Chapter 2: Coastal environments

2.1 The coast as a system

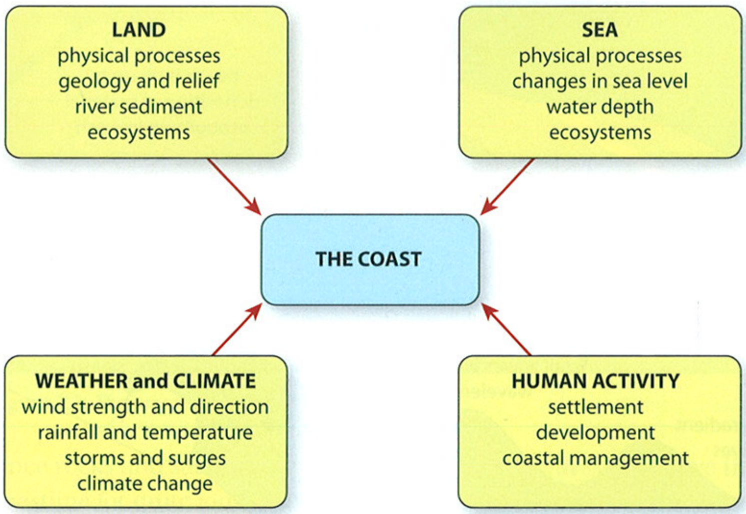


Figure 2.1: *Factors affecting the coast*

Introduction

This chapter looks at the coast, its landforms and the processes that produce them. Vital parts of the coast are its ecosystems. They are rich in biodiversity and resources. The exploitation of these resources is threatening their survival. This is just one of number of conflicts occurring as development and conservation come face to face. The need for proper management of the coast is great.

The coast, like the drainage basin, is an open system. It involves inputs, flows (processes), stores and outputs (for more on this, see Figure 2.31 on page 54). The coast is the transition zone between the land and the sea. The **coastline** is the actual frontier between the two. The coast is therefore made up of two parts – onshore and offshore – located either side of the coastline. The onshore zone can extend up to 60 km inland. The offshore zone reaches as far as 370 km out to sea.

Beyond the offshore zone lie what are known as 'international waters'. They belong to, and are shared by the global community of all nations.

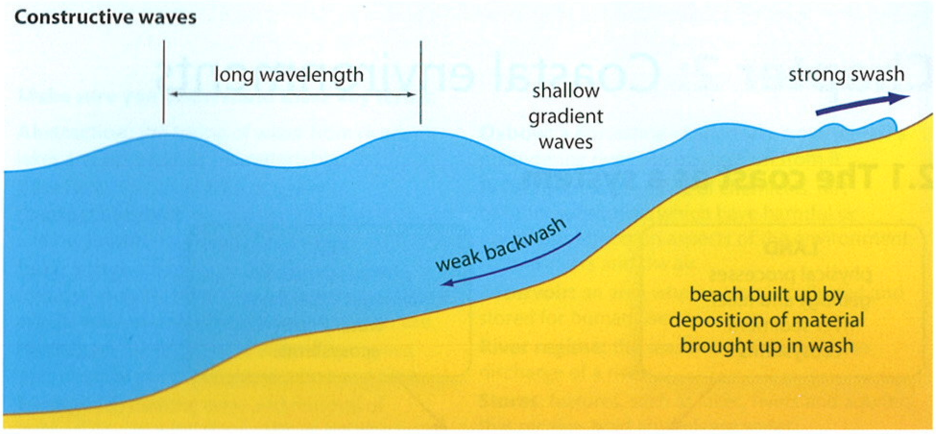
The coasts of the world are very diverse in terms of their landscapes and **ecosystems**. Figure 2.1 identifies the main factors behind these differences. The diagram reminds us that coasts are the meeting point of not just land and sea, but also the atmosphere. Because of this, weather and climate are important factors. Human **settlement** and **development** add to the coastal diversity.

The physical processes shaping the landforms of the coastline fall into two groups: **marine** (sea) and **terrestrial** (land).

Marine processes

Waves do much of the work of marine processes. They erode, transport and deposit materials. Waves are created by winds as they blow over the surface of the sea. It is the friction between the wind and the water that sets waves in motion. The strength of waves depends on the strength of the wind. It also depends on the length of time and distance over which the wind has been blowing (**the fetch**).

As waves near the coast, they enter into shallower water. Friction with the sea bed causes the wave to tip forward so that it eventually breaks. The resulting forward movement of water, called the **swash**, runs up the **beach** until it runs out of energy. The water then runs back down the beach under gravity. This is called the **backwash**.



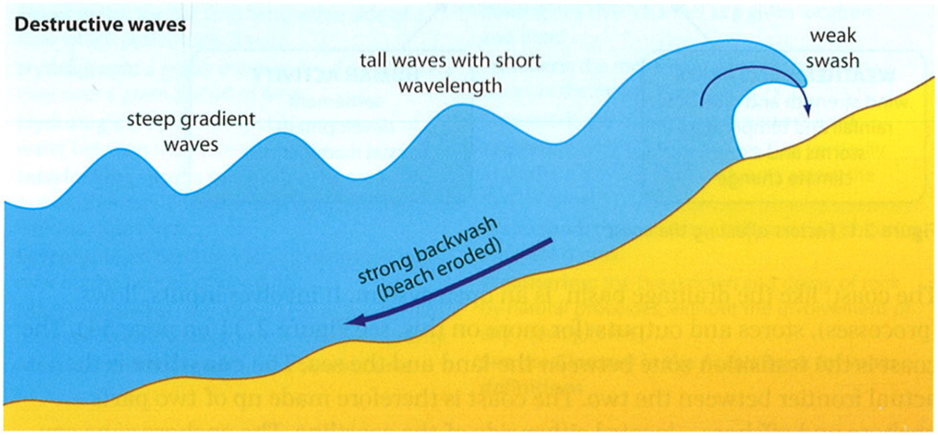


Figure 2.2: *Constructive and destructive waves*

The balance between the swash and backwash of waves creates the difference between **constructive** and **destructive** waves (Figure 2.2). In **constructive waves**, the swash is stronger than the backwash. As a result, material is moved up the beach and much is left there (deposition). In **destructive waves**, the backwash is stronger. Material is dragged back down the beach (**erosion**) and moved along the coast by **longshore drift** (transport).

It is destructive waves that do much of the erosion along a coast. They cut away at the coastline in a number of different ways:

- **hydraulic action** – this results from the force of the waves hitting the cliffs and forcing pockets of air into cracks and crevices
- **abrasion** – this is caused by waves picking up stones and hurling them at cliffs and so wearing the cliff away
- **corrosion** – the dissolving of rocks by sea water.

Attrition is a process whereby the material carried by the waves becomes rounded and smaller over time as it collides with other material. It does not erode the coast as such but does form small pebbles and sand.

Be sure you know the difference between the following pairings:

- marine and terrestrial
- swash and backwash
- constructive and destructive waves
- abrasion and attrition.

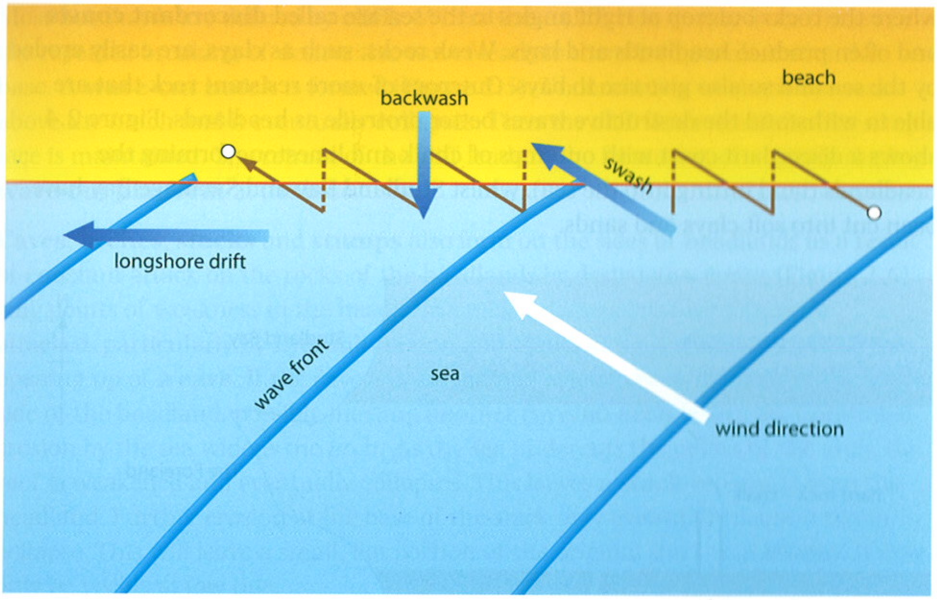


Figure 2.3: *The process of longshore drift*

Once rocks and sand are detached from the cliff, waves can move them along the coastline for quite long distances. This process is known as **longshore drift** (Figure 2.3). Generally speaking, the smaller the material, the further it is likely to be moved by waves as it is lighter. Eventually, the waves are unable to move so much material and the material will be deposited to create new landforms.

Smaller or lighter materials will be moved further by waves because they need less wave energy to transport them

Land processes

There are three main processes at work on the landward side of the coastline:

- **weathering** – the breakdown of rocks which is caused by freeze-thaw and the growth of salt crystals, by acid rain and by the growth of vegetation roots
- **erosion** – the wearing away of rocks by wind and rain
- **mass movement** – the removal of cliff-face material under the influence of gravity in the form of rock falls, slumping and landslides.

2.2 Coastal landforms

The interaction of the processes described in Part **2.1** produces a variety of different coastal landforms. These landforms are broadly divided into those that result from coastal erosion and those due to coastal deposition.

Erosional landforms

By far the most common coastal landforms are the alternations of **headlands** and **bays** which give many coastlines their irregular appearance. Destructive waves clearly play an important role in their formation. The nature of the coastal rocks also plays a part. The direction in which rocks occur in relation to the coastline affects the resulting landforms. Coasts where the rock outcrops run parallel to the sea are called **concordant coasts** and often produce straighter coastlines. Coasts where the rocks outcrop at right angles to the sea are called **discordant coasts** and often produce headlands and bays. Weak rocks, such as clays, are easily eroded by the sea and so also give rise to bays. Outcrops of more resistant rock that are able to withstand the destructive waves better protrude as headlands. Figure 2.4 shows a discordant coast with outcrops of chalk and limestone forming the headlands (land jutting into the sea), whilst Studland Bay and Swanage Bay have been cut into soft clays and sands.

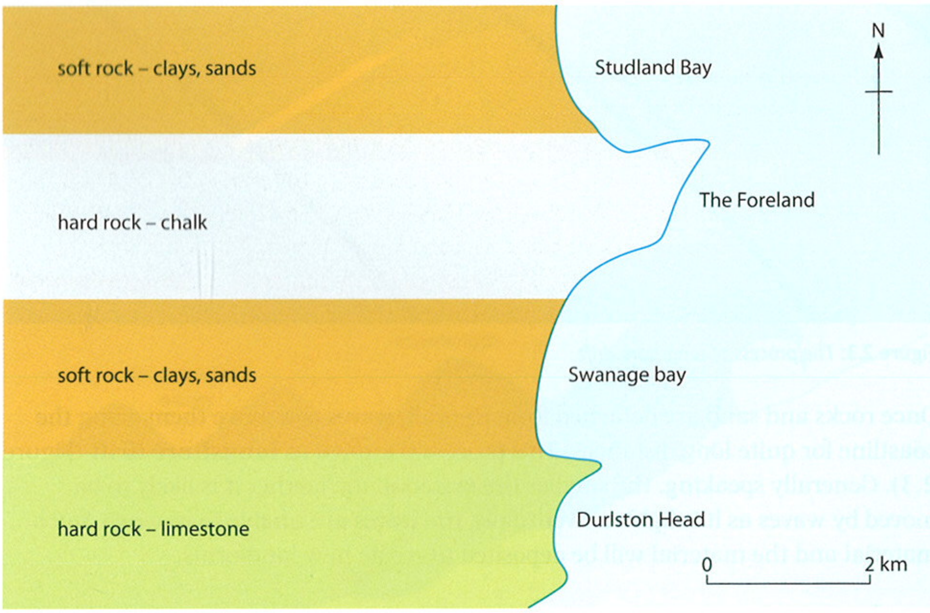


Figure 2.4: *Sketch map of part of the Purbeck coast, southern England*

What is the difference between a concordant coast and a discordant coast?

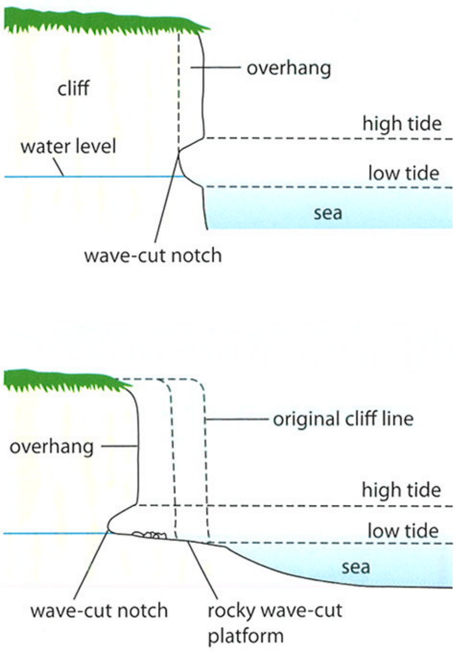


Figure 2.5: *The formation of cliffs and wave-cut platforms*

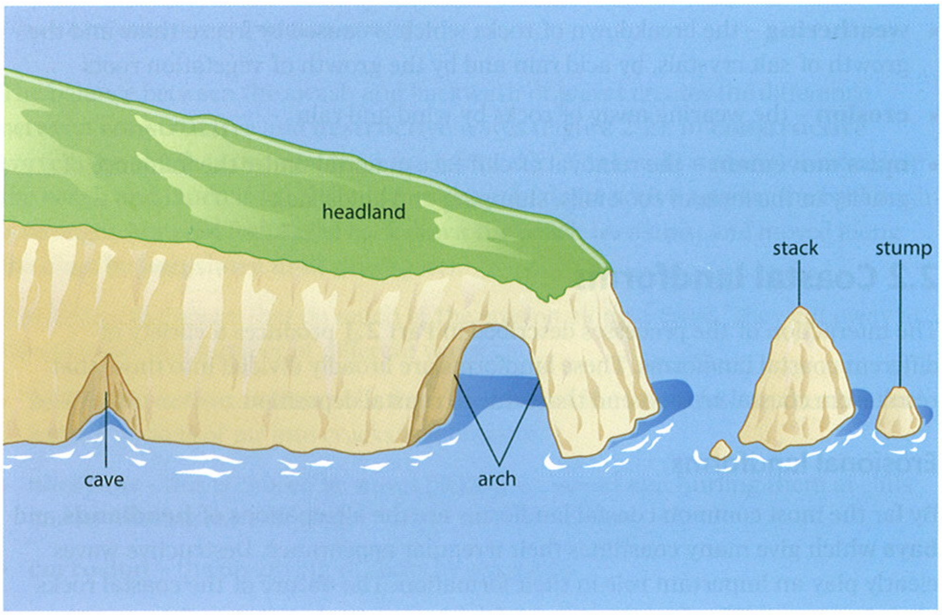


Figure 2.6: *The formation of caves, arches, stacks and stumps*

Most headlands are defined by **cliffs**. Where these cliffs rise steeply from the sea, the repeated breaking of destructive waves leads to them being undercut at the base. A **wave-cut notch** is formed (Figure 2.5). Undercutting weakens the rock above the notch and it eventually collapses. Thus the cliff face retreats but its steep face is maintained. The retreat of the cliff leads to the formation of a gently sloping **wave-cut platform** at the base.

Caves, **arches**, **stacks** and **stumps** also form on the sides of headlands as a result of constant attack on the rocks of the headlands by destructive waves (Figure 2.6). Any points of weakness in the headland's rocks, such as faults or joints are attacked, particularly by hydraulic action and abrasion. This is likely to lead to the opening up of a **cave**. If the cave is enlarged and extends back through to the other side of the headland, possibly meeting another cave, an **arch** is formed. Continued erosion by the sea widens the arch. As the sea undercuts the pillars of the arch, the roof is weakened and eventually collapses. This leaves a **stack** separated from the headland. Further erosion at the base of the stack may eventually cause it too to collapse. This will leave a small, flat portion of the original stack as a **stump**. It may only be visible at low tide.

Figure 2.7: *Old Harry Rocks, southern England*

On Figure 2.7 identify:

- a cave
- an arch
- a stack.

An excellent example of these erosional features is Old Harry Rocks (Figure 2.7) at the end of the chalk headland separating Swanage Bay from Studland Bay in southern England (Figure 2.4).

Depositional landforms

Depositional landforms are produced on coastlines where mud, sand and shingle accumulate faster than they can be moved away by the waves. This usually happens along stretches of coastline dominated by constructive waves (where the swash of water coming onto the beach is stronger than the backwash).

Beaches are the most common depositional landform. They result from the accumulation of material deposited between the storm- and low-tide marks. The sand, shingle and pebbles come from a number of sources. Much of it is material that has been eroded elsewhere and that is being moved along the coast by longshore drift. Some comes from offshore as a result of waves picking it up from the sea bed and rolling it in towards the land. From the opposite direction, rivers feed mud and silt into the coastal zone via their estuaries (mouths). The deposition of this river material then takes place at the heads of sheltered bays.

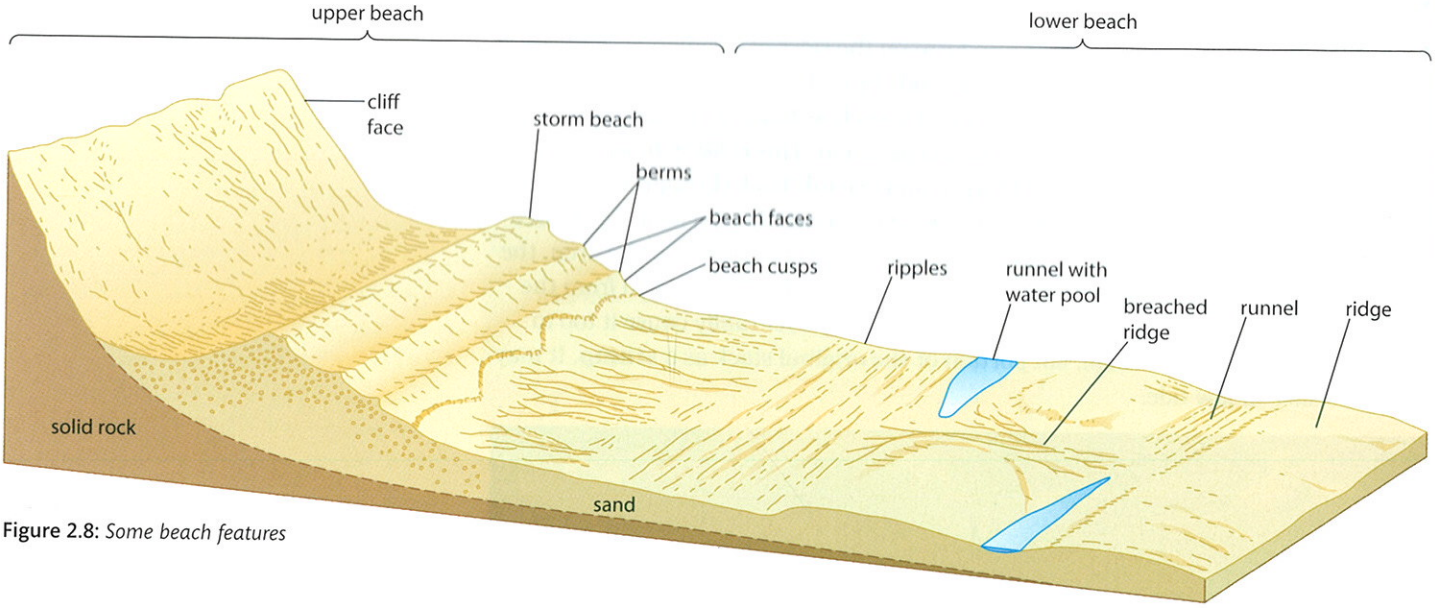


Figure 2.8: *Some beach features*

Many beaches show a number of very small features (Figure 2.8). For example, at the top end there will be a **storm beach** made up of large material thrown up during storm conditions. A series of small ridges, known as **berms**, mark the positions of mean (average) high-tide marks. Beach cusps – small semicircular depressions – are formed by the movement of the swash and backwash of waves up and down the beach. In general, the finer the beach material, the more gently inclined the overall beach.

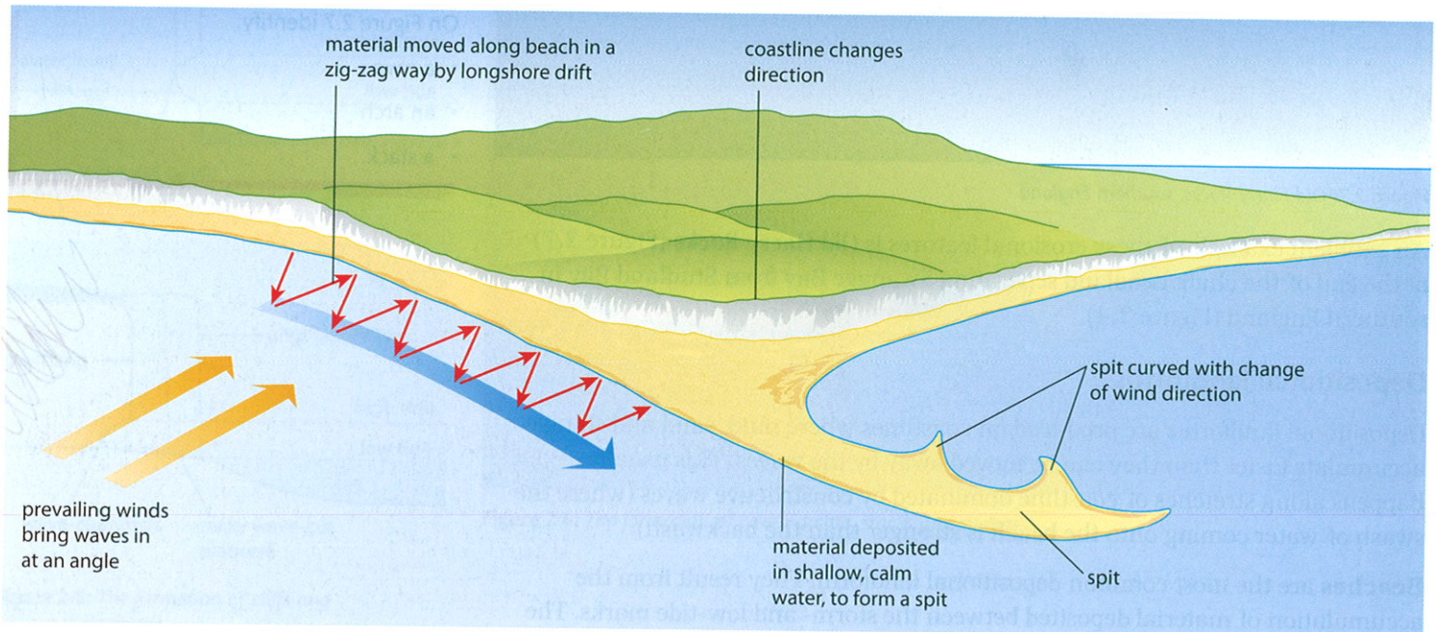


Figure 2.9: *The formation of a spit*

Spits are long narrow beaches of sand or shingle that are attached to the land at one end. They extend across a bay, an **estuary** or where the coastline changes direction. They are generally formed by longshore drift in one dominant direction (Figure 2.9). At the end of the beach, the material being transported by longshore drift is deposited. At a river estuary, the growth of the spit also causes the river to drop its sediment. This occurs mainly on the landward side (rather than the seaward side) of the spit and salt marshes may form. The waves and wind may curve the end of the spit towards the land.

If a spit develops in a bay, it may build across it and link the two headlands to form a **bar**. The formation of a bar is only possible if there is a gently sloping beach and no sizeable river is entering the bay. In this way, bars can straighten the coast and any water on the landward side is trapped to form a **lagoon**. A classic example is to be found at Slapton in southern England (Figure 2.10).

Figure 2.10: *Slapton Ley showing the lagoon to the left of the bar*

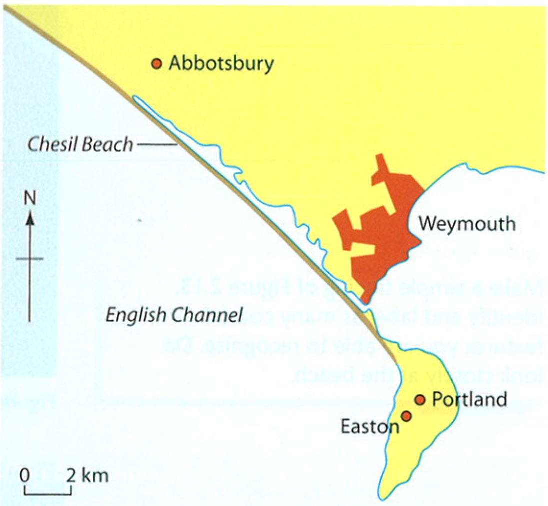


Figure 2.11: *Chesil Beach, southern England*

Tombolos are spits that have continued to grow seawards until they reach and join an island. The 30km long Chesil Beach on the south coast of England links the isle of Portland to the mainland (Figure 2.11). The formation of this tombolo was due, not only to longshore drift, but also by offshore sediments being rolled towards the coast.

Cuspate forelands are triangular-shaped accumulations of sand and shingle that extend seawards (Figure 2.12). It seems likely that many of them develop as a result of longshore drift occurring from two different directions. At a change in the direction of a coastline, sediment will be brought from both directions, causing the cuspate foreland to develop.

Figure 2.12: *The cuspate foreland at Dungeness, southern England*

Sand dunes are depositional landforms in coastal areas. However, their formation is only indirectly related to coastal processes. Beaches are the source of the sand which, when dry, is blown inland by the wind to form dunes. Over long periods of time, the wind blows the sand up into a series of ridges running parallel to the coastline. Gradually the older ridges become colonised by vegetation and this helps to stabilise them (see Figure 2.23 on page 47).

Make a simple tracing of Figure 2.13. Identify and label as many coastal features you are able to recognise. Do look closely at the beach.

Figure 2.13: *A stretch of the Jurassic coast*

Finally, we need to realise that many of these coastal landforms are put to good use by people. They offer opportunities that are exploited by various economic activities. For example, sandy beaches and the many stretches of fine scenery are exploited by tourism, as along the Jurassic coast of southern England (Figure 2.13). This is now designated a World Heritage site. Some of the world's most famous golf courses are laid out on sand dunes. Marinas are being built on the shores of estuary mouths sheltered by spits. Exposed coasts are now being used by wind farms. Nuclear and thermal power stations at the coast are further evidence of the energy industry exploiting these areas (Figure 2.12). More examples of human use of the coast follow in Part **2.3**, and the resulting conflicts are explored in Part **2.6**.

Research why the Jurassic coast of southern England has been recognised as a World Heritage Site.

2.3 Factors affecting coasts

Figure 2.1 on page 33 showed that there are other factors besides coastal and land processes affecting the coast, particularly the coastline and its landforms.

Geology

As shown in Figure 2.4 on page 36 the difference between hard and soft rocks is a strong influence on the shape of the coastline. A coastline made up of weak rocks, such as clays and sands, will be easily eroded back by destructive waves. Bays will be created. Coastlines of more resistant, harder rock will not be eroded so quickly.

They often jut out into the sea, often as headlands. The difference between hard and soft rocks will also have an impact on the shape and characteristics of cliffs (Table 2.1).

	Hard rocks	Soft rocks
Shape of cliffs	High and steep	Generally lower and less steep
Cliff face	Bare rock and rugged	Smoother; evidence of slumping
Foot of cliff	Boulders and rocks	Few rocks; some sand and mud

Table 2.1: Contrasts between cliffs made of hard and of soft rocks

So geology affects the coastline in two different ways:

- in plan view – headlands and bays
- in vertical section – the height and shape of cliffs.

Vegetation

In general, the longer a coastal landform, such as a sand dune, has existed, the greater the chances that it will be colonised by vegetation. In order to survive, the vegetation has to be able to cope with the particular conditions, such as high levels of salt in both the air and the soil. The major impact of vegetation is to help protect and preserve coastal landforms. This is well shown in the cases of sand dunes (see Figure 2.24 on page 48) and mangrove swamps (see Figure 2.20 on page 45).

Sea-level changes

One of the obvious effects of global warming and climate change is that low-lying coasts will be drowned by rising sea levels. This problem will be made worse by the fact that many of the world's most densely populated areas are located on coastal lowlands (see also Chapter **7.8** on page 200). In fact, rising sea levels are nothing new. During the Ice Age, sea levels also changed, but to a much greater extent. They fell as more and more of the world's water was locked up in ice sheets and glaciers. The sea levels then rose again as the ice sheets and glaciers melted.

Figure 2.14: *A fjord in Norway*

Figure 2.15: *A raised beach*

A rising sea-level gives rise to what is called a **submergent coastline**. The main features are **rias** (drowned river valleys) and **fjords** (drowned glacial valleys) (Figure 2.14).

An **emergent coastline** is associated with a falling sea level. The most common landforms are **raised beaches** (Figure 2.15). These are areas of wave-cut platform and their beaches now found at a level higher than the present sea level. In some places, **relict cliffs** with caves, arches and stacks are found where there are raised beaches.

Can you pick out the raised beach and relict cliffs in Figure 2.15?

Human activities

Human activities can have significant effects on sea processes and also on the character of the coast. At this stage, we need only identify the main ones. They will be explored and explained in more detail in later sections of this chapter. The main ways include:

- **settlement** – coastal lowlands have proved attractive to people and their settlements throughout history and throughout much of the world. Many of the world's most densely populated areas are located on the coast,
- **economic development** – people have taken advantage of the particular economic opportunities that the coast offers, such as land for agriculture and industy (Figure 2.16). Fishing and the chance to trade either along the coast or overseas lead to the building of ports and harbours. As was illustrated at the end of Part **2.2**, the coast is often used for tourism and in the energy business,
- **coastal management** – for many centuries, people have sought to control the coastline, for example, by protecting stretches of coastline from high rates of either erosion or deposition by building sea walls and groynes (see Figure 2.37 on page 59).

Why is the coast attractive to human settlement and development?

Figure 2.16: *Coastal development*

Look closely at Figure 2.16. What different land uses can you identify?

As a result of these and other human activities, the natural landscapes and features of the coast can be greatly changed. So too the actual shape of the coastline.

2.4 Coastal ecosystems and their distributions

Given the large amounts of development and settlement which have taken place in the coastal areas of the world, it is easy to forget that the coast is home to a variety of ecosystems. In their natural state, coasts can be very rich in **biodiversity**. In this section, we will look at four different ecosystems. Two of them, coral reefs and mangroves, have tropical distributions. The other two, salt marshes and sand dunes are common across the world.

Coral reefs

Coral reefs are a unique marine ecosystem. They are built up entirely of living organisms (Figure 2.17). Reefs are huge deposits of calcium carbonate made up mainly of corals. Their global distribution is shown in Figure 2.18. It is mainly controlled by four factors:

- **temperature** – coral growth needs a minimum water temperature of 18°C. They grow best between 23°C and 25°C
- **light** – is needed for the coral to grow; because of this need, corals grow only in shallow water
- **water depth** – because of the need for light, most reefs grow where the sea is less than 25 metres deep
- **salinity** – since corals are marine creatures, they can only survive in salt water.

Figure 2.17: *Section of a coral reef*

At a local level, there are other factors affecting where coral reefs develop:

- **wave action** – corals need well oxygenated salt water; this occurs in areas of strong wave action