



A field report on Pwlldu bay, Gower

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1 Introduction



Figure 1.1: Area of study © Ordnance Survey, 2021

The main features of the bay have been shaped over millions of years, but the beach and the cliff plateaus show unique features that mark out the physical landscape's interaction with human industry and habitation.

The area of study in this report is Pwlldu bay, as shown in Figure 1.1.

The Bishopston valley, Pwlldu bay and the headlands that surround them are all subject to a mix of continual physical processes that have determined how the bay looks today. These include pedogenesis, which has allowed vegetation to spring up at the backshore, fluvial processes through Bishopston valley, the slow retreat of the cliffs and – most famously – the depositing and shifting of the shingle ridges across the beach.

2 Paleozoic: The creation of Gower

2.1 Bedrock

The bedrock of Gower Peninsula is almost all Upper Palaeozoic (c. 215 - 364 million years old (Ma)). The oldest rock is Devonian Old Red Sandstone, which appears at the summits of hills at Rhossili Down, Cefn Bryn and Llanmadoc Hill (Shakesby & Hiemstra, 2015). During the Carboniferous period (359.2 - 299 Ma), the whole of what is now Gower was passing through the equator, under warm, tropical seas. The seas contained precipitated lime and the remains of marine animals, which sank to the bottom, eventually forming limestone (Mullard, 2006). This marine history can be seen in the fossilised remains of aquatic fauna, such as brachiopods (see Figure 2.1) and coral (Mullard, 2006). Around 50% of the bedrock of Gower is Carboniferous limestone (Bridges, 1997).

During the Triassic period (252-201 Ma), the climate warmed and Gower was semi-arid: the evaporation of a lake south of Gower left deposits of sediments such as mudstones (Mullard, 2006). There are few remnants of this Triassic Rock on Gower and no Mesozoic rocks have been found at Pwlldu (Bridges, 1997). There may have been



Figure 2.1: Rock pool in limestone on Pwlldu beach with fossilised brachiopod shells.

deposits from the Mesozoic epoch covering the whole of Gower at one time, but if so, they have been entirely cleared by erosion (except for small Triassic deposits at Port Eynon) by marine processes early on in the Cenozoic epoch (Bridges, 1997) (Mullard, 2006).

The Carboniferous limestone forms a wide plateau 60m above the sea, ending at cliffs (Shakesby & Hiemstra, 2015), thought to have

been levelled out by marine erosion around 70 Ma when the sea once again covered the entire peninsula (Natural Resources Wales, 2014).

2.2 Deformations

The bedrock is deformed from collisions that took place as the continents converged to form the supercontinent Pangaea (Shakesby & Hiemstra, 2015). Evidence of the collision can be seen in the folds of the bedding, which in some places is vertical or near vertical, and the numerous faults in the peninsula (Shakesby & Hiemstra, 2015). Pwlldu head lies on a synclinal axis (Bridges, 1997) and exposed limestone on the eastern side of the head reveals the beds lying at a gradient (see Figure 2.2 and Figure 2.3).

The collisions also resulted in many faults being created through the limestone (see



Figure 2.2: Pwlldu head. Red line shows gradient of bedrock strata.



Figure 2.3: Limestone strata showing deformations and glacial till, West of Pwlldu bay.

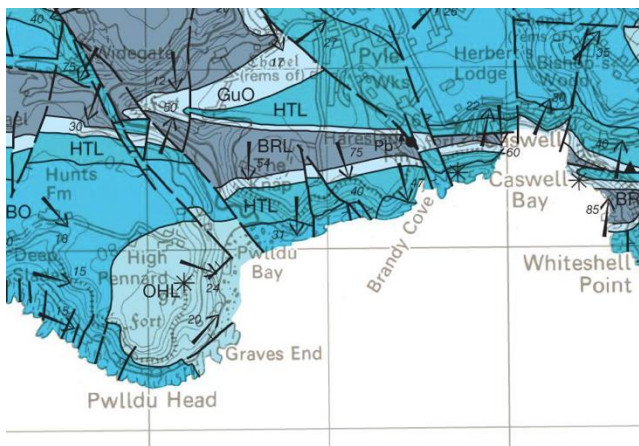


Figure 2.4: British Geological Society map of Pwlldu. HTL: Hunts Bay Oolite; OHL: Oxwich Head Limestone. Dashed line signifies a fault line.

Figure 2.4) and, together with the anticlinal and synclinal folds of the bedrock, it is these faults that have shaped the contours of the bays and headlands (as discussed in section 3.2 below). The fault that lies NW/SE down Pwlldu bay bisects the bay into rocks of different ages.

3 Pleistocene: Shaping the landscape

3.1 Glaciation

During the Pleistocene, Gower was variously covered by ice-sheets in several glacial and interglacial cycles (Bridges, 1997). Opinion differs on the extent of the last glacial maximum, but it is generally thought that the maximum does not extend as far as Pwlldu (Bridges, 1997; Shakesby & Hiemstra, 2015). Pwlldu therefore does not bear the direct signs of mechanical glacial erosion; however, the proglacial environment was also an active erosional environment, with a large supply of meltwater during the warmer months. The water increased sediment flow into Pwlldu, making flow till deposits made up of glacial sediment (Holden, 2005) and the area still retains substantial deposits from glacial till and peri-glacial erosional material, formed from freeze-thaw mechanical



Figure 3.1: Cemented raised beach deposit overlying limestone shore platform at Pwlldu bay



Figure 3.2: Cemented deposits at the West side of Pwlldu bay

weathering, settled above the beach (see Figure 2.3) (Bridges, 1997).

Shallow layers of cemented sand and pebbles are visible on the backshore above wave-cut platforms of Carboniferous limestone (see Figure 3.2 and Figure 3.1). The exact origin and age of these raised beach deposits, seen frequently along the South coast of Gower, is debated (Shakesby & Hiemstra, 2015), but they indicate that the relative sea level used to be higher as a result of retreating glaciation. There is evidence that there were several of these interglacial periods and the deposits could have been the result of more than one; Shakesby & Hiemstra (2015) suggests that the most likely interpretation is that the deposits were laid during oxygen isotope (OI) stage 5e (191 – 123 thousand years ago), when sea levels were at their last peak relative to today.

The raised beaches have been gradually eroded by hydraulic wave action and corrosion.

3.2 Carving the valley and bay

A fault divides the east and west of Pwlldu bay (see Figure 2.4). Erosion has exploited this fault line, over millions of years forming Bishopston Valley and Pwlldu bay (Mullard, 2006). Marine erosion and sub-aerial chemical weathering would have acted on the weaknesses in the rock, slowly carving out the bay. There is also likely to have been some

peri-glacial physical weathering around the same place during periods of colder climates, when the temperatures were cold enough for the water in the cracks in the rock to have frozen.

The line of the steep river valley from Bishopston also follows the weaknesses caused by the fault line. Due to solubility of limestone and presence of carbonic acid in the water flowing over the rock, underground courses and extensive cave systems are created, which drain the water away, so there tends to be very little surface drainage over limestone. Bishopston valley holds several karstic sinkholes and cave systems and it has been suggested the valley was created by their collapse (NRW, 2014). However, more recently it is thought the valley was formed from surface fluvial erosion, principally from glacial meltwater, suggesting there may have been limited drainage as a result of the karstic systems being blocked or slowed by ice (Shakesby & Hiemstra, 2015).

The meltwater would have been an efficient erosional agent, due to its velocity and suspended sediment of glacial till, which added mechanical erosion to the chemical erosion, primarily by carbonation of the limestone, promoted by the frequent supply of fresh water (Holden, 2005).



Figure 3.3: 3D composite image of Bishopston valley emerging onto Pwlldu beach. © Google 2021

While minor chemical weathering continuing to act upon the major caves in the walls of the valleys is likely – possibly with increased acidity as a result of CO₂ from the overlaying vegetation and soil – the water table is now much lower down the valley and there is no longer as much water flow through the rock.

There are caverns closer the bottom of the valley, from where it is possible to discern the flow of water under the surface. The relative lack of surface flooding has led to the valley remaining narrow and steep in this part. However, the valley becomes much wider as it approaches the beach, with a relatively wide flood plain covered in alluvial deposits extending to the walls of the valley, indicating that there has been increased surface fluvial erosion as the river surfaces. The river as a whole is straight, but there is a single wide meander as it enters the beach (see Figure 3.3). The meander may be a result of a band of harder limestone occurring on the East side of the valley (see Figure 2.4) and also fluvial deposits, as it slows down around the spur.

4 Holocene: Coastal and soil processes

4.1 Coastal processes

The cliffs are situated back from the sea, so are subject to very little marine erosion (Bridges, 1997). Closer to the nearshore, potholes and smooth karstic formations are found on the surface of the wave-cut platforms, showing evidence of ongoing chemical erosion of the limestone, indicating a more significant erosional agent than mechanical marine action. Figure 4.2 and Figure 4.1 show the same formations changing over 150 years, evidence that the hard limestone is relatively resistant to wave action.



Figure 4.2: Recent photograph looking south west towards Pwlldu head. Red circle shows same rock formations as Figure 4.2.



Figure 4.1: glass negative looking south west towards Pwlldu head © John Dillwyn Llewelyn, circa 1850.

As visible in Figure 4.1, the coast of Pwlldu is influenced by softer periglacial material on top of cliffs creating gradual slopes by solifluction. The steeper drop-off at Pwlldu head shows an outcrop of harder limestone, likely subject to more sudden rock falls.

4.2 Storm beach

The large quantities of pebbles on the beach are primarily from centuries of limestone quarrying carried out from the 1600s. Before railways, the cheapest and easiest method of transporting heavy cargo was by sea, and there was a thriving demand for lime from the Devon agricultural sector (Plant & Jones, 2001). The proximity of the beach, as well as its relatively sheltered south-easterly orientation, made Pwlldu an ideal quarrying port.

Smaller rocks not loaded onto ships were discarded onto the beach, gradually building up the materials that formed the shingle ridges.

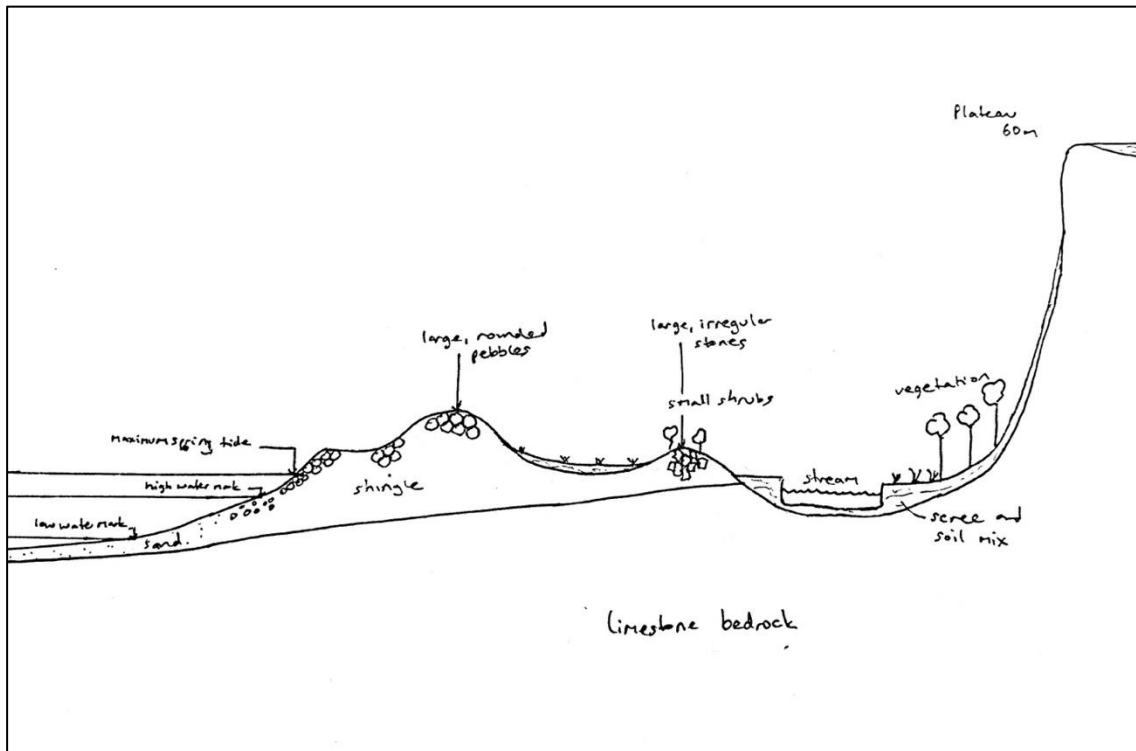


Figure 4.3: Field sketch of a simplified cross section of Pwlldu beach, looking WSW (not to scale).

As illustrated in Figure 4.3, the beach clast has been sorted by swash and backwash processes, with larger pebbles at the top of the ridges, and the clast decreasing in size down the beach, ending in sand. On the other side of the large middle ridge, the stones are larger and more irregular, indicating they have not been subject to as much marine abrasion as the more rounded pebbles closer to the tide mark. The berms mark the highwater maximums, with a distinct difference in size of material (see Figure 4.4).



Figure 4.4: Pebbles on beach berm. Red line shows approximate maximum spring tide mark.

The quarry face is partly covered by vegetation; however, the ridges carved by quarried materials sliding down to the beach are still apparent (see Figure 4.5).



Figure 4.5: Pwlldu quarry. The slides are apparent in the bottom right of the photo. Photo © Tim Hoddy 2013

The bay's history of quarrying also determined the buildings that are still present today: the two houses on the beach are the remaining public houses that served the quarry workers and sailors (Plant & Jones, 2001).

Pebbles have also been found that do not appear to originate from the surrounding rocks. It is possible that some of these may have been glacial deposits, brought down to the beach by fluvial processes. However, much of the foreign material arrived on visiting ships as ballast, dumped on the beach to make space for limestone cargo (Plant & Jones, 2001). Being igneous rocks from coastal Devon (Mullard, 2006), they are visibly distinct from the limestone pebbles.



Figure 4.6: Aerial photo of Pwlldu beach taken 16 August 2016. © Landsat 2016

The ridges have diverted the course of the river and slowed down its drainage to the sea, resulting in an area of freshwater marsh at the backshore, the dark-coloured pools possibly giving Pwlldu its name. A limited amount of water can be seen to drain slowly through the shingle and re-emerge on the West side of the beach, below the final ridge. The position of the

ridges has shifted in stormy weather, but the south-east orientation of the beach shelters the bay from major storms which tend to be south-west directional. During times of heavy rainfall, the impact of the fluvial processes on the shingle can be seen in the reposition of the West-side of the storm beach into a delta-shaped deposit (see Figure 4.6)

4.3 Sand

Glacial erosion carried large amounts of sand and gravel into South Wales, which material was then transported by meltwater into rivers and out into the Bristol Channel (Mullard, 2006). Wind brought tidally-exposed sand back onshore beginning in approximately 1st millennium BC and continuing until the 18th century (Mullard, 2006), with particularly stormy weather in the 13th, 14th, 17th and 18th centuries being the source of much of the aeolian sand deposits on the south coast of Gower (George, 2015b). The orientation of Pwlldu towards the South East may have acted as a barrier to many of these marine sand storms, which were sufficiently serious and frequent that they may have been responsible for some Gower settlements to have been abandoned (Mullard, 2006).

To the extent that there was any sand deposited on the backshore of Pwlldu beach, it is now covered by shingle; the foreshore does include stretches of sand and given the bay's sheltered nature, there is limited erosion of beach sediment.

4.4 Soil

After the last glacier retreated, soil began to form on the clifftops and in the river valley. In common with the near coastal areas around the South of Gower, the soil on the cliffs surrounding Pwlldu is slightly acidic but base-rich, with a loamy texture (Cranfield Soil and Agrifood Institute, 2021). The soil profile reflects both the geological and anthropological history of the area: the soil is a mixture of weathered limestone, gravel from glacial till, organic matter from vegetation and human-deposited lime (Mullard, 2006). It is likely the latter of these that lends the soil on the plateau above Pwlldu its base-rich fertility, which is important for the agricultural use of the land as it neutralises the acid. On top of the cliff, soil is shallow and dry, as a result of the porous limestone, through which water freely drains. The soil in the river's flood plain and downstream on the beach is more influenced by alluvial and fluvial deposits from upstream, as well as organic matter from the valley woodlands.

5 Management and conservation

5.1 Conservation status

Gower was the first designated Area of Outstanding Natural Beauty in the UK. The natural features of its coastline, formed by geological forces, and the rich and varied habitats it supports, were the principal reasons for its designation (National Association for Areas of Outstanding Natural Beauty, 2021). The designation is useful for co-ordinating management efforts, but it has also encouraged visitors. Pwlldu and Bishopston Valley is also designated as a site of special interest for geological and biological features (Countryside Council for Wales, 2010).

5.2 Tourism and recreation

Large numbers of visitors to Gower tend to congregate at honey pots, particularly those places where recreational activities such as surfing, walking and swimming are available (NRW, 2014). The large number of visitors sometimes cause problems such as congestion on roads, coastal erosion around footpaths, and trampling.

However, although there remain pressures from tourism on Pwlldu, because of the steep sides of the valley, the bay is relatively isolated from the rest of Gower. This has been the case for centuries: when the sea was the principal transport for commercial activities, the coast of Devon could be reached more easily than Swansea (Holt, 1996). This contrasts with nearby Caswell, with a much shallower profile and wide, sandy beach, enabling development to take place – including a road, car park and café – close to the beachfront. Caswell's evolution as a popular destination has been heavily influenced by its proximity to Swansea; on the other hand, as discussed in section 6, Pwlldu's proximity to Devon over the Bristol Channel had a larger impact on the human side of its development.

5.3 Conservation on the beach



Figure 5.1: Honeycomb worm reef, Pwlldu beach

It is partly the quarrying history of Pwlldu's history that makes it special in conservation terms, given the dramatic difference between the marine nearshore and the freshwater habitat sheltered behind the shingle ridges.

From the clifftops, to the backshore, to the intertidal zone, the bay supports a diverse range of niche habitats and highly specialised species. Each of these habitats will have its own conservation threats and management needs. This is evident when passing through the intertidal zone up the beach and onto the backshore, as the vegetation and animals vary drastically and quickly. The intertidal zone contains rock pools and runnels, which remain wet at low tide (see Figure 5.2), allowing marine species to survive. The wave-cut platforms host reefs of honeycomb

worm (*Sabellaria alveolata*) (see Figure 5.1), which is locally threatened by pollution, trampling and beach development (Jackson, 2008).



Figure 5.2: Common species photographed in intertidal zone, Pwlldu. (a) Dog whelk (*Nucella lapillus*). (b) Green-leaf worm (*Eulalia viridis*), orange sea sponge (*Hymeniacidon perleve*). (c) Sea slater (*Ligia oceanica*) and beadlet anenome (*Actinia equina*) (d) Common starfish (*Asterias rubens*)

By contrast, the backshore is usually dry and sheltered, allowing plants to live in cracks in the limestone, supporting invertebrates and birds in the freshwater marshland behind shingle that rests at a steep angle, providing relatively high ridges that act as effective barriers to rough weather. Small shrubs of blackthorn (*Prunus spinosa*) are able to survive in the shingle itself, indicating a flow of fresh water from the stream.

There are paths cut through the slopes towards the bay, showing signs of erosion. However, the cut paths are also important for conservation in parts: while they are not “naturally” formed, the bare soil is important for burrowing habitats (Mullard, 2006), for example the path up from the West side of the beach contains the nest of the yellow-legged mining bee (*Andrena flavipes*).



Figure 5.3: Painted nomad bee at entrance of nest of yellow-legged mining bee (*Andrena flavipes*), its cleptoparasitical host

Additionally, Pwlldu supports numbers of rare or nationally scarce plant species (Countryside Council for Wales, 2010). The biodiversity reflects the variety of different niche habitats that occur in a relatively small area.

The dense woodlands in Bishopston valley are part of the Gower Ash Woods SAC, primarily as such as a result of its ash population. The ash woods are now significantly threatened as a result of Ash dieback (*Hymenoscyphus fraxineus*), a one-off biological event likely caused by human imports of infected saplings that will dramatically change the landscape of the valley in a relatively short amount of time.

5.4 Agriculture

Being on top of limestone, which is freely draining, the landscape is semi-arid; however, the flat plateau above Pwlldu is very fertile and widely used as arable land and pasture. The drainage could potentially cause problems of leaching, where rainwater passing through the soil on top of the plateau is part of the catchment of Bishopston valley, causing agricultural pollutants to end up in the river and freshwater marshes at the beach, and ultimately the sea.

6 Conclusion

The shape, use and conservation of Pwlldu can all be linked directly back to the formation and deformation of its Carboniferous limestone bedrock. The overall shape was determined by geological folds and faults, and the water courses in Bishopston valley follow caves created by the solubility of the rock. Even recent human history is inextricably linked to the properties of limestone: its agriculturally-important alkalinity has influenced the soil profile atop the cliffs and the human geography of the beach, driven by quarrying.

The species that carve out a niche in the bay also have adapted to live in this specialised environment, which can vary dramatically across the landscape and depending on weather. Any conservation strategy must take this into account.

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