Chapter 6 Sediments and Sedimentary Rocks

In this textbook, we divide sedimentary rocks into two main types: **clastic** and **chemical**. Clastic sedimentary rocks are mainly composed of material that has been transported as solid fragments (clasts). Chemical sedimentary rocks are mainly composed of material that has been transported as ions in solution. It's important *not* to assume that mechanical weathering leads only to clastic sedimentary rocks, while chemical weathering leads only to chemical sedimentary rocks. In most cases, millions of years separate the weathering and depositional processes, and both types of sedimentary rocks tend to include at least some material derived from both types of weathering.

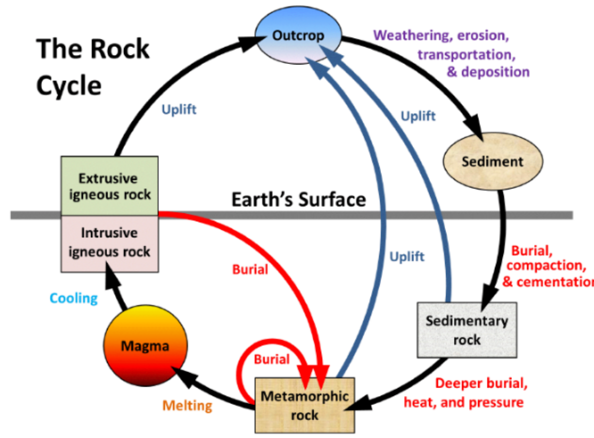

Figure 6.0.2 The rock cycle, showing the processes related to sedimentary rocks on the right-hand side.

6.1 Clastic Sedimentary Rocks

A **clast** is a fragment of rock or mineral, ranging in size from less than a micron (too small to see) to as big as an apartment block. The smaller ones tend to be composed of a single mineral crystal, and the larger ones are typically composed of pieces of rock. As we've seen in Chapter 5, most sand-sized clasts are made of quartz because quartz is more resistant to weathering than any other common mineral. Many of the clasts that are smaller than sand size (less than 1/16th millimetre) are made of clay minerals. Most clasts larger than sand size (greater than 2 millimetres) are actual fragments of rock, and commonly these might be fine-grained rock like basalt or andesite, or if they are bigger, coarse-grained rock like granite or gneiss. Sedimentary rocks that are made up of "clasts" are called clastic sedimentary rocks. A comparable term is "detrital sedimentary rocks".

Transportation

One of the key principles of sedimentary geology is that the ability of a moving medium (air or water) to move sedimentary particles—and keep them moving—is dependent on the velocity of flow. The faster the medium flows, the larger the particles it can move. This is illustrated in Figure 6.1.3. Parts of the river are moving faster than other parts, especially where the

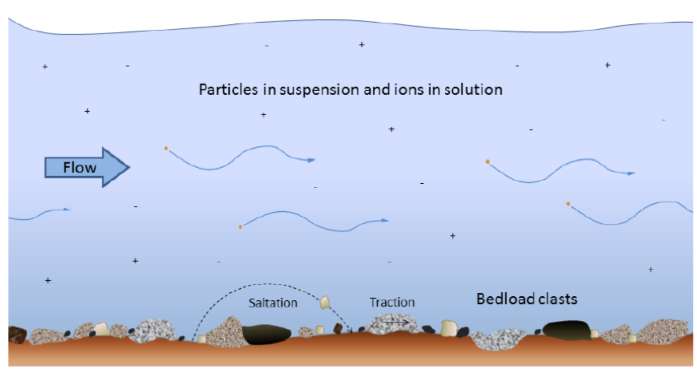

Figure 6.1.4 Transportation of sediment clasts by stream flow. The larger clasts, resting on the bottom (bedload), are moved by traction (sliding) or by saltation (bouncing). Smaller clasts are kept in suspension by turbulence in the flow. Ions (depicted as + and – in the image, but invisible in real life) are dissolved in the water.

slope is greatest and the channel is narrow. Not only does the velocity of a river change from place to place, but it changes from season to season.

Clastic sediments are deposited in a wide range of environments, including glaciers, slope failures, rivers—both fast and slow—lakes, deltas, and ocean environments—both shallow and deep. If the sedimentary deposits last long enough to get covered with other sediments they may eventually form into rocks ranging from fine mudstone to coarse breccia and conglomerate.

Lithification is the term used to describe a number of different processes that take place within a deposit of sediment to turn it into solid rock (Figure 6.1.5). One of these processes is burial by other sediments, which leads to compaction of the material and removal of some of the intervening water and air. After this stage, the individual clasts are touching one another. **Cementation** is the process of crystallization of minerals within the pores between the small clasts, and especially at the points of contact between clasts. Depending on the pressure, temperature, and chemical conditions, these crystals might include a range of minerals, the common ones being calcite, hematite, quartz and clay minerals.

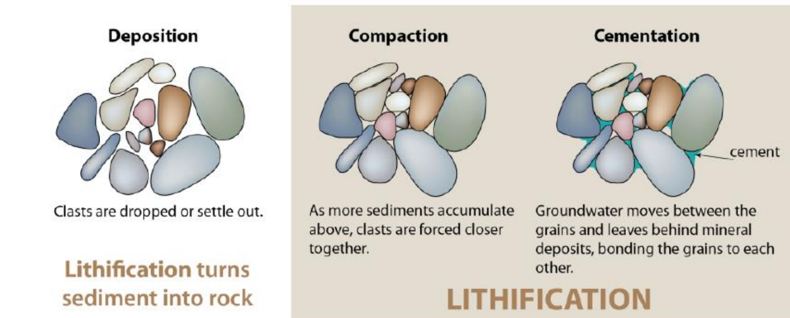

Figure 6.1.5 Lithification turns sediments into solid rock. Lithification involves the compaction of sediments and then the cementation of grains by minerals that precipitate from groundwater in the spaces between these grains. Source: Karla Panchuk (2016) CC BY 4.0

There are different clastic sedimentary rocks. **Mudrock** is composed of at least 75% silt- and clay-sized fragments. If it is dominated by clay, it is called **claystone**. If it shows evidence of bedding or fine laminations, it is **shale**; otherwise, it is mudstone. Mudrocks form in very low energy environments, such as lakes, river backwaters, and the deep ocean.

Sandstone is a common and important sedimentary rock. Sandstones are mostly made up of sand grains of course, but they also include finer material—both silt and clay. The term **arenite** applies to a so-called clean sandstone, meaning one with less than 15% silt and clay.

Clastic sedimentary rocks in which a significant proportion of the clasts are larger than 2 millimetres are known as **conglomerate** if the clasts are well rounded, and **breccia** if they are angular. Conglomerates form in high-energy environments such as fast-flowing rivers, where the particles can become rounded. Breccias typically form where the particles are not transported a significant distance in water, such as alluvial fans and talus slopes.

6.2 Chemical Sedimentary Rocks

Whereas clastic sedimentary rocks are dominated by components that have been transported as solid clasts (clay, silt, sand, etc.), chemical sedimentary rocks are dominated by components that have been transported as ions in solution (Na^+, Ca^{2+}, HCO_3^-, etc.). There is some overlap between the two because almost all clastic sedimentary rocks contain cement formed from dissolved ions, and many chemical sedimentary rocks include some clasts.

The most common chemical sedimentary rock, by far, is **limestone**. Others include **chert**, **banded iron formation,** and **evaporites**. Biological processes are important in the formation of some chemical sedimentary rocks, especially limestone and chert. For example, limestone is made up almost entirely of fragments of marine organisms that manufacture calcite for their shells and other hard parts, and most chert includes at least some of the silica tests (shells) of tiny marine organisms (such as diatoms and radiolarians).

Limestone

Almost all limestone forms in the oceans, and most of that forms on the shallow continental shelves, especially in tropical regions with coral reefs. Reefs are highly productive ecosystems populated by a wide range of organisms, many of which use calcium and bicarbonate ions in seawater to make carbonate minerals (especially **calcite**) for their shells and other structures.

Dolomite (CaMg(CO3)2) is another carbonate mineral, but *dolomite* is also the name for a rock composed of the mineral dolomite.

Evaporites

In arid regions many lakes and inland seas have no stream outlet and the water that flows into them is removed only by evaporation. Under these conditions, the water becomes increasingly concentrated with dissolved salts, and eventually some of these salts reach saturation levels and start to crystallize. In most cases minor amounts of carbonates start to precipitate when the solution is reduced to about 50% of its original volume. Gypsum (CaSO4·H2O) precipitates at about 20% of the original volume and halite (NaCl) precipitates at 10%.

6.3 Depositional Environments and Sedimentary Basins

Sediments accumulate in a wide variety of environments, both on the continents and in the oceans. Some of the more important of these environments are illustrated in Figure 6.3.1.

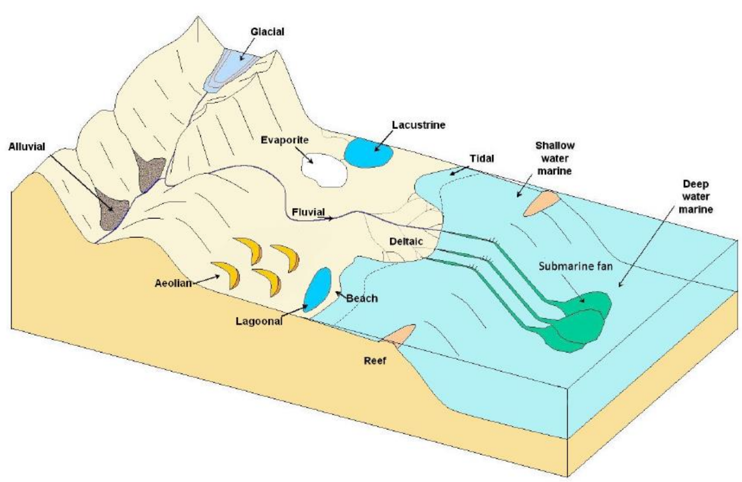

Figure 6.3.1 Some of the important depositional environments for sediments and sedimentary rocks.

Continental Environments:

1. **Lacustrine:** characterized by the deposition of sand near the edges, as well as silt, clay, and organic matter within the lake.
2. **Fluvial:** moving water in streams transports and deposits gravel, sand, silt, and organic matter, particularly in swampy areas.

3. **Aeolian:** found in deserts and coastal regions, involve wind as the primary transport mechanism, depositing sand and silt.

4. **Glacial:** In glacial environments, gravity, moving ice, and water transport sediments to valleys, plains, streams, and lakes, where glacial till, gravel, sand, silt, and clay are typically deposited.

Transitional Environments:

1. **Deltaic:** Deltaic environments, formed by moving water in deltas, typically see the deposition of sand, silt, clay, and organic matter, especially in swampy regions.

2. **Beach:** Beach environments are shaped by waves and longshore currents, which transport and deposit gravel and sand on beaches, spits, and sand bars.

3. **Tidal:** Tidal environments, found in tidal flats, are dominated by tidal currents that deposit silt and clay.

Marine Environments:

1. **Deep Water Marine:** are characterized by the deposition of clay, carbonate mud, and silica mud on deep-ocean abyssal plains.

2. **Shallow Water Marine:** Shallow water marine environments on shelves, slopes, and lagoons are influenced by waves and tidal currents, leading to the deposition of carbonates in tropical climates, and sand, silt, and clay in other regions.

3. **Submarine Fan:** In submarine fan environments, underwater gravity flows transport and deposit gravel, sand, and mud on continental slopes and abyssal plains.

4. **Reef:** In reef environments, waves and tidal currents transport carbonates, which are deposited in reefs and adjacent basins.