4 Sedimentary Rocks

Adapted by Lyndsay R. Hauber & Joyce M. McBeth (2018) University of Saskatchewan from Deline B, Harris R & Tefend K. (2015) "Laboratory Manual for Introductory Geology". First Edition. Chapter 10 "Sedimentary Rocks" by Bradley Deline, CC BY-SA 4.0.

4.1 INTRODUCTION

We are particularly interested in the history and events that occur on the surface of the Earth because it is easier to directly observe and test, and has direct relevance to our lives and history. Sedimentary rocks are the pages in which history is written, since they contain powerful environmental indicators, traces of life, and chemical signatures that can inform us about many subjects, from the occurrence of ancient catastrophes to the productivity of life.

The identification of sedimentary rocks is more than applying names, since each name is a loaded term that conveys information regarding its history, where it was formed, potentially when it was formed, and the processes that lead to its formation. Each sedimentary rock is a puzzle, and by identifying a set of rocks, how they are layered, the fossils within, and patterns in the rocks, a geologist can reconstruct an entire environment and ecosystem. Solving these puzzles is both an academic exercise to better understand the world around us and a tool for finding the resources that are important to our lives. In particular, fossil fuels and other natural resources are, or are contained within, sedimentary rocks such as coal, natural gas, petroleum, salt, and the materials that go into wallboard or in the making of cement. Therefore, a better understanding of sedimentary rocks and how and where they are formed directly influences your everyday life.

4.1.1 Learning Outcomes

After completing this chapter, you should be able to:

- Describe how erosion and weathering relate to the formation of sedimentary rocks
- Identify sedimentary rocks and their features
- Describe the formation and history of different types of sedimentary rocks

4.1.2 Key Terms

- Biochemical Sedimentary Rocks
- Chemical Sedimentary Rocks
- Chemical Weathering
- Clast
- Clastic Sedimentary Rocks
- Dissolution
- Erosion
- Hydrolysis
- Maturity
- Mechanical Weathering
- Oxidation
- Sorting

4.2 WEATHERING AND EROSION

Sedimentary rocks are formed by the weathering, erosion, deposition, and lithification of sediments. Sedimentary rocks are composed of pieces of other rocks, which are broken down by a process called weathering. There are two basic ways that weathering occurs in nature. First, rocks can be physically broken into smaller pieces (e.g. hitting a rock with a hammer), which is called **mechanical weathering**. Alternatively, rocks can be broken down and altered at the atomic level (e.g. dissolving salt in water), which is called **chemical weathering**. There are multiple ways each type of weathering can occur and, therefore, both the rate that rocks break down and how they break down varies dramatically depending on the area and environment.

The most prevalent type of mechanical weathering is the collision, breaking, and grinding of rock by the movement of a fluid, either water or air. The size of the carried sediment depends on the type of fluid and speed of the movement. A fast fluid (e.g. a rapidly flowing river) can carry large particles and cause immense amounts of weathering, while a slow fluid (e.g. a calm stream) would hardly cause any weathering. The density of the fluid also controls the size of particle that can be transported; for instance, a denser fluid, like water, can carry larger particles than a less dense fluid, like air. Another common method of mechanical weathering is called frost wedging, which occurs when water seeps into cracks in the rock and freezes. Water expands when frozen, which puts pressure on the rock and can potentially split boulders. The addition and subtraction of heat or pressure can also cause rock to break, which can cause rocks to shatter when cooled very quickly or immense pressure is released. Finally, plants, animals, and humans can cause significant amounts of weathering. These sediments then undergo **erosion**, which is the transport of sediment from where it is weathered to where it will be deposited and turned into a rock.

Rocks can also be chemically weathered, most commonly by one of three processes. The first is called **dissolution**, where a mineral or rock is completely broken apart in water into individual atoms or molecules. These ions can then be transported with the water and redeposited as the concentration of ions increases, generally due to evaporation. Chemical weathering can also change the mineralogy and weaken the original material, which is also caused by water. A mineral can undergo **hydrolysis**, where a hydrogen atom from the water molecule replaces the cation in a mineral; this normally alters minerals like feldspar into a softer clay mineral. Additionally, a mineral can undergo **oxidation**, where oxygen atoms alter the valence state of a cation; this normally occurs on a metal and is commonly known as rusting.

Chemical and mechanical weathering can work together to increase the overall rate of weathering. Chemical weathering weakens rocks, making them more prone to breaking physically, while mechanical weathering increases the surface area of the sediment, which increases the surface area that is exposed to chemical weathering. Therefore, environments with multiple types of weathering can erode very quickly.

4.3 IDENTIFYING SEDIMENTARY ROCKS

Classification of sedimentary rocks is largely based on differentiating the processes that lead to their formation. The biggest division in sedimentary rock types is based on the primary type of weathering that leads to the material building the sedimentary rock. If the rock is largely made from pieces of rock (called **clasts**) that have been mechanically weathered, the rocks are referred to as Detrital or **Clastic Sedimentary Rocks**. These rocks are composed of broken pieces of other rocks. In this case, the mineralogy of the clasts is not important, but we need to note the properties of the sediment itself. Alternatively, if the rock is largely the product of chemical weathering, the classification is based on the composition of the material and the processes involved in the materials precipitation from solution. **Chemical Sedimentary Rocks** form from the inorganic precipitation of minerals from a fluid. Crystals begin to form if the ions present within a fluid, such as water, become very concentrated, either by the addition of more ions or the removal of water by freezing or evaporation. In this case, the identification of the type of sedimentary rocks is based on the minerals present. If organisms facilitate the precipitation of these minerals from water we refer to the rocks as **Biochemical Sedimentary Rocks.** An example of biochemical precipitation is the formation of skeletal minerals in many organisms: from starfish and clams that grow calcite, to sponges that grow silica-based material, to humans that have bones made of hydroxyapatite. Now we can discuss the identification and formation of particular sedimentary rocks.

4.3.1 Clastic Sedimentary Rocks

Weathering and erosion occur normally in areas that are at high elevation, such as mountains, while deposition occurs in lower areas such as valleys, lakes, or the ocean. The sediment is transported from the area of erosion (e.g. the “source”) to area of deposition (e.g. the “sink”) by ice, water, or air. The sediment changes during its journey; we can recognize the amount of change, the distance traveled, and the transport mechanism, by looking at its maturity (e.g. Figure 4.1). **Maturity** is defined as the texture and composition of a sedimentary rock resulting from varying amounts of erosion or sedimentary transport. Imagine a mountain composed of granite, and let us explore how the sediment from this mountain changes as it makes the long journey via river to the ocean. First, the rock is mechanically breaking down into smaller pieces, which creates sediment that has jagged large and small clasts, and all of the minerals remain. The sizes of clasts in these rocks can range from large boulders, to cobbles, to pebbles, to the smallest particles, clay. As this sediment is transported in the river, the clasts collide with each other and the rocks get smaller and the sharp edges are broken off. Also, as the slope of the land decreases the river slows, leaving behind the large boulders and cobbles, while carrying away the smaller particles. Now, sediments further from the source will be more uniform in size, which is a process called **sorting**. Chemical weathering also occurs, altering the feldspars into clay-sized particles. In the end, the granite is reduced from boulders and cobbles close to the mountain, to pebbles in the rivers, to pure and uniform quartz sand at the beach, and miniscule clay grains on the ocean floor. Therefore, different clastic rocks are found in different areas and have traveled different distances.

In the lab, we will look at four types of clastic rocks, conglomerate, breccia, sandstone, and shale. Conglomerate is an immature sedimentary rock (e.g. it has been transported a short distance) that is a poorly sorted mixture of clay, sand, and rounded pebbles. The mineralogy of the sand and pebbles (also called clasts) can vary depending on its source. These rocks would be found on the continent in several types of deposits, such as ancient landslides or pebble beds in rivers. Breccia is an immature sedimentary rock that is a poorly sorted mixture of clay, sand, and angular pebbles. The mineralogy of the clasts can vary depending on its source. These rocks would be found on the continent in several types of deposits, such as next to fault zones and debris flows. Sandstone is defined as a clastic sedimentary rock that consists of sand-sized clasts. These clasts can vary from jagged to rounded, and can contain many minerals or just quartz. Therefore, sandstone ranges from being relatively immature to mature, which makes sense, since we can find layers of sand associated with mountain rivers, to pure white quartz beaches. Last we have shale, which is composed of clay particles and has a finely layered or fissile appearance. This extremely mature sedimentary rock is made from the smallest particles that can be carried by wind or barely moving water and can be found thousands of miles away from the original source.

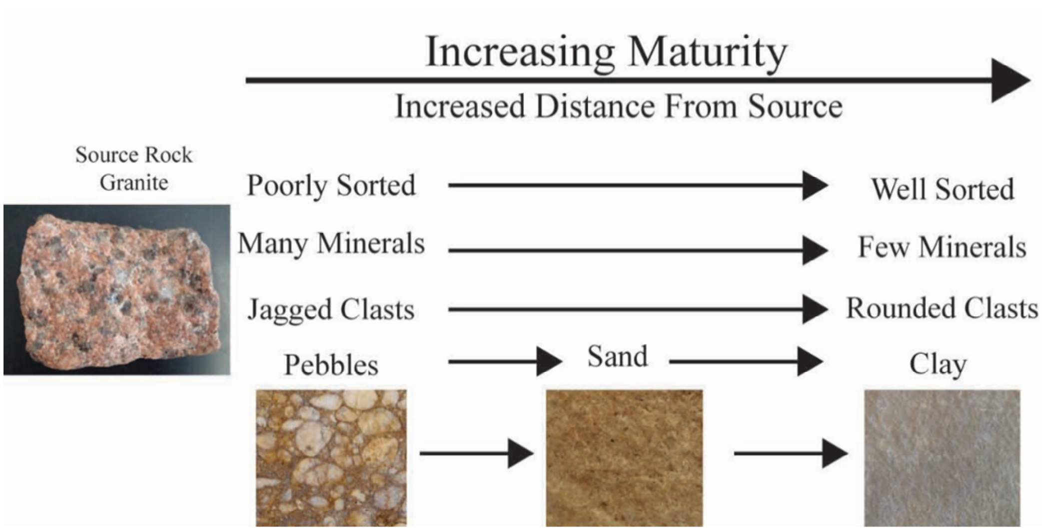


Figure 4.1 | Maturity in clastic sedimentary rocks showing how the sediments change as they are eroded further from their source.
Source: Bradley Deline (2015) CC BY-SA 3.0

4.3.2 Biochemical and Chemical Sedimentary Rocks

As mentioned before, biochemical and chemical sedimentary rocks either precipitated directly from water or by organisms. The most recognizable chemical sedimentary rocks are evaporites, which are minerals that are formed by the precipitation of minerals from the evaporation of water. You have already examined multiple examples of evaporites in a previous lab, such as halite and gypsum. In this lab, we will focus on siliceous and carbonate biochemical sedimentary rocks. Chert is a rock composed of microcrystalline varieties of quartz, and thus it has properties that are associated with quartz itself, such as conchoidal fracturing and hardness greater than glass. Chert is often formed deep in the ocean from silicious material that is either inorganic (e.g. silica clay) or biologic (e.g. skeletons of sponges and single-celled organisms) in origin. Carbonates are one of the most important groups of sedimentary rocks and can result in distinctive landscapes (e.g. karst) and human hazards (e.g. sinkholes). Limestone is a sedimentary rock composed of the carbonate mineral calcite and can vary greatly in its appearance, depending on how it is formed, but can easily be identified by its chemical weathering. Limestone composed of calcite undergoes dissolution in acids, meaning it effervesces dramatically when we apply dilute HCl. As with chert, limestone can be formed inorganically from a supersaturation of calcium and carbonate ions in water in varying environments, from caves to tropical beaches. Limestone that consists of crystals of calcite or microcrystalline masses of calcite is called crystalline limestone. Alternatively, limestone can be formed biologically with the most striking example called a fossiliferous limestone, which are rocks made of fragmented carbonate (calcite or its polymorph aragonite) shells or coral.

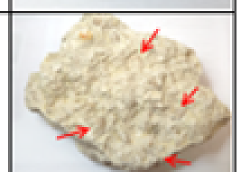
	Composition	Texture and Properties	
Detrital Sedimentary Rocks			
Shale	Fine rock fragments smaller than 1/16 mm	Clay-sized particles that cannot be differentiated by the naked eye. May be fissile, splits into distinctive layers	
Sandstone	Medium rock fragments between 1/16 mm and 2 mm	Composed of sand-sized rock fragments. The fragments can vary in mineralogy, including mainly quartz, along with feldspar, and clay	
Breccia	Coarse, angular rock fragments ranging in size, with the largest >2 mm	Poorly sorted mixture of rock fragments, including angular or sub-angular pebbles	
Conglomerate	Coarse, rounded rock fragments ranging in size, with the largest >2 mm	Poorly sorted mixture of rock fragments, including rounded or sub-rounded pebbles	
Chemical and Biochemical Rocks			
Limestone	Calcite crystals or microcrystalline calcite	Masses of large, interlocking calcite crystals or microscopic crystals not visible with the naked eye	
Fossiliferous Limestone	Calcareous skeletal fragments of coral or shells	Consisting of fossils or fossil fragments	
Oolitic Limestone	Calcite concretions, formed around sand or shell fragments	Aggregates of oolites, small spherical calcite concretions	
Chert	Cryptocrystalline Quartz	Microcrystalline polymorphs of quartz, formed by the recrystallization of siliceous skeletons. Conchoidal fracturing; scratches glass	
Rock Salt	Halite and sylvite crystals	Fine- to coarse-grained crystalline structure, with a salty taste and cubic cleavage	

Table 4.1 | Classification of Sedimentary rocks.
Source: Lyndsay Hauber & Joyce M. McBeth (2018) CC BY 4.0 after Bradley Deline (2015) CC BY-SA 3.0