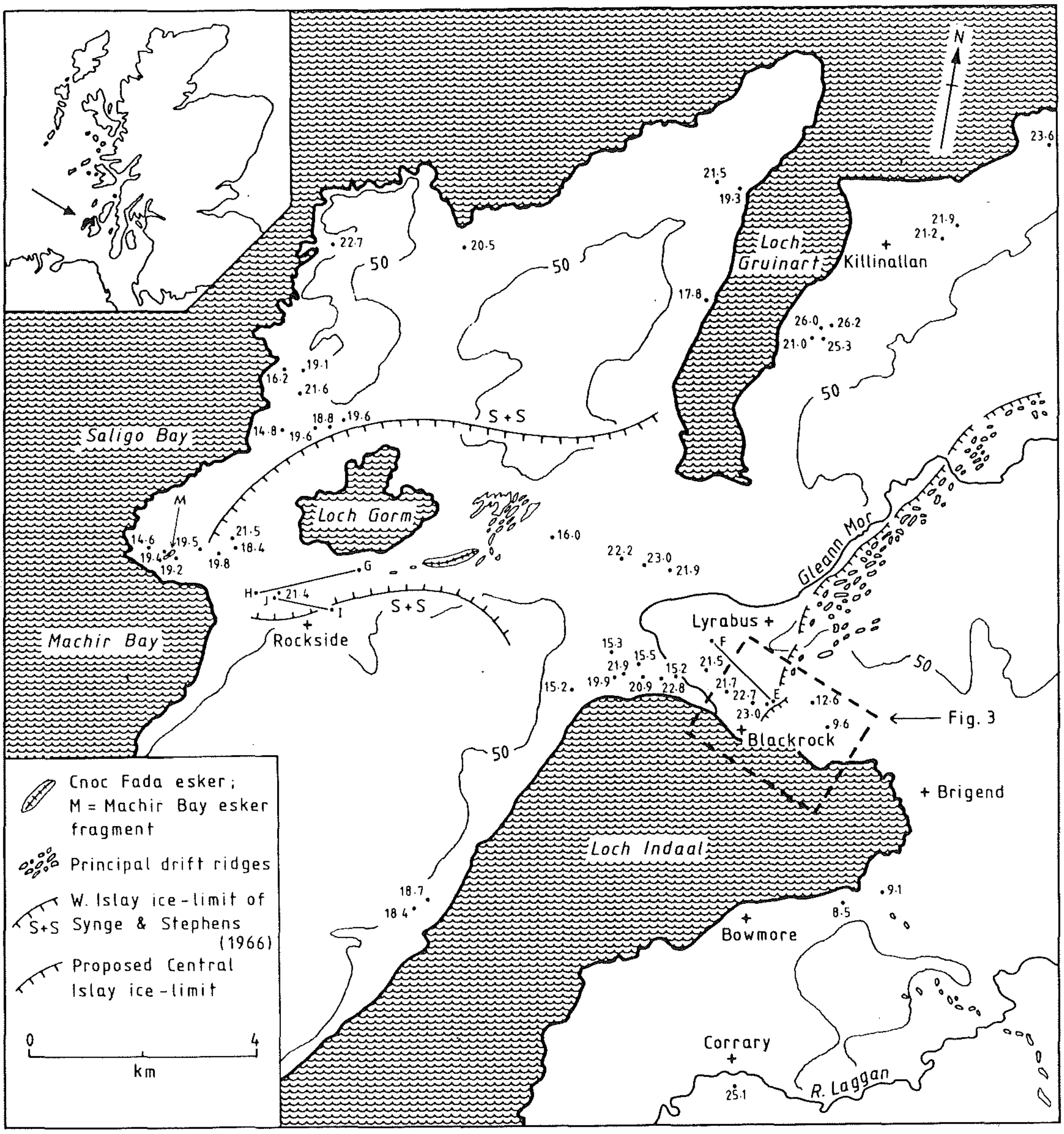

Fig.2 The altitudes of raised coastal terrace fragments (metres O.D.) in central and western Islay. The locations of outwash profiles EF, GH and IJ are also shown.

1. Near Lyrabus in Islay (Fig. 2) an extensive area of hummocky drift ridges 500-700 m wide extends SW-NE for c. 8 km. The mounds, generally 5-10 m high, form a chaotic assemblage of ridges and depressions and include many linear features, the most conspicuous of which is 400 m long and 15 m high. The western margin is defined by several elongate ridges that form the SE flank of the Gleann Mor

valley. Farther south between Lyrabus and Loch Indaal, the western limit of hummocky drift, although recognisable, is less well defined. However, 400 m north of Blackrock an extensive gravel terrace fragment extends NW for over 1 km (Fig. 2 profile E-F; Fig. 3).

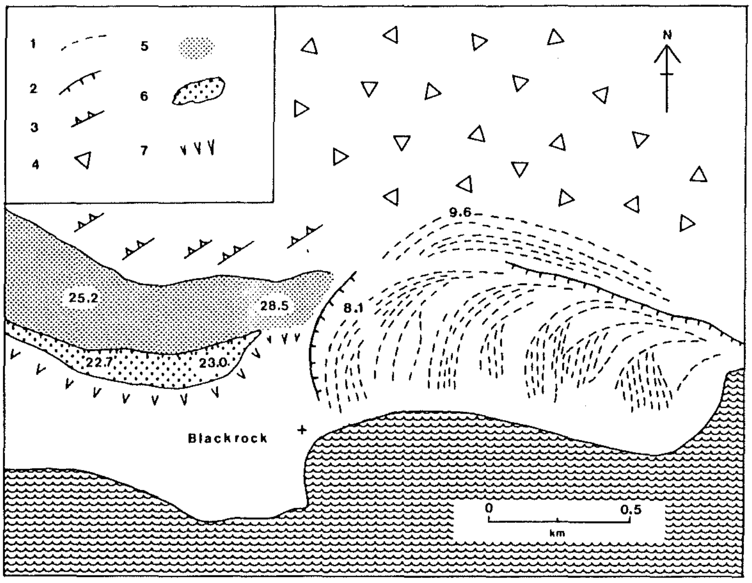

Fig.3 Raised shore features and fluvioglacial deposits at Blackrock, central Islay (see Fig.2). 1. Postglacial shingle ridges 2. Clifflines 3. Rock ridges 4. Glacial till 5. Fluvioglacial sediments 6. Lateglacial coastal terrace 7. Degraded slopes.

The feature declines in altitude NW from 28.5 to 22.5 m and has an average gradient of 5 m/km. The SW edge of the terrace fragment forms the backing cliff of several raised coastal terrace fragments that vary between 23.0 and 21.5 m (Figs. 2, 3). The raised beach at 21.5 m merges upslope with the inclined gravel surface which is interpreted as glacial outwash. Thus the contemporary sea-level is placed at 21.5 m.

The outwash and raised beach surfaces terminate eastward at a cliff (Fig. 3) below which is an extensive area of vegetated shingle ridges. The ridges rise in altitude inland where they are replaced by an undulating surface of drift. The boundary between the drift and the raised beach deposits is defined by a vegetated shingle ridge, 700 m long, the crest of which is at 9.6 m (Fig. 3). The latter shingle ridge is the highest of a complex series of raised beach ridges in this area that were produced during and after the culmination of the Main Postglacial transgression. As a result, the absence of any Lateglacial shoreline fragments south of Lyrabus indicates a local fall in the marine limit of c. 12 m and hence implies the former existence in central Islay of a stationary ice-margin during general deglaciation of the area. The ice-marginal landforms near Lyrabus are therefore referred to as the central Islay moraine complex. Farther east between Blackrock, Brigend and Bowmore, raised coastal terrace fragments are poorly developed; the highest feature being at 9.1 m (Fig. 2).

On the S side of Loch Indaal raised shorelines are poorly defined although a conspicuous terrace fragment occurs at 25.1 m at Corrary (Fig. 2). Consequently, there is tentative evidence for a fall in the marine limit on the S side of Loch Indaal. Farther inland, several drift ridges are present (Fig. 2). The features vary in height between 5 and 15 m and are occasionally 200 m long. However, although the ridges are linearly aligned (Fig. 2) they cannot be shown to be an end moraine complex.

2. East of Loch Gorm a series of sub-parallel drift ridges are aligned SSW-NNE across the E-W trending Loch Gorm valley (Fig. 2). The ridges are curvilinear, generally 5-10 m high and are composed of till. SW of the ridges at Cnoc Fada (Fig. 2) a well-defined sinuous esker 8-12 m high extends WSW over a distance of 1.5 km. North of Machir Bay, a separate esker ridge 150 m long and 6-10 m high protudes above Lateglacial marine sediments (Fig. 2, M). South of Loch Gorm, near Rockside (Fig. 2, G-H) a major terrace fragment composed of coarse gravels, 1 km long and 120 m wide, declines westward towards Machir Bay where it passes beneath accumulations of blown sand. The terrace fragment, which declines from 32.6 to 22.8 m with an average gradient of 9.8 m/km, is interpreted as outwash graded to a sea-level lower than c. 23 m. The latter feature is succeeded farther south by a smaller terrace fragment (Fig. 2, I-J), 500 m long and 150 m wide, that declines in altitude westward and terminates at a raised shoreline which is at 21.4 m. The steeply sloping fragment declines from 26.0 to 22.1 m with a gradient of 7.8 m/km and is similarly interpreted as outwash but is graded to a contemporary sea-level of c. 21.5 m. Although both terrace fragments are succeeded eastward by till, no end moraines are present.

The distribution of drift ridges, esker fragments and fluvioglacial deposits in this area are unrelated to the ice-limit depicted by Synge and Stephens (1966). There is no morphological evidence for the latter ice-limit. The E-W alignment of the esker fragments and the fluvioglacial deposits parallel to the trend of the Loch Gorm valley suggests a pattern of topographically-controlled ice decay unrelated to any major ice stillstands. This hypothesis is supported by the distribution of raised shoreline altitudes, the Lateglacial marine limit varying little in altitude throughout this area (Fig. 2).

LATEGLACIAL SHORELINES

The mean altitudes of the terrace fragments when plotted on height-distance diagrams exhibit preferred alignments of points. In addition, identification of separate Lateglacial shorelines is aided in central Islay where many terrace fragments occur in staircases and thus cannot be synchronous. Inspection of the height-distance diagrams and shoreline gradients in conjunction with constraints on correlation imposed by the field evidence indicates that the NE-SW projection plane most closely approximates the projection aligned orthogonal to the uplift isobases. The NE-SW height-distance diagram shows two prominent Lateglacial shorelines (L1 and L2) (Fig. 4).

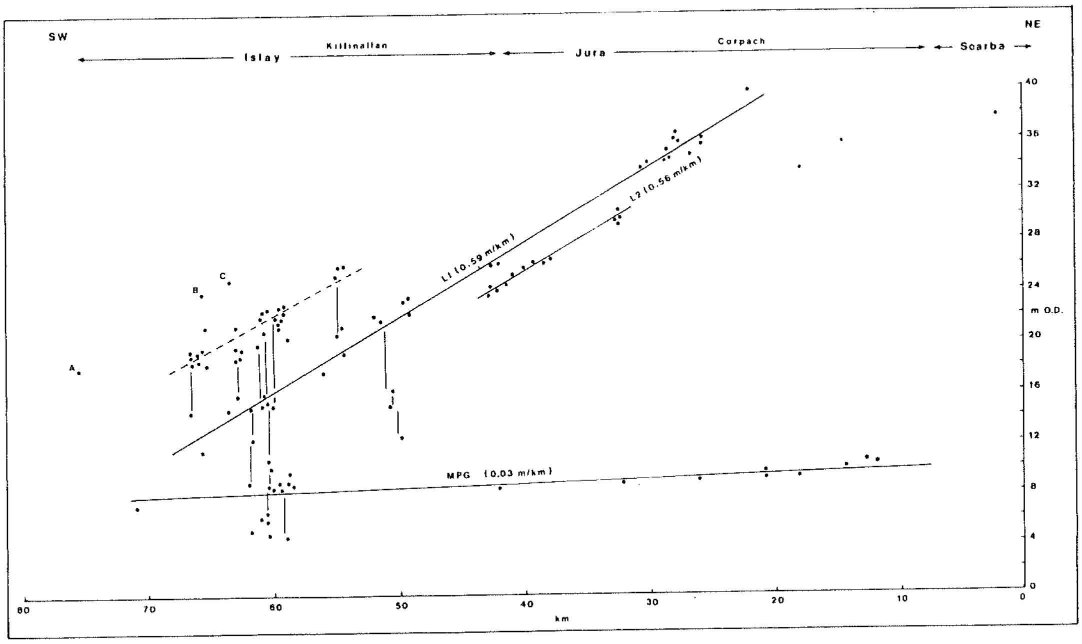

Fig.4 Shoreline height-distance diagram for Islay, Jura and Scarba. Vertical lines denote locations of terrace staircases. Terrace fragment altitudes are shown by dots. Fragments A-C are referred to in text. MPG denotes Main Postglacial Shoreline.

Shoreline L1 is a conspicuous feature in Islay and Jura and declines in altitude SW from 40 m in NW Jura to 15 m in central Islay. However, in SW Jura, 13 terrace fragments occur at altitudes c. 2 m below the general level of shoreline L1. These are believed to represent a separate shoreline (L2). Terrace fragments of shoreline L2 appear to be absent in Islay although it is likely that they are present within the sloping shoreline L1 array of points. Linear regression analysis of shorelines L1 and L2 indicate that they possess regional gradients respectively of 0.59 m/km and 0.56 m/km.

The height-distance diagram also indicates, with the exception of fragments A, B and C (see below) the presence in Islay of a separate band of shoreline altitudes above shoreline L1. However, the large vertical range of these points suggests that the group of terrace fragments are composite, having been produced during several periods of shoreline development prior to the formation of shoreline L1. In NE Islay and Jura, there are no raised shoreline fragments older than shoreline L1 (Fig. 4). It is therefore inferred that the latter areas remained ice-covered during the formation of the highest shoreline fragments in western and central Islay. Shoreline L1 extends NE as far as Corpach Bay, NW Jura (Fig. 4). The absence of this shoreline north of Corpach Bay most probably indicates the contemporary presence of ice. Similarly the absence of shoreline L1 inside the central Islay ice-limit indicates that large areas of central and eastern Islay remained ice-covered after the deglaciation of NE Islay and west Jura. In NE Islay the raised coastal terrace fragments that are eroded into the Coir Odhar moraine form part of shoreline L1 and indicate that the moraine predates the latter shoreline (see Day 3).

Fragments A, B and C (Fig. 4) appear to represent a separate feature. Fragment A occurs in SW Islay at Portnahaven (Fig. 1) while the latter two features occur respectively at Corrary (Fig. 2) and 6 km farther south at Glenegadale. High Lateglacial raised shorelines are absent from south and SE Islay, a fact noted by Synge and Stephens (1966). Similarly, Lateglacial raised shore features are poorly developed in east Jura.

Summary

The only extensive end moraines in West Scotland that are present outside the Loch Lomond Advance moraines are the Wester Ross Readvance moraines in NW Scotland (Robinson and Ballantyne, 1979). The latter moraines are associated with a shoreline that has a regional gradient of 0.33-0.39 m/km (Sissons and Dawson, 1981). The regional gradients of shorelines L1 and L2 (0.59 m/km and 0.56 m/km) are markedly steeper than the Main Wester Ross Shoreline and are therfore probably older features. The presence of ice in eastern and central Islay during the formation of shorelines L1 and L2 is demonstrated by the c. 12 m drop in the marine limit at the central Islay moraine. The magnitude of the fall in the marine limit indicates the occurrence in eastern and central Islay of a major ice stillstand that interrupted the decay of the Late-Devensian ice-sheet. Evidence for the contemporary presence of ice in south and SE Islay and east Jura is inconclusive. The Coir Odhar moraine in NE Islay was produced prior to shorelines L1 and L2 thus cannot be related to the Loch Lomond Advance. It has recently been suggested (Sissons, 1981) that the last Scottish ice-sheet was much smaller than previously envisaged and that it probably terminated amidst the Inner Hebridean islands. It is entirely possible that the central Islay moraine represents one of several marginal positions of this ice-sheet at or near its maximum extent. Alternatively the moraine may represent a prolonged halt during general deglaciation.

Additional Information

(a) Shelly till site (by Loch Gruinart) (NR 282703)

West of Loch Gruinart an eastward flowing stream has incised through superficial deposits to produce a section of stratified sands and gravels which overlie an argillaceous, fossiliferous, brown (Munsell 7.5 YR 4/4) drift. The surface of the deposit occurs above the level of the highest raised shoreline in this area. Thus the upper gravels were probably deposited in association with glacial meltwater. The till contains shells (Synge and Stephens, 1966) and has been found to contain arctic bivalve fragments, principally the thin-shelled Palliolum groenlandicum. Numerous shell fragments were collected and subsequently identified as P. groenlandicum (J.D. Peacock, pers. comm.).

Fabric analysis of the drift shows it to be multimodal with a dominant mode at 150° NNE-SSW, a mean dip of 21.26° and a resultant vector of 160.9°. The predominant lithology is quartzite (34%). Bowmore sandstone, soft sediments, dolerite and hornblende schist comprise the remaining lithologies, exotic rocks being absent.

(b) Cultoon Bog (NR 198567)

Cultoon Bog is located in SW Islay (Fig. 5). The basin is believed to represent an infilled valley, the outlet of which is blocked by till accumulations. The basin is remarkable for the great thickness (> 22 m) of unconsolidated sediments enclosed within it. At present, the lithostratigraphy of the sediments are known from 25 boreholes. The results of these investigations are shown in Fig. 5. At the eastern end of the basin, the grey clay and the upper part of the pink clay unit are highly carbonaceous. The most remarkable aspect of the sediments is the great thickness of the pink clay: in nearly every instance coring failed to reach the base of the deposits. The ages of the deposits are unknown and one may speculate that lake sedimentation was operative during the Late-Devensian when much of Islay remained covered by ice.

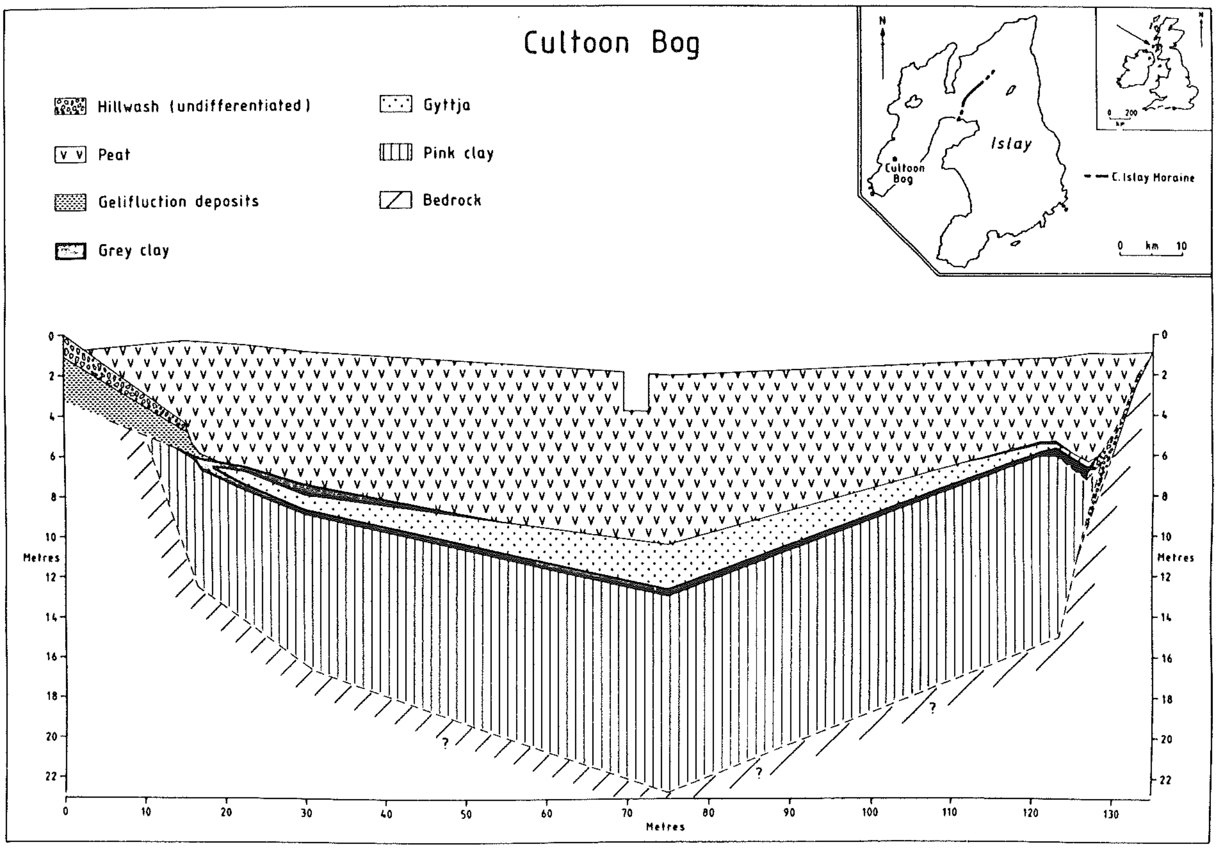

Fig.5 Stratigraphy of Cultoon Bog, Isle of Islay.

Day 2: RUANTALLAIN - SHIAN BAY, WESTERN JURA

LATEGLACIAL DEPOSITIONAL SHORELINES

Introduction

In Jura certain coastal areas are characterised by extensive unvegetated raised ridge and swale topography. The only detailed study of these coastal features was by McCann (1964) who measured the altitude of several raised shingle ridges and concluded (p. 13),

> "... the highest shingle deposits in W Jura represent the work of the Late-glacial sea during the period of maximum submergence and are equivalent to the highest raised beach terraces of the mainland of W Scotland ... these features are part of the 100 foot beach shoreline."

In N Islay and W Jura McCann also reported the presence of a "100 foot" shoreline characterised by distinct "beach terraces" that bear a closer altitude relationship than raised shingle ridges to the former water planes.

Two types of lateglacial raised shoreline assemblage occur between Ruantallain and Shian Bay. Firstly, raised coastal terraces and cliffs cut in drift are conspicuous features along long stretches of coastline. Secondly, raised shingle spreads often occur as extensive staircases of shingle seaward of the highest coastal terrace. Together, these landforms record the morphological action of former wave activity from ice-sheet deglaciation to the cold periglacial conditions of the Loch Lomond Stadial.

Raised coastal terraces produced during the highest stand of the lateglacial sea are conspicuous features along this stretch of coastline. These are usually characterised by a platform and cliff eroded in till. The raised platform generally extends seaward beneath adjacent raised beach ridges while the cliff, although generally low, is easily recognisable in the field. In W Jura north of Ruantallain a high coastal terrace forms a clear feature as far as N Shian Bay.

The only reference to the Islay and W Jura terraces is by McCann (1964, p. 13) who stated that,

> "... in NW Islay the inner angle of the terraces is between 85 and 92 feet (25.9-28.0 m) above H.W.M. and in SW Jura is 98 feet (29.9 m). It is reasonable to postulate on the basis of these figures that the maximum level of the Late-glacial sea in the Islay Jura region was just in excess of 100 feet above present H.W.M."

1. Loch a Mhile to Ruantallain

South of Loch a Mhile a high coastal terrace is locally well-developed. Measurements of 6 terrace fragment altitudes indicate an average altitude of 34.4 m. Farther south at Ruantallain 10 measurements of a well-developed fragment indicate an average altitude of 33.9 m.

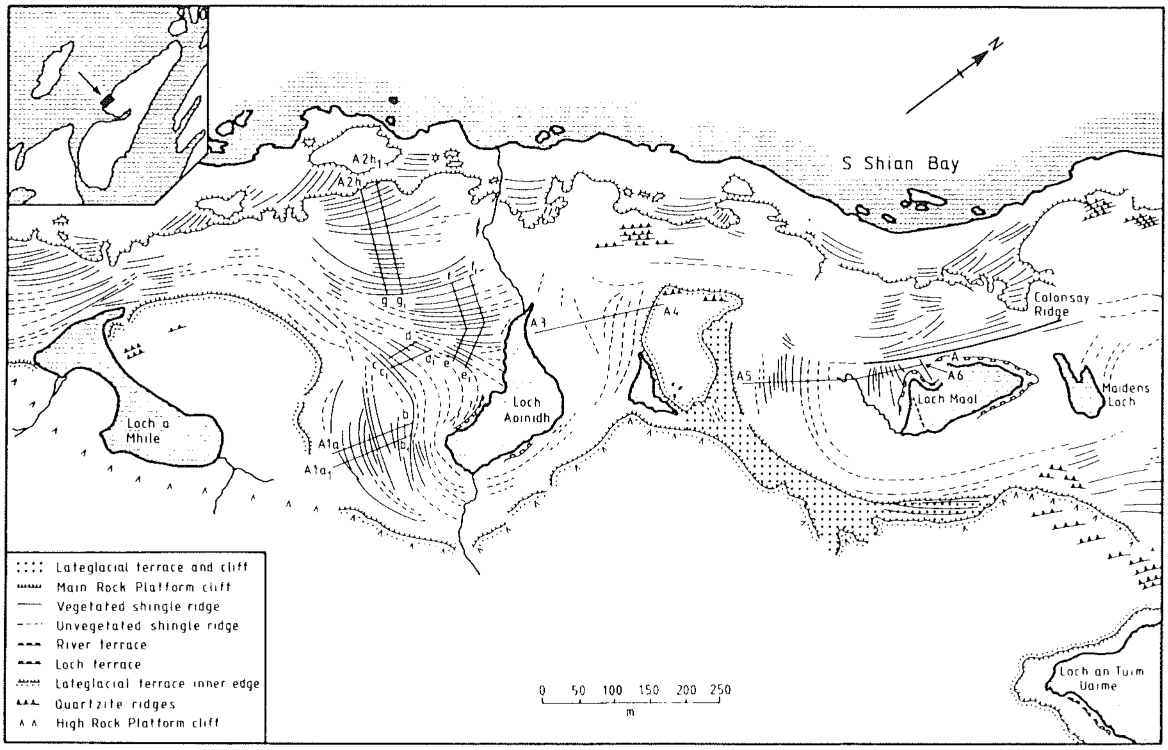

Fig.6 Raised shore features and measured profile locations, W Jura.

2. W Glenbatrick, SW Jura

A high coastal terrace is locally well-developed W of Glenbatrick on the south side of Loch Tarbert where it separates the backing quartzite slopes from a wide area of raised ridge and swale topography. Measurement of 9 altitudes on 2 well-developed terrace fragments here gave average altitudes of 29.5 and 29.9 m.

3. Loch Aoinidh Dhuibh

A well-developed raised coastal terrace is almost continuously present along the inner margin of the Loch Aoinidh embayment (Fig. 6). The terrace is separated into two parts by a stream that drains into the loch. The terrace overlies the High Rock Platform whose cliffs are here over 50 m high. The terrace surface is primarily composed of sand and is succeeded seaward by a series of 55 raised beach ridges several of which impound Loch Aoinidh. The average altitudes of the northern and southern terrace fragments are respectively 35.1 m and 35.4 m. South of the Loch Aoinidh embayment the average altitude of a well-develped terrace fragment is 34.7 m.

4. Small Arc, N Aoinidh

Small Arc represents a former sea connection between S Shian Bay and Loch Aoinidh Dhuibh and is flanked by a raised coastal terrace and cliff (Fig. 6). The southern area is occupied by a loch that is impounded seaward by a raised shingle ridge. Numerous levelled peat probes in this area indicated that the altitude of the highest coastal terrace is 36.4 m.

5. Big Arc, S Shian Bay

In this area the highest lateglacial coastal terrace, although interrupted in places by small stream channels, forms an almost continuous feature for a distance of 600 m and is succeeded seaward by an area of undulating ridge and swale topography (Fig. 6). Measurements of the northern and southern terrace fragments gave average altitudes of 36.3 and 36.8 m respectively.

6. Loch an Tuim Uaime

Loch an Tuim Uaime is impounded by a series of vegetated and unvegetated beach ridges. Landward of the highest beach ridge is a broad terrace fragment the average altitude of which was determined as 35.0 m, the same altitude as the surface of the loch.

7. Golden Spread, N Shian Bay

In this area a high unvegetated shingle ridge is separated from a till cliff by a broad terrace (Fig. 6). The average altitude of the northern fragment of the terrace was measured as 36.2 m and the altitude of the southern fragment as 36.4 m. Both fragments revealed a maximum altitude range along their lengths of 0.4 m. Approximately 350 m farther south the average altitude of a high terrace fragment located landward of the highest raised beach ridge is 35.75 m.

Altitude Analysis

The shoreline altitudes mentioned above are included in the shoreline height-distance diagram (Fig. 4). The plotted altitudes indicate a regular decline in terrace fragment altitudes from 40 m in NW Jura at Corpach Bay to 33.9 m at Ruantallain. However across Loch Tarbert, between Ruantallain and Glenbatrick, there is a sharp decline in altitude from 33.9 m to 30.5 m, a drop in altitude of over 3 m in a distance of 1.3 km. Thereafter all terrace fragment altitudes measured in SW Jura decline regularly in altitude to the SW from 30.5 m to 24.1 m. In contrast the altitudes of the NE Islay fragments are markedly higher than the farthest south ones in SW Jura (26.4 m compared with

24.5 m). Since the highest shoreline forms an almost continuous feature from north of Shian Bay to Ruantallain and shows a regular decline in altitude SW on the height-distance diagram, it is believed that the terrace fragments in this area were formed approximately synchronously. However, the drop in terrace fragment altitudes across Loch Tarbert between Ruantallain and Glenbatrick strongly suggests that the SW Jura terrace fragments were formed later than those between Ruantallain and Corpach Bay. Visual inspection of Fig. 4 indicates that the altitudes of the NE Islay terrace fragments are aligned with those between Ruantallain and Corpach Bay and may therefore correlate with them. The terrace fragment altitudes obtained between Corpach Bay and Ruantallain together with the altitude values from Islay (see p.6) were analysed by linear regression and a shoreline gradient of 0.59 m/km obtained (Fig. 4, L1). Similarly the SW Jura shoreline altitudes were analysed by linear regression and indicate a shoreline gradient of 0.56 m/km (L2).

Interpretation

The simplest explanation for the drop in terrace fragment altitudes across Loch Tarbert between Ruantallain and Glenbatrick and the corresponding rise in terrace fragment altitudes between SW Jura and NE Islay is that during deglaciation SW Jura remained ice-covered while the sea invaded the coastal areas of NE Islay and W Jura (between Ruantallain and Corpach Bay). The drop in altitude of the terrace fragments in NW Jura between Corpach and Glendebadel (Fig. 4) also suggests that during L1 shoreline formation between Corpach and Ruantallain the area north of Corpach Bay remained covered by ice.

LATEGLACIAL SHINGLE RIDGES: RUANTALLAIN - SHIAN BAY, W JURA

The only previous study of the W Jura raised shingle spreads was by McCann (1964). For this reason it is worthwhile here to summarise his conclusions regarding the age and the origin of the deposits. McCann (1964, pp. 8-9) believed that the W Jura shingle ridges were formed during the general retreat of the lateglacial sea following deglaciation. He suggested that there was an initial rapid fall in relative sea-level from 100 feet (30.5 m) to 75-80 feet (22.9-24.4 m) above H.W.M. when there was a short halt. Thereafter relative sea-level fell at a slower rate and was interrupted by a second halt at 55-60 feet (16.8-18.3 m) above H.W.M. when a large shingle ridge (the Colonsay ridge) was formed in S Shian Bay. McCann also suggested that the large volumes of shingle were derived from the lateglacial marine erosion of till deposits that formerly mantled the surface of the High Rock Platform.

1. Bagh Righ Mhor, E Ruantallain

At Bagh Righ Mhor a spectacular shingle spread extends seaward from 36.8 m to 21.0 m. Unlike the other raised shingle spreads of W Jura the Bagh Righ Mhor spread is not developed upon a pre-existing High Rock Platform but is instead banked against the rocky coastal slopes. As a result the ridge and swale topography is here poorly defined and is characterised by gentle convexities and concavities in the shingle profile. The highest ridge is the most conspicuous feature of the shingle spread and varies laterally in altitude between 39.4 m and 38.6 m. Seaward of this ridge the lower shingle deposits consist of a series of poorly developed ridges and swales.

2. N of Bhrein Port

N of Bhrein Port a series of 25 ridges separated by swales extends 190 m seawards from the high lateglacial terrace to the top of the Main Rock Platform cliff. The shingle surface is concave in profile and is characterised, particularly at altitudes below 32 m, by well-defined ridges and swales. The highest ridge is the most conspicuous feature of the shingle staircase and lies at 39.2 m. Seaward of this ridge the shingle surface descends steeply to 35.1 m where a secondary ridge is banked against its frontal slope. On the lower shingle surface the most noticeable drop in altitude occurs between 24.3 m and 22.6 m. Suites of raised beach ridges associated with similar breaks of slope occur at 28 m, between 22.0 m and 22.5 m and also between 19.4 m and 20.3 m.

3. Loch a Mhile

Seawards of Loch a Mhile a shingle staircase consisting of 14 ridges separated by swales declines in altitude from the loch margin to the top of the Main Rock Platform cliff (Fig. 6). The shingle ridges overlie the High Rock Platform and are separated from it by locally thick accumulations of till. Levelled profiles across the ridge and swale topography indicate two distinct slope units. Firstly, the four highest ridges range in crest altitude from 36.8 m to 33.2 m and are succeeded seaward by a ridge at 31.5 m. Seaward of this ridge the shingle profile is convex and is characterised by a sequence of ridges and swales that extends seawards for approximately 80 m. The highest ridge reaches a maximum altitude of 36.8 m and lies c. 1.5 m above the level of the loch.

4. Loch Aoinidh Dhuibh

Within the Loch Aoinidh Dhuibh embayment there exists the most complex sequence of lateglacial coastal forms in Britain (Fig. 6). In total 55 beach ridges separated by swales extend seaward from the lateglacial coastal terrace to the top of the Main Rock Platform cliff. The raised shingle ridges overlie the W Jura High Rock Platform which in this area reaches a maximum width of 650 m. Loch Aoinidh is succeeded landwards by the High Rock Platform cliff, which here reaches heights of 50-70 m. North and south of the embayment two thick peat bogs overlie a series of inclined quartzite ridges that locally protrude above the generally even surface of the platform. Despite their low relief the rock ridges formerly exerted an important control on the development of the adjacent beach ridges. McCann considered that the distribution of beach ridges was related to the following level of the lateglacial sea and that,

> "... During the maximum period of submergence with sea-level falling from 115-100 feet (35.1-30.5 m) above present H.W.M. beach ridges were formed around the margins of the embayment, and the separation into two areas, one under the influence of refracted waves from the SW and the other under the direct influence of

> waves from this direction, is apparent. With the continued fall of sea-level from 100-85 feet (30.5-25.9 m) newer and lower beach ridges were deposited on the northern side of the bay parallel to the older ridges, but in the southern part the alignment of the ridges changed and became progressively more nearly north-south, for, as the sea-level fell and the sea occupied less of the embayment, the effect of the headland in refracting the dominant waves became less important ... the last stage in (beach ridge) development was the deposition of 18 curved, parallel ridges between 85 and 56 feet (25.9-17.1 m) above H.W.M. Within this embayment ... there is a gradual fall in height from the highest shingle ridge to the lowest."

In the inner part of the embayment the highest beach ridges form sweeping arcuate features that lie approximately parallel to the high lateglacial terrace. The ridges exhibit little altitude variation along their lengths and in only one instance does the lateral altitude variation of an individual ridge exceed 0.3 m (Fig. 7). There is also no noticeable change in the size of

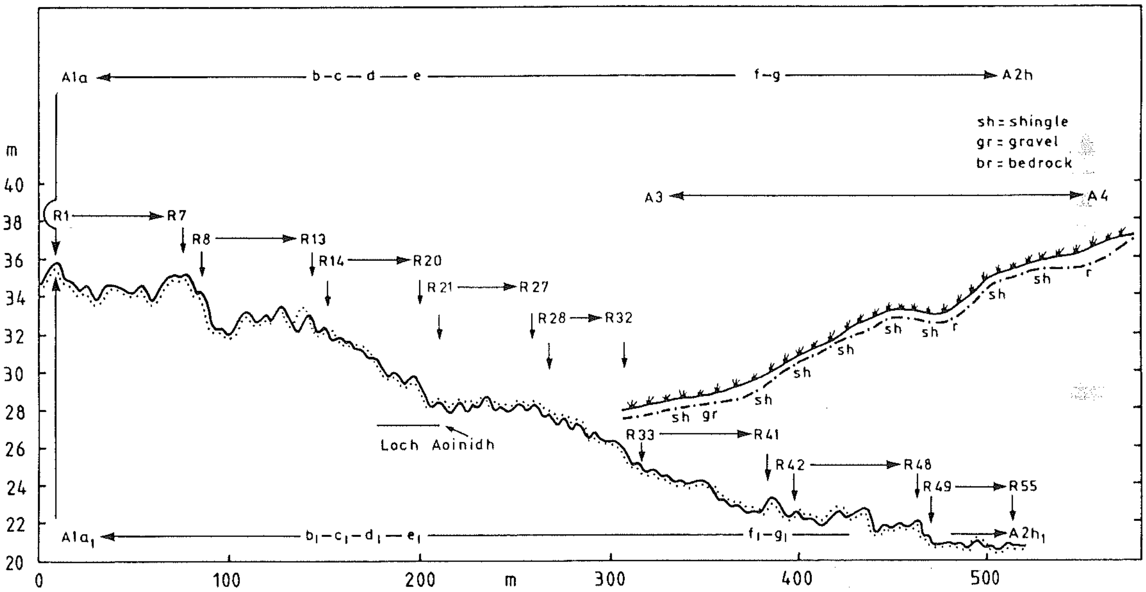

Fig. 7 Lateglacial shingle ridge profiles by Loch Aoinidh, west Jura. Individual ridges show little lateral altitude variation. Profile locations are shown on Fig. 6.

debris along the lengths of individual ridges. In the centre of the embayment there is a change in the orientation of each successive beach ridge. Here the ridges terminate on the SW shore of the loch and are responsible for its serrated configuration. Farther seaward the lower ridges located on the western margin of the embayment face westward and descend seaward in altitude as a continuous staircase of unvegetated ridges and swales.

In addition to profiles measured on the unvegetated beach ridges, levelling was combined with peat probing in the vegetated area N and S of the loch (Fig. 7). Along the inner edge of the embayment the highest 8 beach ridges occur at 36.0-33.8 m and are separated from the lower ridges by a distinct break in the slope profile that occurs between 34.3 and 31.9 m. The break in slope coincides with a deep swale that is replaced seawards by an area of undulating ridge and swale topography, 60 m in width, the surface of which ranges between 33.4 and 31.9 m.

North of Loch Aoinidh the vegetated surface is underlain by two distinct groups of ridges (Fig. 7) that are separated from each other by a marked break in slope. Seaward of ridge R13 a staircase of 7 low-amplitude ridges (R14-R20) descends from 32.3 m to 28.2 m. At the base of R20 there is an extremely well-developed third break of slope. Here a series of 7 ridges (R21-R27) between 28.6 m and 27.8 m extends westward for 60 m as an almost horizontal spread of cobbles. The ridges that impound Loch Aoinidh (surface 27.2 m) extend northwards where they are buried by vegetation. These ridges are succeeded westwards by 27 ridges separated by swales that mantle the High Rock Platform and terminate seaward at the Main Rock Platform cliff. Here the shingle surface is concave in profile and is characterised by several large broad ridges (e.g. R37, R41, R44, R45 and R48) separated by suites of low-amplitude ridges and swales. In the southern area of the embayment a high ridge can be traced beneath a cover of vegetation towards Loch a Mhile. The crest altitude of this ridge varies between 36.1 m and 36.4 m.

5. <u>S Shian Bay</u>

The S Shian embayment contains a complex pattern of raised ridge and swale topography, raised coastal terraces and lochans impounded by raised coastal deposits (Fig. 6). McCann suggested that there was evidence here of pauses or oscillations of relative sea-level that interrupted the general retreat of the lateglacial sea. McCann (1964, p. 14) noted that there is,

> "... a change from a relatively steep to a more gentle seaward slope in the surface of the shingle deposits at 75-80 feet (22.9-24.4 m) above H.W.M. The steeper upper slope reflects a rapid fall in sea-level from the maximum to about 75-80 feet, when there was a short halt, followed by a second fall of sea-level at a slower rate which is reflected in the more gentle lower slope. The second feature is the division of the shingle deposits at the southern end of the Shian embayment of the Inter-glacial platform into two distinct parts, separated by the wide hollows occupied by small lochs. The upper shingle deposit shows the marked break of slope, while the lower part, damming the lochs

> is a quite separate shingle bank at a lower level of 55-63 feet (16.8-19.2 m) above H.W.M. The development of this wide lower ridge at that locality must be due, in part, to the fact that the outer part of the old marine platform there is very low, but it may also be due to a second halt in the fall of relative sea-level at 55-60 feet (16.8-18.3 m)."

The raised shingle deposits and impounded lochans are located on the High Rock Platform surface that here occurs at exceptionally low altitudes. In the southern and eastern parts of the embayment the highest marine deposits form a conspicuous arcuate terrace banked against the inner edge of the High Rock Platform. In the south of the embayment the terrace trends westwards away from the inner edge of the high platform cliffline and is flanked by a series of peat-covered rock skerries that protrude above the High Rock Platform surface. The northern end of the terrace surface forms an undulating belt of ridges and swales that is replaced southwards by a flat vegetated surface. The continuity of the flat terrace surface is interrupted at Small Arc by three vegetated beach ridges that mantle the terrace. Throughout this area the inner edge of the high terrace is well-defined and is succeeded landward by the High Rock Platform cliff (Fig. 6).

The frontal slope of the raised terrace is mantled by two vegetated beach ridges (Fig. 6). The higher ridge reaches a crest altitude of 30.7 m and is succeeded seaward by a lower arcuate vegetated ridge, 600 m in length, that parallels the high terrace along its length. In the centre of the S Shian embayment the ridge crest is at 24.6 m and it rises in altitude westwards to reach a maximum altitude of 26.4 m the seaward base of the beach ridge being at 20.2 m. In the south of the embayment the ridge is concave to the north while above it a series of 8 parallel ridges rises in altitude to the high coastal terrace (Fig. 6). Below the 24.6-26.4 m ridge, 13 unvegetated ridges descend parallel to each other from 26.4 m to 17.5 m where they form the western shoreline of Loch Maol (surface 15.3 m).

The western margin of the lower 13 ridges is truncated by a large N-S trending shingle ridge (the Colonsay ridge), 480 m long, that impounds a series of lochs (Fig. 6). The Colonsay ridge declines in altitude southward from 20.3 to 18.9 m, this being accompanied by a progressive decrease in the size of the shingle cobbles. Thus it is inferred that deposition of the ridges south of Loch Maol was contemporaneous with the southward progradation of a large shingle spit. Since these ridges decline in altitude northward, it is concluded that the progradation of the shingle spit occurred during a period of falling sea-level. When sea-level was at c. 17.5 m, Loch Maol was finally sealed from the sea by the southward progradation of the shingle spit. It follows that the Colonsay ridge, advocated by McCann (1964) as representing a major halt in the retreat of the Lateglacial sea, was produced during a period of falling sea-level. Seaward of the Colonsay ridge, a staircase of Lateglacial shingle ridges declines regularly in altitude and merges at c. 14 m with Postglacial shingle accumulations. Thus the retreat of the Lateglacial sea was uninterrupted by any <u>major</u> stillstands or transgressions.

Interpretation

The occurrence of large shingle ridges that protrude conspicuously above the sloping surface of a raised shingle spread can be interpreted in either of two ways. Firstly it can be argued that large ridges are formed during a short period of time as a result of storm activity. Secondly, in contrast, large ridges can be interpreted as the product of repeated storm wave activity during a long period of relative sea-level stability. Since modern storm ridges in W Jura and NE Islay have been repeatedly formed and destroyed by storm waves it cannot be maintained that large beach ridges represent the morphological effect of individual storms. Instead it is more likely that prolonged storm wave action during periods of relative sea-level stability is responsible for the formation of the large shingle ridges.

Wave activity in the study area has resulted in the formation of two beach ridge types. Firstly high-amplitude beach ridges are formed during storms and exhibit marked regional variations in crest altitude. Secondly low-amplitude beach ridges occur in the intertidal zone and are the result of moderate wave activity. If storm waves were responsible for the formation of all raised beach ridges in the study area it might therefore be expected that the measured ridge crest altitudes when plotted on a shoreline height-distance diagram would show a random scatter of points and render it impossible to identify any synchronous raised shorelines. Consequently the altitudes of all surveyed raised beach ridge crests between Ruantallain and N Shian Bay were plotted in a NE-SW projection plane on a shoreline height-distance diagram (Fig. 8).

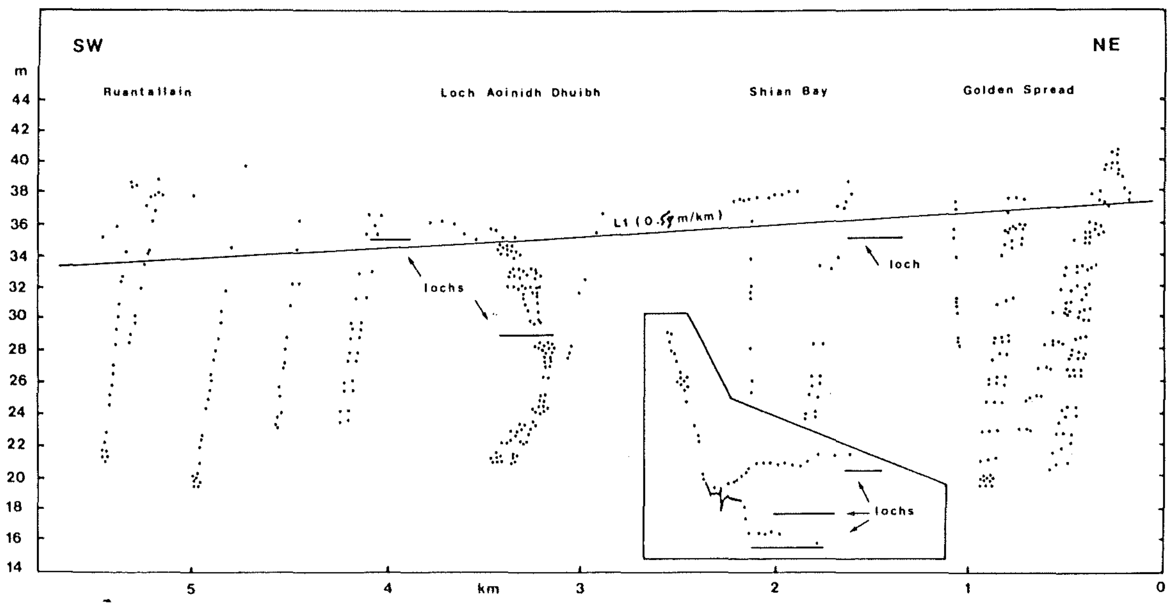

Fig.8 Shoreline height-distance diagram of lateglacial beach ridge crests between Ruantallain and Shian Bay, W Jura. Lateglacial shoreline L1 is also shown (gradient 0.59m/km).

The beach ridge altitudes when so plotted exhibit distinct altitude patterns (Fig. 8). An alignment of ridge crest altitudes along sloping planes is readily apparent. The alignment of crest altitudes is most apparent between Ruantallain and Loch Aoinidh, the area most exposed to open Atlantic fetch. The most likely explanation of the observed pattern of crest altitudes is that moderate wave activity, rather than storms, was responsible for the formation of many of the ridges, the sloping alignment of altitudes indicating the differential isostatic tilting of individual shorelines.

Although most shingle spreads are located in relatively exposed coastal locations, the Loch Aoinidh Dhuibh beach ridges are in a sheltered embayment and as a result they are extremely sensitive indicators of former sea-level changes. The sheltered environment in which the Loch Aoinidh ridges were formed is clearly demonstrated by the lack of altitude variation along the lengths of individual ridge crests (Fig. 7). When plotted on a height-distance diagram the crest altitudes group into several distinct clusters (Fig. 8) and correspond to the stepped shingle profile shown in Fig. 7. The gradual seaward decline in altitude of the beach ridges suggest that here the general relative marine regression from 36 m to 21 m was not interrupted by any major relative marine transgression. The clustered nature of the Loch Aoinidh crest altitudes also suggests that the general marine regression associated with shingle ridge formation was characterised by a series of regressional phases separated by stillstands rather than by a continuously falling sea-level.

In the Loch Aoinidh Dhuibh area the largest-amplitude ridges and swales (R1-R8) occur above 32 m and most probably reflect early lateglacial storm activity rather than changes of sea-level. A possible period of relative sea-level stability is indicated by ridges R9-R14 between 32.0 and 33.5 m, this being followed by a period of general marine regression and the formation of ridges R15-R20. This in turn was followed by a second period of marine stability indicated by ridges R21-R27 between 28.6 m and 27.8 m which impound Loch Aoinidh Dhuibh (surface 27.2 m) (Fig. 7). After this period further marine regression occurred and accompanied the formation of a series of 28 low-amplitude beach ridges (R27-R55).

The progressive seaward decline in ridge crest altitudes shown in the W Jura shingle profiles indicates that, although relative marine stillstands may have occurred during this period, there were no major sea-level oscillations. Below c. 25 m most of the W Jura shingle spreads terminate seawards at the top of the Main Rock Platform cliff and as a result regional patterns of lower lateglacial sea-level changes cannot be established.

At several locations in W Jura the high shingle ridges are separated from the underlying High Rock Platform by accumulations of till that contain numerous angular quartzite clasts. In SW Jura raised till platforms are overlain by shingle ridges while in W Jura (between Ruantallain and N Shian Bay) and NE Islay the High Rock Platform is overlain at several locations by glacial till. It is therefore most likely that the quartzite shingle cobbles of the lateglacial ridges were derived from the marine erosion of till that formerly mantled large areas of the High Rock Platform. Destructive lateglacial waves most probably resulted in the seaward removal of debris and its later deposition as beach ridges by constructive wave action. The distribution of the raised shingle ridges is also the result of the sloping lateglacial shorelines that in W Jura permitted the deposition of shingle ridges on the High Rock Platform. In NE Islay however, owing to the steep gradients of the lateglacial shorelines, the latter could only develop on the seaward part of the platform.

Summary

The pattern of sea-level changes in W Jura is more complicated than suggested by McCann. Deglaciation first occurred between Ruantallain and Corpach Bay and also in NE Islay. Marine incursion into these deglaciated areas resulted in the formation of the L1 shoreline. During the formation of this shoreline SW Jura remained ice-covered. At a slightly later date SW Jura was also deglaciated and this was accompanied by the formation along the SW Jura coast of shoreline L2. During this period high shingle ridges were formed between Ruantallain and N Shian Bay. Subsequently glacio-isostatic uplift of the land surface resulted in a general marine regression that was associated with the deposition of the W Jura shingle ridges. The distribution and height variations of the highest shingle ridges in W Jura suggest that they were formed during storms.

In contrast, it is suggested that many of the lower shingle ridges were formed by moderate wave action. The distribution and altitude of shingle ridges in the Loch Aoinidh embayment show that the general lateglacial marine regression was uninterrupted by any major reversals of sea-level. Instead the beach ridge altitudes suggest that the marine regression was characterised by a series of regressional phases separated by stillstands. At Loch Aoinidh periods of relative sea-level stability occurred when sea-level was at 33.5-32.0 m and at 28.6-27.9 m. It is also concluded that the period of relative sea-level stability at 55-60 feet (16.8 m - 18.3 m) above H.W.M. proposed by McCann, did not occur.

FOSSIL ROCK PLATFORMS: THE MAIN ROCK PLATFORM

Introduction

A raised shore platform in Dalraidan quartzite is developed along the coast of W Jura. The feature was originally considered as having been formed by the postglacial sea. Later it was suggested that since modern platform development on hard rock coasts of the British Isles was minimal it was unlikely that the postglacial sea could have formed such a wide platform. The feature was therefore proposed as interglacial in age. The platform was correlated with a low till-covered interglacial platform in Ireland. Later Gray (1974) described a well-developed platform along the Firth of Lorn and eastern Mull and showed that it declines in altitude W and SW with a gradient of 0.16 m/km. Gray (1974) considered that the platform (referred to by him as the Main Rock

Platform) is interglacial in age and attributed its regional altitude variation to later tectonic subsidence.

Sissons (1974b) showed that in SE Scotland a buried erosional shoreline (the Buried Gravel Layer) declines in altitude eastward with a gradient of 0.17 m/km and argued on several grounds that this shoreline is of the same age as the Main Rock Platform of W Scotland, both having been formed during the cold climate of the Loch Lomond Stadial (Younger Dryas). Sissons suggested that evidence of glacial modification of the platform was unconvincing and believed instead that, since delicate stacks and arches occur on the platform surface in areas where glacial erosion was formerly intense, the platform is unlikely to be of an interglacial age. Later Gray (1978) measured the Main Rock Platform in Knapdale, Kintyre and neighbouring areas and found that it declines in altitude southwards with a gradient of 0.12 m/km. Gray abandoned the interglacial hypothesis and concluded that the feature is Late-glacial in age and owes its origin to periglacial shore erosion.

Morphology

The platform of W Jura is the SW continuation of that described farther north and east by Gray and is thus referred to here as the Main Rock Platform. However in SW Jura, the Main Rock Platform crosses a low intertidal rock platform (the Low Rock Platform) that passes beneath thick accumulations of glacial till. The Low Rock Platform surface is glacially striated and is characterised by numerous pot-holes and water-rounded rock. This second shore platform varies in altitude between 1 and 2 m OD and is horizontal throughout Jura, Scarba, NE Islay, Colonsay and Oronsay the feature being separated from the Main Rock Platform by a small cliff generally 1-4 m in height. In contrast the Main Rock Platform varies regionally in altitude and possesses a number of morphological characteristics that are common to all localities where platform fragments occur:

1. Platform fragments are often exceptionally well developed in areas where the maximum fetch is only several hundred metres.

2. The platform fragment surfaces, although generally horizontal, are often irregular in detail and do not possess the well-developed ramp abrasion profiles characteristic of platforms formed by marine abrasion.

3. Numerous raised sea-stacks and natural arches protrude above the platform while pot-holes and water-rounded rock surfaces are rarely present. In addition the cliff backing the platform is often indented by numerous geos and caves: in the study area 97 raised caves have been identified.

4. The platform surface has numerous crescentic concussion scars that have resulted from the former beating of shingle on the rock surfaces.

5. There is no evidence of glaciation of the Main Rock Platform.

W Jura

The Main Rock Platform is continuous in this area and is locally overlain by postglacial shingle accumulations. The feature is eroded in Dalradian quartzite and is 50-150 m wide. The cliff is here ca. 10- 15m high and is indented by numerous fossil sea-caves all of which are believed to be floored by postglacial marine deposits. The platform is unglaciated and is characterised by jagged inclined quartzite ridges. The cliffline is typically crenulate and forms the frontal edge of the adjacent High Rock Platform. Delicate lateglacial beach ridges frequently mantle the top of the Main Rock Platform cliff. The platform in this area occurs at ca. 3 m OD and is virtually continous along the W Jura coastline north of Ruantallain (Fig. 9).

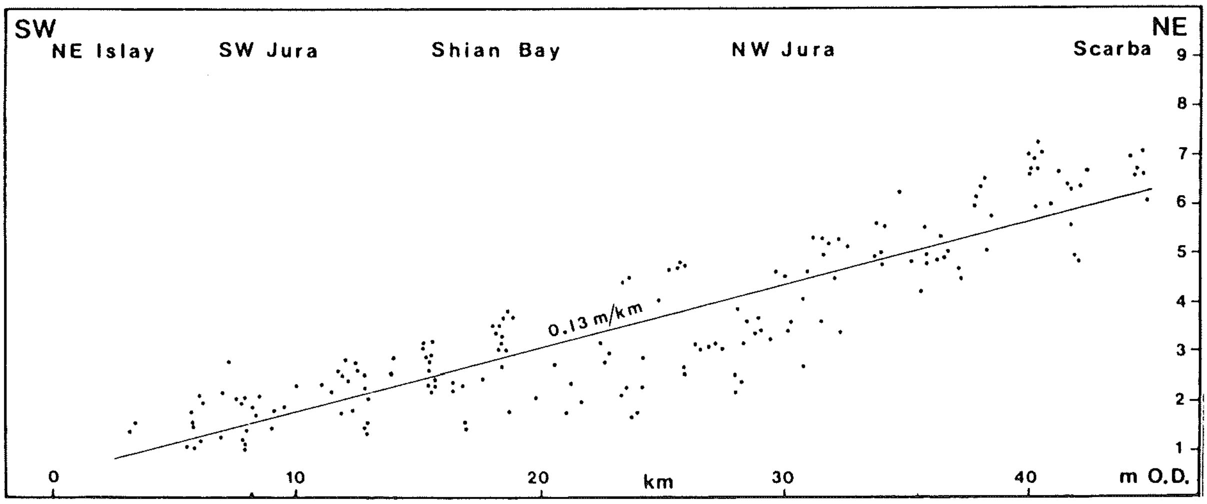

Fig. 9 Height-distance diagram of Main Lateglacial Shoreline (Main Rock Platform) in NE Islay, Jura and Scarba.

From the shoreline diagram it can be seen that the platform declines in altitude to the SW from 7 m OD in N Scarba to sea-level in NE Islay and has a gradient of 0.13 m/km. The values are consistent with those measured in neighbouring areas farther north by Gray (1978, Fig. 5c) where the platform rises in altitude NE with a similar gradient from 7 m OD on Luing (immediately north of Scarba) to 10 m OD in the Oban area.

Measurement of Main Rock Platform width and cliff height at 526 regularly spaced locations in W Jura was undertaken in order to determine the amount of rock formerly removed from the coastal zone. Since the Main Rock Platform merges with and crosses the Low Rock Platform in NE Islay and SW Jura these areas were excluded from the analysis, for it is likely here that the Main Rock Platform developed partly on the pre-existing Low Rock Platform surface. From these measurements the product of platform width and cliff height indicates that an average of 2,074 m^3 of rock per metre of coast was removed. If it is assumed instead that a uniform seaward slope was in existence prior to platform development, an average of 1,037 m^3 of rock per metre of coast was removed. This figure is equivalent to the removal of almost 50 million m^3 of rock from the W Jura coast. It should be noted however that the values of 2,074 m^3 and 1,037 m^3 of rock per metre of coast are mean volumes of rock removal and that locally much larger volumes of rock were removed during platform development. For example at Ruantallain as much as 9,800 m^3 of rock per metre of coast may have been removed.

Interpretation

Age

The interglacial hypothesis fails to explain the occurrence on the platform surface of delicate stacks and arches, the calculated shoreline gradient of 0.13 m/km away from the centre of glacio-isostatic uplift and the absence of evidence demonstrating glaciation of the platform.

The regional gradient of the feature is extremely difficult to explain unless the feature is interpreted as having been formed since the decay of the last (Devensian) ice-sheet. Since the gradient of the highest Lateglacial shoreline in Jura and NE Islay is 0.59 m/km and that of the Main Postglacial Shoreline is 0.03 m/km it is likely that the platform was produced during part of the intervening period. These figures are consistent with formation of the feature during the Loch Lomond Stadial, being similar to gradients calculated for areas farther north and east by Gray (0.12 m/km and 0.16 m/km) and for SE Scotland by Sissons (1974b)(0.17 m/km).

Origin and Rates of formation

Assuming a duration of 1,000 years for the length of the Loch Lomond Stadial, it can be calculated from the data given earlier that in this area, if a uniform seaward slope was in existence prior to platform development, the average rate of rock removal was 1.04 m^3 per metre of coast per year: equivalent to a cliff retreat rate of 7 cm/year This figure may be compared with a maximum rate of cliff retreat of 0.9 cm/year above a fossil rock glacier in Jura interpreted as also having formed during this period and with a value of 1.7 cm/year (Sissons, 1976b,p. 189) for cliff retreat above a fossil protalus rampart in Wester Ross. The above figures for inland cliff retreat are not directly comparable however, since unlike coastal cliffs, the cliff face areas behind the fossil rock glacier and protalus rampart were gradually buried by talus aggradation.

It therefore appears that the formation of the Main Rock Platform during the cold climate of the Loch Lomond Stadial demands very special conditions in order to explain its origin in such a comparatively short period of time. Sissons (1974b) and Gray (1978) suggested that these conditions were characterised by processes of frost-shattering of rock in the semi-diurnally wetted intertidal zone and cliff base. Gray (1978) added that marine abrasion and debris removal may have been assisted by the apparent storminess during the Loch Lomond Stadial. In addition he proposed that since diurnal temperature fluctuations in W Scotland during the Loch Lomond Stadial were most probably greater than in high latitude coastal areas, very intense frost-shattering of rock in the coastal zone would have favoured the development of wide platform fragments.

HIGH ROCK PLATFORM

Although the origin of this feature is discussed in detail on Day 3, some observations on the High Rock Platform of W Jura are approriate here. Between Ruantallain and Shian Bay the quartzite platform has an average width of 350 m and in places is as wide as 600 m. Here the platform is backed by a degraded cliffline up to 50 m in elevation. North of Shian Bay, the platform reaches similar widths although here the backing cliff is a much more poorly developed feature. In both areas the frontal edge of the platform comprises the backing cliff of the Main Rock Platform.

The low quartzite ridges that interrupt the regular seaward slope of the high rock platform surface are intermittently developed along this stretch of coastline. It is not clear, however, whether these ridges are the result of differential coastal erosion during shoreline formation or have resulted from later glacial modification of the platform surface. Direct evidence of the selectivity of glacial erosion occurs north of Loch a Mhile where a well-developed striated and ice-moulded stack (NR 51398501) protrudes above the platform surface. The W Jura platform, unlike that in NE Islay, is everywhere overlain by copious quantities of high raised beach deposits. At only two locations in W Jura have till deposits been found to separate the high rock platform from the overlying beach gravels. One of these is at Bhrein Port (NR 50688405) 1 km north of Ruantallain where a wedge or orange till (in situ) embedded in a platform depression between two inclined quartzite ridges is overlain by thick accumulations of raised shingle. At the other location, on the banks of a stream channel 150 m north of Bhrein Port (NR 50948415), the relationship between the till and the platform surface is again clearly defined. Here the inner edge of the high platform is choked by 2.5 m of creamy lodgement till that is in turn overlain by several raised shingle ridges. Thus, the deposition of the lateglacial beach ridges is separated from the erosion of the High Rock Platform by an intervening period of glaciation.

Day 3: NE ISLAY

THE LOW ROCK PLATFORM

Although intertidal shore platform fragments are common features of the Hebridean coastline their age and origins have never been considered in detail. In W Jura, NE Islay and Colonsay low intertidal rock platform fragments are conspicuous along long stretches of the coast and vary in size from narrow ledges to wide foreshore platforms that locally reach widths of 1 km (Dawson, 1980).

NE Islay

On the foreshore beneath Rhuvaal lighthouse, NE Islay, two distinct rock platforms are visible. Both platforms occur in the intertidal zone but are markedly different not only in width but also in morphology. The lower rock platform is the more conspicuous and forms an almost continuous feature along the NE Islay coastline. This platform is generally 100 m in width and in the Coir Odhar embayment it reaches a maximum width of almost 300 m. With the exception of the area near Rhuvaal lighthouse this platform is succeeded landward by quartzite backing cliffs generally 30-35 m in elevation. The platform surface is similar in every respect to the SW Jura feature and, like it, declines in altitude very gently seaward. In addition, the smooth ice-moulded surface of the lower platform and its considerable width strongly suggest that it forms part of the same feature described in SW and NW Jura. At Rhuvaal, however, the inner edge of the lower platform is separated from the main cliff by a second shore platform, which is 10-25 m wide. Between the two platforms is a cliff 1-2 m high. Unlike the lower platform, the surface of the higher platform (i.e. the Main Rock Platform) is characterised by protruding angular quartzite ridges and a marked absence of smooth rock surfaces and pot-holes. This platform can be traced as a horizontal feature for a considerable distance along the coast and since its frontal cliff cuts across different beds of quartzite, there can be no doubt that here two separate intertidal shore platforms occur.

Interpretation

Since the intertidal shore platform fragments that occur in NW Jura are located in bays, they cannot easily be explained as the product of modern marine erosion. The presence in this area of polished and ice-moulded intertidal platform surfaces described by previous writers and observed by the present writer shows that the platform fragments were formed prior to the last glaciation. The restricted distribution of platform surfaces in this area may therefore be attributable to later glacial erosion that removed platform fragments from headlands yet did not entirely destroy fragments located in bays.

In SW Jura till deposits overlying the platform indicate that here the platform has been overridden by ice since its formation. In NE Islay and Colonsay the presence of similar ice-moulded intertidal rock platform fragments up to 1 km in width strongly suggests that they were also formed prior to the last glaciation during a long period of relative sea-level stability. Since the SW Jura and NE Islay platform fragments are similar in morphology to those described from NW Jura, the simplest explanation is that the platform fragments described above are of the same age. In addition the occurrence of intertidal platform fragments in areas of restricted fetch suggests that some agency other than wave action (possibly frost action) has contributed to their formation. The marked contrast in width between the wide platform fragments of NE Islay, SW Jura and Colonsay and the much narrower platform fragments of NW Jura may reflect regional variations in glacial erosion. For example the sea area by NW Jura is characterised by glacially-overdeepened trenches while to the south and west the deep trenches are replaced by shallow shelf areas. It is in the latter areas that the intertidal platform is best developed. The regional horizontality of the shore platform fragment altitudes supports the hypothesis that the platform is of interglacial age.

Sissons (1982) suggested that the Low Rock Platform described by the author formed part of a set of separate interglacial rock platforms that were produced during several periods of interglacial wave erosion. The author (1980) suggested that the Low Rock Platform was a distinct feature throughout the Scottish Hebrides and proposed that it was formed during interglacials. This view was based on the fact that many glacial intertidal rock platforms are well developed in areas unaffected by glacio-isostatic uplift. For example, extremely wide intertidal rock platforms eroded in granite are present in the Channel Isles and many well-developed fossil rock platform fragments are present in the intertidal zone of SW England. At present, the author believes that tht latter features and the Low Rock Platform of Scotland were produced durings interglacials but in particular were produced at the ends of interglacials by periglacial shore erosion in association with southward excursions of the N Atlantic polar oceanic front.

THE COIR ODHAR MORAINE, NE ISLAY

McCann (1964) described a terminal moraine in NE Islay that he considered to have been formed during the Highland (Loch Lomond) Readvance. McCann noted that the moraine occurs on top of a high coastal rock platform and concluded that it represented the outer margin of a valley glacier that flowed seaward from a corrie located farther inland (McCann, 1964, p. 5). He stated that, since raised beach deposits were incorporated within the moraine, a readvance of ice had occurred in NE Islay that was contemporaneous with the Highland Readvance identified in Jura by Charlesworth. McCann (1964, p. 5) stated that,

> "... the outer face of the morainic ridge at 77 feet (23.5 m) above high water mark is unmodified by marine erosion showing that the sea must have fallen below this level before the onset of the readvance of the ice."

Later, Synge and Stephens (1966, pp. 107-8) concluded that the moraine was,

> "... one of a series of drift ridges deposited by the general glaciation on this coast ... the seaward edge of this "moraine" is the erosion scarp, or cliff, of the Late-glacial marine limit. An accumulation of rounded beach gravels occurs at the foot of this small cliff at 96-99 feet (29.3-30.2 m) OD ... (the) marine limit along this stretch of coast is uniform in height, and uninterrupted by any later glacial phase."

Morphology

The feature forms two distinct NW-facing arcuate ridges that are separated by a small embayment 200 m in width. On both sides of the embayment the ridges mantle a well-developed high rock platform. East of the embayment a well-defined ridge curves inland to the lower hillslopes. On the W side of the embayment an arcuate ridge extends for 500 m to end at the base of the cliff backing the High Rock Platform.

In situ exposures of the material composing the E ridge occur at NR 400785. Here two sections reveal angular quartzite blocks embedded in a matrix of stiff orange clay. The deposits, together with the morphology of the feature, indicate clearly that it is a moraine. Rounded raised beach cobbles mantle the outer edge of the ridge. Careful investigation failed to confirm McCann's observation of raised beach cobbles embedded in situ within the moraine.

On both sides of the embayment the outer margin of the moraine is cliffed and the cliff forms the inner edge of a well-developed raised shoreline. This shoreline forms the marine limit in the area and is a clear feature along considerable stretches of the NE Islay coastline.

The backing cliffs at the head of the embayment are composed of stratified sand and gravel deposits that have been deeply incised by several streams that drain into the embayment. The stratified deposits are composed of sub-angular gravel generally less than 10 cm in diameter in a matrix of coarse grey sand. The deposits rise in altitude inland until they merge into till-mantled quartzite ridges. In the area behind the moraine ridge the absence of exposures makes it impracticable to define the areas where the High Rock Platform is replaced by stratified deposits. The lateral extent of sand and gravel behind the moraine ridge is obscured by thick peat accumulations. The stratified deposits descend seaward from over 42 m to 30 m and have an average slope of 4 cm/m. The raised shoreline varies little in altitude with most fragments occurring between 26 and 27 m, while the highest level of raised beach cobbles is at 31.4 m (NR 400785).

The stratified nature of the inland deposits and the absence of large cobbles suggests that deposition occurred in an alluvial environment where water velocities were sufficient to transport only small-sized debris. The measured altitudes of the sand and gravel deposits imply that these deposits are graded to the raised shoreline altitude of 26-27 m. It is therefore reasonable to suggest that since the sand and gravel surface is graded to the altitude of the raised shoreline, both are of the same age and since the outer edge of the moraine forms the backing cliff of the raised shoreline, moraine formation occurred approximately contempraneously with the formation of the shoreline.

THE HIGH ROCK PLATFORM

The existence in the Scottish Inner Hebrides of a well-defined high rock platform and associated backing cliffs was first noted by Wright (1911, p. 100) who described

> "... a pronounced and locally well-preserved shoreline of pre-glacial age at a height varying from 90 to 135 feet (27.7-44.1 m) above sea-level ..."

that occurs in Colonsay, Oronsay, NE Islay, Mull, Iona and the Treshnish Isles.

Wright (1911) considered that the high rock platform fragments described by him were of the same age and defined the shoreline as 'pre-glacial' in the sense of its having been formed prior to the only apparent glaciation of the district in question. Wright stated that the pre-glacial age of the feature was proven by

> "... the repeated ice-moulding of its surface and above all, the superposition in some localities of large masses of boulder clay."

McCann later suggested that the term 'inter-glacial' be used instead of 'pre-glacial' since glacial erosion during the Quaternary

> "... must surely have resulted in more than the trifling amount of surface modifications of the platform seen in Colonsay and Mull."

Recently Sissons (1982) has suggested that the High Rock Platform in western Scotland represents a series of isostatically-tilted shorelines produced during the last and previous glacials by frost action and wave action. Sissons suggested that this interpretation accorded with the view that there was a considerable period during the last glaciation when the margin of the Scottish ice-sheet occupied a relatively stable position amidst the Hebridean islands. Since during such periods the land would have been isostatically depressed, high platforms and cliffs could have been formed or reshaped by periglacial coastal processes (Sissons, 1982). In this way the variation in the altitudes of the features are explained as the product of glacio-isostatic tilting. Large scale erosion of these features requires the former existence of periods of relative sea-level stability during which periglacial shore erosion could operate on coastlines where glacio-isostatic deformation of the land surface proceeded at the same rate as eustatic sea-level change. As a result platform formation has been related to periods of ice sheet advance or readvance (Sutherland, 1981).

The High Rock Platform of W Jura and NE Islay: Morphology and distribution

In NE Islay a high rock platform is almost continuous between Lon Cnuasachd (NR 405787) and the headland of Mala Bholsa. This platform is also well developed farther south between Mala Bholsa and Killinallan (NR 313716) where it locally reaches widths of over 1 km. East of Mala Bholsa the platform is spectacularly developed having a maximum width of 650 m and being backed by a cliff up to 60 m in height. Along the entire length of the NE Islay coastline the cliff backing the high platform is a degraded feature and is characterised by accumulations of vegetated talus and slumped or soliflucted till that blanket the rock face of the cliff and obscure the platform inner edge. The platform declines gently in altitude seaward and its surface is free of stacks; its frontal edge forms the backing cliff of the Low (intertidal) Rock Platform.

At Mala Bholsa and Aonan na Mala (NR 375777) the platform is indented by numerous geos that at one location cut across its entire width. Between Aonan Port an-t-Struthain (NR 384780) and Aonan na Mala several exposures reveal accumulations of till that directly overlie the platform surface and which are, in turn, overlain by raised beach gravels. Here the distribution of the high raised beach gravels is limited to the seaward areas of the platform surface, generally below 27 m. Landward of these high beach gravels the platform surface is overlain by till while farther east along the NE Islay coast the platform is overlain by the Coir Odhar moraine.

Owing to the presence of deposits on these platform fragments the platform inner edge is only visible at six locations along stream channels and on the sides of geos. The six measured altitudes are the only published values for the inner edges of glaciated high rock platform fragments in Scotland. They indicate only minor regional variations in altitude over a distance of ca. 28 km (Table 1). One slightly higher platform

Table 1

High Rock Platform fragment altitudes, N Islay and W Jura

	Mean altitude (m.O.D.)	Grid Reference (NR)
1.	32.7	37747780
2.	33.6	37547770
3.	34.1	53858915
4.	32.1	50948415
5.	34.9	35007432
6.	34.0	34347309
7.	35.4 *	38597780

* denotes site where altitude is for platform surface

altitude (35.4 m) is known for the surface of the platform in NE Islay (NR 38597780). The continuity in the field of the W Jura and N Islay platform fragments suggests strongly that they are part of the same platform.

Since the Coir Odhar moraine in NE Islay overlies the adjacent high rock platform it is clear that the formation of the NE Islay platform pre-dates the deposition of the moraine. In addition, since it has already been shown that the Coir Odhar moraine was formed during general deglaciation of the study area, it is clear that in NE Islay the high platform pre-dates at least one period of general glaciation.

The origin of the high rock platform in N Islay and W Jura is problematic although an estimate of the length of time required to produce the feature is instructive. In W Jura, the Main Lateglacial Shoreline is eroded in the adjacent high rock platform. Both features are formed in Dalradian quartzite and are continuous along 7 km of coastline. A minimum rate of cliff retreat of 7 cm/year was calculated for the Main Lateglacial Shoreline and is equivalent to the removal by periglacial shore erosion of approximately 1 m^3 of rock per metre of coast per year. Comparison of the dimensions of both shorelines indicate that the formation of the W Jura high rock platform by similar periglacial shore erosion processes would require a minimum period of ca. 8,000 years. The high rock platform of N Islay is a much wider feature (up to 1.3 km), is backed by high cliffs (up to 70 m) and is also formed in Dalradian quartzite. Formation of the widest high rock platform fragment in N Islay by periglacial short erosion would require ca 28,000 years of erosion. The occurrence of such prolonged coastal erosion during a single period of cold climate is unlikely due to glacio-isostatic instability of the land surface and glacio-eustatic changes in sea-level. It would therefore appear clear that the N Islay and W Jura high rock platform represents the product of several periods of periglacial shore erosion.

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