Ocean Waves
Reading

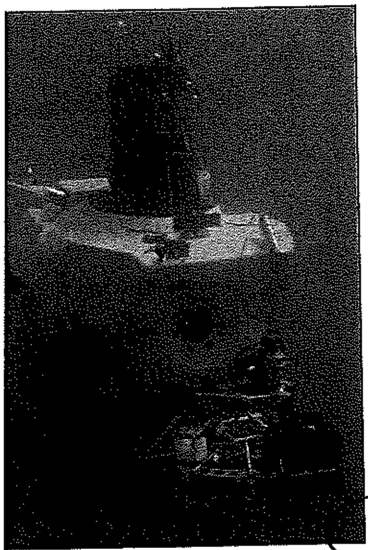


Figure 3.2.6 The DSV *Alvin* has taken 12 000 people on over 4000 dives to observe the life forms that cope with super-pressures and move in total darkness.

Hydrothermal Vents

When tectonic plates come apart deep under the sea, cold water moves down through the crust into contact with the molten lava, where it is heated and moves back up through the ocean floor. This superheated liquid—sometimes as hot as 400 °C—carries with it nutrients rich in dissolved minerals from the magma below. Together, the rising warm, mineral-rich fluids, combined with hydrothermal vent fields as a source of energy, produce bacteria that serve as food for a highly diverse food chain of organisms. At the upper end, these may include tubeworms, snails, shrimps, crabs, fish, and octopi. Since scientists confirmed their existence in the late 1970s, more than 300 new species have been discovered at hydrothermal vents. Such a system is found in the Endeavour Hydrothermal Vents, located 2250 metres deep southwest of Vancouver Island.

Ocean Waves

Like running water, ocean waves are agents of erosion, transportation, and sediment deposition. Along the shores of oceans and lakes, waves break against the land, tearing it down in some places and building it up in others.

Surface waves are movements at the water's surface. Most wave energy comes from the frictional force of wind blowing over the surface. Even when a slight breeze travelling at less than 3 kilometres per hour starts to blow across the water, small waves appear almost instantly. If the breeze dies down, the waves disappear as suddenly as they formed. If the wind is over 3 kilometres per hour, more stable waves are formed and move with the wind.

The basic parts of a wave, as well as the movement of water particles within it, are illustrated in Figure 3.2.7. The *crests* (tops) of the waves are separated by *troughs*. Wave height can be determined by measuring the vertical distance between the bottom of the trough and the crest. Similarly, wave length can be calculated by measuring the horizontal distance separating two successive crests. The *period* of the wave is found by recording the length of time it takes for two consecutive wave crests to pass a fixed point.

The height, length, and duration of a wave depend on three factors: wind speed, length of time the wind has blown, and the *fetch* (distance that the wind has travelled

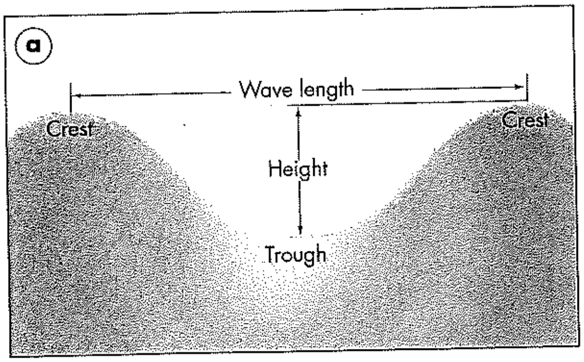
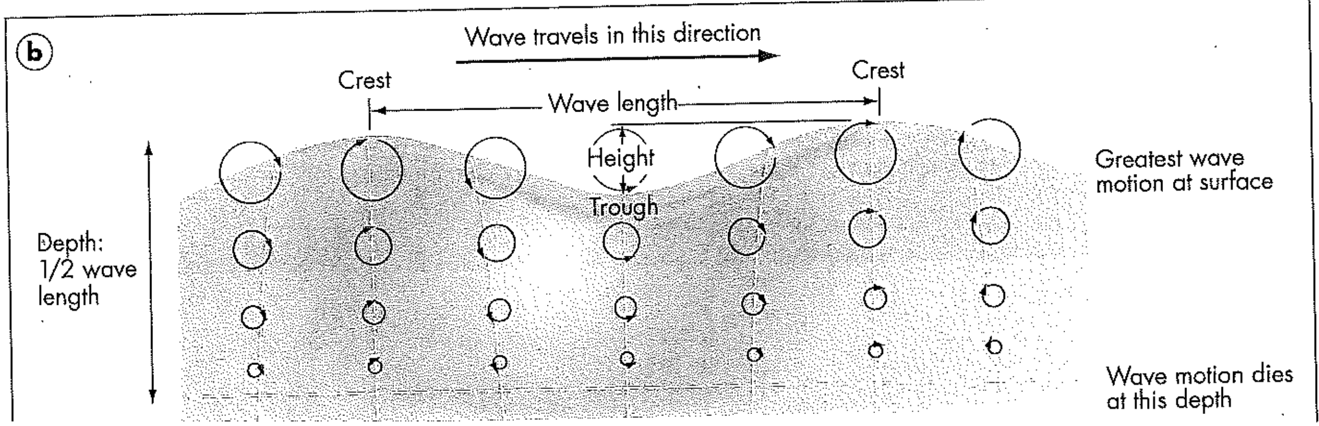


Figure 3.2.7 a) Parts of a wave and b) wave motion



across open water). As the amount of energy that is transferred by the wind to the water increases, the height and steepness of the waves also increases.

As the wind moves over the surface of the water, it transfers some of its energy to the water itself. As this energy moves through the water, it causes the water molecules to move in a circular motion, with the water particles returning almost to their original positions. In shallower water, the circular wave motion is squeezed into an elliptical orbit that flattens out as it goes deeper (Figure 3.2.8).

As wave height and steepness increase, so does the friction between the wind and water. Increased friction results in increased energy transfer. This is why, in areas where the wind is able to blow for long distances or long durations over open water, wave height and wave length can be much greater.

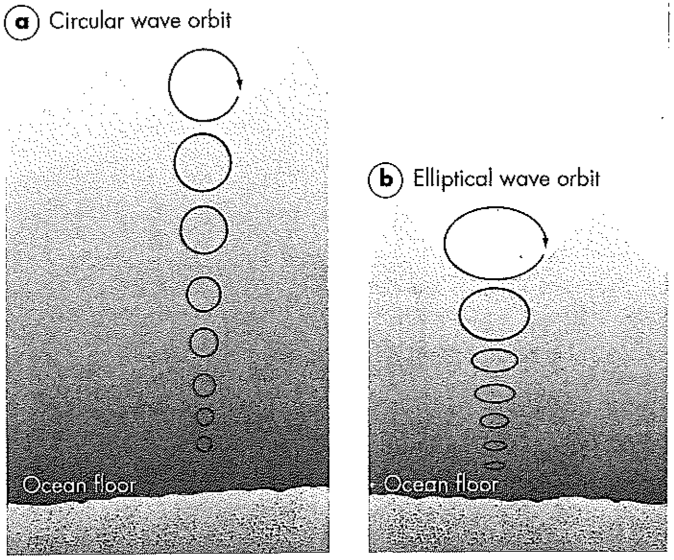


Figure 3.2.8 a) Circular and b) elliptical wave orbits. Identify three factors that determine the height, length, and period of a wave.

Breaking Waves

As long as a wave remains in deep water, it is unaffected by water depth. However, when the wave approaches the shore, the water becomes shallower and begins to influence wave behaviour. At a depth of about one-half its wave length, the wave is said to "feel bottom" (Figure 3.2.9). The water movement at the wave's base slows. As the wave continues to advance toward the shore, the water at the wave's top continues to move forward at a slightly faster rate than the rest, and the waves farther out to sea begin to catch up, decreasing the wave length. As the speed at the wave's base continues to slow, and the length of the wave diminishes, wave height begins to build until a critical point is reached: the steep wave front is no longer able to support the wave, and it breaks (collapses) and moves up the shore. *Surf* is the turbulent water created by these breaking waves. When the energy from the advancing wave has been spent, the water then flows back down the beach slope toward the ocean as *backwash.*

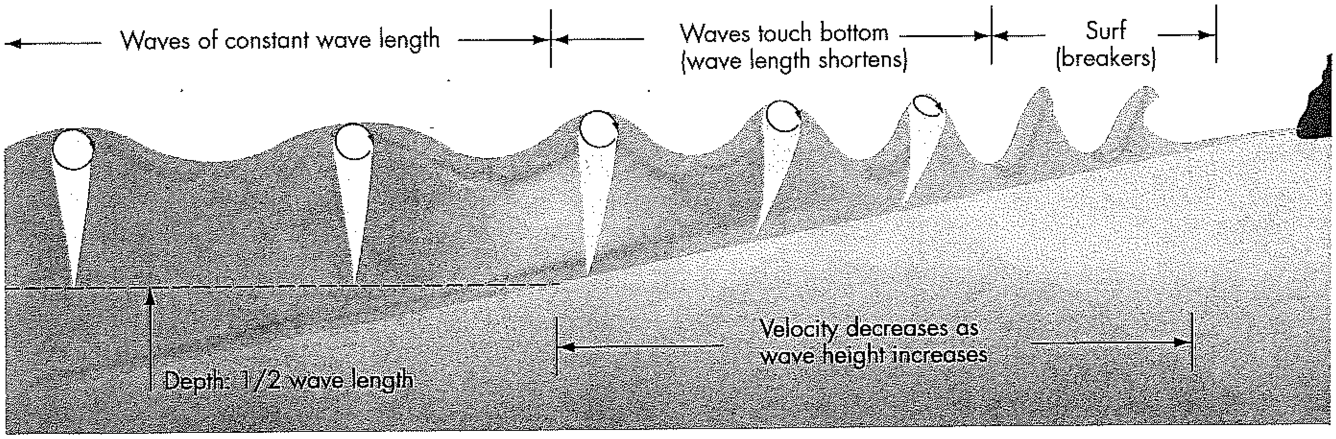
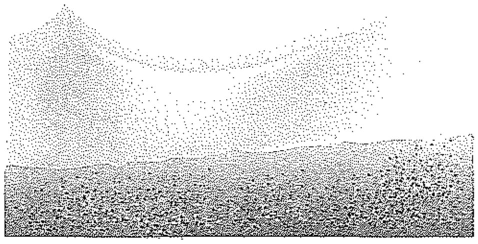
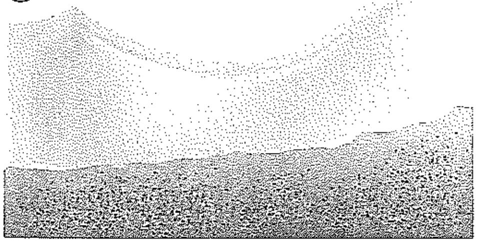


Figure 3.2.9 Dynamics of a breaking wave

ⓐ Spilling breaker



ⓑ Plunging breaker



ⓒ Surging breaker

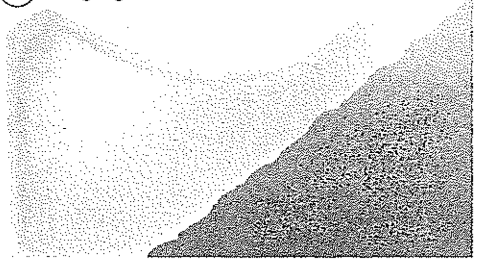


Figure 3.2.10 Three types of breaking waves: a) spilling breaker, b) plunging breaker, and c) surging breaker. Explain what happens when a wave breaks.

Scientists and surfers identify three types of breaking waves (Figure 3.2.10). *Spilling breakers*, found on gradually sloping coasts, break slowly over a long distance, with the crest spilling gently down the front of the wave. These breaking waves carry deposits such as sand and dump it onto beaches, thereby building them up. Although spilling breakers are safest for swimmers and surfers, more experienced surfers prefer the larger *plunging breakers*. These waves, found on steeper coasts, slow down more quickly, with their crests curling over their front until they plunge (crash) toward the base. Plunging breakers can loosen and transport rocks and sediments along the shore, causing erosion. The third type of breaking waves, *surging breakers*, appear on very steep coastlines, where waves build up very suddenly and break right on the beach. Such waves can knock swimmers over and pull them out into deeper water.

By the time breaking waves reach a shoreline, they may have travelled unimpeded for hundreds or even thousands of kilometres. Suddenly, they slam into a barrier—the shoreline—that will no longer allow them to advance. The resulting transfer of wave energy erodes and transports sediment along the shoreline.

Wave Refraction

An important factor in shoreline processes is *wave refraction*—the bending of waves. Wave refraction influences energy distribution along the shore and therefore plays an important role in where, and to what degree, sediment erosion, transportation, and deposition will take place.

Rarely do waves approach the shore straight on; instead, most waves move toward the shore at an angle (Figure 3.2.11). However, when these waves make contact with the bottom, they are bent until they become parallel with the shoreline, regardless of the original direction of the wave.

headland
a point of land, usually high and with a steep cliff face, extending out into a body of water

Where a **headland** projects out into the water, refraction causes the impact of the waves to be concentrated against the sides and end of the headland. In the bays and inlets, wave impact is weaker. This is because as the waves reach the shallow waters in front of the headlands sooner than they do in the bays, they are bent parallel to the head, almost wrapping around it, and strike it from all sides. Over time, this process has the effect of straightening what would otherwise be an irregular coastline.

Although waves are refracted, most still reach shore at some angle, however slight. This means that as the water breaks and washes up the beach, it does so on a diagonal

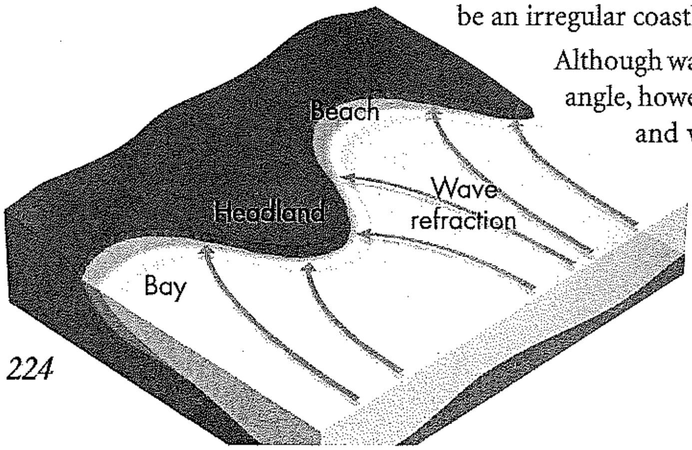


Figure 3.2.11 Wave refraction. What impact does wave refraction have on irregular coastlines?

(at an oblique angle). When gravity causes the water to withdraw back toward the ocean, the backwash goes straight back perpendicular to the shoreline rather than in the opposite direction. This pattern of water movement affects sediment transport, moving the particles in a zigzag pattern along the beach (Figure 3.2.12). This movement, called *beach drift*, has the ability to transport sand and pebbles hundreds or even thousands of metres in a single day.

Oblique waves also produce currents within the surf zone that flow parallel to the shore. This is called the *longshore current*. Because the water in this zone is turbulent, longshore currents have the ability to move fine, suspended sand and can roll larger particles along the bottom. When the volume of sediment transported by longshore currents is added to that moved by beach drift, the total amount can be quite large.

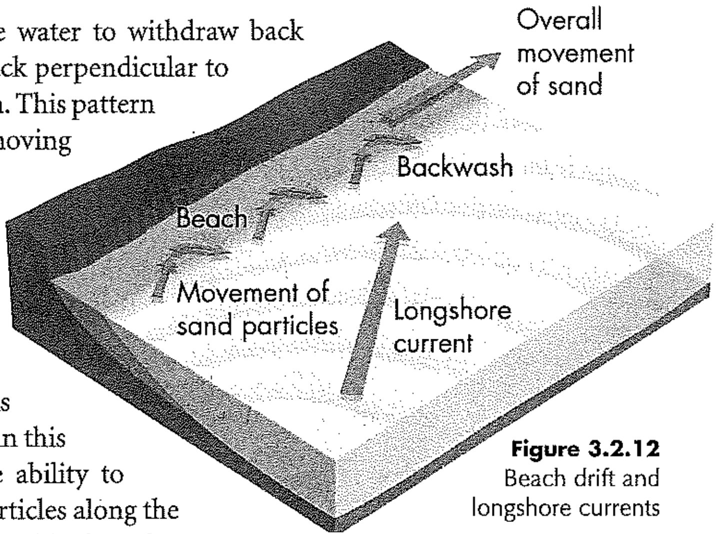
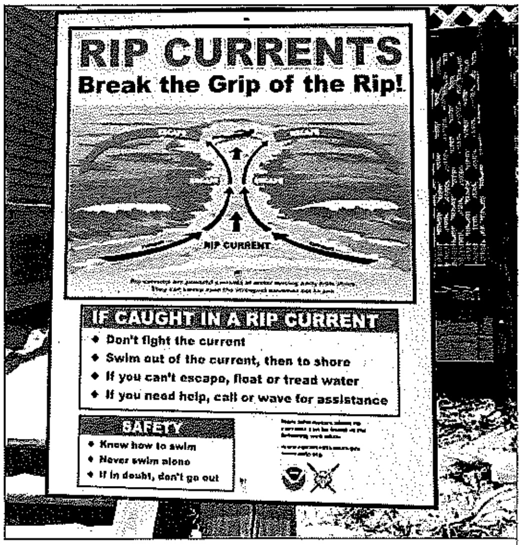


Figure 3.2.12 Beach drift and longshore currents

If backwash becomes concentrated in a particular area at a particular time—for example, through a break in a sand bar—the result can be a *rip current*. This is a narrow but powerful current running perpendicular to the shore out to the ocean. Rip currents can travel at 8 kilometres per hour or faster. Just as the water rushes out of a bathtub when you unplug the drain, in a rip current water that has accumulated rushes out to sea when it finds an opening. Rip currents can catch swimmers off guard and swiftly pull them out to sea, and accounts for 80 percent of all beach rescues. Experienced surfers, however, use rip currents as a short cut to get quickly back out to sea. Because rip currents can move sediment offshore, they also cause shoreline erosion.



RIP CURRENTS

Break the Grip of the Rip!

IF CAUGHT IN A RIP CURRENT
- Don't fight the current
- Swim out of the current, then to shore
- If you can't escape, float or tread water
- If you need help, call or wave for assistance

SAFETY
- Know how to swim
- Never swim alone
- If in doubt, don't go out

Figure 3.2.13 This sign shows the formation of a rip current. Explain how a rip current moves.

Wave Erosion

When weather is calm, wave action is minimal. However, high waves produced by storms can be destructive. The impact of such **hydraulic pressure**, the pressure exerted by water, can be such that each wave that breaks throws thousands of tonnes of water against the land. This process can transport large amounts of loose sediment, eroding the waterfront. Such *shoreline recession* is a great concern in many areas of the Great Lakes, along the St. Lawrence River, and in many coastal communities worldwide. The resulting hydraulic pressure can also open up cracks and fractures along the weak points in rocks beside the shore. Water is forced into every opening, breaking off small rock fragments and widening and lengthening pre-existing cracks.

Wave action can also cause corrosion and abrasion (Figure 3.2.14). *Corrosion* occurs when minerals are dissolved by water. For example, the rock in a limestone headland will crumble, especially where the water is slightly acidic. *Abrasion* occurs when the water picks up rock fragments and sand and grinds and scours the shoreline. This process not only weakens and wears away the shoreline; it also

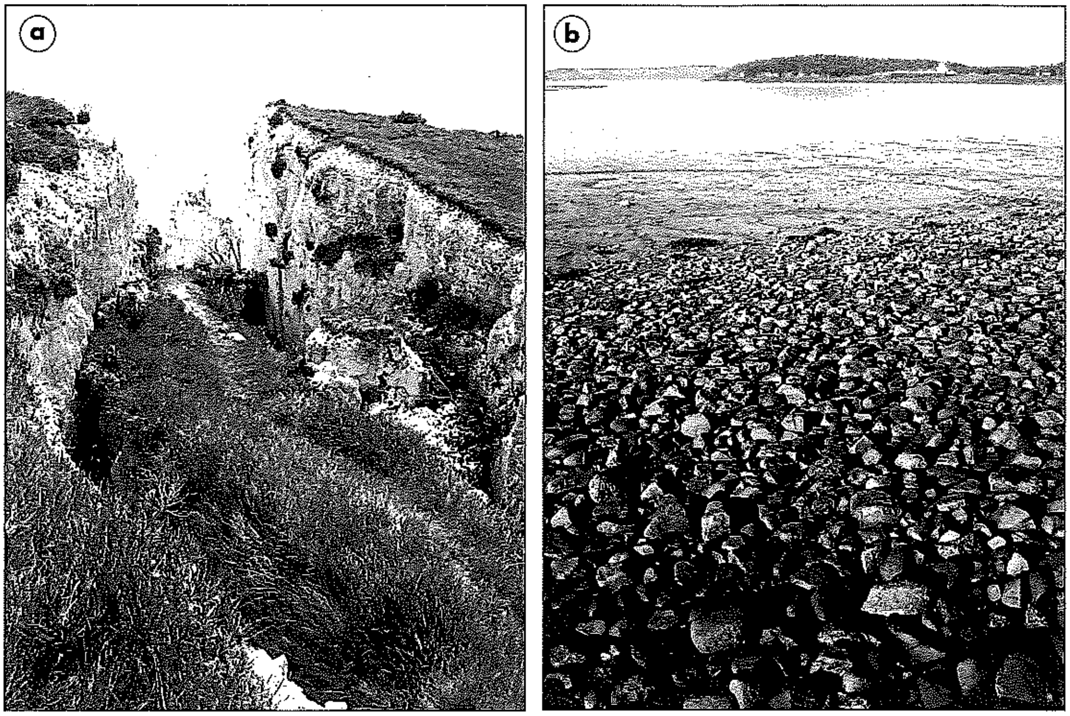


Figure 3.2.14 a) Effects of corrosion are evident in the limestone "White Cliffs of Dover" in southeastern England. b) Beach cobbles in the Bay of Fundy, Nova Scotia, show the effects of abrasion.

breaks down the abraded material, making it easier to transport. Abrasion is most intense in the surf zone. In many areas, the presence of cobbles (smooth, rounded stones and pebbles) along the shore are reminders of the grinding action of rock on rock in the surf zone.

REVIEW AND REFLECT

1. What is hydraulic pressure, and how does it contribute to shoreline erosion?
2. Account for different landscapes created as a result of corrosion and abrasion.
3. Why are beaches often called "rivers of sand"?
4. Describe how beach drift and longshore currents move sediments differently.
5. Using diagrams, describe the motion of a water particle as a wave passes.
6. If you were a novice surfer, for what kind of breaking waves should you look?

Shoreline Features

The effects of wave erosion result from the cutting action of the surf against a shore. In places where beach drift and longshore currents are active, several unique depositional features may develop. The photos that accompany the table in Figure 3.2.15 illustrate some of these processes.