Lab 4 - Identification of Sedimentary Rocks

Introduction

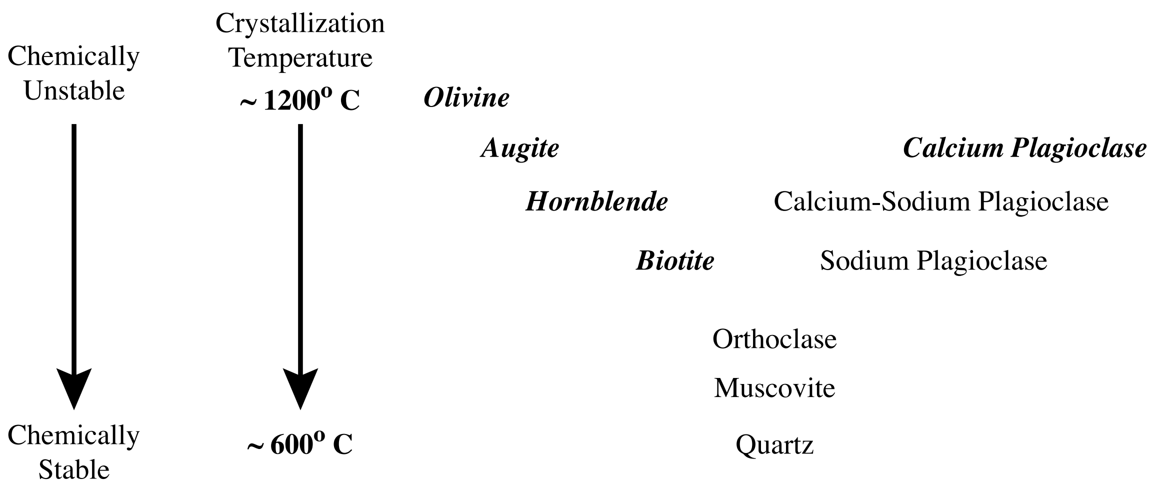
Sedimentary rocks are the second great rock group. Although they make up only a small percentage of the rocks in the earth's crust (~5%) these rocks are formed by processes that occur at or near the earth's surface. Almost 75% of the earth's surface is covered by a thin blanket of sedimentary rock. These are the rocks that most people think of when you hear the word "rock".

Sedimentary rocks form from a material called sediment. The word "sediment" literally means "to sediment". **Sediment** are pieces of material that have settled out of air, ice or water later to become **lithified** or turned into a sedimentary rock. It is the composition of this material and the method of lithification that determines what type of sedimentary rock will be formed.

Types of Sediment

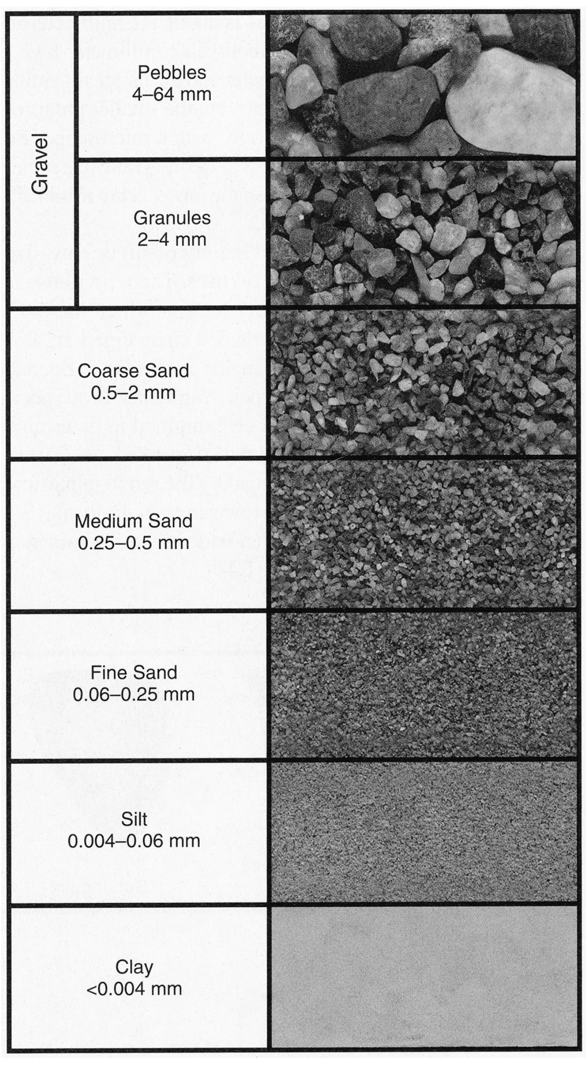
Most of the rocks that make up the earth's crust (the other 95% that is not sedimentary rock) initially formed under conditions of very high temperatures and/or under high pressures that exist deep within the earth's crust. These rocks are not stable under the lower temperatures and pressures that exist at the earth's surface. Upon exposure to the earth's surface, these unstable rocks will undergo a series of processes called **weathering** that will both chemically and physically break the unstable rock down into smaller pieces. Sediment derived from the weathering of pre-existing rock is called **detrital sediment**.

Bowen's Chemical Stability Series



Bowen's Chemical Stability Series. Minerals that form at higher temperatures are chemically unstable and will decompose more readily to clay. Minerals that form at lower temperatures are chemically more stable and will decompose into clays only after higher degrees of weathering. Quartz is the only mineral that will not chemically decompose to clay.

Surface water in the form of rivers and streams is one of the most powerful agents for weathering rocks. Most rivers have their source waters or head waters at higher elevations (highland or mountain regions). Here, the fast flow of the water allows it to move very large pieces of rock. These large **clasts** (pieces of rock) tend to be very angular at the beginning of their journey, but as they are moved along the river bed they bang into each other and, eventually, become rounded into **pebbles**. Eventually, the pebbles of rock themselves begin to break down into their individual mineral constituents to become **sand**. The process of large angular clasts becoming large rounded pebbles and then into sand is called **physical weathering**, as a physical force is being applied to the individual clasts to first round them, then break them down. Once the sediment becomes sand-sized, **chemical weathering** begins to break the individual minerals down even further. Water begins to react chemically with the minerals in the sediment to convert them into a very fine-grained substance called **clay**. Virtually all silicate minerals will decompose into clay in time when exposed to surface waters. The only silicate mineral that is chemically stable at the earth's surface (meaning it will not decompose into clay) is the mineral quartz. Thus most detrital sediment formed from pre-existing rocks, is ultimately composed of quartz and/or clay.



Detrital sediment is identified and named for the size of the individual clasts within the sediment. Large clasts, greater than 2 mm in diameter are called gravel. Medium-sized clasts, between 2 mm and 1/16 mm are called sand. Sand-sized clasts are of a size range where individual clasts are visible to the naked eye. Fine-grained clasts, between 1/16 and 1/256 mm, are called silt. Silt-sized clasts are too small to see with the naked eye, but you can feel the grains as a grit. And very fine-grained clasts, less than 1/256 mm in diameter, are called clay. Clay-sized clasts are too small to see and clay feels very smooth to the touch.

A second type of sediment is called nondetrital sediment. **Nondetrital** sediment forms from pieces of pre-existing life; either animal life or plant life. The largest concentration of animal life in the world is in the oceans. Here many of the animals create hardparts, shells, skeletons, teeth, etc., from chemicals that they biologically extract from ocean water. Where large concentrations of this life exists or where storms can wash hugh amounts of this life onto a beach, vast accumulations of these hardparts can build up over time. There are also places on the earth where hugh amounts of plant life exists, notably swamps and lagoons. In these places when plants die they can become buried in fine muds and preserved as another type of nondetrital sediment.

A final type of sediment, **chemical sediment,** forms from the evaporation of chemical-rich water. When unstable silicate rocks break down chemically, they create quartz and clays and also quite a few other metals and chemical compounds, many of which become dissolved in the waters that are transporting the sediment. Thus, most of the water on the earth's surface contains large amounts of dissolved chemicals in them. Since most running water on the earth's surface ends up in the oceans, the oceans of the world are rich in dissolved chemicals (in fact, it is from these chemicals that sea life creates its hard parts.) If some of these waters were trapped in such a way that they are allowed to evaporate, the dissolved chemicals will be left behind as chemical sediments.

Classification of Detrital Sedimentary Rocks

The classification of sedimentary rock is similar to that of igneous rock; by texture and mineralogy. There are 3 types of textures in sedimentary rocks corresponding to the 3 types of sediment; detrital sediment, nondetrital sediment and chemical sediment.

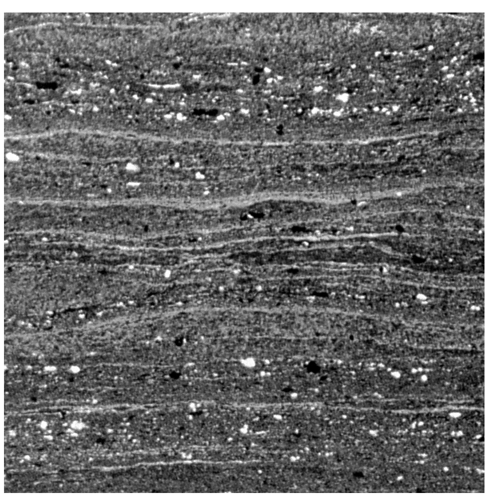
Detrital sediment is derived from the physical and chemical weathering of pre-existing rock. Ultimately, much of that pre-existing rock started out as igneous rock, meaning rock whose mineralogy begins with Bowen's reaction series. Bowen's reaction series is more then the sequence of minerals and the order in which they form in igneous rock. It has also been described as a chemical stability series. Because of the high temperatures in which they form, most silicates are unstable when exposed to the earth's surface and will decompose to clay. The higher a mineral's position is on Bowen's reaction series, the higher the temperature that it formed and the more chemically unstable it is. Thus olivine, the highest mineral on Bowen's reaction series, is extremely chemically unstable and, under the right conditions, will begin to convert to clay within a few years of its exposure to the earth's surface. Whereas, the silicate mineral quartz, the lowest mineral on Bowen's reaction series, is the only chemically stable silicate mineral; the only silicate mineral that will not convert to clay. Thus, the mineralogy of detrital sedimentary rocks depends on it's degree of weathering. It can contain some unstable minerals if the degree of weathering is low; but if the degree of weathering is high it will consist only of quartz and/or clay.

To make a detrital sedimentary rock the detrital sediment from which it is composed must be **lithified** or turned into a sedimentary rock. For silt and clay-sized sediment this is a simple matter of compacting the sediment and drying it out (**dehydration**). For coarser-sized sediment compaction and dehydration alone will not lithify the rock. Coarser sediment requires exposure to air and then allowing chemical-rich surface water to flow between the grains and evaporate. This water will leave behind the chemicals it contained in the open spaces between the sediment grains and these chemicals will acts as natural cements to hold the sediment grains together. This is a process known as **cementation**. Naturally occurring cements are all minerals that you are familiar with. Hematite, limonite, calcite, gypsum and, in rare cases quartz (quartz will not convert to clay but can be dissolved and most surface water contains a small portion of dissolved quartz) all can act as natural cements to lithify a detrital sedimentary rock.

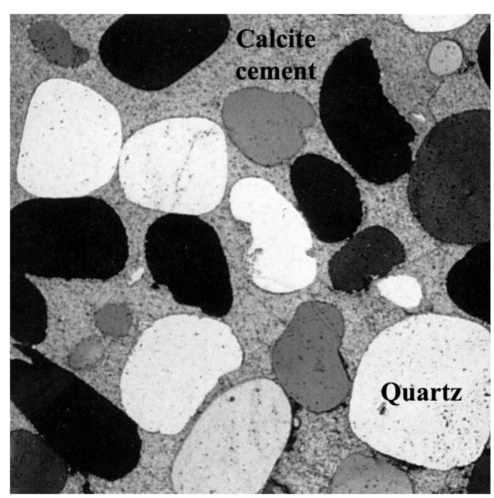
A detrital sedimentary rock is named primarily for the size of its clasts:

- lithified angular gravel-sized clasts	= **breccia**
- lithified rounded gravel-sized clasts	= **conglomerate**
- lithified sand-sized clasts	= **sandstone**
- if sand is pure quartz	= the sandstone is called "**arenite**"
- if sand contains unstable silicates	= the sandstone is called "**arkose**"
- lithified silt-sized clasts	= **siltstone**
- lithified clay-sized clasts	= **shale**

a.



b.



a. Very fine clays and small silt grains in a shale (picture magnified 100 times). b. Rounded quartz sand grains cemented together by calcite in an arenite (picture magnified 20 times).

Classification of Nondetrital Sedimentary Rocks

Nondetrital sediment consists of the hard parts of either dead animals or dead plants. Most marine life extracts the mineral calcite from sea water to make their hard shells or skeletons. Calcite is a mineral that dissolves fairly readily in the presence of fresh water. Exposure to a large quantity of this material, say on a beach, and over a period of time, rainwater trickling through the shells will dissolve a portion of these shells and evaporate and leave the calcite behind. Thus, seashells and other marine hard parts are said to be "self-cementing".

A third type of limestone consists of little sand-sized spheres of calcite called ooids. Ooids form in warm tropical waters that contain large amounts of dissolved calcite. Here waves can move around small bits of sand and pieces of seashells while the calcite forms when the waters evaporate and coat the sand grains with concentric layers of calcite. Ooids, like seashell, can get washed onto a beach where they can become cemented and turned into a rock

- fresh broken seashells cemented by calcite	= **coquina**
- very old broken seashells cemented by calcite	= **fossil limestone**
- calcite ooids cemented by calcite	= **oolitic limestone**

Normally when plants die they are decomposed by bacteria or eaten by various organisms, or both happens, and the plant is totally destroyed. But in swamps and lagoons where plants die and are buried under protective layers of mud, they will slowing became compacted over time and will be slowly converted to a form of carbon called **coal**. Coal is classified according to its **rank**, or amount of carbon it contains:

- lowest rank ---> a mass of plant plant pieces, very little carbon	= **peat**
- higher rank ---> a few plant bits remain, about 50% carbon	= **lignite**
- higher rank ---> no plant remain, layered, mostly carbon	= **bituminous coal**
- highest rant ---> pure carbon, has distinct conchoidal fracture	= **anthracite**

Classification of Chemical Sedimentary Rocks

Throughout the earth's history sea level has increased and decreased many times. At certain points in our earth's history much of what we know of as "dry land" was covered in shallow seas. When the seas retreated it left a great deal of sea water stranded on land. In many places on the earth, this sea water evaporated and left behind thousands of feet of Chemical Sedimentary Rocks. These rocks are composed of thick layers of either halite or gypsum. These are called monomineralic rocks because they are rocks composed of a single mineral. A rock composed or pure halite is called **rock salt**. A rock composed of pure gypsum is called **rock gypsum**. Remember that any mineral that forms from a liquid (whether it is magma, lava or water) forms minerals that have strong interlocking grain boundaries. Thus, rock salt and rock gypsum do not need compaction or cementation to be lithified, they are lithified as they form from the evaporation of sea water.

SEDIMENTARY ROCK IDENTIFICATION KEY

TEXTURE	COMPOSITION	Clast Size	LITHIFICATION	CHARACTISTICS	Rock Name
DETRITAL TEXTURE	quartz + cement	Gravel	cementation	large angular gravel with various cements	Breccia
	quartz + cement	Gravel	cementation	large rounded gravel with various cements	Conglomerate
	quartz, orthoclase, muscovite + cement	Sand	cementation	quartz, orthoclase, muscovite sand with various cements	Sandstone (arkose)
	quartz + cement	Sand	cementation	pure quartz sand with hematite, calcite, limonite or gypsum cements	Sandstone (arenite)
	quartz + cement	Silt	cementation	very fine quartz grit with some clay/iron cement holding it together	Siltstone
	clay	Clay	compaction	very fine smooth clay, black or gray, often with small plant fossils	Shale
NONDETRITAL TEXTURE (pieces of life)	calcite	VARIOUS	cementation	dull gray with fossil shells, often cemented with calcite	Fossiliferrous limestone
	calcite	VARIOUS	cementation	orange, tan, white crushed sea shells loosely cemented with calcite	Coquina
	carbon	very fine	compaction	jet black, very soft, very light weight, layered carbon	Bituminous coal
NONDETRITAL TEXTURE (precipitants)	calcite	Sand	cementation	small round balls of calcite cemented by calcite	Oolitic limestone
	gypsum	very fine	crystallization	very soft, fine-grained gypsum, white to light gray in color	Rock gypsum
	halite (minor clay)	VARIOUS	crystallization	light gray, granular halite, often mixed with small amounts of clay	Rock salt

Rock Texture	Rock Composition	Characteristic Features	NAME

Lab 4 - Sedimentary Rocks

1. What is the difference between the shape of the clasts between your conglomerate and your breccia samples ?

2. What minerals are present in the arkose that are missing in the red arenite (red sandstone) sample ?

3. Pure quartz sand is white in color. Why is your red sandstone colored red ?

4. How can you easily distinguish the difference between your arenites and your siltstone sample ?

5. How can you easily distinguish the difference between your siltstone and your shale sample ?

6. Both the coquina and the fossiliferous limestone represents ancient storm deposits on a beach. How can you distinguish between these two samples ?

7. Ooids are spherical chemical precipitants made of calcite that are often mistaken for quartz sand. What simple test could you use to tell the difference between them ?

8. How can you tell that bituminous coal is composed of the ancient carbon remains of plants ?

9. Shale often contains bits of fossilized plant material. It can easily be confused with coal. Describe how you could tell the difference between shale and coal.

10. What test could you use to confirm that rock gypsum is made up of pure gypsum ?