

**CLASSIC
LANDFORM GUIDES
No. 7
Classic Landforms
of the
Gower Coast**

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Published by the Geographical Association
in conjunction with the

British Geomorphological Research Group



**THE GEOGRAPHICAL ASSOCIATION
343, FULWOOD ROAD, SHEFFIELD, S10 3BP**

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Cover photograph: Steeply dipping limestone rocks at Three Cliff Bay with a natural arch.

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ISBN 0 948512 06 7

Geomorphologists study landforms and the processes that create and modify them. The results of their work, published as they invariably are in specialist journals, usually remain inaccessible to the general public. We would like to put that right. Scattered across the landscapes of England and Wales there are many beautiful and striking landforms that delight the eye of the general public and are also visited by educational parties from schools, colleges and universities. Our aim in producing this series of guides is to make modern explanations of these classic landforms available to all, in a style and format that will be easy to use in the field. We hope that an informed understanding of the origins of the features will help the visitor to enjoy the landscape all the more.

The relevant maps for the area covered in this booklet are the Ordnance Survey 1:50 000 Landranger Sheet 159 and 1:25 000 Sheets SS 49/59 Gower (North), SS 48/58/68 South Gower (and the Mumbles).

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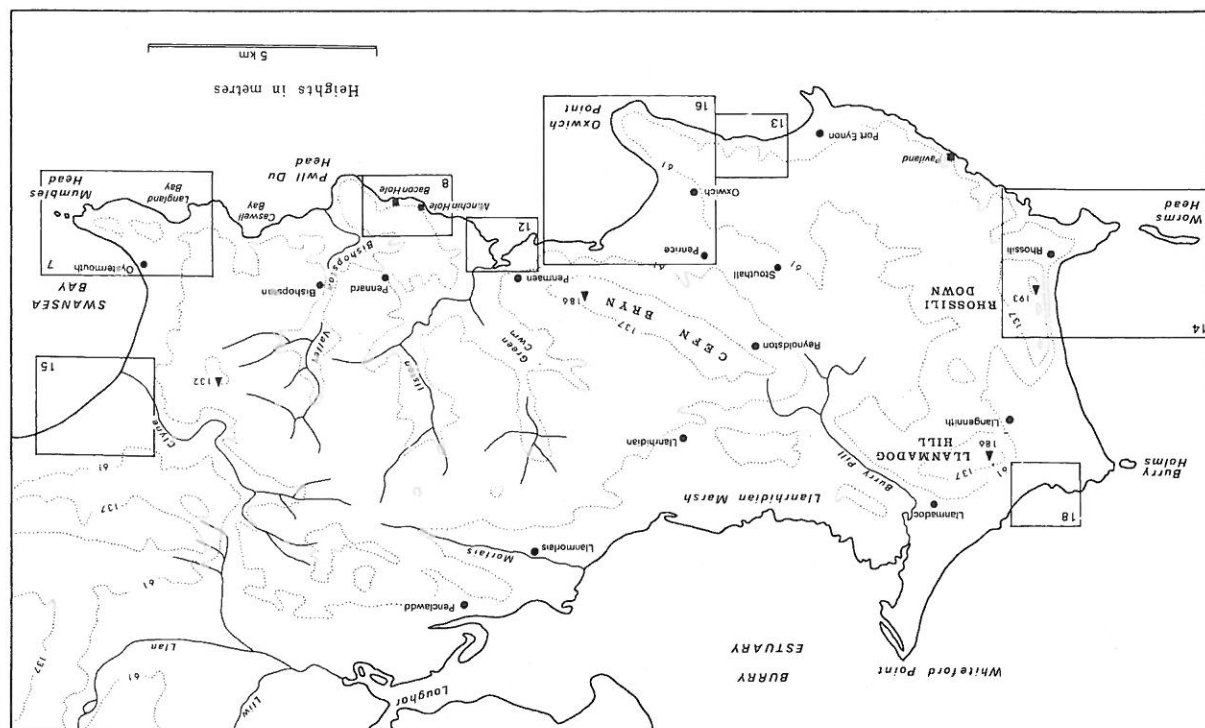


Fig. 1. General map of the Gower peninsula showing areas studied in detail.

INTRODUCTION

The Gower peninsula is one of the best-known and most attractive parts of the coast of South Wales. It extends westwards from the City of Swansea, lying between Swansea and Carmarthen Bays, bounded to the south by magnificent limestone cliffs with sandy bays and to the north by the extensive marshes of the Burry Estuary. The coastline includes the limestone cliffs, raised beaches, fossiliferous caves and their associated glacial and solifluction deposits. In some places, blown sand covers the solid rocks as at Pennard and Oxwich, but the dune complex of Whiteford Point overlies boulder clay. Alluvial silts on the northern side of the peninsula form Llanrhidian Marsh (Fig. 1).

The Geological Background

The oldest rocks to crop out in the Gower peninsula are the sandstones and conglomerates of the Devonian Old Red Sandstone which form low rounded hills rising to 180 m (Fig. 2). These Devonian rocks appear in the cores of anticlines, the axes of which trend in a NNW-SSE direction (Fig. 3). Surrounding these low hills the Carboniferous Limestone forms a plateau at about 60 m above sea level, ending abruptly in the cliffs of the south coast. Both Old Red Sandstone and Carboniferous Limestone are tightly folded so that if they could be straightened out the width of the peninsula would be doubled! The limestones extend northwards as far as a line between Llanrhidian and Oystermouth, north of which Millstone Grit and Coal Measures crop out in a scarp and vale landscape extending from Swansea Bay across the peninsula to form the north coast between Llanrhidian and Gowerton. These strata dip northwards in response to the regional dip of this part of the southern rim of the South Wales coalfield basin. The succession of solid geological formations represented in Gower is given in Table I.

Table 1 Geological divisions and their lithology

System	Unit	Lithology
Triassic	Penarth Group	Conglomerate
	Coal Measures	Sandstones, shales and coals
	Millstone Grit	Sandstones and shales
Carboniferous	Carboniferous Limestone	Limestones and shales
	Old Red Sandstone	Conglomerates and sandstones

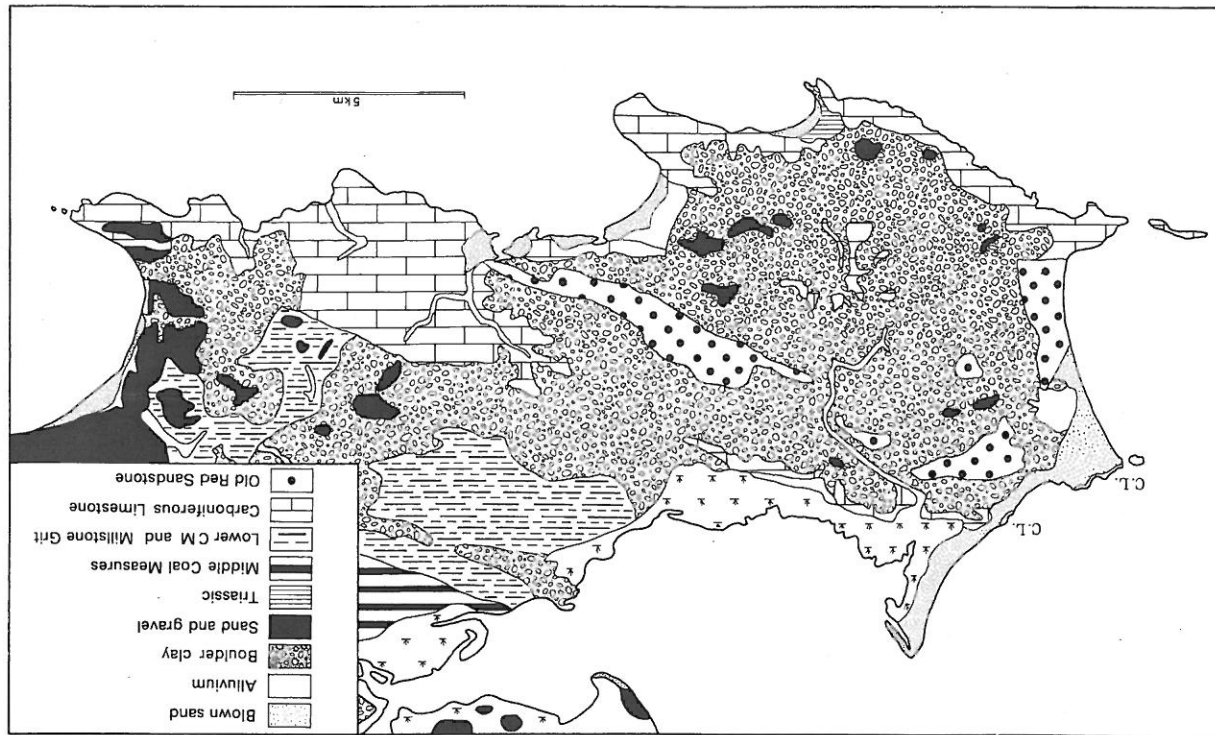


Fig. 2. Solid and drift geology of the Gower peninsula.

A small outcrop of Triassic rocks occurs at Port Eynon and numerous fault zones contain red material which may possibly be Triassic also, but no further Mesozoic rocks occur. A long-running controversy exists about a former cover of Jurassic and Cretaceous rocks upon which the present drainage system of South Wales originated, eventually to be superimposed upon the underlying Palaeozoic rocks. Some substance is lent to this theory by the recent discovery of Liassic rocks on the sea floor south of a fault parallel to the south Gower coast. The former presence, or absence, of a Mesozoic cover is not directly relevant to the present discussion, but the Triassic remnant at Port Eynon is significant because it proves that some of the relief of Gower was already in existence in Triassic times as this small remnant lies on the floor of the valley. Much of the lower-lying land of South Wales, including Swansea Bay, may have been buried by unconsolidated Triassic deposits. If Mesozoic rocks ever covered Gower, then all were removed by the Tertiary when the landscape may have been trimmed by the sea to give the well-known marine abrasion platforms at 60 m (200 ft), 130 m (425 ft) and 180 m (600 ft) above present sea level (Fig. 4).

The geological history of Gower is completed by events in the Pleistocene Ice Age and Recent times. Gower has been invaded twice by glaciers which have left drifts of different character. The first glaciation took place in Pre-Ipswichian times (Table 2) when ice from the Irish Sea basin extended across South Wales, including southern Gower, where it deposited a mixed drift, including pebbles of micro-granite from the Scottish Island of Ailsa Craig. At the same time, northern Gower was probably affected by ice from the South Wales coalfield. After the emplacement of the raised beaches during the Ipswichian interglacial, ice from the South Wales coalfield again pushed down the major valleys of South Wales in the Devensian until it impinged upon north Gower and extended eastwards into Swansea Bay. Controversy exists about the extent of ice cover in Gower; some opinions about the location of the ice margin are indicated in Fig. 5. It was during this final glacial episode, particularly as the ice was retreating from the district, that several of the anomalous drainage features of Gower were established as a result of meltwater streams in, below, or alongside the decaying ice. Ice-free areas were affected strongly by solifluction and the deposits of the earlier glaciation were redistributed.

Methods of dating Pleistocene materials can be described as relative or absolute. The relative age of a sequence of deposits of different lithologies can be determined by assuming that the lowest bed is the oldest and that the materials above must be younger. In this method, the position of the beds indicates the age and from their lithology much can

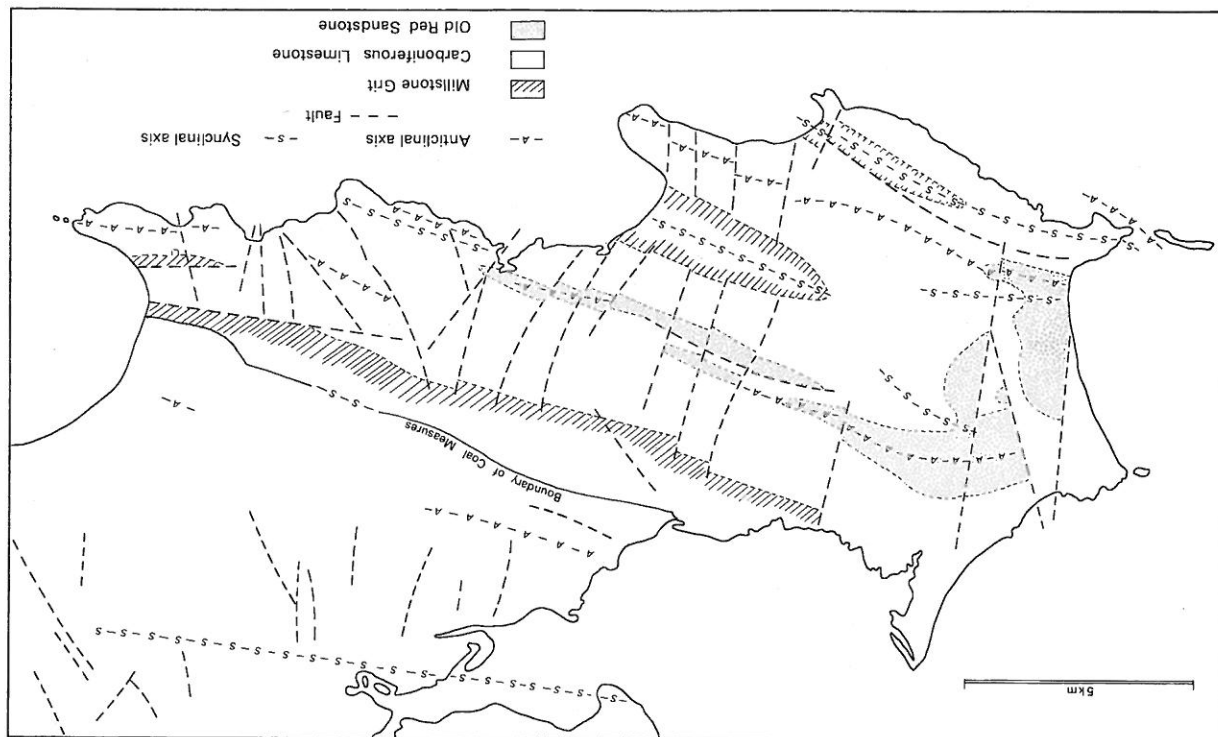


Fig. 3. Geological structure of the Gower peninsula.

be deduced about the events surrounding their deposition. However, some care must be taken as solifluction can lead to an inverted sequence of deposits in a downslope position with the youngest upslope materials being removed first to become the lowest and apparently the oldest of a new deposit. Absolute dating by the radio-carbon method is based upon the content of ^{14}C present in organic materials incorporated in a mineral deposit. As the ^{14}C decays with age, a measure of the amount remaining can give satisfactory dates for organic remains of the last 30,000 years BP. For older deposits the method is unreliable, and even within the effective limits of the method it is difficult to ensure that samples have not been contaminated by roots and carbon of a more recent origin.

An alternative absolute method of dating which uses a ratio of different types of amino acids can be used for fossil organic materials. This enables the time scale to be extended beyond that achieved by ^{14}C dating. Dates produced by this method indicate that the formation of the Patella beach took place 125,000 years BP and that the inner beach of Minchin Hole can be assigned to a date of 210,000 BP. Pleistocene events in Gower, presented in Table 2, show an overwhelming concentration of evidence from the last major glaciation, the Devensian. The raised beaches and some of the earlier cave deposits are Ipswichian in age and the older drifts are Pre-Ipswichian, probably Wolstonian.

Geological events in Recent (Flandrian) times have been dominated by the rise in sea level and the subsequent movement of sand dunes inland

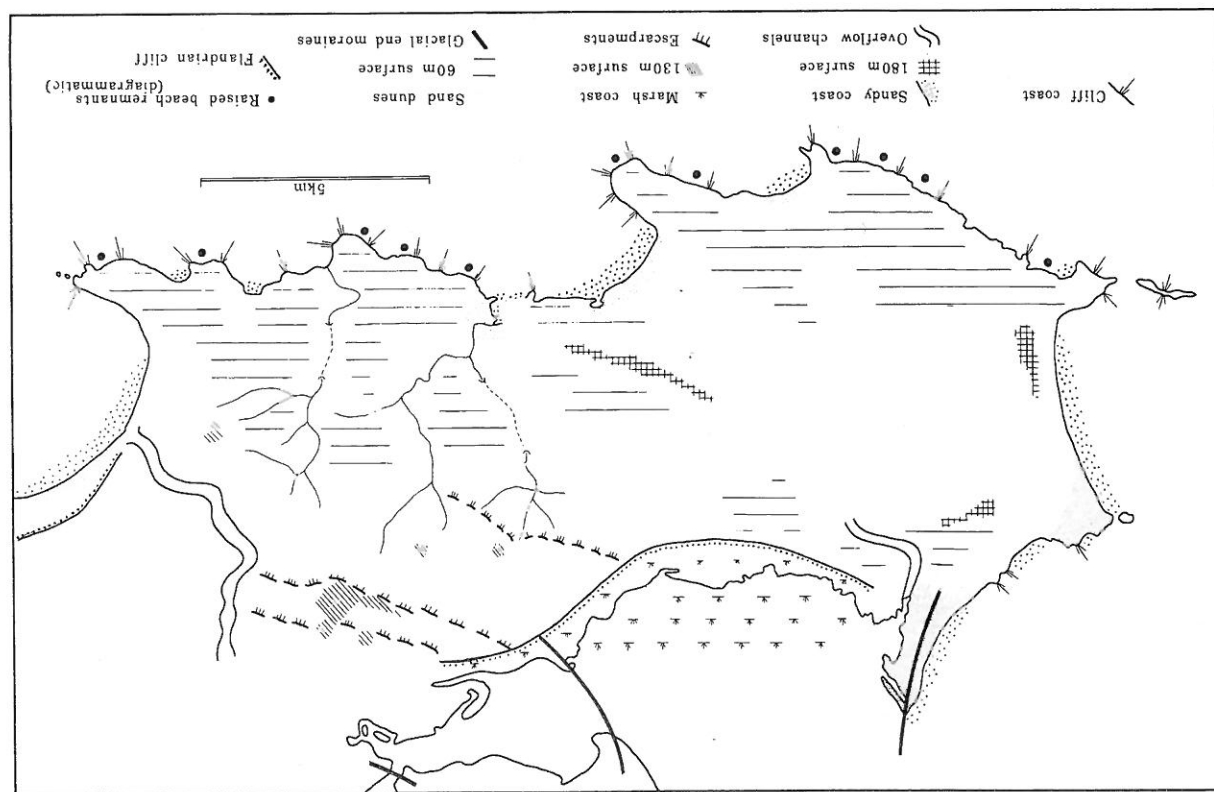


Fig. 4. Geomorphological elements of the Gower peninsula.

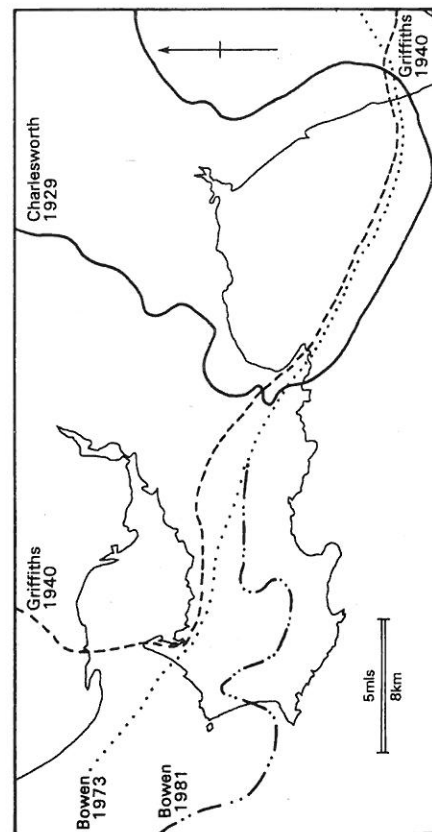


Fig. 5. Devensian ice limits according to several authors.

from the coast. Within the Burry estuary, the rising waters of the sea during the Flandrian transgression (between 10,000 and 5,000 years ago) caused the deposition of sediment in the calm waters behind the morainic dumps at the mouth of the estuary to form the basis of the Llanrhydian salt marshes. Low cliffs were produced in the redistributed coastal glacial drifts of the Gower peninsula and behind the more recent marshlands in Swansea Bay. A period of extra storminess between the fourteenth and eighteenth centuries resulted in the migration of sand dunes inland from the coast where farm lands and villages were deserted as the sand swamped them.

Table 2 Pleistocene deposits of Gower

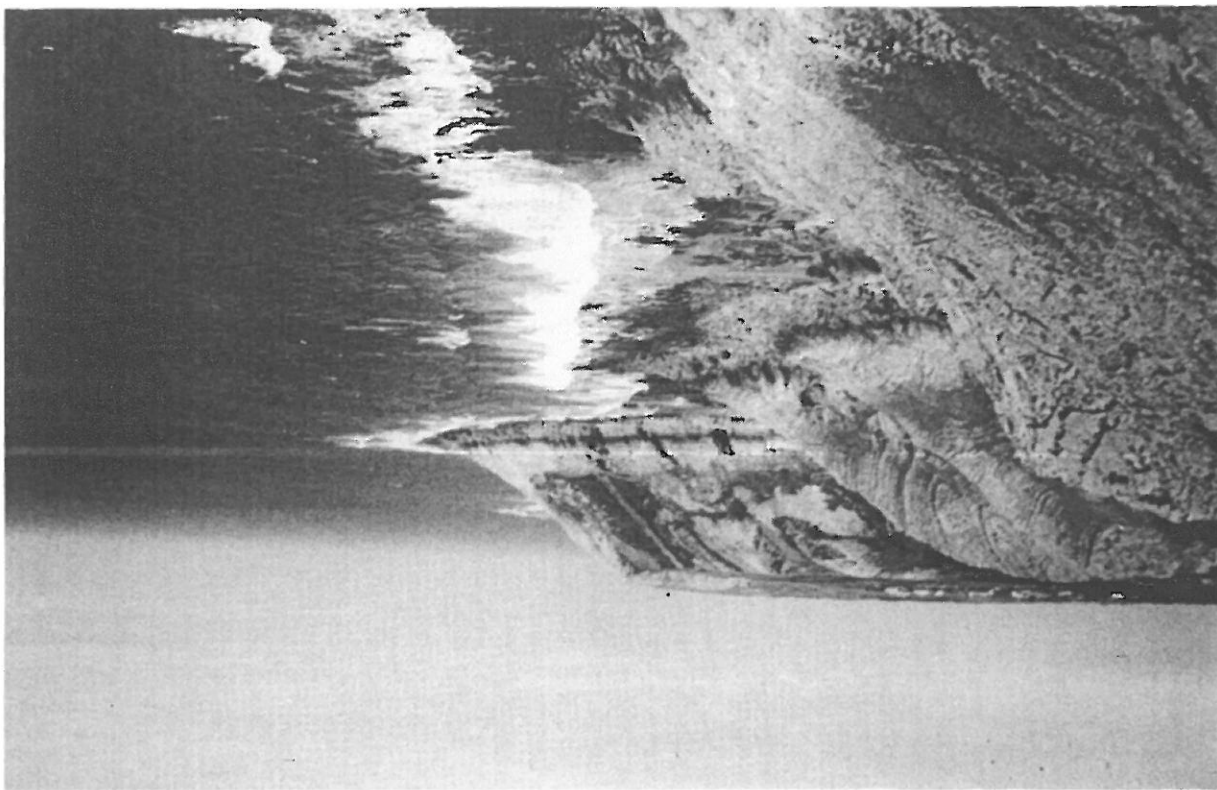
	Devensian (cold stage)		Ipswichian (warm stage)		Pre-Ipswichian (cold stage).	
	late	mid	early	Patella beach	Patella beach	Older drifts of Gower
Langland	silty loam	glacial drift	angular limestone head	Patella beach	Patella beach	Patella beach
Deep Slade	silty loam	re-distributed glacial drift	soliflucted soil and angular limestone head	Patella beach	Patella beach	Patella beach
Minchin Hole	-	inner & outer talus mounds		Neritoides bed	Patella beach	Patella beach
Horton	silty loam	re-distributed glacial drift	angular limestone breccia		Patella beach	Patella beach

THE LIMESTONE CLIFFS OF GOWER

The folds of the Carboniferous Limestone are reflected in the broad outline of the south Gower coast. From Mumbles westwards, a succession of anticlines and synclines intersect the coast at an acute angle (Fig. 3). Mumbles Head, Pwll Du Head, Oxwich Point, Port Eynon Point and Worm's Head are all anticlinal features and the larger bays between them are formed by the intervening synclines. This broad pattern is complicated by many faults, including several major ones, which trend in a north-south direction. Earth movements have imparted a tightly folded nature to the rocks so the dip encountered at different places along the south Gower coast ranges from strata bedded almost horizontally to rocks with angles of dip up to and even beyond vertical. Examples may be seen of rocks which dip inland and towards the sea. Although the textbooks remark upon the influence of structure upon the stability of cliff forms, there is currently little active erosion taking place along this coast. The most active geomorphological processes on these cliffs are subaerial; only a narrow zone at the bottom of the cliffs is currently being attacked by marine erosion. At low tide a shore platform can be seen at the foot of the cliffs, truncating the limestone strata (Plate 1). Most of the wave energy is dissipated upon the Carboniferous Limestone rocks of this shore platform. The presence of unconsolidated drift deposits and raised beaches on the limestone cliffs is evidence of very little erosion being accomplished during the 10,000 years of Recent geological time.

The origin of various slope deposits on the upper parts of the Gower cliffs can be traced to processes which were active during the last glacial or succeeding periglacial periods. Frost-shattered scree material mantles many slopes below protruding buttresses of limestone (Fig. 6). Much of this fossil scree material has been covered by vegetation and a thin rendzina soil developed on slopes of 30–35°, but some areas can still be seen where active scree occurs at the surface. Some of the scree has been cemented by calcium carbonate and now forms overhanging masses (Fig. 9). Glacial drift from two periods of glaciation may also be seen on the cliff slopes. East of Langland Bay, till and glacio-fluvial material of Devensian age form low cliffs at the foot of the slopes. Further westwards, pre-Devensian materials occur at the foot of the cliffs where they have been redeposited by solifluction. Lastly, there is the presence of an aeolian deposit derived from outwash plains, lying to the south of Gower and now covered by the sea. This loess has been partly redeposited by periglacial processes as is shown by the presence of stone-lines in it. The loess occupies the upper metre of many coastal sections

Plate 1. Cliffs in the Carboniferous Limestone at Pennard. Steep dips and even overfolding can be seen with waves breaking over the shore platform at the foot of the cliffs.



west of the assumed edge of the Devensian ice margin. All these features may be observed along the south coast of Gower; specific features and their locations are described in the following sections.

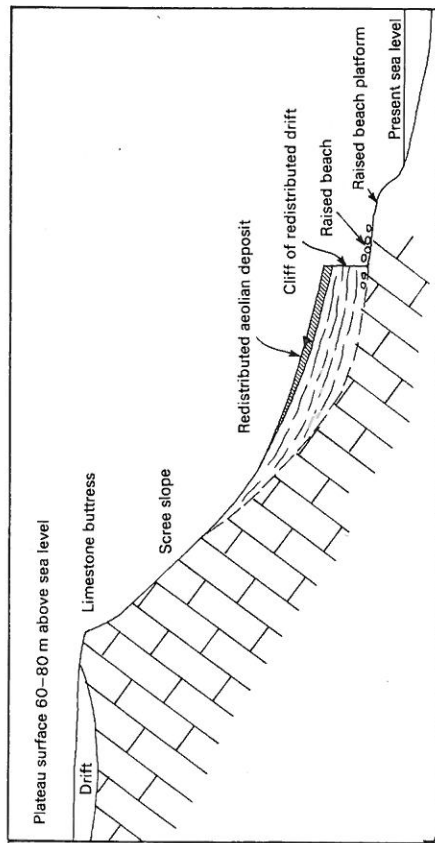


Fig. 6. Elements of the cliff profile (after Bowan and Henry, 1984).

Mumbles and Langland Bay

Mumbles Head is the easternmost extremity of the Gower Peninsula. Following the B4433 road from Oystermouth towards the headland, with Swansea Bay to the left, an anticlinal flexure of the Carboniferous Limestone can be seen on the right-hand side of the road. The rocks revealed in this outcrop dip steeply towards the north-east and form the northern limb of the anticline. Before reaching the headland, the road passes through a cutting which also shows the northeasterly dip. At the headland the road turns southwestwards at the rear of Bracelet (also known as Broadslade) and Limeslade Bays. South-westerly dipping strata can be seen on Tutt Head between Bracelet Bay and Limeslade on the southern limb of the Mumbles Head anticline (Fig. 7). Despite the complexity of the underlying geological structure, Mumbles Hill has a well-developed plateau surface, as can be seen from the main road at West Cross (SS 615 895). Mumbles Head is formed by two islands, the geological structure of which can readily be appreciated. At low tide it is possible to walk across to the outer head. Almost beneath the light-house on the outer island is Bob's Cave, hollowed out of the rocks of the pitching anticline. Evidence of the north-south pattern of faulting can be appreciated at Mumbles where faults separate the two islands from the

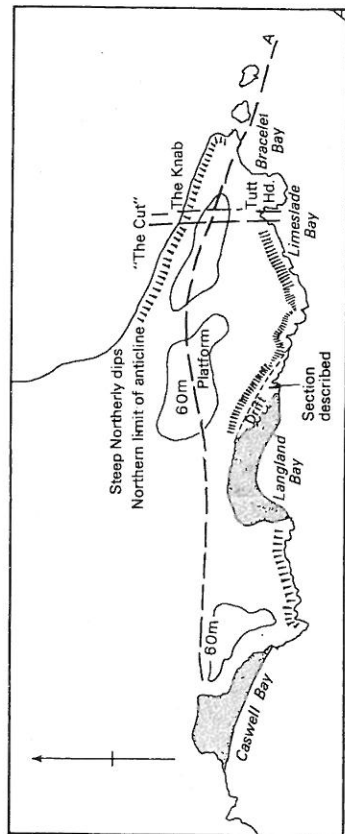


Fig. 7. Geomorphological elements of Mumbles and Langland Bay.

mainland, but also between The Knab and Limeslade Bay where a deep gash in the rocks has been excavated in the past for iron ore. Although almost completely refilled its position can be clearly seen on the map and in the field. Bracelet Bay has been eroded at the southern end of this fault which contained the iron-rich deposits sought by miners.

At Langland, the southern limb of the Mumbles anticline has been breached by the sea and the Carboniferous Limestone can be seen to dip southwards on both sides of the bay. The limestone cliffs east of Langland are partly covered by unconsolidated glacio-fluvial deposits which form a low cliff of about 14 m, actively worked upon by the sea. At the base of this cliff section (SS 613 871), the drift is grey in colour and more compact. This is covered by a brown stony drift, composed of glacio-fluvial material and till, crudely stratified with indications of having been deposited close to the margin of the Devensian ice sheet. The section is capped by a thin layer (about 1 m) of almost stoneless silty drift, interpreted as a decalcified and redistributed loessial deposit.

At certain places along this section an orange-brown sandy material containing limestone fragments can be seen to lie between the drift and the raised beach platform upon which it rests. This deposit has been interpreted as blown sand from the foreshore to which has been added frost shattered debris. The sand was exposed as sea level fell and the frost shattered debris accumulated as a result of the onset of the colder climate associated with the advance of the Devensian ice sheet.

Pwll Du Head to Three Cliff Bay

This stretch of coast with its raised beaches is probably the most interesting as well as being easily accessible. Pwll Du Head is an

anticlinal headland, capped by the plateau formed by the 60–65 m surface. Immediately to the west of Pwll Du Head is Hunts Bay and a small valley leading inland known as Deep Slade. The two large caves of Bacon and Minchin Hole are situated in steep cliffs between Hunts Bay and Heatherslade Bay at Southgate. Steep cliffs with raised beach remnants continue between Heatherslade and Three Cliff Bay (Fig. 8 and Plate 1).

A raised beach is clear evidence that the relationship of land and sea has changed; either sea level has changed or there has been uplift of the land relative to the sea. Raised beach remnants may be seen at many places along the Gower coast, but some of the best examples occur at Deep Slade and Heatherslade Bays (Fig. 8). The exposures of these deposits at Heatherslade are best approached by following the path down from the car park at Southgate (SS 555 874). Just before crossing onto the rocks at the foot of the path there is a low cliff in solifluction debris from beneath which emerges an elevated, dissected shore platform. At several places on this shore platform, at about 8 m above sea level is a cemented pebbly deposit, firmly grouted into the Carboniferous Limestone rocks (Plate 2). The pebbles of this deposit are well rounded, consisting mainly of limestone but including other rocks as well as fossils of the gastropod *Patella vulgata*, a limpet which has given its name to this raised beach – the Patella beach. There are other shells present, and all of the beach material is cemented with calcium carbonate. The floor of Heatherslade Bay is characterised by a shore platform which is partly

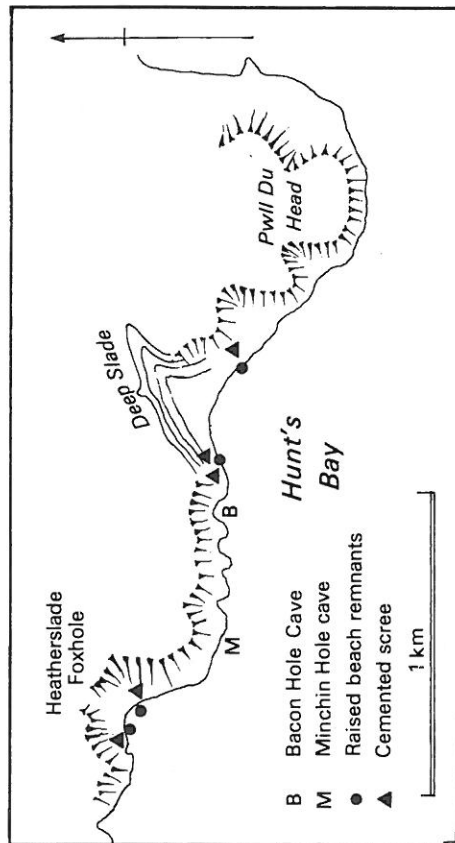


Fig. 8. Geomorphological elements of the coast from Pwll Du Head to Three Cliff Bay.



Plate 2. Remnant of raised beach, Heatherslade Bay.

covered with sand. This lower platform is at approximately the level of the sea at the present day and a casual inspection might suggest it relates to the present sea level. However, on the eastern side of the bay another remnant of cemented pebbles with sand and fossils can be seen on this surface (the Heatherslade raised beach). The remnant is eroded and little remains, but it is, without doubt, similar to the material of the Patella raised beach; it, too, consists mainly of rounded limestone fragments but contains a greater quantity of far-travelled material from the South Wales coalfield rocks than in the higher Patella beach. A higher sea level in the Flandrian and a lower sea level in the Devensian have both occurred since this beach remnant was deposited and now the sea has returned to approximately the same level as before. As it lies in the zone of the breaking waves, this lower beach remnant is being eroded gradually. Raised beach material has been preserved in the two large caves of Bacon Hole and Minchin Hole (see following section on caves).

A consensus of opinion places the Patella beach as Ipswichian in age, c. 125,000 years BP, being formed during the last major interglacial period. It is thought this interglacial may have been warmer than the present-day climate because red soils, like the *terra rossa* found in the Mediterranean countries, were developed over the limestone. As the Devensian glaciation began, these soils were the first to be affected and moved by solifluction over the edge of the plateau and down onto the

Patella beach. Frost shattering of the limestone contributed the angular limestone fragments which can be seen interlayered with the red soils on the western side of Hunts Bay (SS 562 868) (Plate 3). Scree cemented with calcium carbonate may be seen adjacent to the section on the western side of the bay (Fig. 9). This redeposited soil material passes upwards into crudely stratified solifluction material with increasing numbers of far-travelled pebbles in the upper layers. At the centre of the bay, the low cliff is composed of frost-shattered rock fragments in a variable matrix which is obviously of a South Wales coalfield provenance rather than of local Gower origin.

Examination of the stones comprising these deposits indicates that they are not lying in a random manner (Fig. 10). If the direction of the long axes of a number of these stones is plotted, a strong orientation downslope is apparent, confirming the role of solifluction in their accumulation. The upper 1 to 1.5 m of the low cliff at the back of the beach at Hunts Bay comprises silt which is regarded as having an aeolian origin. However, as the silt contains the occasional pebble, it too is thought to have accumulated as a slope wash deposit after being first laid down as loessial material derived from the outwash deposits lying on the floor of the Bristol Channel in the immediate post-glacial period when sea levels were still low.



Plate 3. Layered angular limestone fragments and red soil material at Hunts Bay.

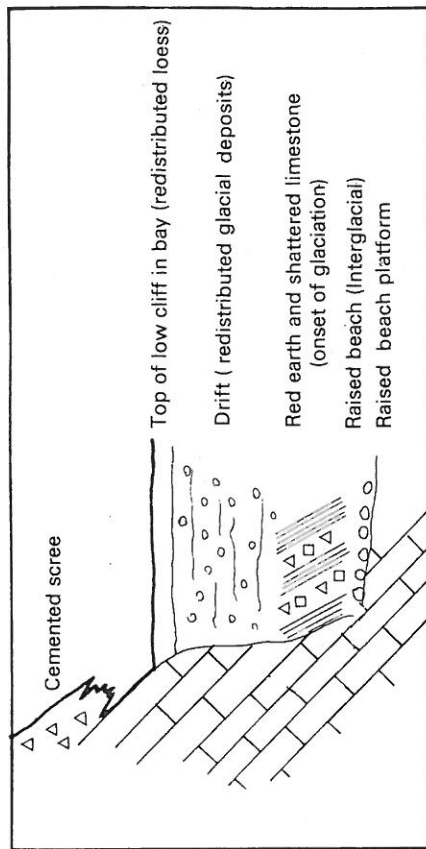


Fig. 9. Section of deposits at Hunts Bay.

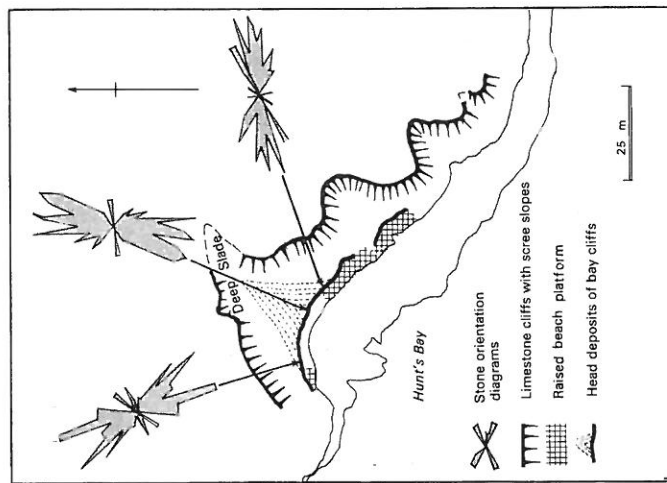


Fig. 10. Stone orientation diagrams at Hunts Bay (after Harris, 1973).

Caves

There are several large caves along the coast of Gower, developed where faults occur in the Carboniferous Limestone. At times of high sea level the sea has been able to exploit the weaknesses of the fault zone to excavate a cave. After sea level dropped enlargement of the caves took place by frost action, particularly during the cold conditions of the Devensian glaciation when frost-shattered debris fell from the roof to accumulate on the cave floor. On the face of the cliffs, frost-shattering partially or even completely buried the cave entrance, sealing inside the deposits and any included fossils. When sea level rose after the Devensian glaciation the caves began to be re-exposed as the frost-shattered debris was washed away (Fig. 11). Extinct animal bones had

been discovered in a cave near Nicholaston as early as 1792, and during the nineteenth century it became fashionable to excavate the caves for the remains of straight-tusked elephant, soft-nosed rhinoceros, mammoth, bison, reindeer, cave bear, wolf and hyena. Unfortunately, both amateur and professional collectors of the last century dug in an unscientific manner so that much valuable information about former climatic changes with which these deposits and their included fossils were associated has been lost. (See later section on Paviland Cave).

Further evidence of raised beaches has been found in the sediments preserved in Bacon Hole and Minchin Hole. These large caves are situated between Hunts and Heatherslade Bays and can only be approached by difficult cliff paths. These caves are not recommended for class visits and the deposits within the caves must not be disturbed by unauthorised digging. Within Minchin Hole, the following sequence of deposits has been described upwards from the floor of the cave.

- i) An inner beach lying upon a wave-smoothed rock floor and composed of bedded grey sand with fine shingle layers and containing a pre-Ipswichian faunal assemblage dated 210,000 years BP, covered by an incipient stalagmite crust. The pre-Devensian sea level was at least 3 m higher than at present.
- ii) A lower red cave earth with some mammalian remains including the narrow-nosed rhinoceros and northern vole. There is evidence of a stalagmite crust deposited over this material.
- iii) An outer beach - the Patella beach. This was formed at a time of higher sea level and cut into the lower cave earth. It contains a mixture of boulder, shingle, sand and shell fragments dated 125,000 years BP. It lies between 6.20 and 12.40 m OD and is embanked against the inner beach.
- iv) A pink sandy clay overlies the Patella beach on the western wall of the cave. It contains gastropods and formerly was thought to be another, higher raised beach (the Neritoides beach) but is now interpreted as a transition from the Patella beach to the overlying cave earth.
- v) Brown cave earth with limestone fragments containing abundant mammalian and bird remains. An interglacial fauna including narrow-nosed rhinoceros, elephant, red and fallow deer, pig, lion, spotted hyena, red fox, bank vole, field vole, and in the upper part,

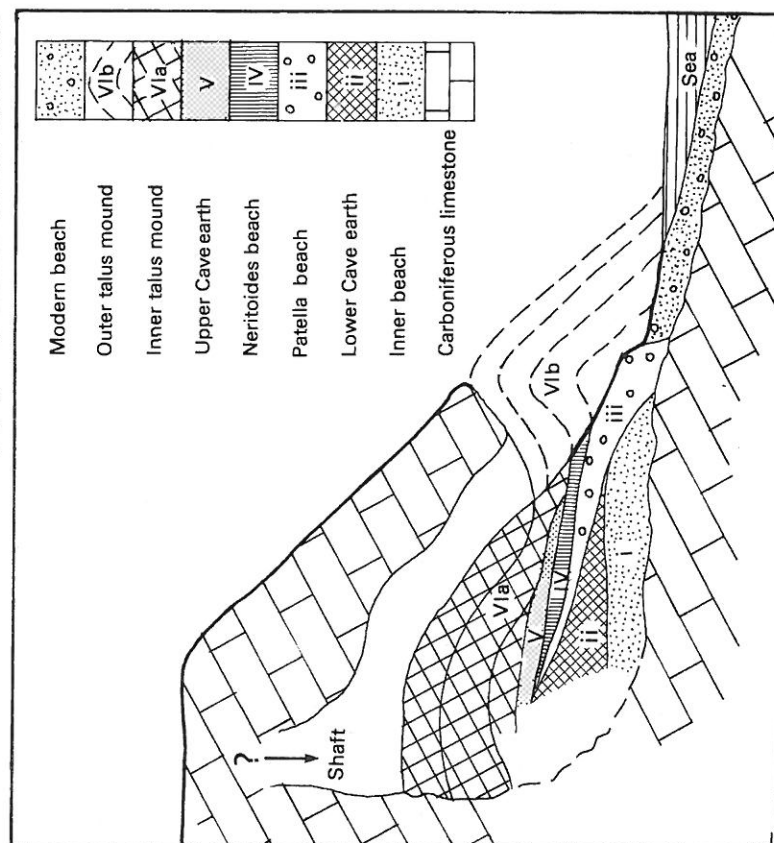


Fig. 11. Section through Minchin Hole Cave (after Bowan, 1977).

northern vole. This evidence suggests an interglacial climate which was warm but then turned colder.

- vi) Inner and outer talus mounds. The outer talus mound has largely been eroded and can only be seen as fragments of limestone and aeolian material adhering to the cave walls near the entrance; the inner talus mound consisting of angular limestone blocks in a matrix of a red cave earth covered by a thick stalagmite crust (after Bower, 1977; Bower and Henry 1984).

It would appear that the outer talus mound formerly blocked the cave entrance and preserved the deposits inside. Whilst the full implications of this sequence are not completely understood, it appears that the cave earths represent cold periods with low sea levels and the high sea levels and raised beaches represent the warmer intervals. Investigations in Bacon Hole indicate a similar succession of deposits and confirm the general sequence of events.

Three Cliff Bay

Between Heatherslade and Three Cliff Bay, steep cliffs occur in which the steeply dipping limestone strata can be seen to be overfolded (Plate 1). At Three Cliff Bay, the steep dip and faulting have combined to give the three pyramidal peaks from which the bay is named as well as the cave which penetrates through to the northern side of the inclined limestone strata to give a natural arch (Plate 4). The western extremity of the bay is marked by Great Tor where the bedding planes of the limestone are vertical (Fig. 12).

Pennard Pill reaches the sea at Three Cliff Bay after following a steeply incised course across the limestone outcrop. Evidence from seismic examination of its valley south of Parkmill suggests it was occupied by glacier ice and over-deepened by glacial scouring. Subsequently the valley was infilled with alluvial deposits. The seaward end of the valley is barred by a low shingle ridge, composed mainly of partially rounded limestone fragments, extending from the eastern side of the valley, where a valley-side scree, cemented by calcium carbonate, may be inspected. The Pennard Pill meanders over the alluvial infill and escapes seawards around the western end of this low shingle ridge. Until the mid-1960s, a sand dune system extended from the western side of the bay causing the stream to be sharply diverted across the front of the shingle ridge. Although the sand dunes have been eroded, the stream still

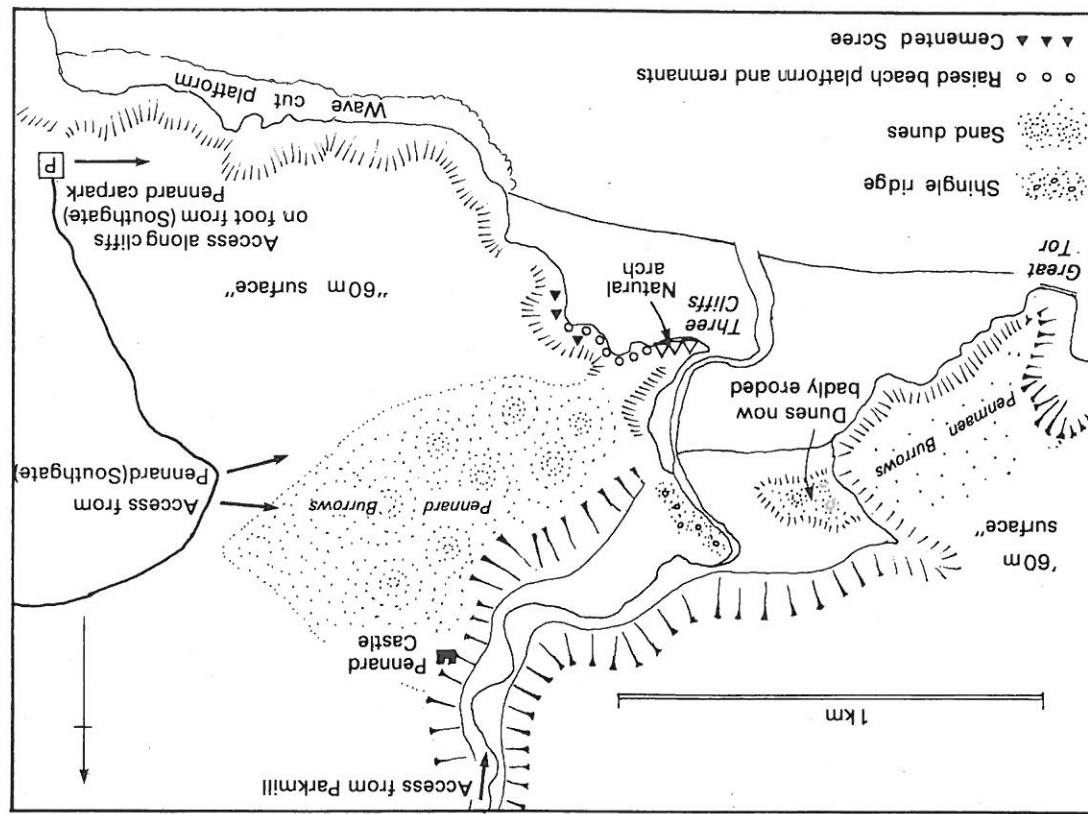


Fig. 12. Geomorphological elements of Three Cliff Bay.

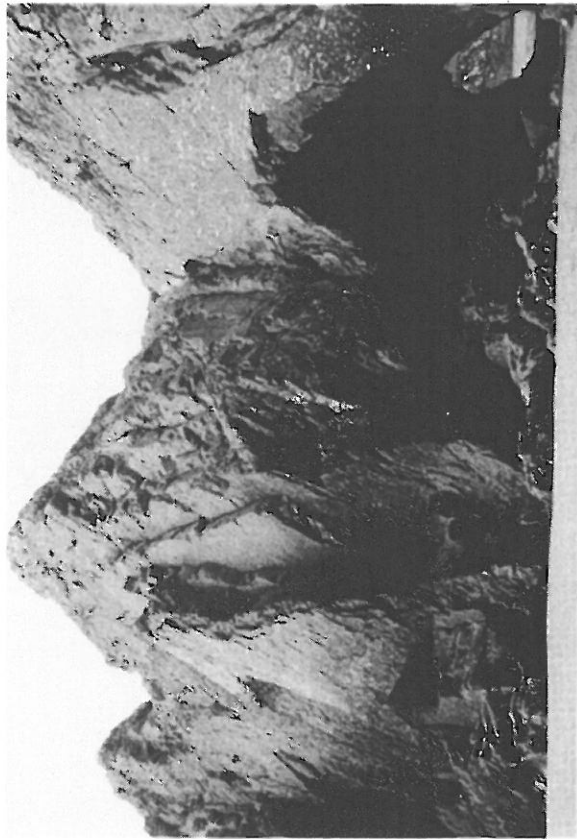


Plate 4. Steeply dipping limestone rocks at Three Cliff Bay with the natural arch.



Plate 5. Pennard Castle surrounded by sand which covers the eastern valley side and extends onto the plateau.

crosses to the eastern valley side and enters the sea immediately west of the limestone outcrop forming the three cliffs.

The high tidal range of the Bristol Channel leaves exposed a large area of sand between low and high water marks and the wind has blown sand into the Pennard Pill valley where dunes occur. It has also been blown up the eastern side of the valley where the castle and former village of Pennard were overwhelmed by sand. Historical records reveal extra storminess beginning in the fourteenth century; the church near Pennard Castle was abandoned in the sixteenth century and sand incursion continued until the end of the eighteenth century (Plate 5).

Oxwich Point to Rhossili

South of the hamlets of Oxwich Green and Slade the coastal path from Oxwich Point to Port Eynon follows the edge of an interesting solifluction terrace. This terrace is about 100 m wide and 5 m above sea level and lies in front of the former limestone cliffs. Three small dry valleys lead down from the limestone plateau to the north and probably acted as channels along which drift material was transported by solifluction in a periglacial environment (Fig. 13a).

Overlying the remnants of the raised beach, layers of coarse head in a red matrix can be seen. This in turn is overlaid by a finer deposit of head

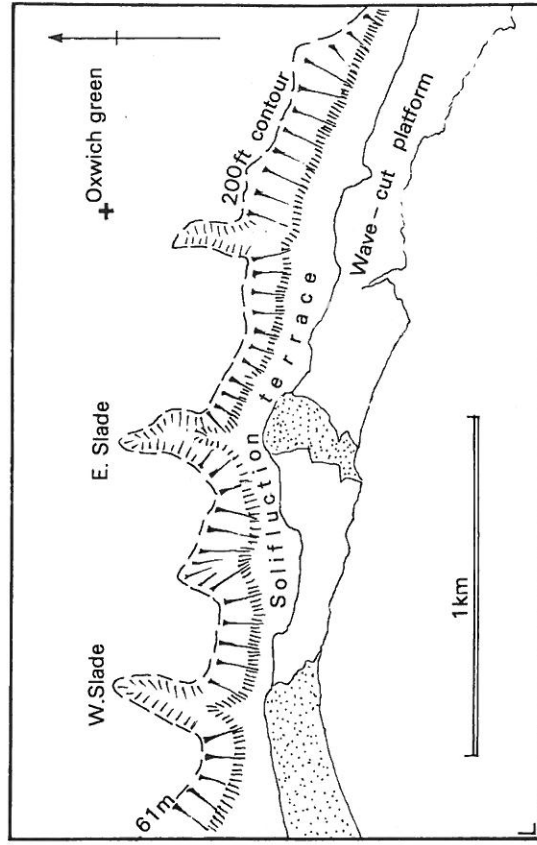


Fig. 13a. Solifluction terrace at Slade.

and re-distributed silty loess material which smoothly covers any irregularities in the coarser heads beneath. These re-deposited materials have a fan-like form extending from the mouths of the small valleys which helps to confirm the origin of their constituent materials. This terrace on the northern shore of Port Eynon Bay was outside the area glaciated by Devensian ice and so the terrace at East and West Slade contains only re-distributed drift from the earlier pre-Ipswichian glaciation which brought erratics of Ailsa Craig microgranite and fragments of local South Wales sandstone (Fig. 13b).

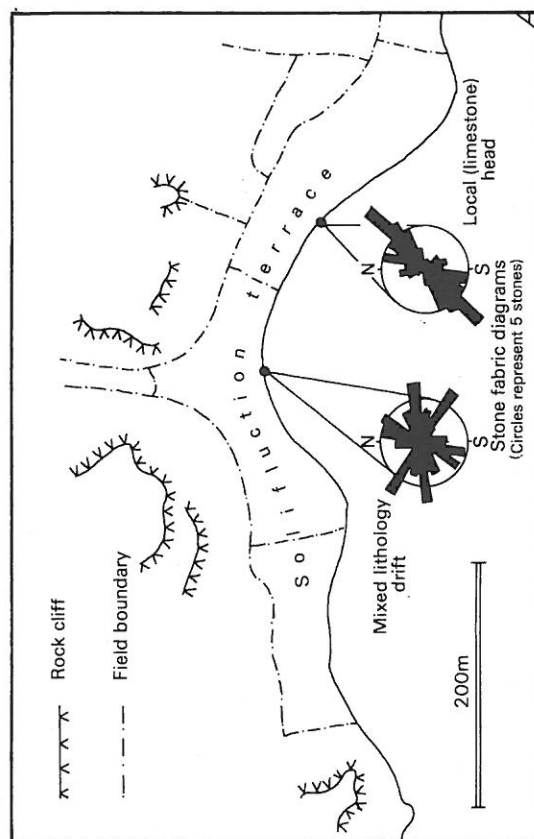


Fig. 13b. Stone orientation diagrams at East Slade (after Bowan and Henry, 1984).

The South Gower National Nature Reserve

From Port Eynon Point to Rhossili the cliffs of Gower are a National Nature Reserve administered by the Nature Conservancy Council and owned by the National Trust and the Glamorgan Trust for Nature Conservation. The public may use the footpath along the cliffs but people are requested not to pick wild flowers nor enter any fenced areas where erosion control schemes are in operation. Some restrictions may be placed on access during the nesting season (mid-March to July). This part of the coast is only accessible by vehicle at Rhossili and Port Eynon and by footpaths from the B4247 road. Similar features occur on this stretch of coast to those described previously in this guide but they are

less accessible and school parties normally should not be brought to this part of the Gower Coast.

The most famous of Gower's caves is Paviland Cave or Goat's Hole; it is reached from the B4247 road by a footpath from Pilton Green. This cave contained one of the richest archaeological finds in Britain. In 1823 Professor Dean Buckland of Oxford excavated the 'Red Lady of Paviland', a headless skeleton which was covered in red ochre, apparently buried there with ivory trinkets. It turned out to be a male skeleton which has subsequently been dated to c. 18,500 BP. Over 800 stone implements were found together with the bones of several animals. The 'Red Lady' now resides in the University Museum in Oxford.

Worms Head

The western extremity of the Gower peninsula is the island of Worms Head. It is also part of the South Gower National Nature Reserve and a National Trust advisory centre is situated in the former coastguard cottages near the carpark at Rhossili (Fig. 14). Visitors are reminded that they should not visit the island between mid-March and July during the nesting season, but they are welcome to walk to the end of the headland where the Nature Conservancy Council has a small information centre in the old coastguard lookout. (This is only manned during the holiday season.)

Approaching Worms Head from Rhossili, it is immediately obvious that the surface of the headland has a level plateau-like appearance at 60 m above sea level, and that this plateau surface is cut across the Carboniferous Limestone which is here in the form of a fractured anticline. The surface of the inner head of the island is remarkably level at about 30 m also cut across the folded limestone rocks. Any visitor to the island of Worms Head should follow the tide out across the causeway and should bear in mind that there are only about two hours on either side of low tide when it is possible to walk across. Tidal currents between the headland and the island are very strong and on no account should swimming be contemplated.

Rhossili Bay

The gently shelving, 5 km sandy beach at Rhossili is the largest of the Gower beaches. It is situated between two anticlinal flexures in the Carboniferous Limestone which form the promontories of Worms Head and Burry Holms. The western flank of Rhossili Down is interpreted as a fault scarp, abruptly cutting off the Old Red Sandstone rocks on the

western side of Rhossili Down. Inland from the beach a terrace of solifluction debris occurs with a 10–15 m high cliff (Fig. 14 and Plate 6). It is argued that west-facing slopes favoured more intense solifluction during the periglacial period. An examination of the material in this low cliff reveals angular local rock materials incorporated in a reddish-brown matrix, derived from the steep slopes of the Old Red Sandstone. About 1 km south of Hillend, outwash deposits and till replace the solifluction debris in the low cliff (SS 415 898). Below the modern storm beach a brown clayey till has been observed similar to that seen at Broughton Bay. It would appear that ice extended into Rhossili Bay, and by inference, well into Carmarthen Bay, which is further south than hitherto thought. Drift which has a mixed provenance also occurs on Worms Head. Previously this material had been interpreted as a deposit of the earlier pre-Ipswichian glaciation, but as it can be seen to overlie the Ipswichian raised beach, an alternative explanation is necessary. It may represent late Devensian outwash or it may prove to be evidence for a southward extension of ice into Carmarthen and Rhossili Bays. The original village of Rhossili was situated on the solifluction terrace, where remains of a church and farm buildings have been found beneath the sand dunes. Erosion of the solifluction terrace combined with besanding eventually led to the site being abandoned for the present, more exposed, site on the cliff top. On the cliffs south of the present village, beyond the 'old castle', bright red silty clays occur in joints and overlying the limestone. Microscopical examination of thin sections of this clay indicates it to be similar to *terra rossa*, a soil type found today in Mediterranean climates and unlike any soil forming at present in the area. It possibly represents a remnant of an interglacial soil of Ipswichian age. However, this is but one interpretation; other suggestions include remnants of a Triassic cover and the influence of calcium, weathered from the limestone causing simultaneous precipitation of clay and iron in the weathered material immediately overlying the limestone.

North of Hillend, the beach leaves the foot of Rhossili Down and becomes a beach ridge which encloses the low-lying fen of Llangennith Moor. This beach ridge extends to the anticline of limestone which forms the islet of Burry Holms. The solid rocks in this area are covered by sand dunes which attain the height of 60 m. The origin of this sand is from the sand banks lying offshore at the mouth of the Loughor river. Sand accumulation took place after the Bronze Age as artifacts of that period of prehistory were found beneath the dunes. Further movement of sand from the offshore sand banks may have occurred at periods of extra storminess from the fourteenth to the eighteenth centuries as experienced at Pennard and elsewhere in South Wales.

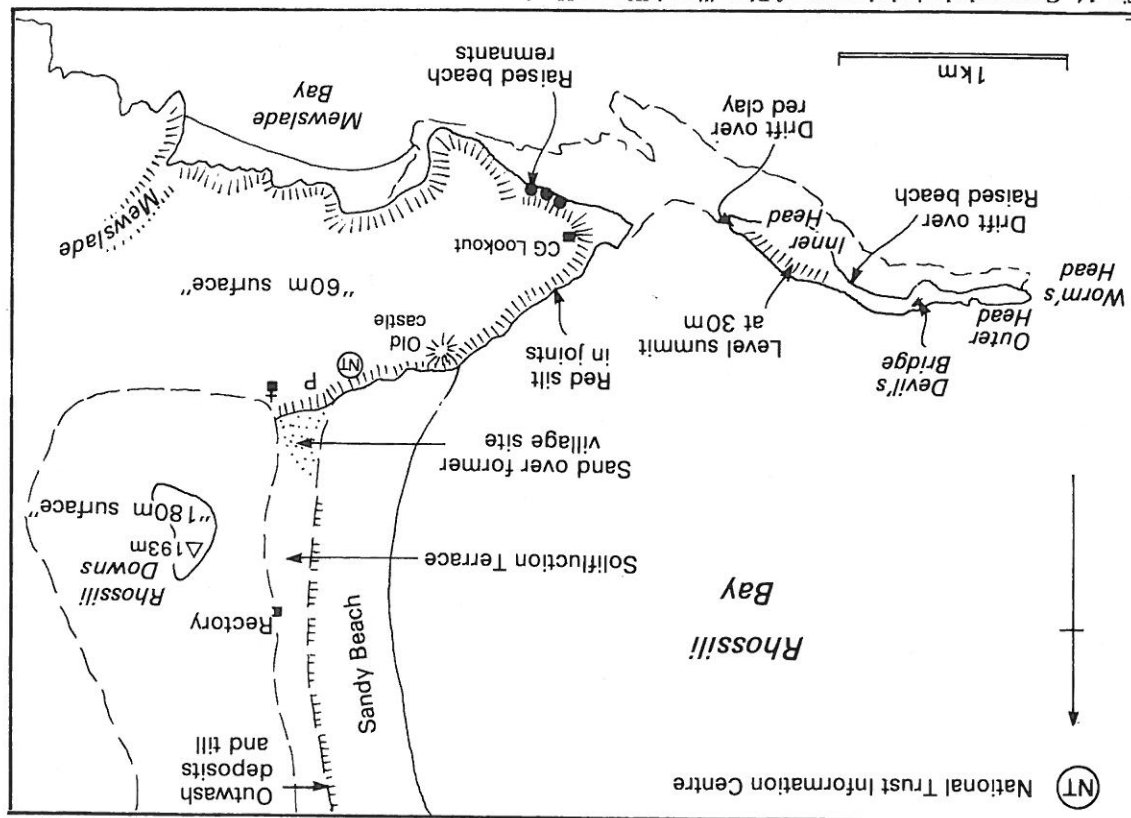


Fig. 14. Geomorphological elements of Rhossili and Worms Head.

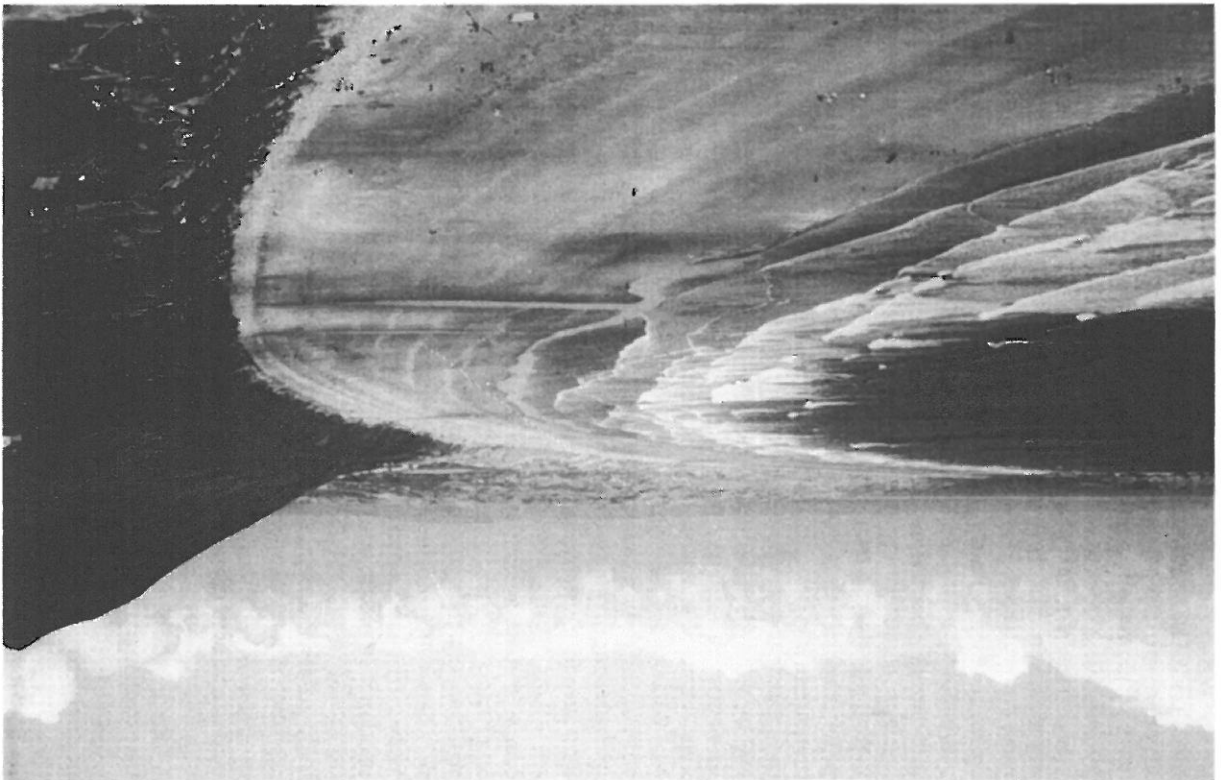


Plate 6. Rhossili Bay, Rhossili Down, with the solifluction terrace partly covered by sand dunes at the rear of the bay. Broughton Burrows and the island of Burry Holms in the distance.

THE SANDY SHORES OF GOWER

Several of the smaller coves of Gower at the foot of the limestone cliffs have sandy floors, but their sandy character is only a minor feature of their geomorphology. The larger bays, determined by the structural features of the peninsula, have extensive sandy areas and these are discussed in this section. These sandy shores include Swansea Bay, Oxwich Bay, Rhossili Bay and Broughton Bay. The bays are floored with Pleistocene or Recent deposits upon which the sand dunes have accumulated to provide a contrasting environment from that of either the cliffs or marshes.

Swansea Bay

Swansea Bay lies to the east of the Gower peninsula where a 15 km wide inlet of the sea is partly protected by Mumbles Head from the exposed waters of the Bristol Channel. In Swansea Bay the rim of the South Wales coalfield basin is breached by downfaulting of the Carboniferous Limestone, Millstone Grit and Coal Measures. This faulting may be partly associated with the strong faulting of the Neath and Swansea Valleys and Moel Gilau disturbances of the South Wales coalfield. Pleistocene deposits accumulated as ice spilled over the escarpments of the coalfield to form a piedmont type of glacier in the embayment (Fig. 5). Any former pre-Ipswichian moraines were reworked and deep hollows were scooped out of the solid rocks. These hollows, off Mumbles Head, are at least 26 m deep and have been infilled with silts and peats to -18 m OD. The upper surface of these deposits has been dated as 10,000 BP, after which the embayment was inundated by the rising sea level of the Flandrian.

Sea level continued to rise until low cliffs were cut in the glacial deposits on the northwest side of the playing fields at Ashleigh Road (SS 621 915) (Fig. 15). A slight fall in sea level since has revealed the sands for the wind to act upon to form dune landscape. No structure is apparent as the dunes are much degraded and have been grassed over to make a golf course. A former railway track also crossed the dunes before entering the Clyne valley at Blackpill. Behind the dunes an area of wet, peaty woodland developed during the Iron Age c. 2500 BP. The dunes appear to have overwhelmed this woodland as tree stumps, still in their growth position, can sometimes be seen on the foreshore between the entrance of the University College and Sketty Lane, where they formerly grew in a very poorly drained soil. The level of most of this poorly

drained land on the landward side of the dunes has now been raised by refuse tipping to form playing fields.

The greater amount of sand occurs on the eastern and northeastern sides of Swansea Bay, where industrialisation has taken place on former dune landscapes. The western side of the bay has little sand and the east-facing Gower shore is cut either in glacial drift or the Millstone Grit rocks as at West Cross where a small anticline may be seen on the foreshore. In the lee of Mumbles Head a stony beach occurs on the steeply dipping north flank of the Mumbles Head anticline.

There appears only to be a finite amount of sand available; very little sand is moving from the floor of the bay on to the dune system at the present time. On the floor of Swansea Bay at Blackpill *Spartina anglica* is attempting to colonise the silty deposits. If it were to be successful, accretion would be rapid and the nature of the foreshore would change considerably. However, the Environment Department of the City Council is attempting to stop the invasion.

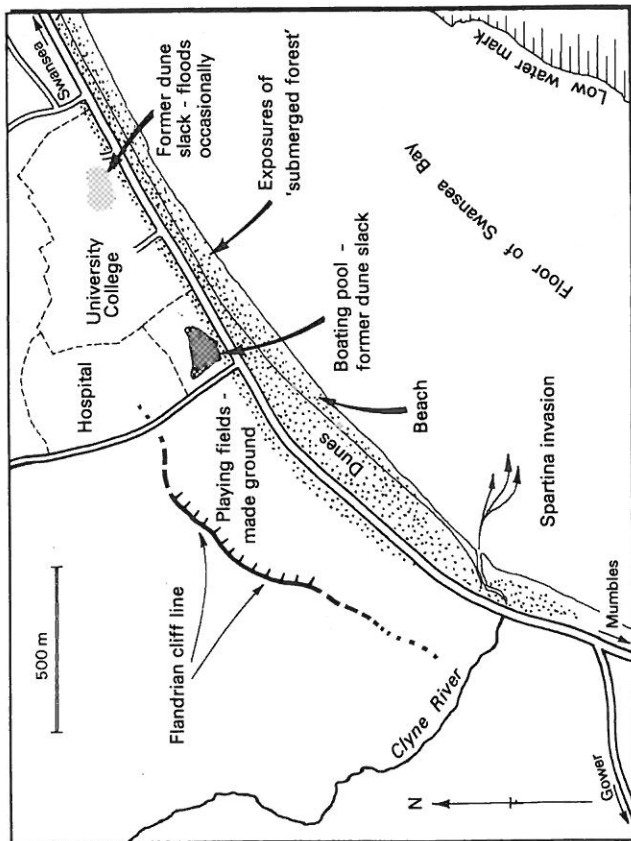


Fig. 15. Geomorphological elements of Swansea Bay.

Oxwich Bay

Oxwich Bay occurs where a synclinal structure including the Carboniferous Limestone and Limestone Shales reaches the coast. The attractive wooded slopes of Nicholaston and Oxwich Point cover strata dipping steeply towards the centre of the bay, but at the head of the bay the overlying softer Limestone Shales form the lower land. A small stream, the Nicholaston Pill, reaches the sea at the eastern side of Oxwich Bay after its waters have passed through the formerly landscaped marshes which lie behind the dune system (Fig. 16).

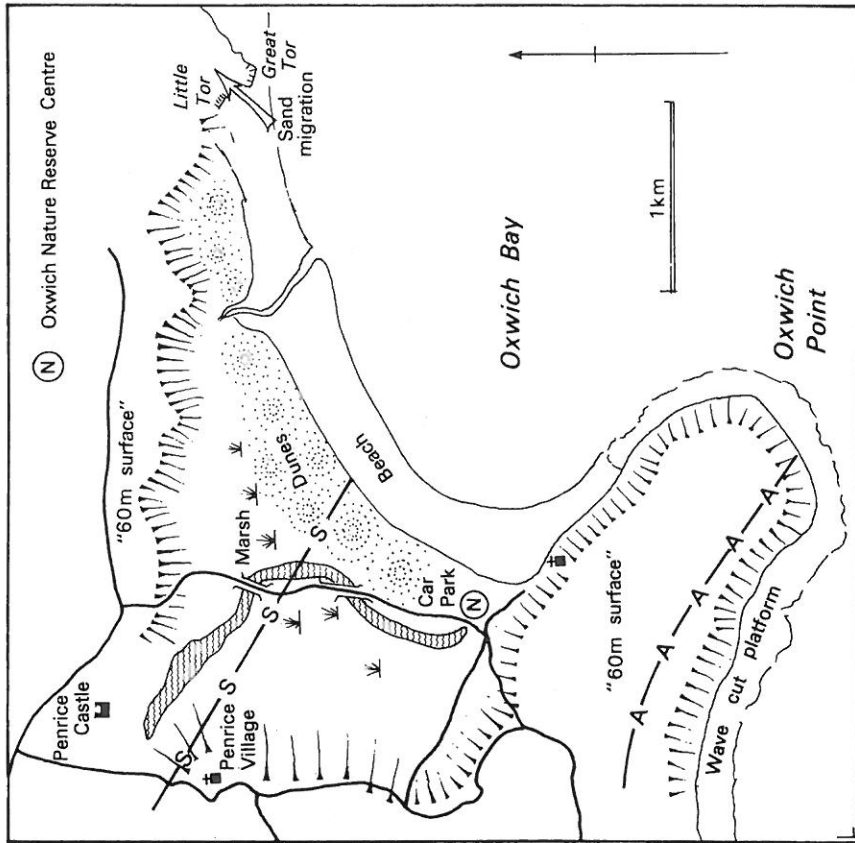


Fig. 16. Geomorphological elements of Oxwich Bay.

The sand dune system of Oxwich has a similar origin to the sands of the Swansea Bay, Rhossili Bay and Pennard areas. Oxwich Bay appears to have acted as a trap in which the sand has been caught as the outwash sands were gradually moved landwards by the rising waters of the Flandrian transgression until they came to rest at the heads of the bays.

Four different types of dune can be seen at Oxwich; these are U-shaped dunes, blow-outs, foredunes and attached dunes. The U-shaped dunes have an ESE-WNW (Fig. 17). As the dominant westerly winds are associated with rain and wet conditions when the sand is less mobile, it is the dry, south-easterly winds which are responsible for their formation. The ends of the U-shaped dunes which point to windward are the first parts of the dune to be stabilised, with the central parts continuing to migrate inland. Removal of sand between the arms of the dune continues until the moist sand near the watertable is reached and a dune slack is formed. When vegetated, these dune slacks have a more varied vegetation owing to the availability of water. Blow-outs are a normal

occurrence on dune landscapes and can lead to the formation of trough-like hollows in the dune system. These become even more common when the dunes are under heavy pressure from the human population and in an extreme situation the whole dune system can be destroyed. The western end of the Oxwich dune system is under the greatest pressure and the Nature Conservancy Council, who are responsible for Oxwich have had to resort to fencing part of the dunes to protect them from destruction.

Foredunes, as their name suggests, occur at the front of the dune system, at the rear of the beach. As accretion is active, these low foredunes are frequently colonised by marram grass. Attached dunes form in the lee of any obstruction to wind flow, this may be vegetation or even part of the U-shaped dunes described previously.

Although the major dune system at Oxwich shows evidence of the southeast winds being dominant in shaping the morphology, it appears that sand migration on the eastern side of the Bay near Great and Little Tor has been in response to the southwest winds. Sand has covered a medieval settlement at Penmaen where remains of a fortified farmstead and church occur.

Access to the dunes or the marshes at Oxwich is usually possible after obtaining permission from the Nature Conservancy Council whose office is adjacent to the car park. Oxwich is one of the National Nature Reserves of the Gower Coast and information about the plant and animal life of the reserve may be obtained upon request.

Broughton Bay and Whiteford Point

The northwestern facet of the Gower coast includes Broughton Bay, backed by glacial drift and sand dunes and the extensive sand dune complex of Whiteford Point. Whiteford Point is a National Nature Reserve to which access is limited; before making a visit advice should be sought from the Nature Conservancy Council centre at Oxwich. The reserve is approached through the hamlet of Cwm Ivy.

The foundation of Whiteford Point is a mass of boulder clay deposited from ice which occupied the Loughor valley during the Devensian glaciation. It is not known how far into Carmarthen Bay this tongue of ice extended, nor what its relationship with ice from the Towy valley might have been. It was formerly thought that the material beneath Whiteford was a terminal moraine, but recently, Pleistocene sediments of Devensian age have been identified in Broughton Bay, west of the Point. Erosion of the dunes by the sea at the western end of Broughton Bay has revealed a series of gentle anticlinal and synclinal folds in thinly bedded, shelly till (Fig. 18). Near to Twlc Point, the limestone headland

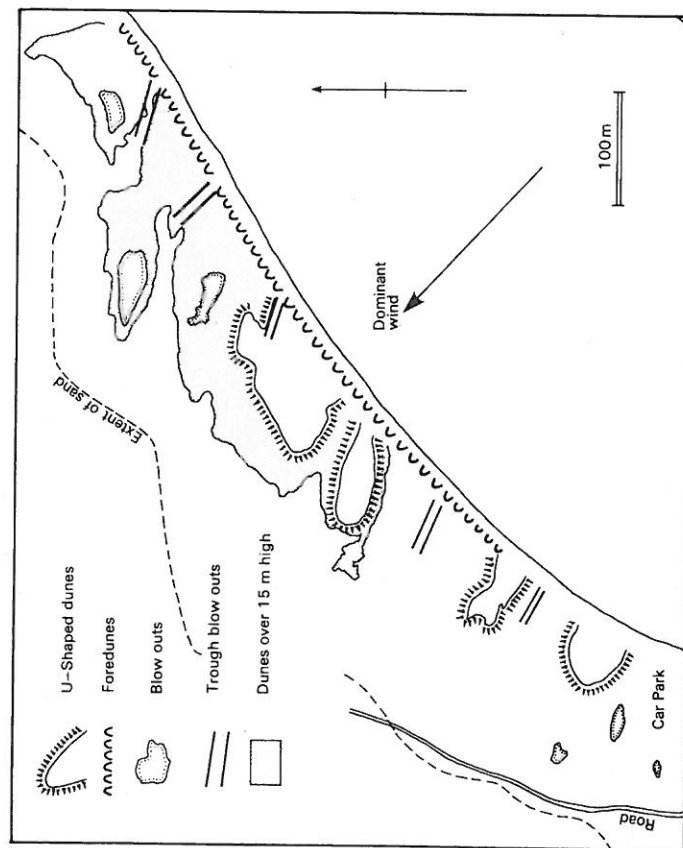


Fig. 17. Oxwich sand dune complex (after Harris, 1974).

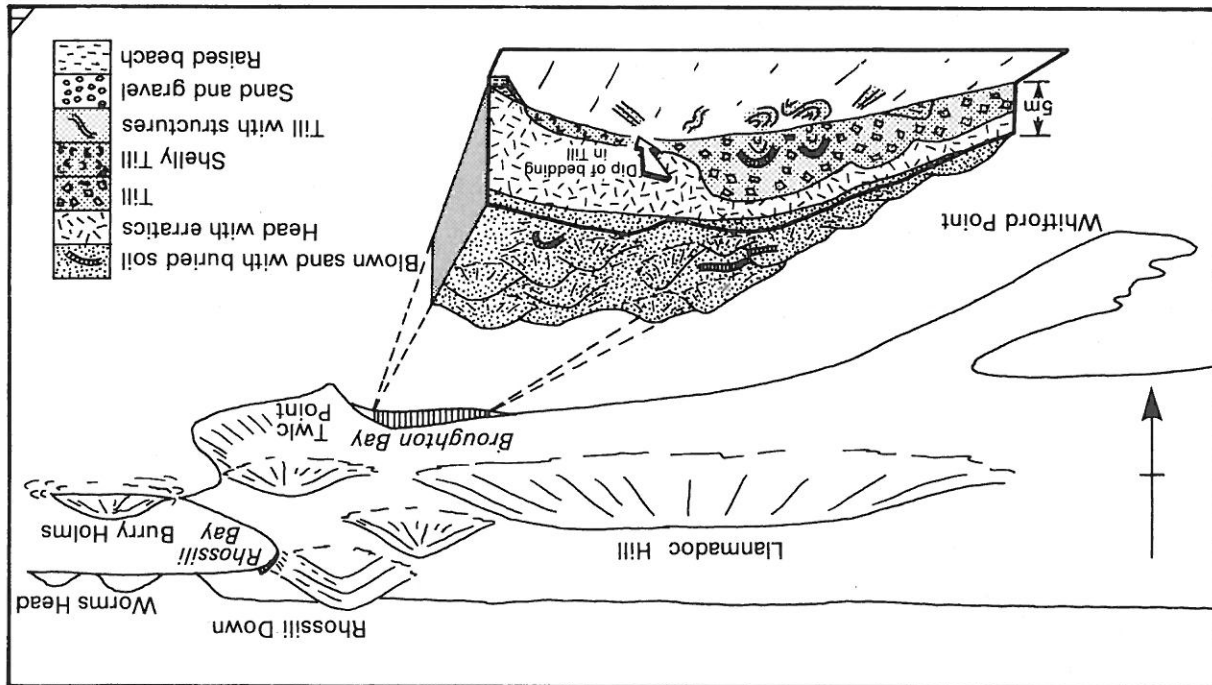


Fig. 18. Geomorphological elements of Broughton Bay.

at the western extremity of Broughton Bay, the dip of these structures increases to 40° . Shells from the till have been dated by amino acid analysis and have a late Devensian age. The stratigraphical sequence includes:

- vii blown sand (5 m)
- vi colluvium (0.5 m)
- v recycled till and head (3 m)
- iv stony till (4 m)
- iii bedded shelly till (3 m)
- ii head (0.5 m)
- i raised beach

The succession is interpreted as being deposited from ice which moved south across Carmarthen Bay to deposit estuarine-derived sediments and shells. It is thought that the structures in the tills were induced as the result of the constriction of ice as it passed through the low col between Llanmadoc Down and Burry Holms, over-riding Cwm Ivy Tor and Hills Tor. However, the detailed interplay of ice from across Carmarthen Bay and ice from the Loughor valley is not known.

As the climate ameliorated after the Devensian glaciation, vegetation re-established itself on the floor of the present estuary, sea level at that time being lower than at present, and in places peat accumulated. Fragments of this peat are occasionally to be seen washed up on the beach after storms.

The foundation of Whitford Point is the mass of boulder clay left by ice formerly occupying the valley of the River Loughor. An exposure of this boulder clay may be seen at the Scar, between the lighthouse (SS 444 974) and the northern tip of the Point. This exposure shows signs of having undergone periglacial conditions as it has frost-cracking patterns in it. Although swamped by the rising level of the sea during the Flandrian transgression the drift does not appear to be much disturbed other than in its immediate surface. Some of the stone content has been sorted from the drift, partially rounded and now forms part of the foundation of the sand dune complex. These rounded pebbles may be seen after storms have washed the accumulating foredunes from the upper part of the beach. A recurved shingle bank and a later recurved sand bank lie at the northern end of the Point, indicating movement of shingle and sand around the Point when suitable conditions for movement occur.

The drift surface presumably must have had some relief which was gradually swamped by the sea. It is interesting to speculate whether

Berges Island, now part of the Point, was ever at one time an island isolated by the rising level of the sea upon which the sand dune complex has eventually been driven. The origin of the sand is the same as has been described for other locations such as Pennard and Oxwich. First it was brought to the present position by the advancing shoreline, subsequently to be re-distributed by wind, beginning in the Bronze Age and continuing until the end of the eighteenth century.

The sand dune complex of Whiteford Burrows which covers the spit is about 3 km long and averages between 400 and 600 m in width. The largest dunes occur in the northeast where they attain a height of 24 m. These dunes are not completely fixed and change their form appreciably. The main dune ridge is 10 to 16 m in height for much of its length but at its landward end, near Cwm Ivy, becomes much wider with dunes between 12 and 16 m high.

West of this main dune ridge is a line of dune slacks and a further line of dunes where sand is actively accumulating. The slacks have steep sides as they are deeply scoured. East of the main ridge is a second line of slacks, larger in size but surrounded by gentle slopes and lower dunes which have become fixed by vegetation. As the dunes rest upon an impervious base of boulder clay, water accumulates during the winter until the low-lying slacks between the dunes are flooded. Those dune slacks which have not been excavated as far as the water-table remain moist for long periods and both situations permit a more varied vegetation to exist.

THE NORTH GOWER COAST

The north Gower coast has a completely different appearance from that of the south coast. Although there is a cliff, it descends from the plateau at about 60 m above sea level into the marshes of the Loughor estuary. The river Loughor completely crosses the South Wales Coalfield in a north to south direction but, having reached the northern side of the Gower peninsula, the river turns abruptly westwards in a down-faulted trough of Coal Measures which forms the estuary. Overlying the Coal Measures is an unknown thickness of boulder clay, covered by muddy fine sands and silty clays which probably resulted from reworked glacial drift or outwash material (Fig. 19). Interbedded peat and sand layers occur between 3.5 and 5.0 m below the surface and intertidal marsh sandy silts complete the succession. The development of the marshes took place naturally until the mid-nineteenth century after which human interference in the course of the Loughor encouraged scour on the northern and accretion on the southern side of the estuary. As a result, marshland on the southern side extended at the expense of the sandflats, encouraged by the introduction of *Spartina anglica* in 1935. Study of old maps and documents has shown that between 1790 and 1900 the marshes increased by 307 ha and in the following 60 years by 252 ha. The highest parts of the marsh have marked stability as is demonstrated by the similarity of creek patterns on old Ordnance Survey maps and archival air photographs. However, the lower reaches of the creeks show considerable variation where they would be affected by sedimentation and the natural tendency of creeks to meander.

The twice-daily ebb and flow of tides involves large quantities of water

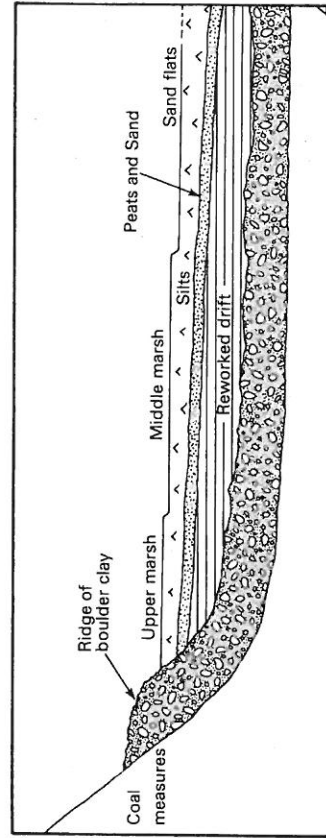


Fig. 19. Section through deposits of Llanrhidian Marsh.

which flow quickly in and out of the creeks. When tides are of sufficient height to cover the marsh interflaves, movement of water is slowed and hindered by the presence of vegetation. In these conditions, sedimentation is encouraged, raising the general level of the marsh. Although the banks of creeks may be undermined by scour, the effects of slumping and frost should not be under-estimated. Slumping of the narrow creek sides can lead to the development of sinuous pans, flooded at spring tides and dried out at neap tides with well-developed polygonal cracking patterns. Vegetation has difficulty in establishing upon these pan surfaces because of the high salt content left as the water evaporates.

The marsh sediments are unconsolidated and easily eroded, consequently the presence of a marsh indicates that a delicate balance exists between erosion and sedimentation. The presence of small breaks of slope on the marsh indicates that the marsh has been built up and subsequently eroded. At the present time it appears that sand is being moved from the unvegetated sandflats to be deposited on the seaward edge of the vegetated marsh where a break of slope is being buried. When erosion of the marsh has occurred at earlier times, it appears that a secondary marsh has developed at a lower level in front of the break of slope which was then preserved. The highest part of the marsh, nearest to the upland, is only flooded by the high spring tides and because leaching by rainwater is sufficient to remove soluble salts from the soil the grass *Festuca rubra* is able to colonise.

The Llanrhidian salt marshes have been allowed to remain in a semi-natural state, being subjected only to grazing pressure by sheep and ponies. Only one small area, Cwm Ivy Marsh, has been embanked and this reclamation took place in 1638. As a result Llanrhidian Marsh is an important site for migratory birds and other birds of the sea shore. Cockles are harvested from the sandflats of the estuary and a local industry is involved in cleaning, boiling and bottling them for the retail market. The shells of cockles have been dumped at several places, but the largest accumulation occurs in the former harbour at Penclawdd which has been infilled.

The other major glacial feature of the Loughor estuary is the recessional moraine which can be seen at the village of Crofty. It is a low ridge of glacial debris which protrudes into the estuary and a similar promontory extends towards it from the northern side, known as Penrhyn Gwyn. After depositing the boulder clay, upon which Whiteford Point is situated, the Loughor glacier front retreated until it was positioned halfway along the present estuary where the accumulation of morainic debris, now partly submerged by the marsh sediments, took place.

CEFN BRYN

It may at first seem strange to climb to the top of one of the higher hills of Gower at a point far removed from the sea to discuss coastal evolution. Yet, from the vantage point of Cefn Bryn (SS 491 900) it is possible to see the extensive plateau surface of Oxwich Point and other parts of south Gower with the same or similar elevation along the south coast. This extensive surface at approximately 60 m above sea level was interpreted as a plain of marine abrasion by Goskar and Trueman in the 1930s. These authors also identified other plains of marine abrasion along the coast of South Wales at 130 m and at 180 m. Looking eastwards from Cefn Bryn it is possible to see a remnant of the 130 m surface on Clyne Common (SS 589 908). This is the only evidence in Gower for an erosion surface at this height, but it is extensive elsewhere in South Wales. The higher hills of Gower have an accordant summit level at approximately 180 m; the eastern end of Cefn Bryn attains 186 m, Rhossili Down, 193 m and Llanmadoc Down 186 m.

Observation reveals that these surfaces have a moderate amount of relief and erosion has lowered the 180 m surface where the road crosses the summit of Cefn Bryn to only 158 m. According to some authorities, the development of all landforms below 215 m has resulted from the dissection of coastal plateaux such as the examples visible in Gower. This implies considerable change in the relationship of land and sea levels since these surfaces were cut. Although it is theoretically possible to say that these surfaces have a sequence from oldest (highest) to youngest (lowest), it is difficult to say when they were formed. It can be established without doubt that they are pre-glacial and correlations have been attempted with early Pleistocene shorelines in southeast England and even the Mediterranean. In view of the considerable amount of tectonic disturbance (revealed by the search for oil around the shores of Britain) it is now thought highly unlikely that correlations can be made over such distances.

Another possible explanation for these almost level surfaces is that they are remnants of a buried Triassic landscape which has been exhumed by erosion. The development of replacement slopes of very low angle (pediments) is a characteristic feature of desert landscapes and may be a more plausible process for the cutting of these surfaces across the complicated folded structures of Gower. These surfaces were subsequently buried by desert detritus which preserved their form throughout Mesozoic time until they were again revealed by erosion. This hypothesis is based upon the evidence, near Port Eynon, of an outcrop of Triassic breccia, which was laid down in a pre-existing valley.

This suggests that in Triassic times (213 – 248 million years ago) some of the relief of the area which was to become Gower was already in being. The presence of the red deposits in joints of the limestone could well be the last remains of unconsolidated desert deposits of Triassic age, most of which have been eroded from the former desert pediments. Pediments at different levels can be seen in desert regions at the present day, simultaneously being cut back into the bedrock. It is an attractive alternative proposal for the origin of these surfaces which seems to have fewer difficulties than are associated with changes of sea level.

GLOSSARY

Anticline. A structure in sedimentary rocks in which the strata are folded in the form of an arch. A pitching anticline is an upfold the axis of which is not horizontal.

Amino Acid Dating. Determination of the age of an organic fossil material by the rate of change of amino acids from one form to another.

Boulder Clay (or Till). Unconsolidated rock material scraped off the landscape by glacial ice and deposited elsewhere; often a clay containing larger stones.

Cave Earth. A mixture of soil material washed into a cave containing rock fragments fallen from the cave roof, often containing fossil bones.

Devensian. The final major glacial stage of the Pleistocene.

Flandrian Transgression. The post-glacial rise in sea level as Pleistocene glaciers melted, flooding low-lying coastal regions.

Head. Deposit of unconsolidated rock material at the foot of slopes under the influence of gravity, a process which was more active in a periglacial environment (see solifluction).

Ipswichian. Name given to geological deposits of the last major interglacial period.

Loess. Silt-sized materials deposited primarily by wind, originating as finely ground rock material resulting from glacial action.

Marine Abrasion Platform. Extensive coastal plateau surfaces, now elevated above sea level, were thought to have been formed by the action of the sea trimming the rocks to an almost level surface. A greatly extended shore platform.

Pediment. An extensive, almost level plain resulting from the process of backwearing of mountain slopes, common in arid and semi-arid regions.

Periglacial. An environment typical of marginal glacial regions, now confined to high elevation or high latitudes where freeze-thaw processes are dominant.

Piedmont Glacier. The union of several valley glaciers in a lobate form on a lowland area.

Raised Beach. Refers specifically to an accumulation of rounded pebbles, sand and included fossils which may be cemented with calcium carbonate and which normally lies on a shore platform above present sea level.

Slack. A low-lying area between sand dunes where the water table lies just below the surface giving moister conditions and resulting in a more varied plant life. Slacks may flood in winter and following heavy rain.

Solifluction. The process of rapid mass movement of thawed, saturated, rock material down slopes under the influence of gravity. It is most common in periglacial environments.

Solifluction Terrace. An extensive accumulation of solifluction debris at the foot of a hillside or cliff.

Syncline. A structure in sedimentary rocks in which the strata are folded in the form of a trough or inverted arch.

Talus. A sloping accumulation of shattered rock material at the foot of a cliff or rock outcrop.

Wolstonian. A name given to geological deposits laid down in the glacial period which preceded the Ipswichian interglacial.

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