The power of waves

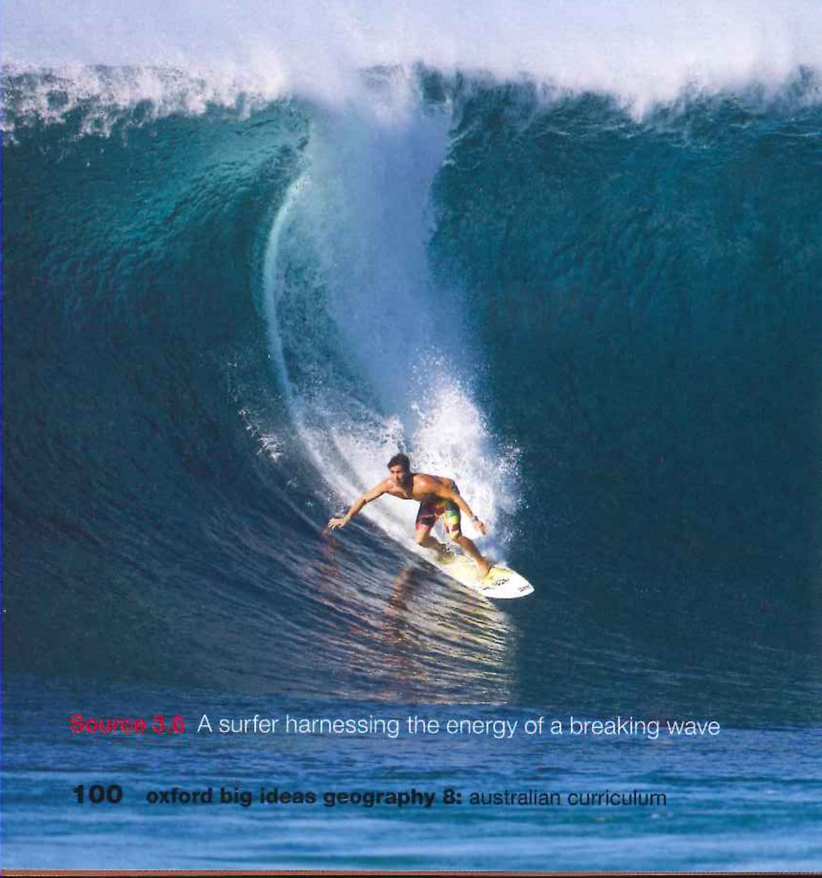
Waves are the main force that shape coastal landscapes. Waves begin at sea when the wind blows across the surface of the water. The water surface rises along with the wind, but then is pulled back down by the power of gravity. This tug-of-war between the drag of the wind and the pull of gravity creates an **orbit** – a circular movement of water (see Source 3.7) beneath the surface. This orbit creates what we see as a wave.

As waves move into the shallower waters near the coast, the bottom of the orbit comes into contact with the sea bed. Friction generated on the sea bed slows the bottom of the wave more quickly than the top. The top (or crest) of the wave continues moving and finally falls forward onto the shore (much as a person can stumble and fall over, head first). The water that falls forward and moves up the shore is called the **swash**. The **backwash** is the water that runs back to the ocean.

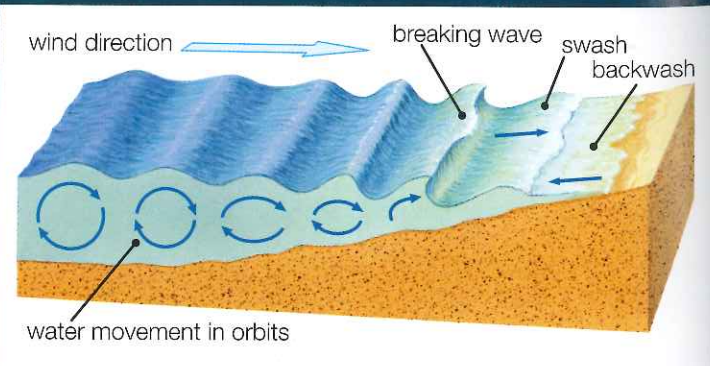
The energy in waves can travel thousands of kilometres before it is released on the coast. This energy then changes the coast in three important ways. Firstly, it erodes the coast by breaking down the rocks of cliffs and headlands into small pieces of stone or sand, eventually forming a beach. Secondly, along with tides and currents, the wave energy transports the sand out to sea and along the coast. Thirdly, the waves deposit the sand in new places, forming new beaches, spits and sand bars.

Longshore drift

Although some waves can hit directly onto a shoreline, most waves hit the coast at an angle. This occurs because of the varied shape of the land and the varying direction of the wind that produces the waves. When the waves hit the coast at an angle, the swash picks up the sand and carries it along the beach rather than just dumping it directly forward onto the shore. The next wave that comes along will also move the sand along the beach until eventually, after hundreds of small zigzags, many grains of sand are moved to one end of the beach. They may pile up to form long deposits of material, such as



Source 3.6 A surfer harnessing the energy of a breaking wave



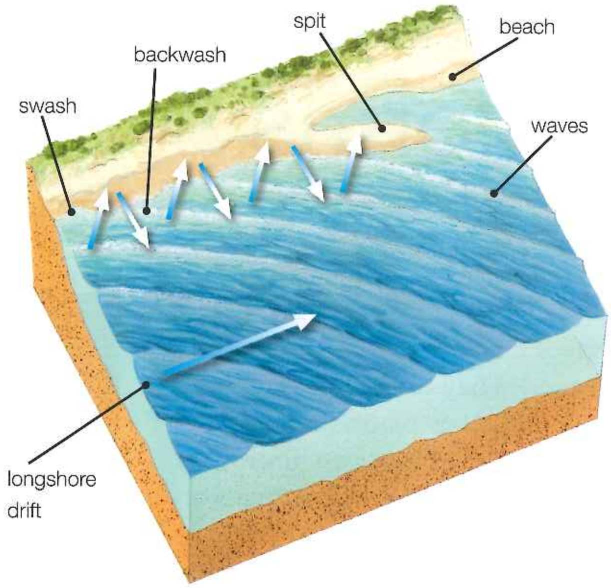
Source 3.7 Formation of waves

spits and **tombolos** (see Source 3.4), or the wind may change direction, causing new waves to carry sand back in the opposite direction. This movement of sand along a coast is called **longshore drift**. It is a major contributor to the shape of the coastline.

Longshore drift is also responsible for many problems faced by those people who live along the coast. The movement of sand can clog harbours and river mouths. Many coastal communities in Australia spend millions of dollars a year digging up the sand moved by longshore drift and putting it back on the beaches where local residents want it.

One of the most dramatic examples of problems caused by longshore drift can be found on England's south-eastern tip, in a town called Dungeness. Here, a nuclear power station has been built near the coast on an ancient and very large spit made of small stones called shingle. For centuries, this shingle has been shifting back and forth along the southern coast. Currently, huge amounts of the small shingle stones have to be moved to prevent the shingle from eroding. Erosion would threaten the station itself, potentially causing sea water to enter the reactor and bring about a nuclear meltdown. A meltdown would result in radioactive contamination – a disaster with devastating effects that could last thousands and thousands of years.

Source 3.8 Longshore drift is threatening Dungeness Nuclear Power Station



Source 3.9 Longshore drift

Check your learning 3.2

Remember and understand

1 What is the difference between swash and backwash?
2 How do waves begin?
3 Why do waves break?

Apply and analyse

4 How do waves change the coast?
5 What do you think happens to sand on a beach where the waves strike directly onto the beach rather than on an angle?

Evaluate and create

6 Describe the journey of a grain of sand on a beach where the waves strike at an angle.
7 Like many beaches around the world, Dungeness is being changed by longshore drift.
   a What are the local authorities doing about this?
   b Why is this particularly serious at Dungeness?
   c Discuss with a partner some other possible solutions. Decide on your best solution and then sketch it so that you can present it to the class.
   d When you have heard all the possible solutions from your classmates, decide on the one you consider to be the most likely to succeed. Explain why you think this would work.

Erosional landforms

Coastal landforms are created in two main ways. This is due to the fact that when waves hit the shoreline their effects can be varied. They can help to create landforms that allow plants and animals to live and thrive, or they can destroy landforms, killing plants and animals or driving them away.

The types of waves that erode and destroy sections of coast are known as **destructive waves**. Destructive waves are tall and frequent, which means they crash into the shoreline, digging out large chunks of land and eroding the beach. Their swash is weaker than their backwash, causing soil and nutrients to be drawn back into the sea rather than deposited on land.

Destructive waves begin in a large, stormy ocean. The waves travel thousands of kilometres, building up energy that is unleashed onto the rocks and sands of the coast. These waves carve the coastline into amazing shapes in much the same way that a sculptor carves shapes from a piece of marble. This process of wearing away is known as erosion, and the landforms created this way are known as erosional landforms.

A stretch of coastline close to the town of Port Campbell in southern Victoria (Source 3.10) provides a good example of erosional landforms. This part of Australia's coast is constantly being battered by waves from the Southern Ocean. As a result, the limestone cliffs in the area are being slowly chipped away, creating an ever-changing coast.

1 Cliff

Cliffs along coasts are formed by the action of waves on rock. The power of the waves erodes softer rock, leaving the more durable rock behind.

3 Gorge

Some caves can be hundreds of metres long. Waves entering long caves can wear away the roof, causing it to collapse and forming a deep gorge.

Source 3.10 A section of coastline near the town of Port Campbell in Victoria

2 Cave

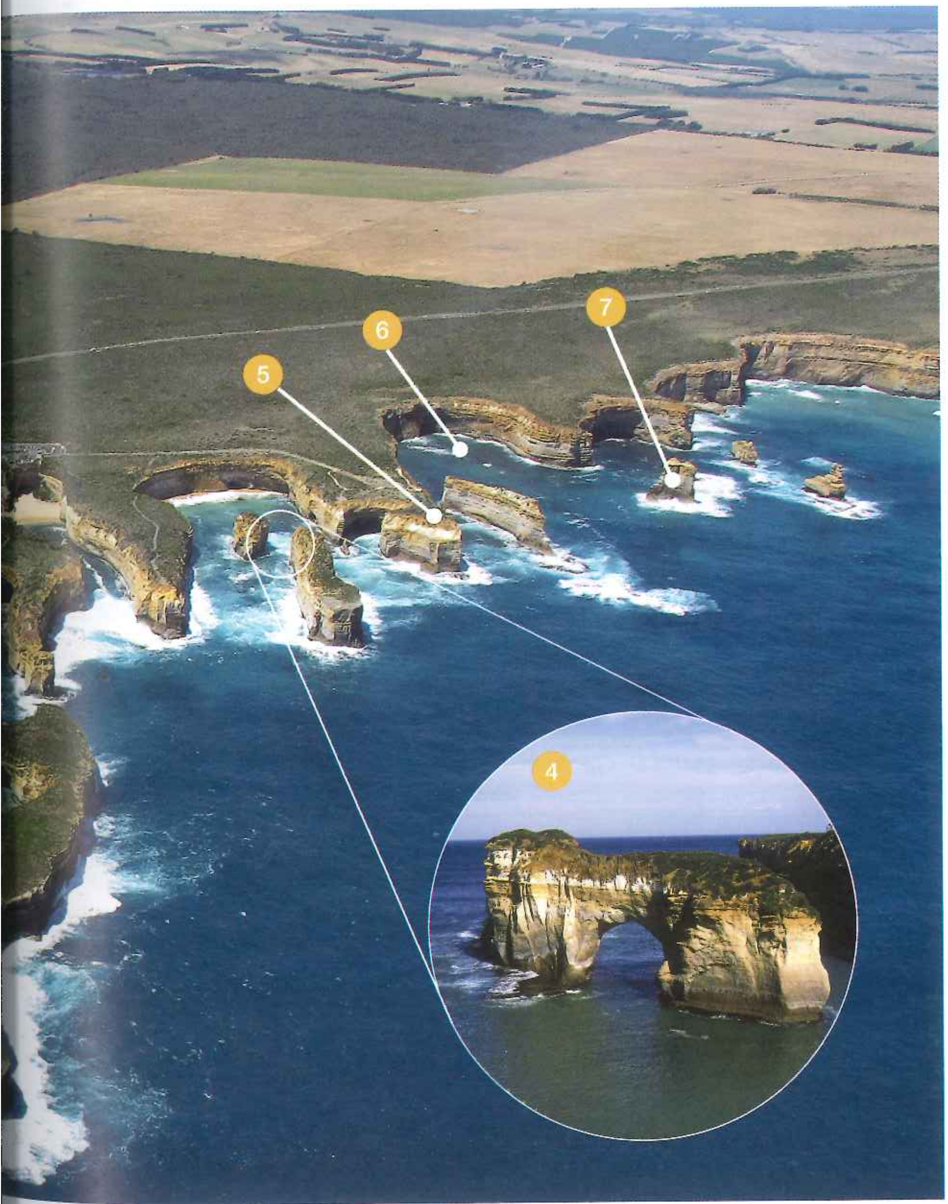
As waves approach the coast they tend to bend around headlands and islands and attack them from the side in a process known as **refraction**. When waves encounter a weak spot in the cliff (such as a section of soft limestone) they wear away the rock. They create a small opening, which is soon enlarged into a cave. The waves can now enter the cave and erode the sides and top.

4 Arch

As waves erode the back of a cave they may penetrate right through the headland and produce an arch. Waves may pass through the arch, eroding the sides and top. The arch here (inset) has recently eroded and fallen into the sea creating two stacks (main image).

5 Headland

Some sections of the coastline are made up of harder rock than other sections. These can resist the energy of the destructive waves longer than the softer parts and remain as headlands – high, rocky outcrops of land.



6 Bay

The softer parts of a coastline wear away more quickly than headlands and become bays.

7 Stack

As the soft rock of arches is eroded by the destructive waves, the rock above the arches eventually falls into the sea leaving behind stacks – vertical columns – of rock.

Check your learning 3.3

Remember and understand

1. Describe what a destructive wave is in your own words.
2. Why do some rocks erode more quickly than others?

Apply and analyse

3. Study Source 3.10.
   a. How many caves, arches and stacks can you identify?
   b. Describe the waves in this landscape. What evidence is there that they are destructive waves?

Evaluate and create

4. Predict what changes might occur in the next few thousand years in the landscape shown in Source 3.10. On a sketch or copy of the photograph, sketch and label the following features of a future landscape:
   - a collapsed stack
   - a new arch
   - a new stack
   - the shape of the new coastline
   - a new gorge.
5. This coastline is moving inland at the rate of about 2 centimetres a year. The Great Ocean Road, which you can see in the background, is about 200 metres from the coast at present.
   a. Estimate the date at which it will fall into the sea.
   b. What other features of the human environment in this region will also change by then?

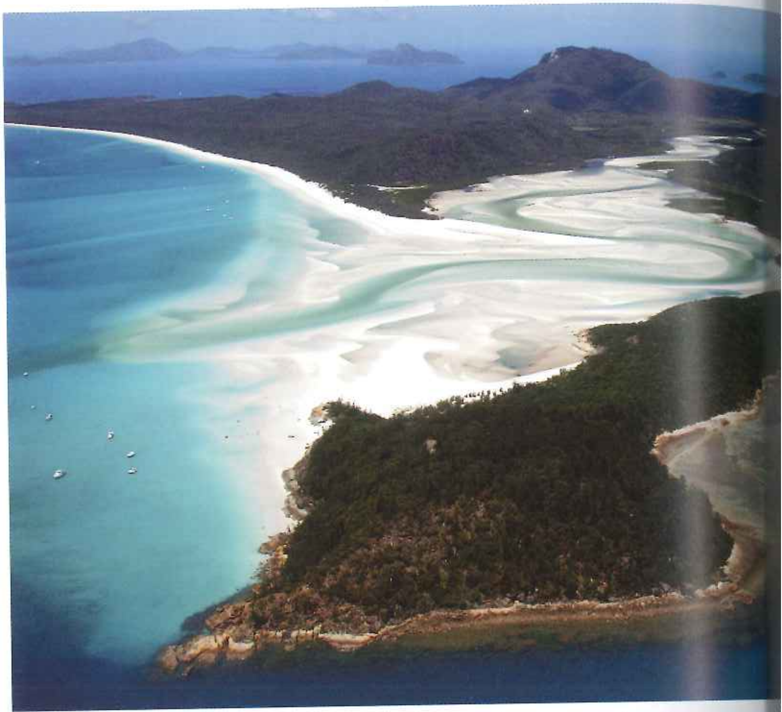
Depositional landforms

Unlike destructive waves, **constructive waves** have characteristics that help to create landforms that allow plants and animals to live and thrive. Constructive waves are long and low which means they begin far out at sea and gently roll onto the shore, allowing for a smooth and gentle landing. In this way, soil and plants are deposited onto the shore. The swash of these waves is slow and strong, which means that materials from the sea can be brought further inland. The backwash, in contrast, is very weak, which means materials are not dragged back into the sea. In this way, a wide, gently sloping beach is formed. Plants can grow and thrive, and the animals that feed on them will settle there.

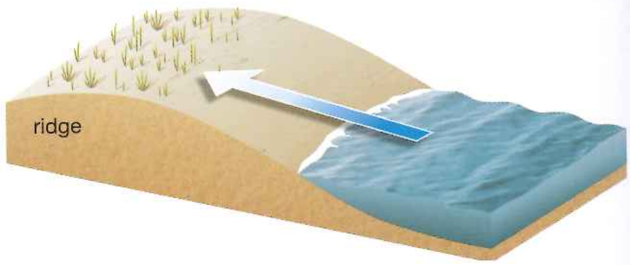
When waves are small and gentle, they do not generate enough energy to erode the land or cause great and sudden destruction. This is generally the case in bays and harbours that are sheltered from strong winds, such as Port Phillip Bay in Melbourne and Sydney Harbour. Sandy soil is moved from the base of cliffs and from the mouths of rivers by the action of the water. It is carried by constructive waves to new sites along the shore and gently deposited there. Whereas erosional landforms are the result of the removal of material from the shoreline, depositional landforms are the result of this addition of material. Constructive waves and the shapes they create are called depositional landforms.

The most common depositional landforms are beaches. A beach is formed when constructive waves carry sand, pebbles and broken coral or shells in their swash and deposit them on the shore (see Source 3.12). These small waves do not have enough energy in their backwash to take the sand back to sea, so it remains as a beach. Storms may bring destructive waves several times a year and wash away parts of the beach, but the slow, gradual process of beach building repairs this damage.

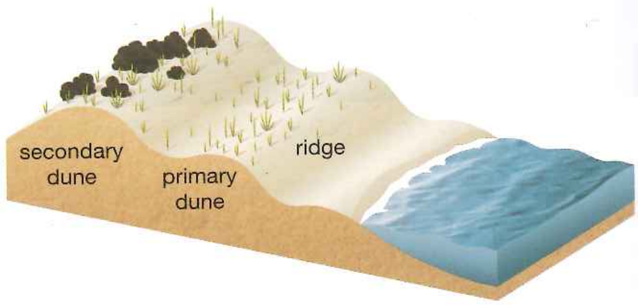
As the tide goes out, the sand dries out and the wind can then pick up individual grains and blow them inland. As the grains move, they may be trapped by an obstruction, such as plants, or they may collect in areas sheltered from the wind. As the sand piles higher it forms **sand dunes** (see Source 3.13). Plants grow on these dunes and hold them together, which allows even larger plants to take root and grow. But if the plants are removed,



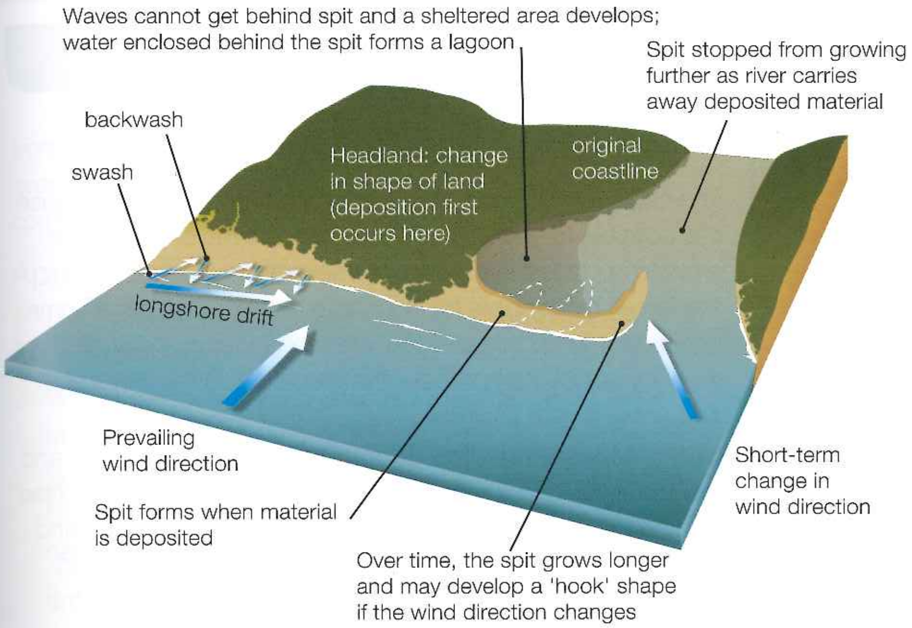
Source 3.11 Whitehaven Beach, Queensland, is an example of a depositional landform.



Source 3.12 Constructive waves carry sand onto the shore where it collects and forms a beach. Wind picks up dry sand and blows it inland.



Source 3.13 Sand is trapped by plants and collects in dunes. Over time larger plants grow over the dunes, holding them together and making them stable.



Source 3.14 How spits form

Source 3.15 A massive blowout dune inches its way across Fraser Island away from the beach.

entire dunes can gradually move further inland, covering roads, car parks, paddocks and plants. These are called **blowout dunes** (see Source 3.15).

As well as moving inland, sand moves along the coast as a result of longshore drift. As sand is deposited along coasts, other landforms can be created by the forces of water and wind.

A **spit** is a long, curved landform that is built up at the mouth of a river, which is where the river widens and ends. A river carries soil and rocks from upstream in its swiftly moving water. This material is dumped at the river mouth, forming a spit. Over time further soil and rocks collect at the river mouth, making the spit larger and more secure. This more stable environment encourages the growth of plants, which, in turn, provide habitats for animals.

Some spits grow so large that a river may be forced to change its course to reach the sea. Over thousands of years, the river mouth may move hundreds of metres along the coast and a stretch of calm water behind the spit, known as a **lagoon**, is formed. These are often home to communities of plants and wading birds, such as herons and egrets.

A **tombolo** is formed when waves curve around an island close to shore and deposit a bar of sand or other sediment on the lee side of the island (the side closest to the mainland). Eventually, enough material builds up on the leeward side that a permanent connection, or tombolo, is made between the island and the mainland (see Source 3.4).

Check your learning 3.4

Remember and understand

1 Why do constructive waves tend to add sand to a beach rather than take it away?
2 What role does the wind play in the formation of sand dunes?
3 What is a lagoon and how does it form?

Apply and analyse

4 Why are waves important to the formation of a tombolo?
5 Is the dune in the photograph of Fraser Island (Source 3.15) advancing towards the camera or away from it? How can you tell?
6 Describe three key steps in the formation of a spit.

Evaluate and create

7 Draw a sketch map of Whitehaven Beach (Source 3.11) showing the locations of sand, sea, rivers and forest. (For more information on sketch maps refer to section GT.2 of 'The geographer's toolkit'.) Remember that a map is a view from above, not on an angle as in the photograph. On your sketch map, use arrows to show the movement of sand.