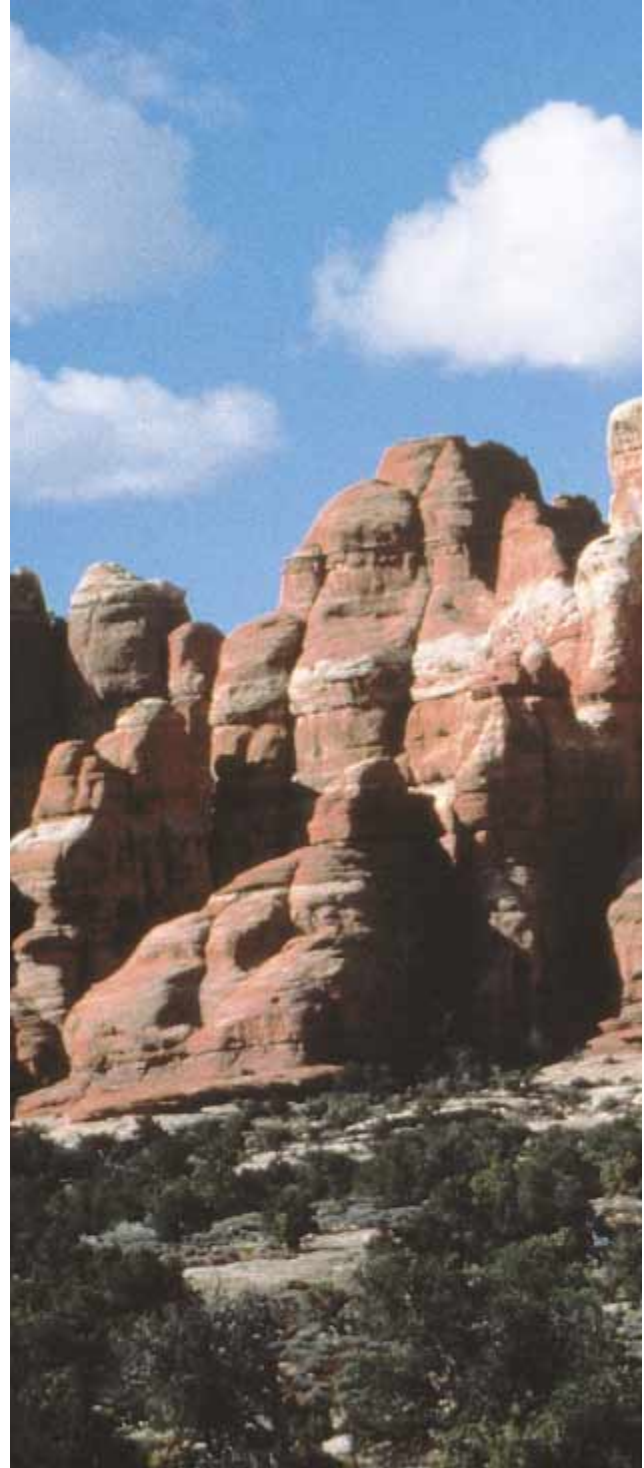


Sedimentary Rocks

Weathering decomposes bedrock. Flowing water, wind, gravity, and glaciers then erode the decomposed rock, transport it downslope, and finally deposit it on the sea coast or in lakes and river valleys. Finally, the loose sediment is cemented to form hard sedimentary rock.

Sedimentary rocks make up only about 5 percent of the Earth's crust. However, because they form on the Earth's surface, they are widely spread in a thin veneer over underlying igneous and metamorphic rocks. As a result, sedimentary rocks cover about 75 percent of continents.

Many sedimentary rocks have high economic value. Oil and gas form in certain sedimentary rocks. Coal, a major energy resource, is a sedimentary rock. Limestone is an important building material, both as stone and as the primary ingredient in cement. Gypsum is the raw material for plaster. Ores of copper, lead, zinc, iron, gold, and silver concentrate in certain types of sedimentary rocks.



Horizontally layered sandstone in eastern Utah has been eroded to produce spectacular towers.



7.1 TYPES OF SEDIMENTARY ROCKS

Sedimentary rocks are broadly divided into four categories:

1. *Clastic sedimentary rocks* are composed of fragments of weathered rocks, called **clasts**, that have been transported, deposited, and cemented together. Clastic rocks make up more than 85 percent of all sedimentary rocks (Fig. 7–1). This category includes sandstone, siltstone, and shale.
2. *Organic sedimentary rocks* consist of the remains of plants or animals. Coal is an organic sedimentary rock made up of decomposed and compacted plant remains.
3. *Chemical sedimentary rocks* form by direct precipitation of minerals from solution. Rock salt, for example, forms when salt precipitates from evaporating seawater or saline lake water.
4. *Bioclastic sedimentary rocks*. Most limestone is composed of broken shell fragments. The fragments are clastic, but they form from organic material. As a result, limestone formed in this way is called a **bioclastic** rock.

7.2 CLASTIC SEDIMENTARY ROCKS

Clastic sediment consists of grains and particles that were eroded from weathered rocks and then were transported and deposited in loose, unconsolidated layers at the Earth's surface. The sand on a beach, boulders in a river bed, and mud in a puddle are all clastic sediments.

Clastic sediment is named according to particle size (Table 7–1). **Gravel** includes all rounded particles larger than 2 millimeters in diameter. Angular particles in the

Table 7–1 • SIZES AND NAMES OF SEDIMENTARY PARTICLES AND CLASTIC ROCKS

DIAMETER (mm)	SEDIMENT		CLASTIC SEDIMENTARY ROCK
256– 64	Boulders Cobbles Pebbles	Gravel (rubble)	Conglomerate (rounded particles) or breccia (angular particles)
2– 1/16	Sand		Sandstone
1/16– 1/256	Silt Clay	Mud	Siltstone Claystone or shale } Mudstone

same size range are called **rubble**. **Sand** ranges from 1/16 to 2 millimeters in diameter. Sand feels gritty when rubbed between your fingers, and you can see the grains with your naked eye. **Silt** varies from 1/256 to 1/16 millimeter. Individual silt grains feel smooth when rubbed between the fingers but gritty when rubbed between your teeth. **Clay** is less than 1/256 millimeter in diameter. It is so fine that it feels smooth even when rubbed between your teeth. Geologists often rub a small amount of sediment or rock between their front teeth to distinguish between silt and clay. **Mud** is wet silt and clay.

TRANSPORT OF CLASTIC SEDIMENT

After weathering creates clastic sediment, flowing water, wind, glaciers, and gravity erode it and carry it down-slope. Streams carry the greatest proportion of clastic

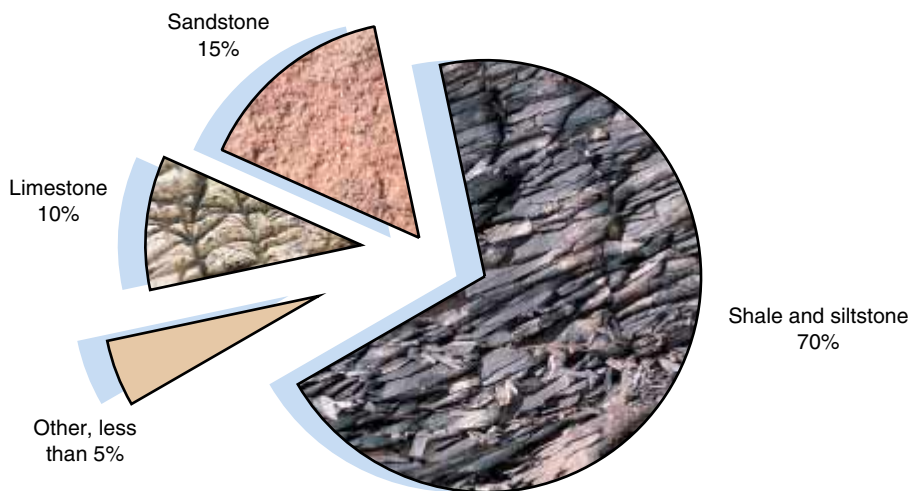


Figure 7–1 Relative abundances of sedimentary rock types.

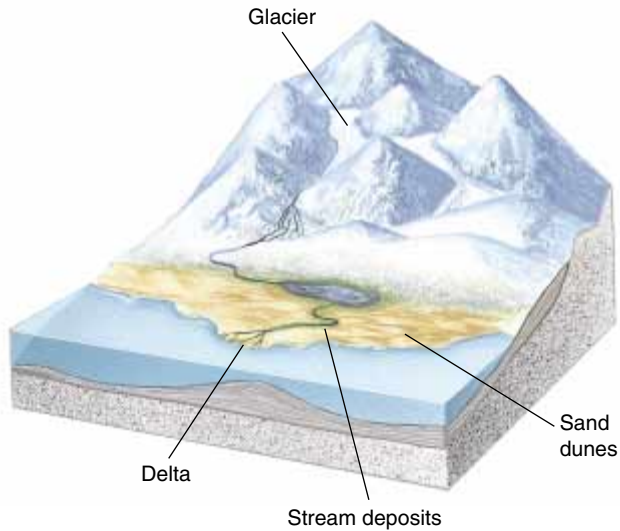


Figure 7-2 Sediment and dissolved ions are transported by water, gravity, wind, and glaciers. They may be deposited temporarily in many different environments along the way, but eventually most sediment reaches the ocean.

sediment. Because most streams empty into the oceans, most sediment accumulates near continental coastlines (Fig. 7-2). However, some streams deposit their sediment in lakes or in inland basins.

Streams and wind modify sediment as they carry it downslope. The **rounded** cobbles shown in Figure 7-3 originally formed as angular rubble in the Bitterroot Range of western Montana. The rubble became rounded as the stream carried it only a few kilometers. Water and wind round clastic particles as fine as silt by tumbling them against each other during transport. Finer particles do not round as effectively because they are so small and light that water and even wind, to some extent, cushion them as they bounce along, minimizing abrasion. Glaciers do not round clastic particles because the ice prevents the particles from abrading each other.

Weathering breaks bedrock into particles of all sizes, ranging from clay to boulders. Yet most clastic sediment and sedimentary rocks are well **sorted**—that is, the grains are of uniform size. Some sandstone formations extend for hundreds of square kilometers and are more than a kilometer thick, but they consist completely of uniformly sized sand grains.

Sorting depends on three factors: the viscosity and velocity of the transporting medium and the durability of the particles. **Viscosity** is resistance to flow; ice has high viscosity, air has low viscosity, and water is intermediate. Ice does not sort effectively because it transports particles of all sizes, from house-sized boulders to clay.

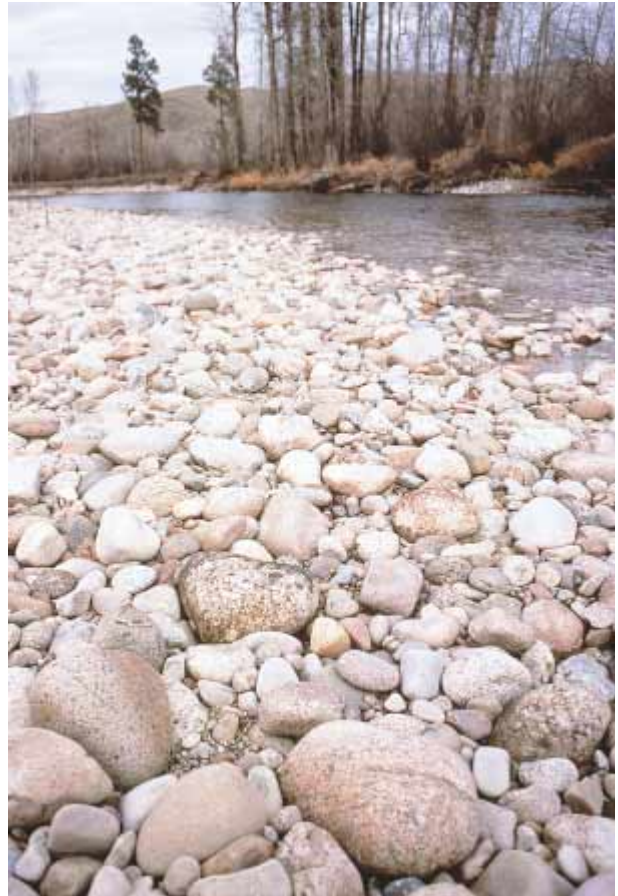


Figure 7-3 Rounded cobbles in the West Fork of the Bitterroot River just below Trapper Peak.

In contrast, wind transports only sand, silt, and clay and leaves the larger particles behind. Thus, wind sorts particles according to size.

A stream transports only small particles when it flows slowly, but larger particles when it picks up speed. For example, a stream transports large and small particles when it is flooding, but only small particles during normal flows. As a flood recedes and the water gradually slows down, the stream deposits the largest particles first and the smallest ones last, creating layers of different-sized particles.

Finally, durability of the particles affects sorting. Sediment becomes abraded as it travels downstream. Thus a stream may transport cobbles from the mountains toward a delta, but the cobbles may never complete the journey because they wear down to smaller grains along the way. This is one reason why mountain streams are frequently boulder choked but deltas are composed of mud and sand.

NAMING SEDIMENTARY ROCK UNITS

A body of rock is commonly given a formal name and referred to as a **formation**. A formation can consist of a single rock type or several different rock types. To qualify as a formation, a body of rock should be easily recognizable in the field and be thick and laterally extensive enough to show up well on a geologic map. Although sedimentary rocks are most commonly designated as formations, bodies of igneous and metamorphic rock that meet these qualifications also are named and are called formations.

Formations are often named for the geographic locality where they are well exposed and were first defined. Names also include the dominant rock type—for example, the Navajo Sandstone, the Mission Canyon Limestone, and the Chattanooga Shale. If the formation contains more than one abundant rock type, the word *formation* is used in the name instead of a rock type, as in the Green River Formation.

A **contact** is the surface between two rocks of different types or ages. Contacts separate formations and separate different rock types or layers within a single formation. In sedimentary rocks, contacts are usually bedding planes.

For convenience, geologists sometimes lump two or more formations together into a **group** or subdivide a formation into **members**. For example, the Madison Group in central Montana consists of three formations deposited about 350 million years ago: the Paine Limestone, the Woodhurst Limestone, and the Mission Canyon Limestone.

DISCUSSION QUESTION

Discuss how you would recognize a contact in the field. Are contacts always horizontal? If not, discuss how a vertical or tilted contact may have formed.

LITHIFICATION

Lithification refers to processes that convert loose sediment to hard rock. Two of the most important processes are **compaction** and **cementation**.

If you fill a container with sand, the sand grains do not fill the entire space. Small voids, called **pores**, exist between the grains (Fig. 7-4a). When sediment is deposited in water, the pores are usually filled with water. The proportion of space occupied by pores depends on particle size, shape, and sorting. Commonly, freshly deposited clastic sediment has about 20 to 40 percent pore space, although a well-sorted and well-rounded sand may have up to 50 percent pore space. Clay-rich mud may have as much as 90 percent pore space occupied by water.

As more sediment accumulates, its weight compacts the buried sediment, decreasing pore space and forcing out some of the water (Fig. 7-4b). This process is called **compaction**. Compaction alone may lithify clay because the platy grains interlock like pieces of a puzzle.

Water normally circulates through the pore space in buried and compacted sediment. This water commonly contains dissolved calcium carbonate, silica, and iron, which precipitate in the pore spaces and **cement** the clastic grains together to form a hard rock (Fig. 7-4c). The red sandstone in Figure 7-5 gets its color from red iron oxide cement.

In some environments, sediment lithifies quickly, whereas the process is slow in others. In the Rocky Mountains, calcite has cemented glacial deposits less

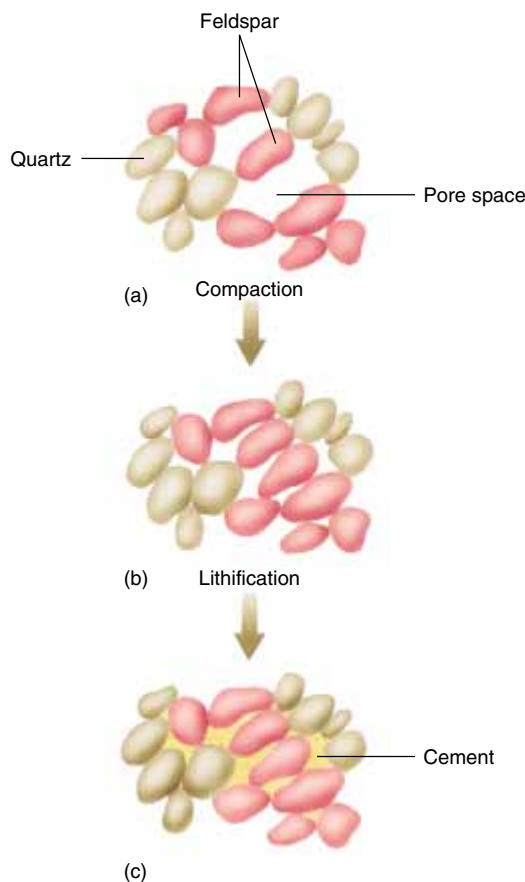


Figure 7-4 (a) Pore space is the open space among grains of sediment. (b) Compaction decreases pore space and lithifies sediment by interlocking the grains. (c) Cement fills pores and lithifies sediment by binding grains together.



Figure 7-5 Red iron oxide cement colors the red sandstone of Indian Creek, Utah.

than 20,000 years old. In contrast, some sand and gravel deposited between 30 and 40 million years ago in southwestern Montana can be dug with a hand shovel. The speed of lithification depends mainly on the availability of cementing material and water to carry the dissolved cement through the sediment.

TYPES OF CLASTIC ROCKS

Conglomerate and Breccia

Conglomerate (Fig. 7-6) and **breccia** are coarse-grained clastic rocks. They are the lithified equivalents of gravel and rubble, respectively. In a conglomerate the particles are rounded, and in a sedimentary breccia they are angular. Because large particles become rounded rapidly over short distances of transport, sedimentary breccias are usually found close to the weathering site where the angular rock fragments formed.



Figure 7-6 Conglomerate is lithified gravel.

Each clast in a conglomerate or breccia is usually much larger than the individual mineral grains in the rock. Therefore, the clasts retain most of the characteristics of the parent rock. If enough is known about the geology of an area where conglomerate or breccia is found, it may be possible to identify exactly where the clasts originated. A granite clast in a sedimentary breccia probably came from nearby granite bedrock.

Gravel typically has large pores between the clasts because the individual particles are large. These pores usually fill with finer sediment such as sand or silt. The next time you walk along a cobbly stream, look carefully between the cobbles. You will probably see sand or silt trapped among the larger clasts. As a result, most conglomerates have fine sediment among the large clasts.

Sandstone

Sandstone consists of lithified sand grains (Fig. 7-7). When granitic bedrock weathers, feldspar commonly converts to clay, but quartz crystals resist weathering. As streams carry the clay and quartz grains toward the sea, the quartz grains become rounded. The flowing water deposits the sand in one environment and the clay in another. Consequently, most sandstones consist predominantly of rounded quartz grains.

The word *sandstone* refers to any clastic sedimentary rock comprising primarily sand-sized grains. Most sandstones are quartz sandstone and contain more than 90 percent quartz. **Arkose** is a sandstone comprising 25 percent or more feldspar grains, with most of the remaining grains being quartz. The sand grains in arkose



(a)



(b)

Figure 7-7 Sandstone is lithified sand. (a) A sandstone cliff above the Colorado River, Canyonlands, Utah. (b) A close-up of sandstone. Notice the well-rounded sand grains.

are commonly coarse and angular. The high feldspar content and the coarse, angular nature of the grains indicate that the rock forms only a short distance from its source area, perhaps adjacent to granite cliffs (Fig. 7-8). **Graywacke** is a poorly sorted sandstone with considerable quantities of silt and clay in its pores. Graywacke is commonly dark in color because of fine clay that coats the sand grains. The grains are usually quartz, feldspar, and fragments of volcanic, metamorphic, and sedimentary rock.

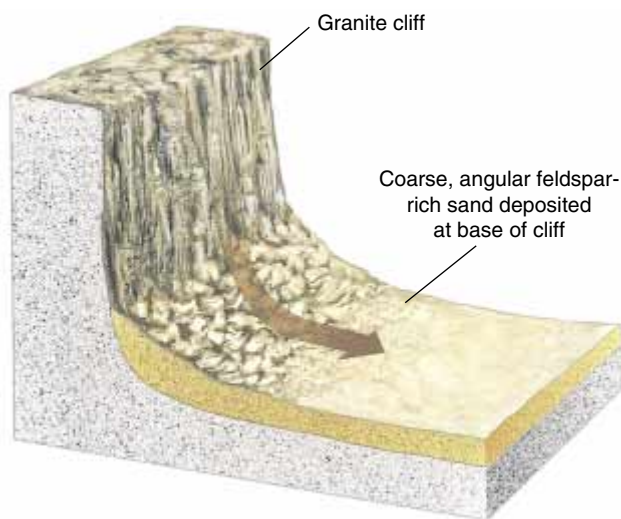


Figure 7-8 Arkose commonly accumulates close to the source of the sediment.

Claystone, Shale, Mudstone, and Siltstone

Claystone, shale, mudstone, and siltstone are all fine-grained clastic rocks. **Claystone** is composed predominantly of clay minerals and small amounts of quartz and other minerals of clay size. **Shale** (Fig. 7-9a) consists of the same material but has a finely layered structure called **fissility**, along which the rock splits easily (Fig. 7-9b). Clay minerals have platy shapes, like mica. When clays are deposited in water, the sediment commonly contains 50 to 60 percent water, and the platelike clay minerals are randomly oriented, as shown in Figure 7-10a. As more sediment accumulates, compaction drives out most of the water and the clay plates rotate so that their flat surfaces lie perpendicular to the pull of gravity (Fig. 7-10b). Thus, they stack like sheets of paper on a shelf. The fissility of shale results from the parallel orientation of the platy clay minerals.

Mudstone is a nonfissile rock composed of clay and silt. In some mudstone and claystone, layering is absent because burrowing animals such as worms, clams, and crabs disrupted it by churning the sediment.

Siltstone is lithified silt. The main component of most siltstones is quartz, although clays are also commonly present. Siltstones often show layering but lack the fine fissility of shales because of their lower clay content.

Shale, mudstone, and siltstone make up 70 percent of all clastic sedimentary rocks (Fig. 7-1). Their abundance reflects the vast quantity of clay produced by weathering. Shale is usually gray to black due to the



(a)



(b)

Figure 7-9 Shale is made up mostly of platy clays. Therefore, it shows very thin layering called fissility. (a) An outcrop of shale near Drummond, Montana. (b) A close-up of shale.

presence of partially decayed remains of plants and animals commonly deposited with clay-rich sediment. This organic material in shales is the source of most oil and natural gas. (The formation of oil and gas from this organic material is discussed in Chapter 19.)

► 7.3 ORGANIC SEDIMENTARY ROCKS

Organic sedimentary rocks, such as chert and coal, form by lithification of the remains of plants and animals.

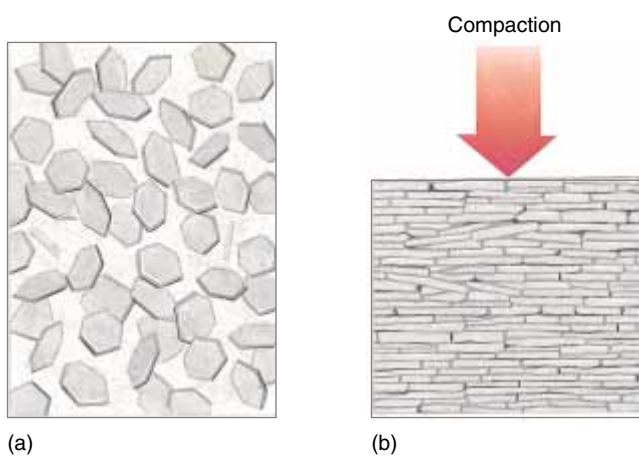


Figure 7-10 (a) Randomly oriented clay particles in freshly deposited mud. (b) Parallel-oriented clay particles after compaction and dewatering by weight of overlying sediments.

CHERT

Chert is a rock composed of pure silica. It occurs as sedimentary beds interlayered with other sedimentary rocks and as irregularly shaped lumps called **nodules** in other sedimentary rocks (Fig. 7-11). Microscopic examination of bedded chert often shows that it is made up of the remains of tiny marine organisms that make their skeletons of silica rather than calcium carbonate. In contrast, some nodular chert appears to form by precipitation from silica-rich ground water, most often in limestone. Chert was



Figure 7-11 Red nodules of chert in light-colored limestone.

one of the earliest geologic resources. Flint, a dark gray to black variety, was frequently used for arrowheads, spear points, scrapers, and other tools chipped to hold a fine edge.

COAL

When plants die, their remains usually decompose by reaction with oxygen. However, in warm swamps and in other environments where plant growth is rapid, dead plants accumulate so rapidly that the oxygen is used up long before the decay process is complete. The undecayed or partially decayed plant remains form **peat**. As peat is buried and compacted by overlying sediments, it converts to **coal**, a hard, black, combustible rock. (Coal formation is discussed in more detail in Chapter 19.)

► 7.4 CHEMICAL SEDIMENTARY ROCKS

Some common elements in rocks and minerals, such as calcium, sodium, potassium, and magnesium, dissolve during chemical weathering and are carried by ground water and streams to the oceans or to lakes. Most lakes are drained by streams that carry the salts to the ocean. Some lakes, such as the Great Salt Lake in Utah, are landlocked. Streams flow into the lake, but no streams exit. As a result, water escapes only by evaporation. When water evaporates, salts remain behind and the lake



Figure 7-12 An evaporating lake precipitated thick salt deposits on the Salar de Uyuni, Bolivia.

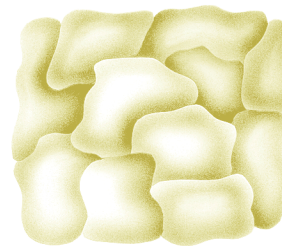


Figure 7-13 Rocks that precipitate from solution have interlocking grains.

water becomes steadily more salty. The same process can occur if ocean water is trapped in coastal or inland basins, where it can no longer mix with the open sea.

Evaporites form when evaporation concentrates dissolved ions to the point at which they precipitate from solution (Fig. 7-12). As the individual crystals precipitate, they interlock with each other to produce grain boundaries like those of an igneous rock (Fig. 7-13). The interlocking texture forms a solid rock, even though the rock may never have been compacted or cemented.

The most common minerals found in evaporite deposits are gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)¹ and halite (NaCl). Gypsum is used in plaster and wallboard, and halite is common salt. Evaporites form economic deposits in many basins and coastal areas. However, they compose only a small proportion of all sedimentary rocks.

Seawater is so nearly saturated in calcium carbonate that calcium carbonate minerals can precipitate under the proper conditions. This process occurs today on the shallow Bahama Banks, south of Bimini in the Caribbean Sea. As waves and currents roll tiny shell fragments back and forth on the sea bottom, calcium carbonate precipitates in concentric layers on the fragments. This process produces nearly perfect spheres called **oöliths**. In turn, oöliths may become cemented together to form **oölitic limestone**. Limestone of this type is a chemical sedimentary rock. However, most limestone is bioclastic, as discussed next.

► 7.5 BIOCLASTIC ROCKS

Carbonate rocks are made up primarily of carbonate minerals, which contain the carbonate ion (CO_3^{2-}). The most common carbonate minerals are calcite (calcium carbonate, CaCO_3) and dolomite (calcium magnesium

¹The $2\text{H}_2\text{O}$ in the chemical formula of gypsum means there is water incorporated into the mineral structure.

carbonate, $\text{CaMg}(\text{CO}_3)_2$). Calcite-rich carbonate rocks are called **limestone**, whereas rocks rich in the mineral dolomite are also called dolomite. Many geologists use the term **dolostone** for the rock name to distinguish it from the mineral dolomite.

Seawater contains large quantities of dissolved calcium carbonate (CaCO_3). Clams, oysters, corals, some types of algae, and a variety of other marine organisms convert dissolved calcium carbonate to shells and other hard body parts. When these organisms die, waves and ocean currents break the shells into small fragments, called **bioclastic sediment**. A rock formed by lithification of such sediment is called **bioclastic limestone**, indicating that it forms by both biological and clastic processes. Many limestones are bioclastic. The bits and pieces of shells appear as fossils in the rock (Fig. 7–14).

Organisms that form limestone thrive and multiply in warm, shallow seas because the sun shines directly on the ocean floor, where most of them live. Therefore, bioclastic limestone typically forms in shallow water along coastlines at low and middle latitudes. It also forms on continents when rising sea level floods land with shallow seas.

Coquina is bioclastic limestone consisting wholly of coarse shell fragments cemented together. **Chalk** is a very fine-grained, soft, white bioclastic limestone made of the shells and skeletons of microorganisms that float near the surface of the oceans. When they die, their remains sink to the bottom and accumulate to form chalk. The pale-yellow chalks of Kansas, the off-white chalks of Texas, and the gray chalks of Alabama remind us that all of these areas once lay beneath the sea (Fig. 7–15).

Dolomite composes more than half of all carbonate rocks that are over a billion years old and a smaller, although substantial, proportion of younger carbonate rocks. Because it is so abundant, we would expect to see dolomite forming today; yet today there is no place in the world where dolomite is forming in large amounts. This dilemma is known as **the dolomite problem**.

The general consensus among geologists is that most dolomite did not form as a primary sediment or rock. Instead, it formed as magnesium-rich solutions derived from seawater percolated through limestone beds. Magnesium ions replaced half of the calcium in the calcite, converting the limestone beds to dolostone.

► 7.6 SEDIMENTARY STRUCTURES

Nearly all sedimentary rocks contain **sedimentary structures**, features that developed during or shortly after deposition of the sediment. These structures help us



(a)



(b)

Figure 7–14 Most limestone is lithified shell fragments and other remains of marine organisms. (a) A limestone mountain in British Columbia, Canada. (b) A close-up of shell fragments in limestone. (© Breck P. Kent)

understand how the sediment was transported and deposited.

The most obvious and common sedimentary structure is **bedding**, or **stratification**—layering that develops as sediment is deposited (Fig. 7–16). Bedding forms because sediment accumulates layer by layer. Nearly all



Figure 7-15 The Niobrara chalk of western Kansas consists of the remains of tiny marine organisms. (David Schwimmer)

sedimentary beds were originally horizontal because most sediment accumulates on nearly level surfaces.

Cross-bedding consists of small beds lying at an angle to the main sedimentary layering (Fig. 7-17a). Cross-bedding forms in many environments where wind or water transports and deposits sediment. For example, wind heaps sand into parallel ridges called **dunes**, and flowing water forms similar features called **sand waves**. Figure 7-17b shows that cross-beds are the layers formed by sand grains tumbling down the steep downstream face of a dune or sand wave. Cross-bedding is common in sands deposited by wind, streams, ocean currents, and waves on beaches.

Ripple marks are small, nearly parallel sand ridges and troughs that are also formed by moving water or wind. They are like dunes and sand waves, but smaller. If the water or wind flows in a single direction, the ripple marks become asymmetrical, like miniature dunes. In other cases, waves move back and forth in shallow water, forming symmetrical ripple marks in bottom sand (Fig. 7-18). Ripple marks are often preserved in sandy sedimentary rocks (Fig. 7-19).

In **graded bedding**, the largest grains collect at the bottom of a layer and the grain size decreases toward the top (Fig. 7-20). Graded beds commonly form when some violent activity, such as a major flood or submarine land-

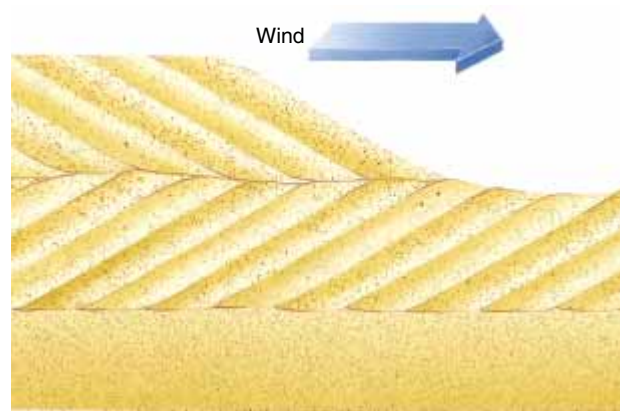
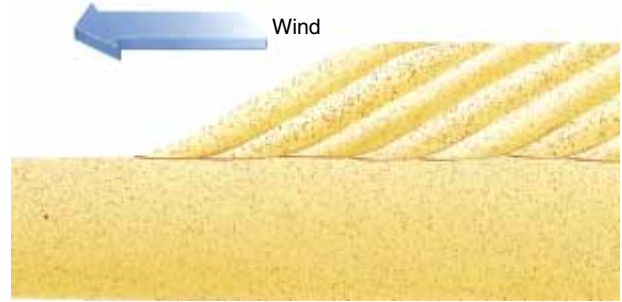


Figure 7-16 Sedimentary bedding shows clearly in the walls of the Grand Canyon. (Donovan Reese/Tony Stone Images)



(a)

Figure 7-17 (a) Cross-bedding preserved in lithified ancient sand dunes in Arches National Park, Utah. (b) The development of cross-bedding in sand as a dune migrates.



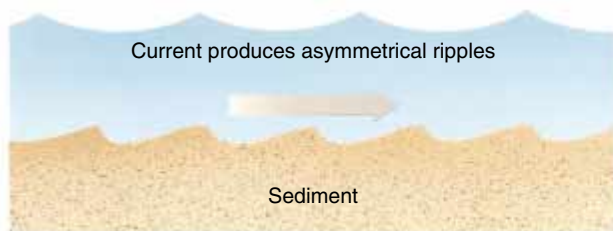
(b)

slide, mixes a range of grain sizes together in water. The larger grains settle rapidly and concentrate at the base of the bed. Finer particles settle more slowly and accumulate in the upper parts of the bed.

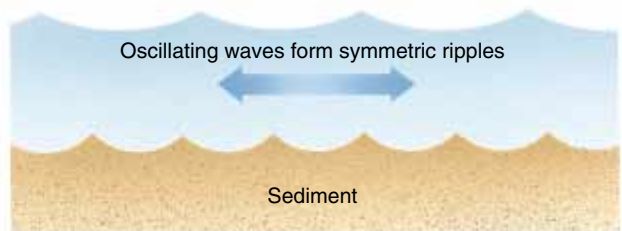
Mud cracks are polygonal cracks that form when mud shrinks as it dries (Fig. 7-21). They indicate that the mud accumulated in shallow water that periodically dried up. For example, mud cracks are common on intertidal mud flats where sediment is flooded by water at high tide and exposed at low tide. The cracks often fill with

sediment carried in by the next high tide and are commonly well preserved in rocks.

Occasionally, very delicate sedimentary structures are preserved in rocks. Geologists have found imprints of raindrops that fell on a muddy surface about 1 billion years ago (Fig. 7-22) and imprints of salt crystals that formed as a puddle of salt water evaporated. Like mud cracks, raindrop and salt imprints show that the mud must have been deposited in shallow water that intermittently dried up.



(a)



(b)

Figure 7-18 (a) Asymmetric ripple marks form when wind or currents move continuously in the same direction. (b) Symmetric ripple marks form when waves oscillate back and forth.



Figure 7-19 Ripple marks in billion-year-old mud rocks in eastern Utah.

Fossils are any remains or traces of a plant or animal preserved in rock—any evidence of past life. Fossils include remains of shells, bones, or teeth; whole bodies preserved in amber or ice; and a variety of tracks, burrows, and chemical remains. Fossils are discussed further in Chapter 9.

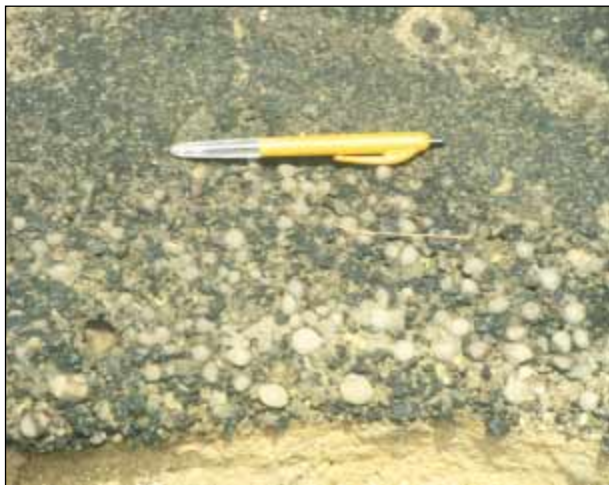


Figure 7-20 A graded bed in Tonga, southwestern Pacific. Larger grains collected near the bottom, and smaller particles settled near the top of the bed. (Peter Ballance)



Figure 7-21 Mud cracks form when wet mud dries and shrinks.

► **7.7 INTERPRETING SEDIMENTARY ROCKS: DEPOSITIONAL ENVIRONMENTS**

Imagine that you encounter a limestone outcrop as you walk in the hills. Entombed in the limestone you find



Figure 7-22 Delicate raindrop imprints formed by rain that fell about a billion years ago on a mudflat. (© Breck P. Kent)

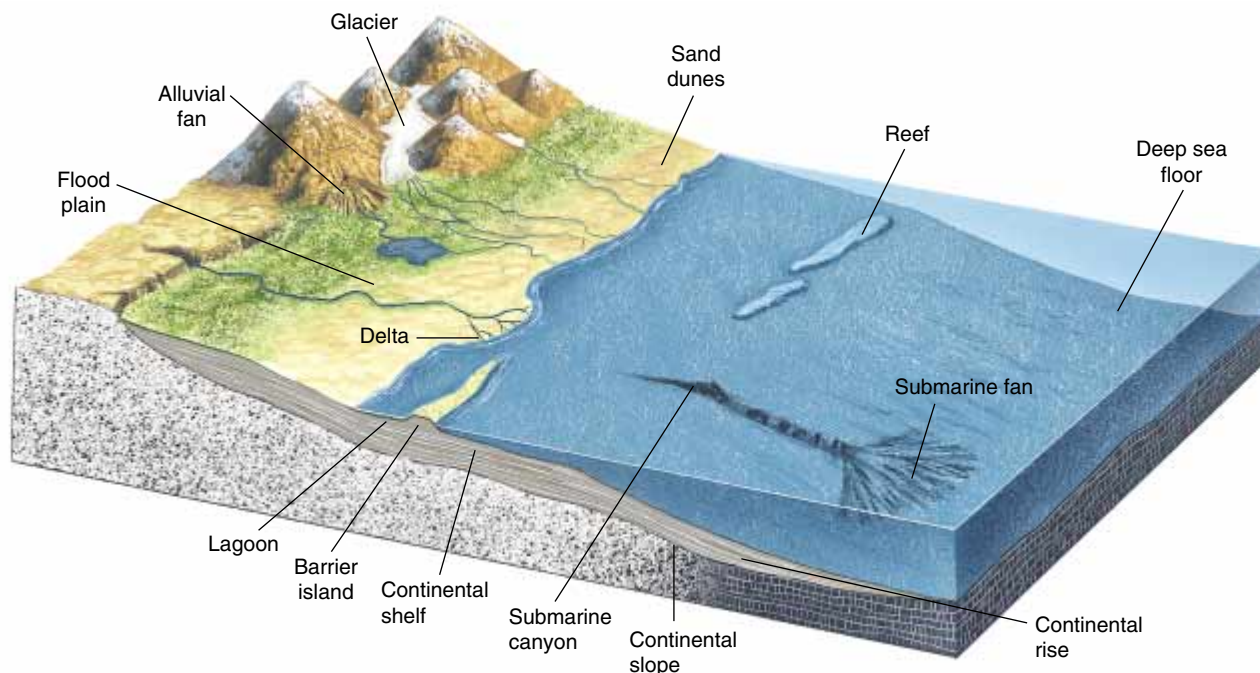


Figure 7-23 Common depositional environments.

fossils of marine clams that lived in shallow water. Therefore, you infer that the limestone must have formed in a shallow sea. Further, since the limestone is now well above sea level, you infer that tectonic forces have lifted this portion of the sea bed to form the hills.

Geologists study sedimentary rocks to help us understand the past. When geologists study sedimentary rocks, they ask questions such as: Where did the sediment originate? Was the sediment transported by a stream, wind, or a glacier? In what environment did the sediment accumulate? If it was deposited in the sea, was it on a beach or in deep water? If it was deposited on land, was it in a lake, a stream bed, or a flood plain?

Geologists answer these questions by analyzing the minerals, textures, and structures of sedimentary rocks. Additionally, the size and shape of a sedimentary rock layer contain clues to its depositional environment. Accurate interpretations of depositional environments are often rewarding because valuable concentrations of oil and gas, coal, evaporites, and metals form in certain types of environments.

Depositional environments vary greatly in scale, from an entire ocean basin to a 3-meter-long sand bar in a stream. Many small-scale environments may be active within a single large-scale depositional system (Fig. 7-23).

SUMMARY

Sedimentary rocks cover about three fourths of the Earth's land surface. **Clastic sediment** is sediment composed of fragments of weathered rock called **clasts**. Clastic sediment is **rounded** and **sorted** during transport and then deposited. Most sediment becomes lithified by **compaction** and **cementation**.

Clastic sedimentary rocks are composed of lithified clastic sediment and are named and classified primarily according to the size of the clastic grains. Common types are **conglomerate**, **sandstone**, **siltstone**, **shale**, **claystone**, and **mudstone**. **Organic sedimentary**

rocks are made up of the remains of organisms. **Coal** and **chert** are common organic sedimentary rocks. **Chemical sedimentary rocks** include **evaporites**, rocks that precipitate directly from solution as lake water or seawater evaporates. Most **limestone** is **bioclastic** and forms from broken shell fragments. **Dolostone** is a carbonate rock in which half of the calcium in calcite has been replaced by magnesium.

Sedimentary structures are features that develop during or shortly after sediment is deposited. They include **bedding**, **ripple marks**, **cross-bedding**, **graded**

bedding, mud cracks, and fossils. Sedimentary structures contain vital clues regarding the sedimentary environments in which sedimentary rocks formed. The interpretation of depositional environments is one of the primary

objectives of the study of sedimentary rocks. Depositional environments include all large- and small-scale environments in which sediments are deposited.

Important Sedimentary Rocks				
Conglomerate	Breccia	Sandstone	Arkose	Graywacke
Claystone	Shale	Mudstone	Siltstone	Chert
Coal	Limestone	Dolostone	Coquina	Chalk

KEY WORDS

clast 110
 bioclastic 110
 clastic sediment 110
 gravel 110
 rubble 110
 sand 110
 silt 110
 clay 110
 mud 110
 rounding 111

sorting 111
 viscosity 111
 lithification 112
 pore 112
 compaction 112
 cementing 112
 quartz sandstone 113
 fissility 114
 nodule 115

peat 116
 chemical sedimentary rock 116
 carbonate rock 116
 bioclastic sediment 117
 bioclastic limestone 117
 dolomite problem 117
 sedimentary structures 117

bedding 117
 stratification 117
 cross-bedding 118
 dune 118
 sand wave 118
 ripple mark 118
 graded bedding 118
 mud crack 119
 fossil 120

REVIEW QUESTIONS

1. Why do sedimentary rocks cover more than 75 percent of the Earth's land surface when they compose only 5 percent of the volume of the continental crust?
2. List the five stages in the formation of sedimentary rocks.
3. How do clastic sediments differ from dissolved sediment and chemical sediment?
4. Define bioclastic sediment.
5. In what ways are clastic sediments modified during transport?
6. Why is the maximum size of particles transported by wind finer than the maximum size transported by streams?
7. Why is the maximum size of particles transported by glaciers coarser than the maximum size transported by streams?
8. Describe how loose clastic sediment becomes lithified to form hard rock.
9. What is pore space in a clastic sediment? How is it modified during lithification?
10. What is the difference between conglomerate and breccias?
11. Why are most sandstones made up predominantly of quartz?
12. In what geologic environment does arkose form?
13. How do shale, sandstone, and limestone differ from one another?
14. How do shales acquire fissility? Why do mudstones lack that property?
15. How do limestones form?
16. What is bioclastic limestone?
17. How do dolomites form? What is the dolomite problem?
18. How does coal form?
19. How do evaporites form?
20. What does cross-bedding in a sandstone tell you about depositional environment?
21. What do the presence of mud cracks in a mudstone tell you about the depositional environment?

DISCUSSION QUESTIONS

1. Field geologists sometimes come upon large sections of sedimentary rocks that have been turned upside down by tectonic activities. How would you use sedimentary structures to determine whether a sequence of sedimentary rocks is upright or overturned?
2. On a field trip you discover a sequence of sedimentary rocks composed of thin black shales containing marine fossils interbedded with layers of gypsum and halite. What can you deduce about the depositional environment of these rocks?
3. Large portions of the Canadian Rockies are composed of limestone and shale. From this information alone, what can you tell about the geologic history of the region?
4. All the large-scale depositional environments are marine, while small-scale depositional environments can be either marine or terrestrial. Explain.
5. What types of sedimentary structures would you expect to find under the following circumstances? a. A catastrophic flood washes a huge amount of mixed sediment into a lake. b. Sand accumulates in a dry, windy environment. The prevailing wind direction shifts periodically, over a few million years. c. Mud collects on the bottom of a large, shallow, inland sea.
6. Why is shale the most abundant sedimentary rock?
7. Would you expect to find large quantities of sedimentary rocks on the Moon? Why or why not? If you do expect to find them, what types would you expect?