Composition of Chalk

Although you may not live anywhere near a coast, parts of your environment were shaped by the ocean. For example, you may be just a few meters away from former seafloor deposits that are now part of the bedrock underground. One such seafloor deposit is chalk. How can you tell that chalk formed on the seafloor?

1. Grind up a small piece of natural chalk into a powder. Make a slide of the powdered chalk.

2. Observe the chalk powder through a microscope. Describe the powder. Are the grains irregular in shape or size? Do some of the grains have patterns?

3. Analyze the powder and hypothesize the origin of the chalk.

**CAUTION:**
Always wear safety goggles and an apron in the lab. Use caution to prevent chalk dust from becoming airborne.

**Observe** In your science journal, describe the composition of the powdered chalk. What is the origin of the chalk? On what evidence do you base your conclusion?

Shoreline Features

Some of the most interesting places on our planet are the seashores, the places where the land meets the sea. They are places of continuous, often dramatic geologic activity, places where you can see geological changes occurring almost daily. Shorelines are shaped by the action of waves, tides, and currents. As waves erode some coastlines, they create some of the most impressive rock formations on Earth. In other areas, waves deposit loose material and build wide, sandy beaches. To understand how waves act in different areas of the coast, let's reexamine the behavior of breakers.

**EROSIONAL LANDFORMS**
You learned in Chapter 15 that waves increase in height and become breakers as they approach a shoreline. Large breakers can hurl thousands of metric tons of water, together with suspended rock fragments, against the shore with such destructive force that they are capable of eroding even solid rock. This destructive action of breakers is most evident at rocky headlands, which are points of land sticking out into the ocean.
Figure 16-1 Wave crests advance toward the shoreline and slow down when they encounter shallow water. This causes the wave crests to bend toward the headlands and move in the direction of the arrows. Wave rays, drawn perpendicular to the wave crests, show the direction of wave travel and bending of wave crests.

Waves move faster in deep water than in shallow water. This difference in wave speed causes initially straight wave crests to bend where part of the crest moves into shallow water, a process known as wave refraction, illustrated in Figure 16-1. Along an irregular coast with headlands and bays, the wave crests bend towards the headlands. As a result, most of the breaker energy is concentrated along the relatively short section of the shore around the tips of the headlands, while the remaining wave energy is spread out along the much longer shoreline of the bays. The headlands thus undergo severe erosion. The material eroded from the headlands is swept into the bays, where it is deposited in the form of crescent-shaped beaches. Can you guess what the long-term effect of this process is? The headlands are worn back and the bays are filled in until the shoreline straightens. Given enough time, irregular shorelines are straightened by wave action.

Landforms of Rocky Headlands Many headlands have spectacular rock formations. Generally, as a headland is gradually worn away, a flat erosional surface called a wave-cut platform is formed. The wave-cut platform terminates against a steep wave-cut cliff, as illustrated in Figure 16-2. Differential erosion, the removal of weaker rocks or rocks near sea level, produces many of the other characteristic landforms of rocky headlands. As shown in Figure 16-3, sea stacks are isolated rock towers or similar erosional remnants left on wave-cut platforms, and sea arches are formed when stronger rocks are undercut by wave erosion. Sea caves are tubelike passageways.
blasted into the headland at sea level by the never-ending assault of the breakers.

**Beaches**

Have you ever visited any of the beaches along the coastline of the United States? Long stretches of our coastlines are lined with wide, sandy beaches. A beach is a sloping band of sand, pebbles, gravel, or mud at the edge of the sea. Beaches are composed of loose sediments deposited and moved about by waves along the shoreline. The size of sediment particles depends on the energy of the waves striking the coast and on the source of the sediment. Beaches pounded by large waves or formed on rocky coasts usually consist of coarse materials such as pebbles and cobbles.

The composition of beach material also depends upon the source of the material. Some Hawaiian beaches consist of black sand, tiny grains of minerals derived from the volcanic rocks that make up most of the Hawaiian Islands. The white and pink sand that form the beaches of southern Florida and the Bahamas has the consistency of cornmeal; these beaches are composed mostly of small fragments of local corals and seashells. Beaches near the mouths of large rivers are composed of the sandy sediments that are washed in by river water and made up of small grains of quartz and feldspar.

**Estuaries**

If you look at the map of the eastern coast of the United States shown in Figure 16-4, you will see rivers and streams entering the ocean. The area where the lower end of a freshwater river or stream enters the ocean is an estuary.
**Figure 16-5** The sloping beach face is shaped by daily wave action, while the dunes behind the beach are affected only by large storm waves. Coastal dunes form from beach sand blown inland. The submerged longshore bar is located in the surf zone.

The water in estuaries is brackish, a mixture of freshwater and salt water. Estuaries are nurseries to the young of many different species, including ocean fishes. **Figure 16-4** reveals many large estuaries, such as Chesapeake Bay and Pamlico Sound.

**LONGSHORE CURRENTS**

Suppose you stood on a beach at the edge of the water and began to walk out into the ocean. As you walked, the water would get deeper for a while, but then it would become shallow again. The shallow water offshore lies above a sand bar, called the **longshore bar**, that forms in front of most beaches, as illustrated in **Figure 16-5**. Waves break on the longshore bar in the area known as the surf zone. The deeper water closer to shore than the longshore bar is called the longshore trough. The waves striking the beach are almost parallel to the shoreline, although the waves seaward of the longshore bar are generally not parallel to the shore. This is another case of wave refraction. The slowing of the waves in shallow water causes the wave crests to bend towards the shore. As water from incoming breakers spills over the longshore bar, a current flowing parallel to the shore, called the **longshore current**, is produced. This current varies in strength and direction from day to day. Over the course of a year, because of prevailing winds and wave patterns, one direction usually dominates.

**Movement of Sediments** Longshore currents move large amounts of sediments along the shore. Fine-grained material such as sand is suspended in the turbulent, moving water, and larger particles are pushed along the bottom by the current. Additional sediment is moved back and forth on the beach face by incoming and retreating waves. Incoming waves also move sediment at an angle to the shoreline in the direction of wave motion. Overall, the transport of sediment is in the direction of the longshore current. On both the Atlantic and Pacific Coasts of the United States, longshore transport is generally to the south.
**Figure 16-6** Longshore currents (A) are driven by incoming waves. Rip currents (B) return water through gaps in the longshore bar out to sea. Rip currents spread out and weaken beyond the longshore bar.

**Rip Currents** Wave action also produces rip currents, which flow out to sea through gaps in the longshore bar. Rip currents return the water spilled into the longshore trough to the open ocean. These dangerous currents can reach speeds of several kilometers per hour. If you are ever caught in a rip current, you should not try to swim against it, but rather swim parallel to the shore to get out of it. **Figure 16-6** illustrates both longshore and rip currents.

**Depositional Features of Seashores**
As a result of wave erosion, longshore transport, and sediment deposition, most seashores are in a constant state of change. Sediments are eroded by large storm waves and deposited wherever waves and currents slow down. Sediments moved and deposited by longshore currents build various characteristic coastal landforms, such as spits and barrier islands, illustrated in **Figure 16-7**. A narrow bank of sand that projects into the water from a bend in the coastline is called a spit. A spit, which forms where a shoreline changes direction, is protected from wave action. When a growing spit crosses a bay, a baymouth bar forms.

**Figure 16-7** Depositional features of coastlines include spits, baymouth bars, lagoons, and barrier islands.
Barrier islands are long ridges of sand or other sediment, deposited or shaped by the longshore current, that are separated from the mainland. Barrier islands can be several kilometers wide and tens of kilometers long. Most of the Gulf Coast and the eastern coast south of New England are lined with an almost continuous chain of barrier islands. The shallow, protected bodies of water behind baymouth bars and barrier islands are called lagoons, which essentially are saltwater coastal lakes that are connected to the open sea by shallow, restricted outlets. Another, somewhat peculiar coastal landform is a tombolo, a ridge of sand that forms between the mainland and an island and connects the island to the mainland. When this happens, the island is no longer an island, but the tip of a peninsula.

All of these depositional coastal landforms, including large barrier islands, are unstable and temporary. Occasionally, major storms sweep away entire sections of barrier islands and redeposit the material elsewhere. Even in the absence of storms, however, changing wave conditions can slowly erode beaches and rearrange entire shorelines. For example, the shoreline of Cape Cod, Massachusetts, is retreating by as much as 1 m per year. Figure 16-8 shows some results of retreating shorelines.

You may wonder how longshore transport can build coastal features that rise well above sea level. Several factors play a role in this. At high tide, a longshore current can deposit sediment on a beach so that it extends in the direction of the longshore current. In addition, storm waves can pile up submerged sediments to heights well above the level of the highest tides. Wherever sediments are exposed at low tide, winds pick up dry sand and build sand dunes.
**PROTECTIVE STRUCTURES**

In many coastal areas, protective structures such as seawalls, groins, jetties, and breakwaters are built in an attempt to prevent beach erosion and destruction of oceanfront properties. *Figure 16-9* illustrates the effects of building structures in areas of longshore transport. These artificial structures interfere with natural shoreline processes and can have unexpected negative effects. For example, seawalls built along the shore to protect beachfront properties from powerful storm waves reflect the energy of such waves back towards the beach, where they worsen beach erosion. Eventually, seawalls are undercut and have to be rebuilt larger and stronger than before. Groins are wall-like structures built into the water perpendicular to the shoreline for the purpose of trapping beach sand. Groins interrupt natural longshore transport and deprive beaches down the coast of sand. The result is aggravated beach erosion down the coast from groins. Similar effects are caused by jetties, which are walls of concrete built to protect a harbor entrance from drifting sand. Jetties trap sand upshore from a harbor and prevent sand from reaching the beaches downshore. Eventually, sand drifts around the jetty and closes the harbor entrance anyway, unless it is removed periodically by dredging. Breakwaters are built in the water parallel to straight shorelines to provide anchorages for small boats.

Breakwaters affect the longshore current in much the same way as offshore islands do. The current slows down behind the breakwater and is no longer able to move its load of sediment, which is then deposited behind the breakwater. If the accumulating sediment is left alone, it will eventually fill the anchorage. To prevent this, all such anchorages have to be dredged regularly at great expense. In general, protective structures cause an overall loss of the sediments that maintain beaches.

*Figure 16-9* The entrance to Channel Island Harbor in Oxnard, California, is protected by jetties and a breakwater (A). Jetties deprive downshore beaches of sand (B). Breakwaters cause beach sand to accumulate and eventually close the anchorage (C).
Changes in Sea Level

At the height of the last ice age, approximately 10,000 years ago, the global sea level was about 130 m lower than it is at present. Since that time, the melting of most of the ice-age glaciers has raised the ocean to its present level. In the last 100 years, the global sea level has risen 10 to 15 cm. It continues to rise slowly; estimates suggest a rise in sea level of 1.5 to 3.9 mm/year. Many scientists contend that this continuing rise in sea level is the result of global warming. Over the last century, Earth's average surface temperature has increased by approximately 0.5°C. As Earth's surface temperature rises, seawater warms up and as it warms, it also expands, which adds to the total volume of the seas. In addition, higher temperatures on Earth's surface cause glaciers to melt, and the meltwater flowing into the oceans increases their volume. Scientists predict that global sea levels could rise another 30 cm in the next 70 years.

Effects of Sea Level Changes

If Earth's remaining polar ice sheets, in Greenland and Antarctica, melted completely, their meltwaters would raise sea level by another 70 m. This rise would totally flood some countries, such as the Netherlands, along with some coastal cities in the United States, such as New York City, and low-lying states such as Florida and Louisiana. Fortunately, this isn't likely to happen anytime soon. However, if Earth's surface temperature continues to rise, an unstable part of the Antarctic ice sheet eventually could melt and cause a rise in sea level of about 6 m. Many of the barrier islands of the Atlantic and Gulf Coasts may be former coastal dunes that were drowned by rising sea levels. Other features produced by rising sea levels are the fjords of Norway, shown in Figure 16-10. Fjords are deep coastal valleys that were scooped out by glaciers during the ice age and later flooded when these glaciers melted.

Figure 16-10 Fjords are flooded U-shaped valleys carved by glaciers. Fjords may be up to 1200 m deep.
Effects of Tectonic Forces  Other processes that affect local sea levels are tectonic uplift and sinking. If a coastline sinks, there is a relative rise in sea level along that coast. A rising coastline, on the other hand, produces a relative drop in sea level. As a result of tectonic forces in the western United States, much of the West Coast is being pushed up much more quickly than the sea level is rising. Because much of the West Coast was formerly under water, it is called an emergent coast. Emergent coasts tend to be relatively straight because the exposed seafloor topography is much smoother than typical land surfaces with hills and valleys. Other signs of an emergent coast are former shoreline features such as sandy beach ridges located far inland. Among the most interesting of these features are elevated marine terraces, former wave-cut platforms that are now high and dry, well above current sea level. Figure 16-11 shows striking examples of such platforms. Some old wave-cut platforms in southern California are hundreds of meters above current sea level. You will identify an emergent coast in the Mapping GeoLab at the end of this chapter.

SECTION ASSESSMENT

1. Irregular shorelines have headlands and bays. Which of these experiences the most severe erosion by breakers? Why?
2. What are sea stacks, and how are they formed?
3. What effect does a seawall have on a beach?
4. If a coast has elevated marine terraces, is it rising or sinking? Explain.
5. Thinking Critically Resort communities such as Ocean City, Maryland, are built on barrier islands. These communities spend thousands of dollars each year to add sand to the beaches along the shoreline. Explain why this is necessary.

SKILL REVIEW

6. Predicting Are rip currents most dangerous on calm days, on stormy days with winds blowing from the land, or on stormy days with winds blowing from the ocean? Explain. For more help, refer to the Skill Handbook.