Geo Factsheet

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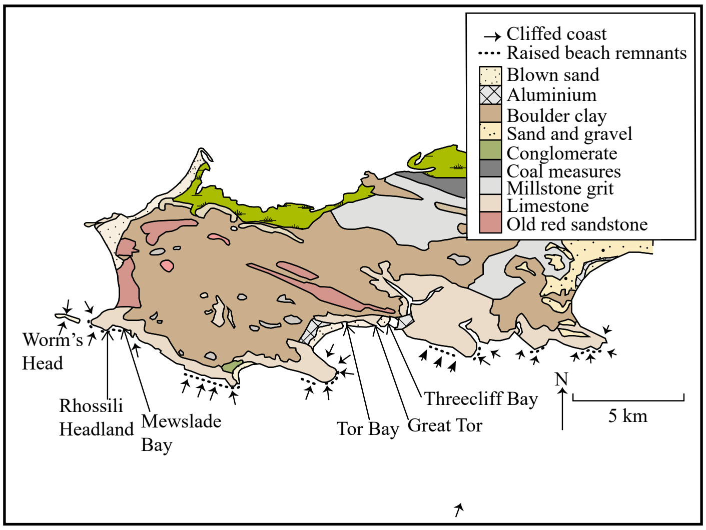
Coastal Erosion Landforms on the Gower Peninsula

The Gower

The rocky southern coast of the Gower Peninsula in South Wales is home to long stretches of limestone cliffs, many of which are fronted by shore platforms. The form of both the cliffs and shore platforms is the result of the interrelationship between marine and subaerial processes and the geological structure and lithology of the coastline. **Figure 1** provides a geological overview of the Gower.

Figure 1. Geology of the Gower Peninsula



What Are Cliffs and Shore Platforms?

Cliffs such as the limestone cliffs found on much of the southern coast of the Gower are common features on rocky coastlines. They are steep or vertical slopes rising from the sea or a shore platform which mark a clear break in slope between coastal hinterlands and the shore. Strictly speaking, a break in slope at the coast is referred to as a cliff if the slope angle exceeds 40°. **Shore platforms** are relatively flat or gently sloping surfaces (between 0 and 3°) that extend seaward from the base of a cliff. Many shore platforms are **intertidal** meaning that they are covered at high tide and exposed at low tide. Cliff and shore platform morphologies vary immensely due to the interaction of a number of factors affecting their development, including the balance between marine and subaerial processes, how these processes are influenced by rock lithology and structure, and fluctuations in sea-level.

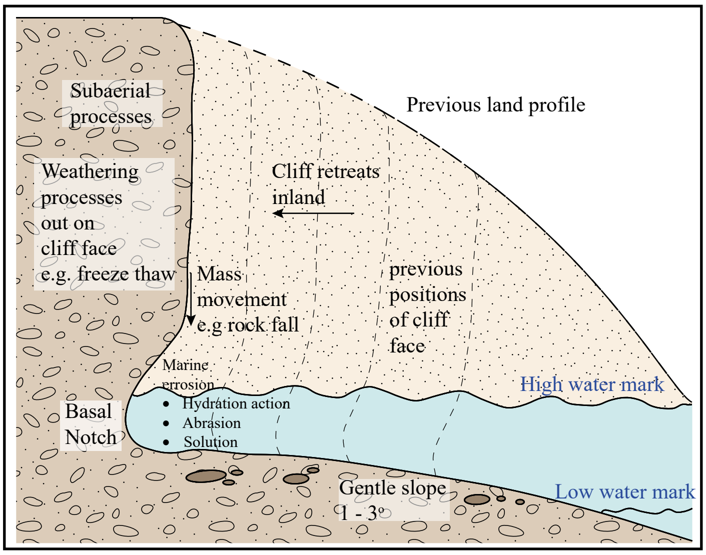
How Are Cliffs and Shore Platforms Formed?

A combination of **marine erosion**, **weathering**, and **mass movement** processes create and shape cliffs and shore platforms. Cliff formation is initiated as waves undercut coastal slopes by hydraulic action and abrasion, creating a **basal notch**. Basal notches cover 1-2 metres vertically and can be up to 3 metres deep, with more pronounced notches being created in resistant rocks that can support and sustain the overhang as it recesses into the cliff base. The rocks overhanging the notch will eventually collapse, aided by gravity, as the notch increases in size, presenting a steeper 'new' cliff face as they do so. The limestone cliffs of the Gower recede by **rock fall**, a mass movement process that is common on steep, bare rock faces, by which small blocks of rock detach and fall from the cliff face.

The pieces of rock are loosened by weathering processes such as freeze-thaw attacking joints within the rock. The **rate** at which cliffs erode and recede is determined by local geology and wave energy.

Continued cliff recession will take place providing that any eroded material is broken down and removed rather than being allowed to accumulate. Continued recession creates shore platforms, which are the base of the rock mass that is 'left behind' as the cliff recedes in a landward direction (**Figure 2**).

Figure 2. The Formation of Cliffs and Shore Platforms



Shore platforms dissipate wave energy and so are self-limiting in terms of the distance they can extend inland (around 500 metres maximum).

As the platform increases in size, waves have further to travel to reach the base of the cliff, meaning that the extent to which they can erode the cliff base is greatly reduced. Erosion then gives way to deposition, allowing beaches to form at the foot of cliffs, whilst the cliff face takes on a more gently-sloping profile as weathering and mass movement take over. Some shore platforms are temporarily or permanently covered by beach material.

Exposed rock platforms may be quite smooth, but more often they are uneven surfaces with many protrusions and indentations or **marine potholes**, which may be filled with saltwater or beach material. Salt and biological weathering help to shape the platform.

Micro-features such as **caves**, **sea arches**, and **blowholes** may form due to differential erosion as cliffs recede (**Figure 3**, **Table 1**, and **Example 1**).

Figure 3. Micro-features

Example 1. Threecliff Bay (see Figure 9).
Threecliff Bay acquires its name from the three linked, pointed peaks that have been created in the rock face due to the steep dip of the rock strata and faults which have created lines of weakness. At one point a cave has eroded through the rock outcrop creating a natural arch created by fracturing along a diagonal fault. The arch is large enough to walk through at low tide.

Example 2. Worm's Head (see Figure 8).

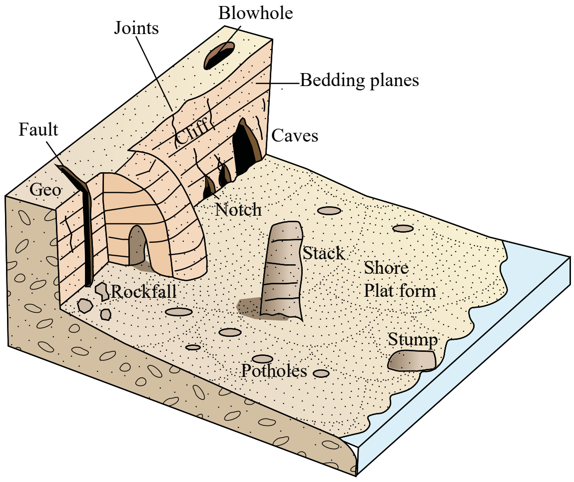


Table 1.

Micro-Feature	**Description and Formation**
Notches and nips	Wave-cut-**notches**, found at the bases of cliffs, are created through the processes of abrasion, solution (*corrosion*), and hydraulic action as waves repeatedly attack the base of a cliff. A small notch is sometimes called a **nip**. The formation of a notch is the starting point and an ongoing indicator for active cliff recession and shore platform formation.
Marine potholes	When shore platforms are ground into by the abrasive power of rock fragments, small depressions may form. These become filled, in part at least, with sand, shingle and pebbles. This material is swirled around as the water, driven by tides, advances and retreats. This swirling of material and abrasion of the platform can form cylindrical, bowl-shaped **potholes**.
Gorges / geos	**Gorges** or **geos** are narrow, steep-sided clefts within cliffs formed by differential erosion aided by the presence of vertical fault planes.
Caves	A **cave** is a depression formed in a cliff face in which the depression depth has become greater than its width. The depression is initiated and enlarged often at the site of a structural weakness in the cliff face where a fault, joint or bedding plane is present.
Blowholes	A **blowhole** may form via the hydraulic and pneumatic action of waves crashing onto the 'ceiling' of the cave, eroding upwards to the point where the land above collapses and falls through.
Sea arches	When two caves form back-to-back on a coastal promontory and deepen over time along a line of geological weakness, which is likely to follow through the promontory, they may eventually meet, creating a **sea arch**.
Stacks and stumps	When the 'roof' of a sea arch collapses, it can leave behind an isolated pillar of rock known as a sea **stack**. The stack is attached to the same sub-marine base as the promontory it was once a part of. Small stacks, which can be inundated by high tides yet revealed at low tide, are known as **stumps**.

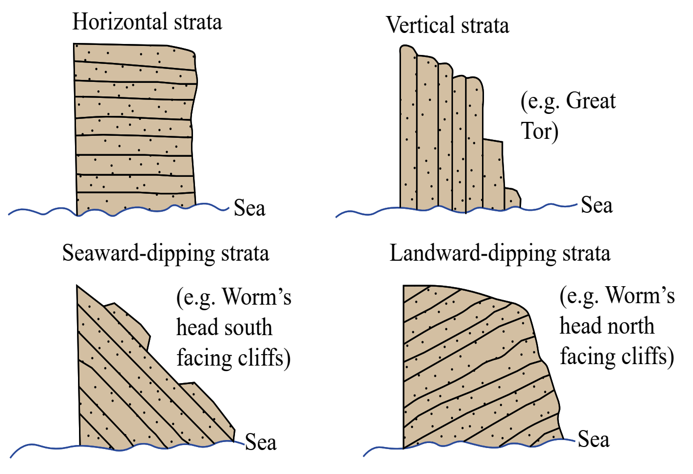
The Importance of Geology

The geology of a coastline is an important factor in determining the rate of cliff recession and the **morphology** of cliffs and shore platforms. The term **structure** refers to the physical characteristics of rocks including faults, joints, bedding, folding, and dip. **Lithology** refers to the chemical and physical composition of a rock, determining how resistant a rock will be to erosion and breakdown by chemical or mechanical processes.

More resistant rocks produce steeper cliffs whereas softer rocks produce more gently-sloping profiles. Most cliffs of the Gower are formed of limestone, which is a relatively resistant sedimentary rock comprised of layers. Cliff morphology is also determined by dip, joints, folds, and faults. **Folding** is when the Earth's crust bends and flexes due to compressional tectonic forces.

Folding usually takes place as part of mountain building processes and can alter the angle of dip. The dip of a bedding plane is the angle that it makes with a horizontal plane. Different dips result in different cliff profiles (Figure 4) whilst structural weaknesses such as joints (fractures within rock along which no displacement can be observed) and faults (a fracture where displacement within the rock is observable) provide zones of weakness at which differential erosion can be initiated, creating micro-features. Compressional earth movements have tightly folded the limestone beds in the south of the Gower peninsula. The angle of dip of the limestone strata ranges from almost horizontal to vertical, creating a variety of cliff profiles (Example 2).

Figure 4. The Influence of Dip on Cliff Profiles



The angle of dip can also influence the form of shore platforms. The intertidal platform, which periodically connects Worm's Head (see later) to the mainland, has a very jagged 'corrugated' appearance due to the heavily tilted beds of limestone, although the jagged layers have been smoothed in part by abrasion, solution, and salt weathering as the limestone has reacted with seawater (Figure 5a and b).

Figure 5a. Uneven 'Corrugated' Platform Surface

Figure 5b. Marine Erosion and Chemical Weathering Have Smoothed the Surface

Sea-level Fluctuations: Relict Cliffs and Shore Platforms

Shore platforms, and the beaches that may be situated on top of them, can become isolated from the action of the sea, separated due to a fall in mean sea level. These raised platforms and fossil beaches create coastal flats, stranded high above present-day sea-level, like that on Rhossili Headland and Inner Worm's Head, sometimes backed by inactive relict cliffs, like those situated at Mewslade Bay. Relict cliffs, no longer subjected to the action to waves, can be identified by their gently sloping, convex profiles, and sometimes vegetated slopes. All evidence of such emergent features on the Gower is found on the rocky south coast where raised beaches made up of pebbles, shells, and sand, which have been cemented together by calcium carbonate, are exposed within cliffs (Figure 6).

Example 2. Great Tor

The almost vertically dipping limestone strata, which creates the headland 'Great Tor', marks a division between Tor Bay and Three Cliffs Bay, separating the two bays at high tide.

The vertical beds, tilted upright from their original horizontal position by folding processes, have created a sheer rock face. The bedding planes (the surface which separates one layer of the sedimentary rock from the next) provide a surface along which the layers can 'slide' away from the rock mass. It is worth noting that movement planes can be marked by faults and joints as well as bedding planes.

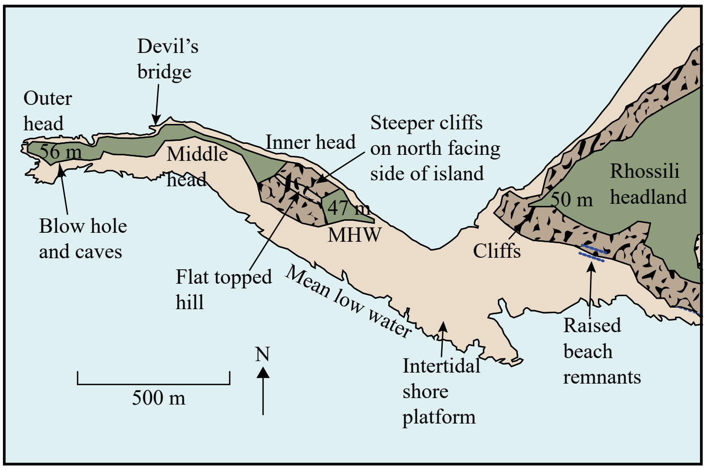
Remnants of a shore platform can just be made out at the base of a cliff, but these cliffs are affected by marine erosion to a much lesser extent than they were in the past. A sandy beach is permanently present on the shore platform. The cliffs of the south coast, situated between Worm's Head and Mumbles Head, presently experience little effect from marine erosion. They are instead subjected to modification by subaerial processes. This is evidenced on the landward side of Great Tor, where the slope angle is less steep than the seaward face and has become vegetated.

Figure 6. Raised Beach Material Exposed on the Rhossili Headland

Worm's Head

Worm's Head is a tidal island, separated from the Gower Peninsula by a shore platform. It is only exposed for 2 ½ hours before and after low tide (see Figure 8b and c). It takes around fifteen minutes to walk across, over the uneven platform, to reach the first of the three sections of the island, the Inner Head (Figure 7). Worm's Head is part of one of the two headlands positioned to the north and south of Rhossili Bay, which was created by the differential erosion of softer Old Red Sandstone situated between harder limestone outcrops.

Figure 7. Worm's Head

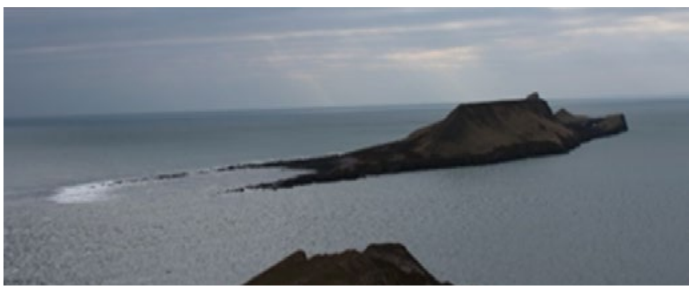


The strata making up the platform connecting the mainland and Worm's Head dips at angles of around 30-45°, creating a 'corrugated' surface (see Figure 5a and b). The platform is full of small faults that have weakened it, meaning that it has been worn down at a faster rate than Rhossili Headland on the mainland and Worm's Head, thus creating the tidal island, which once was attached to the mainland at both high and low tide. The cliffs on the most westerly tip of the island are 56 metres high and the top of the Inner Head is flat, which suggest that it was once a shore platform – part of the same flat area on Rhossili Headland. The cliffs on the north-facing side of the island have a much steeper profile than those on the south side. This is due to the southward direction in which the limestone layers dip (see Figure 4). Differential erosion has taken place as the limestone has retreated; waves have exploited weaknesses in its layers: Devil's Bridge is a natural rock bridge created from a collapsed sea cave within the Middle Head (Figure 8a). Caves and a blowhole are present on the Outer Head. When waves are exceptionally large, water can be seen shooting into the air from the mainland. Remnants of raised beaches, which date to the Ipswichian interglacial (125,000 years BP) when sea levels rose to 6-9 metres higher than present, can be seen exposed on both the Inner and Outer Head (Figure 6b).

Figure 8a. The Middle and Outer Head and Devil's Bridge, Worm's Head. Note the wave-cut platform made of tilted layers of limestone. The high tide mark is clear.

Figure 8b. Worm's Head at Low Tide

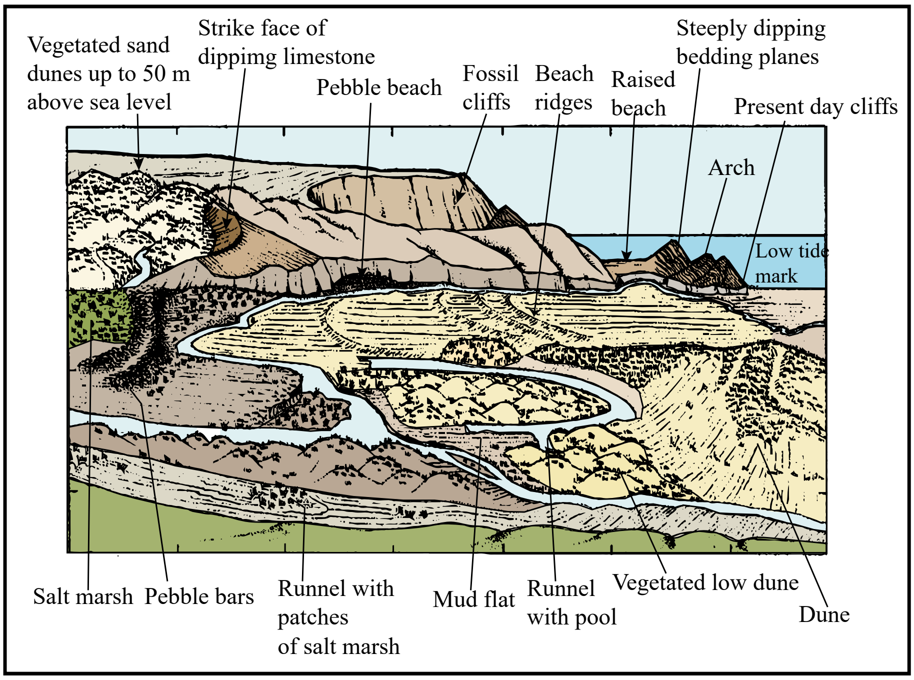
Figure 8c. Worm's Head at High Tide



Summary and Conclusions

Cliffs and shore platforms are formed as coastlines are subjected to marine and subaerial processes and retreat over time. The morphology of these features is influenced by the interaction of, and balance between, marine and subaerial processes, sea-level change, and geological factors. The south coast of the Gower peninsula has many outcrops of dipping limestone strata from which a variety of cliff profiles, shore platforms, and their associated micro-features have been created.

Figure 9. Three Cliffs Bay



Exam Question

(See Figure 9.)

Study Figure 9;
Assess the relative importance of the geomorphological processes that are operating at present and those that have occurred in the past in regards to shaping the landforms shown.

Guidance:

- Use a colour coding system to categorise which landform's occurred when sea-levels were higher (e.g., raised beaches, fossil cliffs, fossil dunes) and those which are being formed by present day processes.
- As this is an assessment question, you need to try to work out the relative importance of the two sets of landforms in creating the landscape.
- The tariff is likely to be between 12 and 16 marks and therefore requires a planned essay, as in A-Level.

Bibliography and Further Reading

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