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# HOLOCENE SHORELINES IN BRITAIN: RECENT STUDIES

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## ABSTRACT

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Recent studies of Holocene shorelines in Britain have included only a few investigations of the nature and positions of shorelines, but five individual categories of mappable shorelines may be recognised. Shorelines in relation to vegetation and to marine transgression and regression have been subjects of extensive study along several parts of coastal Britain. Vegetational change may denote marine transgression or regression but need not denote changes of sea level. Similarly, marine transgression and regression are changes in the position of the land/sea interface rather than events determined by changes of global sea level. About half of the recent shoreline studies in Scotland have been concerned with the gradients of tilted shorelines. A growing interest is the relationship between former shorelines and sites of early human occupation. Few investigations have been concerned primarily with the chronology of Holocene shorelines.

## INTRODUCTION

The publication, in 1966, of a monograph concerned with 'The vertical displacement of shorelines in highland Britain' (*Trans. Inst. Br. Geogr.* 39: 145 pp.) gave impetus to a growing *corpus* of Holocene shoreline studies in the British Isles. Investigations since then have varied greatly in emphasis, as the following thematic discussion shows.

## NATURE AND LOCATION OF SHORELINES

Investigations of the nature, and determination of the positions, of former Holocene shorelines have been remarkably few despite the fundamental importance of these aspects of shoreline and sea-level studies. BINNS (1972, p. 206) suggested that 'most strandlines only mark small climatic and isostatic/eustatic oscillations and are only locally visible', but in certain cases it is upon the evidence of what are no more than small remnants of shore landforms or deposits that imposing theories of shoreline and sea-level changes have been built.

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Clearly, there is need for the accurate definition of shorelines and shoreline positions.

Conventionally, the shoreline of the sea at any given location and any given time is the line of intersection of mean tide level at the given time and the terrestrial surface at the given location (cf. JARDINE, 1975-a, p. 163). For reasons discussed elsewhere (JARDINE, in press), the conventional shoreline cannot be mapped directly and, in practice, frequently the mapped shoreline of any given time is a line joining points located at high-water mark of ordinary spring tides on the contemporaneous coast, although some authors favour the seaward limit of the shore zone as the significant shoreline position (JARDINE, 1979, p. 162; cf. JARDINE, in press).

In mapping practice, in most areas the line that is plotted as the former shoreline is the position of a break of slope that is distinguishable in the field. Five major categories may be recognised. The first comprises junctions between steep cliffs in solid rock and either rock platforms or shore sediments. In the case of Holocene shorelines in Britain few genuine examples of this type are thought to exist because the Holocene sea no longer is regarded as being the 'cliff maker par excellence' that WRIGHT (1928, p. 99) believed it to be. There is good cause, however, to believe that in areas such as that around Oban, in western Scotland (Fig. 1), the shoreline at the (local) maximum of the Holocene marine transgression re-occupied the position of a cliff-and-platform shoreline that had received its essential form a few millennia earlier, c. 11,000 to 10,400 years B.P., around the time of the Loch Lomond Readvance (cf. GRAY, 1974-a, 1978; MCCANN, 1968; JARDINE, 1977-a, p. 115). Small lengths of shoreline formed in E Galloway (Fig. 1, inset) in pre-Holocene times similarly may have been re-occupied by the Holocene sea (JARDINE, 1980-a, p. 40-43).

The second category of relevant break of slope occurs where, occasionally, the junction between an area of former marine or estuarine shore sediments and a terrestrial sedimentary body is marked by an abrupt change of gradient. Examples are certain of the boundaries between Holocene marine sediments and late-Pleistocene kames, kame terraces and eskers that occur in Dumfriesshire and E Galloway, SW Scotland, e.g. in the vicinities of Annan and Dumfries and west of Southerness (Fig. 1, inset). An important principle is well illustrated by the latter case: the position and alignment of a Holocene shoreline may have been pre-determined in late-Pleistocene times by fluvioglacial events that produced a series of elongate terraces and ridges of sand and gravel (JARDINE, 1980-a, p. 42).

Abrupt breaks of slope at junctions between former 'normal' shore sediments and penecontemporaneous storm debris constitute the third category of readily-identifiable former shorelines. A special case occurs where a temporary lagoon existed between the 'mainland' coast and a storm-beach ridge, e.g. on the island of Oronsay, western Scotland (Fig. 1) (JARDINE, 1977-b, Fig. 1).

Low cliffs (c. 2-3 m in height), occurring inland from the present high-tide shoreline in Holocene tidal-flat deposits that accumulated along the northern shore of the Solway Firth (Fig. 1, inset) in the course of the main Holocene marine transgression are examples of a fourth category of recognisable raised shoreline (JARDINE, 1980-a, p. 44). The low cliffs at Solway Firth sites, and at numerous other British sites that have not been investigated extensively in this context, indicate the position of the 'high-water shoreline' of the shore zone that was in existence during a halt or series of halts in a general recession of the sea from its maximal Holocene position.

Perhaps the most interesting category of mapped former shoreline positions is that in the vicinity of the base of an accentuated slope within an area of 'normal' shore sediments. By analogy with present-day shore zones it seems probable that in a given case the relevant former high-tide shoreline was located at or near the top of the area of accentuated slope (rather than at the base of the slope) and the corresponding low-tide shoreline was located several tens, or even hundreds, of metres seawards of the mapped break of slope.

In contrast with the above cases are 'implied' shorelines, such as those that, on the basis of biological evidence preserved in offshore positions, may be inferred to have existed c. 6900 to 5450 B.P. when marine waters occupied the valley that now is the site of Loch Lomond (DICKSON ET AL., 1978). Sedimentary and geomorphological confirmation of the actual existence of the 'implied' shorelines occurs at +13, +12 and +9 m O.D. (DICKSON ET AL., 1978; ROSE, 1980, p. 49).

Conjectural positions of shorelines on the eastern coast of Britain at the maximum of the Holocene marine transgression and at c. 7500, 5000 and 2000 B.P. are shown by OELE ET AL. (1979, colour chart appendix).

## SHORELINES IN RELATION TO VEGETATION

In many present-day settings, transitions in vegetation are characteristic of the shore zone in combination with the landward area immediately adjacent to the shore. On the assumption that replacement of a saltmarsh plant community by terrestrial taxa indicates inception of a marine regression and, *vice versa,* a marine transgression is marked initially by replacement of terrestrial vegetation by saltmarsh plant taxa, fluctuations in the position of former Holocene shorelines have been deduced in a number of British coastal areas. Similar transitions in vegetation are considered by some authors to be indicative of changes of relative sea level, but it should be noted that marine transgression and regression are not necessarily attributable solely to changes of the (mean) level of a marine water body (JARDINE, 1975-b, p. 173-174).

A number of the principles involved in deciphering the relationship between sea-level position and saltmarsh, reed-swamp and fen communities are discussed by TOOLEY (1978, p. 18-22). Regional studies of stratigraphy, vegetational changes and sea-level position that lead directly or indirectly to assessment of former shoreline positions are given in publications by BROOKS (1972, Forth valley), CULLINGFORD ET AL. (1980, Lower Strathearn), DEVOY, (1979, Thames estuary), NEWEY (1966, Forth valley), NICHOLS (1967, Lochar Moss, Dumfriesshire), TOOLEY (1974, Lancashire) and WALKER (1966, Cumberland). In analysing data from the estuary of the River Thames, Devoy summarised the major problems encountered in such studies when he wrote (1979, p. 361), '. . . even where marine/brackish inorganic and freshwater organic facies alternate and a full range of biostratigraphic techniques can be used, the problem of defining the point of sea level rise and its relation to sediment accumulation remains. For although growth will be related to a particular point within the tidal range, the deposits may form from below mean sea level . . . to above mean high water mark of spring tides' (cf. KIDSON & HEYWORTH, 1979, p. 13).

A situation that is of particular significance in relation to shoreline and sea-level studies is where peat accumulation at a given site has taken place continuously over a period of several hundreds of years concurrently with a rise of sea level associated with the main Holocene marine transgression. Cases occur in the Forth valley in E Scotland, at the head of Wigtown Bay in SW Scotland and, possibly, in the Paisley area, near Glasgow (BROWNE, 1980, p. 13). At both West Flanders Moss and East Flanders Moss in the (present) Forth

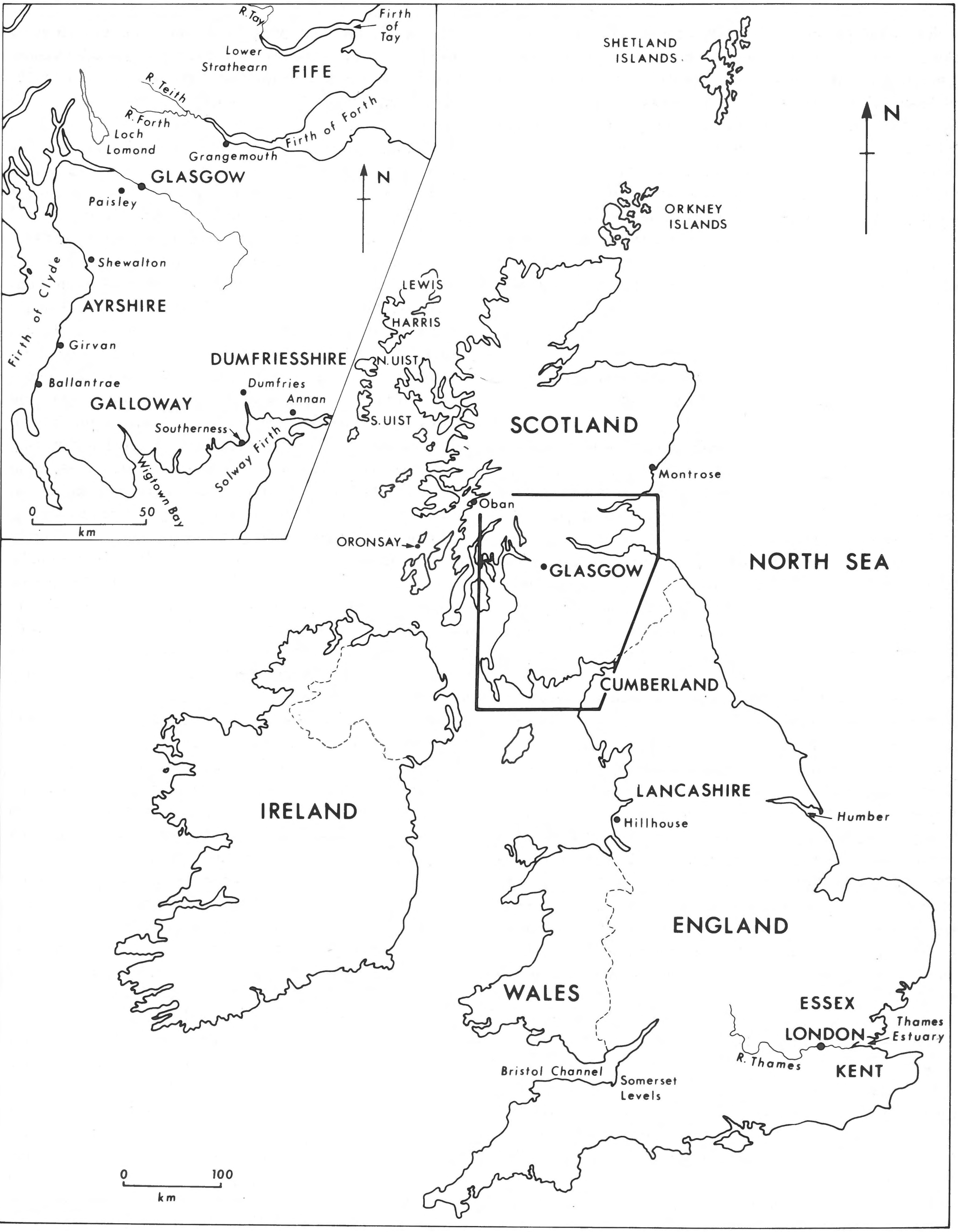


Fig. 1
Map of the British Isles, showing the main localities mentioned in the text. Inset: detail of central and SW Scotland.

valley, simultaneously with the deposition of Holocene 'carse clay' estuarine/marine sediments, large areas of peat formation, fringed with belts of reeds, stood slightly above the level of the accumulating clay. At East Flanders, the area of organic debris was completely surrounded by the sea at times of high tides, whereas, throughout the tidal cycle, the southern edge of the West Flanders peat mass was attached to a ridge formed by the Menteith moraine (SISSONS & SMITH, 1965, p. 254). At Palnure, at the head of Wigtown Bay, accumulation of peat (that bordered a steep, solid-rock shore-cliff) appears to have occurred simultaneously with sea-level rise over a period of several hundred (? 1700) years (JARDINE, 1975-a, p. 166-167; 1975-b, p. 184-185).

## SHORELINES IN RELATION TO MARINE TRANSGRESSION AND REGRESSION

At the beginning of the Holocene, global sea level was still several tens of metres below its present level (at −45 m O.D.: WEST, 1972, Fig. 7), but in many coastal areas of Scotland the *relative* level of the sea was higher than Ordnance Datum. The Holocene shoreline history of Britain is largely concerned with the transgressive and regressive effects produced in two contrasting areas by the continued rise of ocean level until c. 5000 B.P.: the southern part where glacial rebound was negligible; the parts of Scotland, Ireland and northern England where glacial rebound was still in progress after 5000 B.P.

In the foregoing part of this paper and in numerous papers published in Britain between 1966 and 1980 the terms *marine transgression, marine regression, shoreline changes* and *sea-level changes* are inter-linked in such a manner that there is a danger that it will be assumed that the events termed 'marine transgression' and 'marine regression' constitute both changes in shoreline position and in global level of the sea. For reasons given elsewhere, in the opinion of the writer this is not the case (JARDINE, 1975-b, p. 173). The terms 'marine transgression' and 'marine regression' should be applied to movements of the sea relative to the land determined by any cause, rather than to shoreline changes determined mainly by eustatic movements of the sea. If this suggestion is accepted, a variety of changing environmental conditions, brought about by marine transgression and regression, have existed along the British coasts in the course of the last 10,000 years. Examples are discussed below.

In the area known as the 'Somerset Levels', east of the present Bristol Channel (Fig. 1), rivers graded to lower than −30 m O.D. excavated valleys during the period of the last (Weichselian) glaciation and produced a pre-Holocene topography of marked relief. Global sea-level rise prior to c. 6000 B.P. led to flooding of the valleys, with accompanying landward movement of the Holocene shoreline. By c. 4000 B.P. infilling of the valleys with a variety of organic and inorganic sediments had led to seawards movement of the shoreline. Further movement of the shoreline, to its present position, was caused mainly by artificial drainage and building of embankments during the last 2000 years (KIDSON, 1977, p. 282-288 and Figs. 11 & 12; KIDSON & HEYWORTH, 1976, p. 228-234).

Possible positions of the Holocene shoreline in the outer estuary of the River Thames at 9600, 9300, 9000, 8600, 8300 and 8000 B.P. are shown in diagrams published by D'OLIER (1972, Figs. 4 to 9). During the time concerned, high-tide level appears to have risen from c. −45 m O.D. to −17 m O.D. and, in broad terms, the shoreline moved westwards and increased in intricacy as small islands and peninsulas developed. More detailed investigations of the inner Thames estuary and of areas in Essex adjacent to the outer Thames estuary (Fig. 1), covering the period since c. 8500 B.P., illustrate a variety of depositional environments that resulted from marine transgression and regression. Five regression phases, represented by biogenic deposits (mainly products of saltmarsh and fen environments) alternating with four marine transgressions, together with a possible fifth, are recognised in the area of the former Thames estuary between central London and the mouth of the River Medway in north Kent (Fig. 1). In this area, relative sea level for mean high water of spring tides rose from c. −26.5 m O.D. at c. 8500 B.P. to fractionally above O.D. by c. 1750 B.P. (DEVOY, 1979). In the coastal zone of SE Essex, faunal and lithological changes within the 36 m thick succession of Holocene sediments indicate three major transgressive cycles. The first and second cycles are confined to the vicinities of deep Pleistocene channels; the third, possibly initiated c. 7500 B.P., extends across the whole coastal zone. Each cycle consists of a lower division of clays and silts with thin coarser-grained deposits towards the base, and an upper division of sands and sandy gravels. The main environments represented are: salt marsh – lagoon; beach – chenier – barrier-spit; intertidal flat; channel. The evolution of the cheniers, including that of modern examples, has been studied in great detail (GREENSMITH & TUCKER, 1973, 1975, 1976).

Farther north, in the vicinity of the Humber (Fig. 1), a series of marine transgressions and regressions during the period c. 6700 to 2500 B.P., when relative sea level rose from c. −9 m O.D. to c. O.D., is recorded at a number of sites. Much of the evidence is interpreted as being indicative of minor changes of sea level (GAUNT & TOOLEY, 1974, p. 34-38) but, as mentioned above, there may be other equally plausible explanations to account for the presence of the thin organic layers that are interstratified with the sediments that, generally, are estuarine in origin.

The sea-level changes recognised in the Humber area by GAUNT & TOOLEY (1974) were equated with parts of a much more detailed sequence of Holocene sea-level changes that have been suggested for Lancashire, on the west coast of northern England (Fig. 1), in a number of publications by TOOLEY (e.g. 1974, 1976, 1978). The investigations in Lancashire were based almost entirely on boreholes that penetrated sequences of interstratified organic and inorganic sediments.

As a result, the possibility of detecting the positions of former shorelines related to eleven postulated transgressive sequences (and intervening regressions) was severely limited. Tooley, however, discussed the implications of Holocene sea-level changes in Lancashire in relation to a shoreline, the 'Hillhouse coastline', mapped previously by GRESSWELL (1953). TOOLEY (1977, p. 8) stated: 'It is impossible to reconcile the conditions necessary to produce a marine, wave-cut feature at Hillhouse at an altitude of +5.18 m OD with the evidence for quiet brackish-water sedimentation some 4 metres lower, 300 metres seaward and about 1000 years earlier recorded at Hillhouse'.

Shoreline studies of Scottish sites where the emphasis has been on Holocene transgression and regression rather than on the post-formational tilting of the shorelines are comparatively few. The majority of such investigations relate to the Firth of Clyde and northern Solway Firth seaboards of SW Scotland where, initially, JARDINE (1967) distinguished four sedimentary environments related to the 'main' Holocene marine transgression. Later, seven sedimentary environments were recognised: beach; gulf or open-bay; estuarine, lagoonal; coastal-bar; coastal-dune; coastal-marsh. A combination of certain of these sediments constitutes an association termed 'carse deposits' (JARDINE & MORRISON, 1976, p. 177-179). Detailed examination of the deposits in E Galloway and Dumfriesshire (Fig. 1, inset) revealed that near Annan the carse deposits comprise a lower unit containing occasional to abundant remains of marine microfauna and an upper unit in which remains of microfauna are rare but thin layers of plant debris (marking minor, local regressions of the sea) are laterally extensive. In places interruptions, attributable to the movement of gullies in the contemporaneous tidal flats and other local events, occur between the upper and lower units or within the upper unit. In a former gulf east of Dumfries, accumulation of faunally-rich carse deposits in conditions similar to those existing at present in the eastern part of the Solway Firth, was followed by formation of gravel bars near the mouth of the gulf. South-west of Dumfries, deposition of carse sediments containing marine microfauna was succeeded by formation of gravel ridges or accumulation of brackish-water sediments (JARDINE, 1975-b, 1980-a.).

The stratigraphy of deposits that accumulated in the course of the main Holocene marine transgression and subsequent regression in NE Fife was the subject of investigations by CHISHOLM (1971). In abstract (p. 91): 'In protected inlets fine-grained deposits laid down in swamps or lakes form the lower part of the sequence and they are succeeded disconformably by intertidal deposits dating mainly from the period of maximum submergence. In coastal areas exposed to strong wave action, however, beach processes have had a dominating influence on the stratigraphy'. At one locality, discussed in detail, a small inlet extended inland beyond the general limit of the Holocene sea. Marine transgression between c. 7600 and 5830 B.P. was terminated by the development of a sand bar at the mouth of the inlet.

Other studies of Holocene marine transgression and regression at Scottish sites either concentrate, or indirectly provide information, on the palaeoecology of former beach or estuarine sediments. Examples are the investigations by SMITH (1972) and FRANCIS ET AL. (1970, p. 284-286). In wider context, RITCHIE (1966) discussed the effects of the Holocene rise of sea level on the coastal form of the islands of South Uist, North Uist and Benbecula (between the Uists), whilst VON WEYMARN (1974) included consideration of Holocene modifications in a study of the Quaternary development of the coastline of Lewis and Harris (Fig. 1).

An interesting additional topic that has been considered is the hydrological effect of changes of relative sea level at coastal sites in contrasting regions, represented by the Bristol Channel area (KIDSON, 1977, p. 282-288; KIDSON & HEYWORTH, 1976, p. 228-234; 1978, p. 749) and the Forth valley (JARDINE, 1980-b).

## SHORELINE GRADIENTS

One of the most striking characteristics of former Holocene shorelines in northern Britain is their downward and outward tilt from the (presumed) centre of isostatic uplift, terrestrial rebound after deglaciation having continued throughout the Holocene, whereas global sea-level rise virtually ceased at c. 5000 B.P. About half of the published Quaternary shoreline studies in Scotland since 1966 have been concerned with shoreline gradients.

Two main groups of Holocene shorelines may be distinguished: those whose remnants are buried now below later sediments; those whose remnants are visible. Investigated examples of the first group occur both in the (present) valley of the River Forth and its tributaries and in Lower Strathearn (Fig. 1, inset). Gradients of shorelines in the latter area have not been published as yet, although it is known that the relevant deposits exist (CULLINGFORD ET AL., 1980). In the valley of the River Teith, a north-bank tributary of the River Forth, remnants of three buried terraces have been identified at altitudes between +8.4 and +12.6 m O.D., but gradients of the terraces have not been calculated (SMITH ET AL., 1978, p. 105). The terraces have been correlated with buried estuarine/marine features named the High, Main and Low Buried Beaches by SISSONS (1966). These features –also termed buried shorelines– have been identified in the western part of the Forth valley (SISSONS, 1966; 1972; SISSONS ET AL., 1966) and farther east in the same valley near Grangemouth (Fig. 1, inset) (SISSONS, 1969). The High Buried Shoreline is believed to have been formed c. 10,300 to 10,100 B.P., immediately prior to the Holocene, the Main Buried Shoreline c. 9600 B.P. and the Low Buried Shoreline c. 8800 B.P. (SISSONS, 1976, p. 125). Several investigations since 1966 have led to revision of the calculated gradients of the shorelines. As Sissons has pointed out, the situation is complex. In 1976 (p. 125) he wrote: 'The average gradient of the Main Buried Shoreline in the western part of the Forth valley is 0.146 m/km, but this figure conceals significant variations, for the shoreline is horizontal in places and in two localities is dislocated (by 1 m and 1½ m respectively). These variations... show that, in this part of the Forth valley at least, isostatic uplift did not produce the simple tilting of the land that is normally assumed'.

Research into the gradients of the visible Holocene shorelines has not been confined to the Forth valley although it is in the Forth area that measurement has been concentrated. A shoreline termed the Main Postglacial Shoreline has been recognised in several areas, and below this up to three other (later) Holocene shorelines have been identified in certain areas. Comparison of results obtained in a number of areas has been made by GRAY (1974-b, p. 133-136). In summary, Gray notes that the calculated gradient of the Main Postglacial Shoreline varies as follows:

| | | |
|---|---|---|
| Oban area | 0.05 m/km | (GRAY, 1974-b, p. 133); |
| Forth valley | 0.08 m/km | (cf. SISSONS ET AL., 1966); |
| Tay valley | 0.09 m/km | (Cullingford, unpublished); |
| West coast, Scotland | c. 0.075 m/km | (MCCANN, 1966; SYNGE & STEPHENS, 1966). |

Gray points out that the discrepancy between the gradients quoted for the Oban area by McCann and himself probably is due to the inclusion of altitudes related to the late-Pleistocene 'Main Rock Platform' in McCann's calculation of the gradient of the Main Postglacial Shoreline. In places these two coastal forms are almost coincident and therefore are difficult to distinguish. Perhaps it should be noted that SISSONS (1976, p. 126) gives the gradient of the Main Postglacial Shoreline in the Forth valley as 0.076 m/km.

Recently a morphometric comparison of raised (and tilted) shorelines, including Holocene examples, in Fennoscandia, Scotland and Ireland was made by SYNGE (1980).

## SHORELINES IN RELATION TO SITES OF EARLY HUMAN OCCUPATION

'The marine coastal environment has always been an important habitat of man . . .' (JARDINE & MORRISON, 1976, p. 175), so it is natural that in the recent study of Holocene shorelines in Britain consideration should have been given to the relationship between former shorelines and sites of early human occupation. Preliminary work in this field of enquiry was carried out in the valleys of the Rivers Forth and Tay by MORRISON (1969), whilst the relationship between archaeological evidence and shoreline/sea-level changes in southern Britain was considered by AKEROYD (1972). More specifically, JARDINE & MORRISON (1976) discussed the effects of changing coastal environments, in the course of the Holocene, on human occupation at sites in SW Scotland. At the eastern end of the Solway Firth there is evidence, in the form of the remains of a hearth and charcoal, of human occupation before the (local) onset of the main Holocene transgression (JARDINE, 1980-a, p. 9-10), the estuarine/marine environment of the transgressive phase being replaced, near Annan, by either storm-beach gravel or wind-blown sand in the latter of which occur former land surfaces containing traces of human occupation. East of Dumfries, in a former narrow inlet, marine conditions were succeeded by a string of fresh-water lakes in which dug-out canoes were used around 3750 B.P. South-west of Dumfries, near Southerness Point (Fig. 1, inset), an open bay was replaced by a swampy coastal marsh and later by an area of low coastal dunes during the Neolithic, Bronze Age, Iron Age time-span. South of Ballantrae, on the Firth of Clyde coast, Mesolithic and later people occupied sites close to the mouth of the River Stinchar at and immediately after the maximum of the main Holocene marine transgression. Sites at Girvan and Shewalton, in central Ayrshire (Fig. 1, inset), were considered in the same context by MORRISON (1981). Similar studies, dealing with the position of the shoreline in relation to Mesolithic occupation sites on the island of Oronsay, including consideration of storm-beach ridges (JARDINE, 1977-b, 1978), with Holocene environmental changes and human occupation in the area of the Thames estuary (DEVOY, 1980), and archaeology and coastal change in NW England (JONES, 1980) are complemented admirably by general coverage of this topic in Britain in a book by MORRISON (1980).

## CHRONOLOGY OF SHORELINES

Consideration of the relationship between sites of early human occupation and former shorelines is one method that, occasionally, provides information concerning the ages of the relevant shorelines (e.g. JARDINE, 1977-b, 1978). Another (low-reliability) method that may be used is concerned with the presence of drift pumice in shore deposits (BINNS, 1967, p. 14-17). Other methods that have been used to establish the chronology of shoreline changes are either pollen analysis in combination with limited numbers of radiocarbon age determinations (e.g. SISSONS & BROOKS, 1971; DEVOY, 1979) or radiocarbon age determination on its own. Remarkably few of the many studies of Holocene shorelines in Britain are concerned primarily with chronology perhaps because as SMITH ET AL. (1980, p. 225) remark, isostasy was a major element in their formation, raised shorelines are likely to be slightly diachronous. Examples of publications directly concerned with chronology of shorelines are those of SMITH ET AL. (1980, Montrose area, E Scotland), SISSONS & BROOKS (1971, western Forth valley), JARDINE (1971, 1975-b: SW Scotland, 1977-b, 1978: Oronsay), BINNS (1972, several areas in the British Isles, including Ireland).

## CONCLUSION

The variety of investigation of Holocene shorelines in Britain is a direct result of the variability of the exceptionally long shoreline that forms the perimeter of the islands (compared with the length of shoreline present in many other NW European countries), and of the occurrence of a glaciated northern part of the country in which there has been a net fall of relative sea level during the Holocene, compared with an unglaciated southern part in which rise of sea level was restricted virtually to the first 4500 years of the Holocene epoch.

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