3.2 Sources of energy at the coast

In this section you will learn about:

- sources of energy in coastal environments
- high-energy and low-energy coasts

St Nazaré in Portugal is renowned for its huge waves, which attracts surfers from all over the world (Figure **1**). In 2013, Garrett McNamara broke his own world record for the tallest wave ever surfed – the wave was 30 m high. So, how do waves such as this form and what are the factors that determine the energy of a wave?

Figure 1 *Garrett McNamara surfing at St Nazaré in Portugal in 2015*

The Sun and wind – the energy behind the waves

The primary source of energy for all natural systems is the Sun. Heat and light from the Sun is converted by natural processes (such as photosynthesis in plants) to form energy. At the coast the main form of energy is derived from the sea in the form of waves. Although waves can be generated by tectonic activity or underwater landslides creating tsunami, they are mostly formed by the wind.

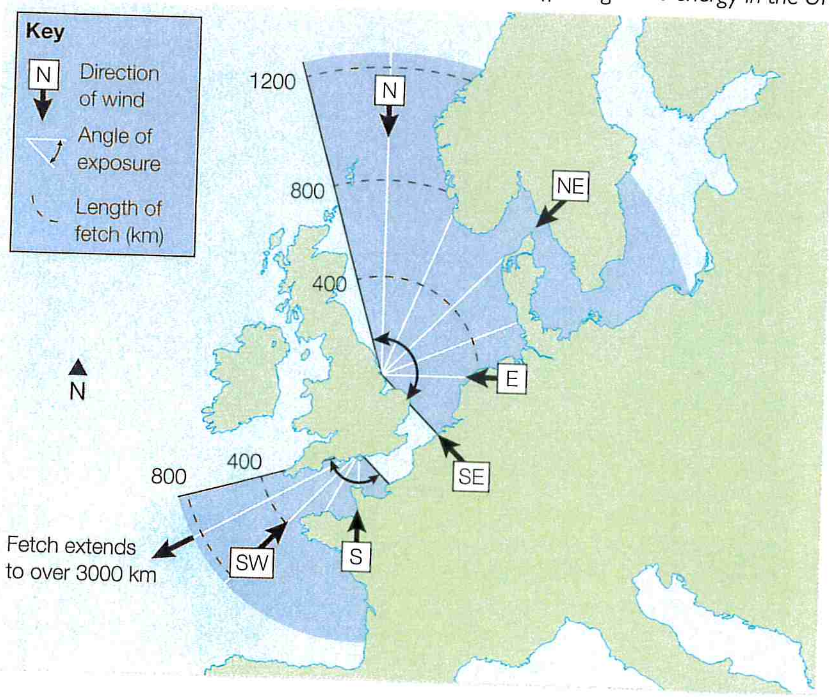
Wind is quite simply the movement of air from one place to another. In much the same way that air escapes from a punctured bicycle tyre, wind moves from high pressure to low pressure. Variations in atmospheric pressure primarily reflect differences in surface heating by the Sun. The greater the pressure difference between two places – called the pressure gradient – the faster (stronger) the wind.

In the UK, the prevailing (dominant) winds come from the south-west, the result from air moving from the subtropical high pressure belt at about 30 °N to the subpolar low pressure belt at about 60 °N. These winds blow over a broad expanse of the Atlantic Ocean and have the potential to transfer a great deal of energy to the waves that approach the UK.

A number of factors affect wave energy:

- The strength of the wind – determined by the pressure gradient.
- The duration of the wind – the longer the wind blows, the more powerful waves will become.
- The fetch – the distance of open water over which the wind blows. The longer the fetch, the more powerful the waves. As Figure **2** shows, the longest fetch in the UK extends for over 3000 miles across the Atlantic Ocean to Brazil. This coincides with the direction of the prevailing wind, accounting for the high energy waves that often affect south and west-facing coasts.

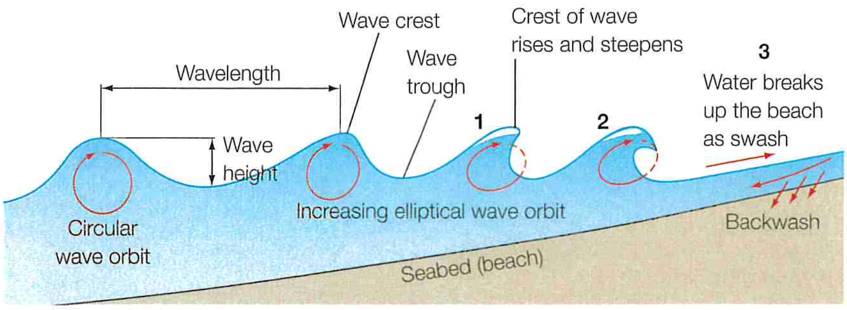
Figure 2 *Fetch affecting wave energy in the UK*



How are waves formed?

As air moves across the water, frictional drag disturbs the surface and forms ripples or waves. In the open sea, there is little horizontal movement of water. Instead, there is an orbital motion of the water particles. Close to the coast, horizontal movement of water does occur as waves are driven onshore to break on the beach (Figure **3**).

Figure 3 *Waves approaching and breaking onshore*



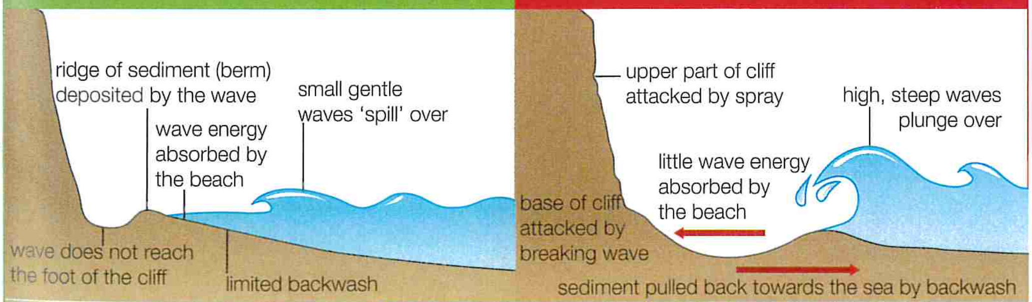
1 The water becomes shallower and the circular orbit of the water particles changes to an elliptical shape.
2 The *wavelength* (the distance between the *crests* of two waves) and the velocity both decrease, and the wave height increases – causing water to back up from behind and rise to a point where it starts to topple over (break).
3 The water rushes up the beach as *swash* and flows back as *backwash*.

Different types of wave

Although waves vary, there are two main types: **constructive** and **destructive** (see Figure **4**). These two types of wave have significant impacts on the processes and landforms occurring at the coast.

Beaches and waves: an example of a negative feedback

Constructive waves are usually associated with relatively gentle beach profiles, enabling waves to surge a long way up the beach. Over time, however, as more beach material is deposited, the profile steepens, working against the propagation of constructive waves. Instead, the waves become more destructive in their nature (plunging rather than surging), removing material from the beach and depositing it just offshore. This can result in the profile becoming less steep, encouraging constructive rather than destructive waves to form. This 'toing and froing' is a balancing act that will, all things being equal, result in a state of *dynamic equilibrium*. Of course, with wind strength and direction changing all the time and beach profiles responding accordingly, the state of balance may not exist in reality.



	Characteristic	
Distant weather systems generate these waves in the open ocean	Formation	Local storms are responsible for these waves
Low, surging waves – with a long wavelength	Wave form	High, plunging waves – with a short wavelength
Strong swash, weak backwash	Wave break	Weak swash, strong backwash
Beach gain (constructive)	Beach gain/loss	Beach loss (destructive)
Usually associated with a gentle beach profile – although, over time, they will build up the beach and make it steeper	Beach profile	Usually associated with a steeper beach profile – although, over time, they will flatten the beach

Figure 4 *Constructive and destructive waves*

Tides and currents

Tides are changes in the water level of seas and oceans caused by the gravitational pull (another source of energy) of the moon and, to a lesser extent, the Sun. The UK coastline experiences two high and two low tides each day. The relative difference in height between high and low tides is called the *tidal range*. The tidal range is also affected by the relative position of the sun and moon – highest during spring tides and lowest during neap tides (see Figure **5**). A high tidal range creates relatively powerful tidal currents (important sources of energy), as tides rise and fall, which can be particularly strong in estuaries and narrow channels. These currents are important transfer mechanisms in transporting sediment either within the coastal system or beyond (as an output).

The tides and tidal range are important factors in determining the precise height and duration of wave processes on a particular beach or a cliff. For example, at either side of high tide, often for a few hours, erosion of a cliff will be spatially concentrated, which results in the formation of a *wave-cut notch* (see 3.6). This will be exacerbated if there is a low tidal range as energy will be concentrated on a small section of cliff for a longer period of time. With a high tidal range, the waves will only break at a specific level on the cliff for a relatively short period of time.

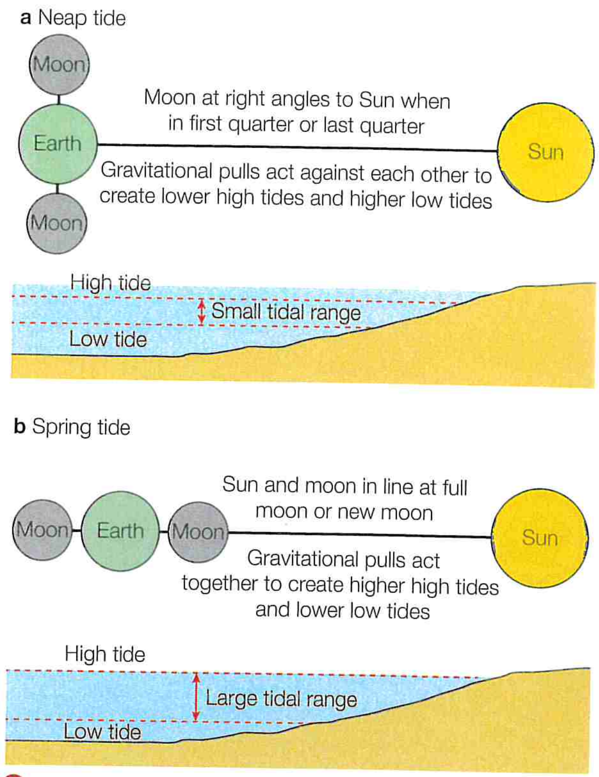
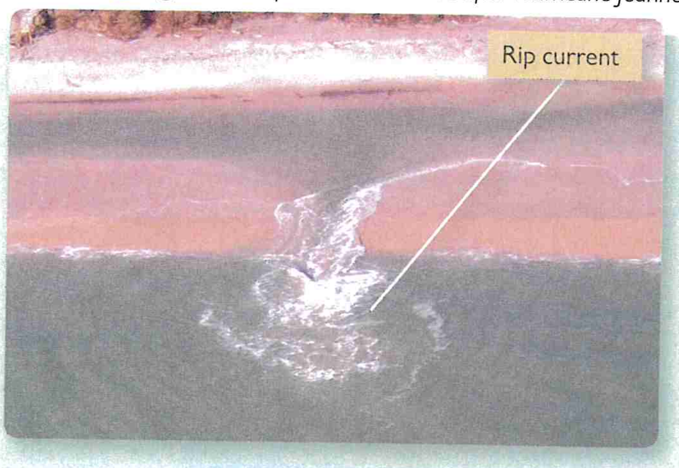


Figure 5 *Spring and neap tides*

Rip currents

You may have heard of *rip currents* – strong localised underwater currents that occur on some beaches, posing a considerable danger to swimmers and surfers (Figure **6**). Rip currents are commonly formed when a series of plunging waves cause a temporary build-up of water at the top of the beach. Met with resistance from the breaking waves, water returning down the beach (the backwash) is forced just below the surface following troughs and small undulations in the beach profile. This fast-flowing offshore surge of water can drag people into deep water where they may drown. Figure **7** shows how to respond if caught in a rip current.

Figure 6 *A rip current in Florida after Hurricane Jeanne*



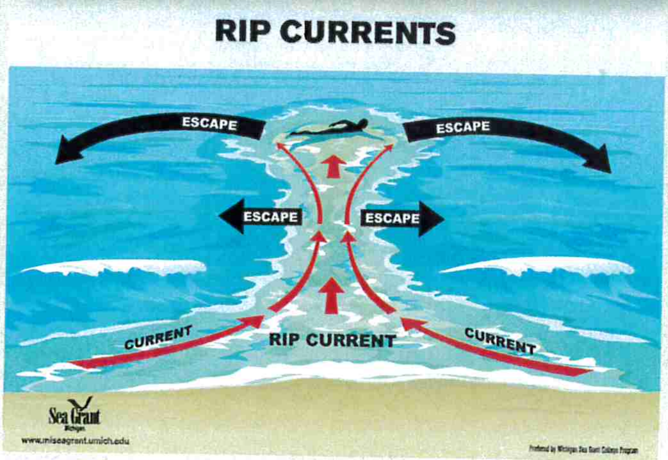


Figure 7 *How to respond to a rip current*

High-energy and low-energy coastlines

Rocky coasts are generally found in **high-energy environments**. In the UK, these tend to be:

- stretches of the Atlantic-facing coast, where the waves are powerful for much of the year (such as Cornwall or north-west Scotland)
- where the rate of erosion exceeds the rate of deposition.

Erosional landforms, such as *headlands*, *cliffs*, and *wave-cut platforms* (sometimes referred to as *abrasion* platforms, even though they are not!), tend to be found in these environments.

In contrast, sandy and estuarine coasts are generally indicative of **low-energy environments**. In the UK, these tend to be:

- stretches of the coast where the waves are less powerful, or where the coast is sheltered from large waves (such as the estuaries and bays of Lincolnshire)
- where the rate of deposition exceeds the rate of erosion.

Landforms such as *beaches*, *spits* and *coastal plains* tend to be found in these environments.

Wave refraction

At a more localised scale, high and low-energy stretches of coast may result from *wave refraction* – the distortion of wave fronts as they approach an indented shoreline (Figure **8**). Wave refraction causes energy to be concentrated at headlands and dissipated in bays. This accounts for the presence of erosive features at headlands (cliffs, stacks) and deposition features in bays (beaches).

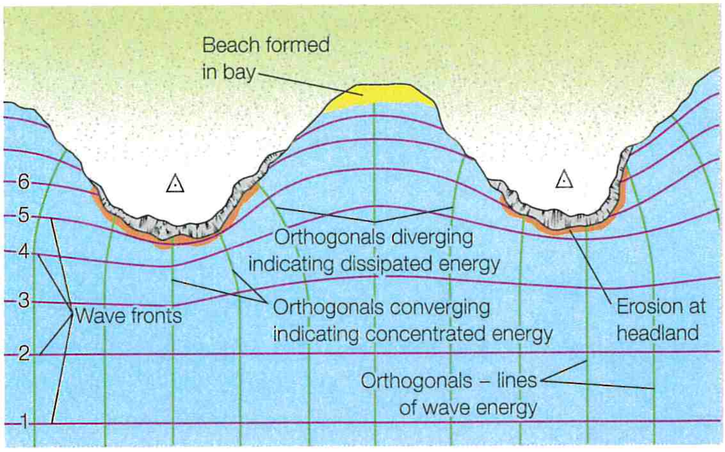


Figure 8 *Wave refraction*

The concept of negative feedback can be seen to operate here. Variations in rock strength lead to the formation of headlands and bays. This causes wave refraction which, in turn, encourages erosion of the headlands and deposition in the bays – working against the erosion of the softer rock that formed the bay originally. If conditions remained stable for a long period of time (which they don't!), a state of equilibrium would be reached, where the shape of the coastline remains static due to a balance between the potential erodibility of the rocks and the effect of wave refraction.

ACTIVITIES

1 Describe the formation of waves and identify the factors affecting the energy of waves.

2 What are the main differences between constructive and destructive waves?

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3 With the aid of a diagram, explain what happens to waves when they approach the coast.

4 Use simple diagrams to explain how wave types and subsequent beach formation can form an example of a negative feedback.

5 Evaluate the role of tides and currents in the development of coastal landforms and landscapes.

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6 With reference to Figure **2**, attempt to show potential high-energy and low-energy stretches of coastline on an outline map of the UK. Write a reasoned commentary to support your map – ensure you refer to both fetch and wind direction.

7 What is wave refraction and how does it demonstrate the concept of negative feedback?