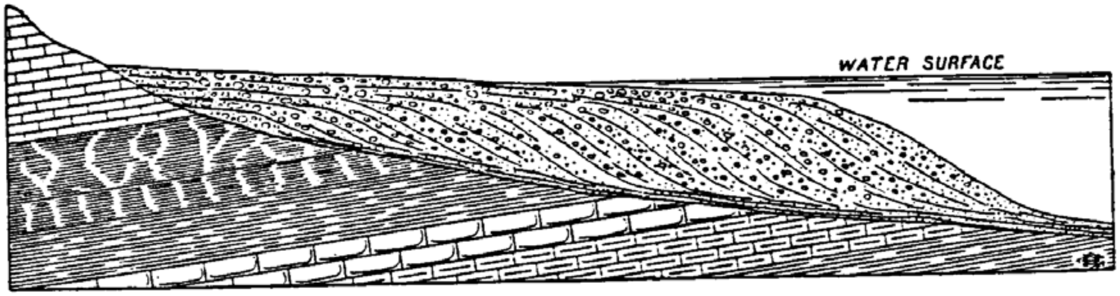

Chapter 3

Sedimentary Rocks

Rivers that flow into the Gulf of Mexico through Alabama and other Gulf Coast states are typically brown, yellow-orange or red in color due to the presence of fine particulate material suspended within the water column. This particulate material is called **sediment**, and it was produced through the **erosion** and **weathering** of rocks exposed far inland from the coast (including the Appalachian Mountains). Sediment transported by rivers eventually finds its way into a standing body of water. Sometimes this is a lake or an inland sea, but for those of us that reside in southern Alabama, it is almost always the Gulf of Mexico. When rivers enter standing bodies of water (e.g., the Gulf), the **sediment load** that they are carrying is dropped and **deposition** occurs. Usually deposition forms more or less parallel layers called **strata**. Given time, and the processes of compaction and cementation, the sediment may be **lithified** into **sedimentary rock**.

It is important to note that deposition of sediment is not restricted to river mouths. It also occurs on floodplains surrounding rivers, on tidal flats, adjacent to mountains in alluvial fans, and in the deepest portions of the oceans. Sedimentation occurs everywhere and this is one of the reasons why your humble author finds sedimentary geology so fascinating.

Sedimentary rocks comprise approximately 30% of all of the rocks exposed at the Earth's surface. Those that are composed of broken rock fragments formed during erosion of bedrock are termed **siliciclastic** sedimentary rocks (or **clastic** for short). Sedimentary rocks can also be produced through **chemical and biochemical** deposition. These processes give

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Figure shows a schematic diagram of a delta complex prograding over top of shallowly dipping strata. From: LeConte, J., 1905. Elements of Geology. D. Appleton and Co., New York, NY, 667p.

rise to a variety of sedimentary rocks including limestones, cherts and the evaporites. **Organic sedimentation,** which involves vegetation, is a special form of biochemical sedimentation. Plant-rich sediment can accumulate to form peat and various types of coal. Chemically and biochemically produced sediment is frequently deposited in the exact same place it is produced. This is known as ***in situ*** **deposition**. However, siliciclastic sediment can be **transported** a long distance from its **source** (the area where weathering and erosion of bedrock is occurring), through the action of wind, water and ice before it is finally deposited. As a result, siliciclastic sedimentary rocks frequently retain physical evidence of sediment transport in the form of **cross-stratification** or other **sedimentary structures.**

Sedimentary rocks are classified on the basis of their origin, mineralogy and texture. In those cases where sediment particles are extremely small, microscopic examination may be required to positively identify the mineralogy and texture of a sedimentary rock (especially those that are siliciclastic). In these situations, siliciclastic sedimentary rocks are normally named according to the size of the grains. This is known as **grain size**.

3.1 Siliciclastic Sedimentary Rocks

3.1-1. Origin

Siliciclastic sedimentary rocks are produced primarily through weathering and erosion of bedrock exposed at the Earth's surface. Since bedrock can be composed of any type of rock (igneous, sedimentary, metamorphic), the type of sediment derived from the erosion of bedrock will vary greatly. Weathering is a complex process which involves elements of **physical** and **chemical** alteration. You are advised to consult your lecture notes and textbook for details on how weathering occurs. In your reading, you will learn that some minerals (e.g., olivine, pyroxene and calcium-plagioclase), are unstable at the Earth's surface and tend to chemically alter very rapidly. These are the minerals that occur near the high-temperature end of Bowen's Reaction Series (see Figure 2.1 in this lab manual). In contrast, quartz (a low temperature mineral in Bowen's Reaction Series), is quite stable at the Earth's surface. It is primarily for this reason that quartz becomes concentrated in sediment with progressive chemical weathering of rocks, whereas olivine, pyroxene and feldspar are preferentially removed. Sediment containing large percentages of unstable minerals tend to occur only in areas near the bedrock source. These sedimentary rocks are said to be **immature** because chemical weathering has not yet had enough time to remove the unstable minerals. Along the Gulf Coast which is a long way from the Appalachian source of the sediment, we see the result of prolonged chemical weathering. Our world renowned beaches are white in color because quartz dominates the sediment. This sand is said to be **mature**.

3.1-2. Textures of Siliciclastic Sedimentary Rocks

The term texture as applied to sedimentary rocks, has the same general meaning as that defined earlier in this lab manual for igneous rocks; *the general appearance or character of a rock.* The textural characteristics that are most important for sedimentary rocks are as follows: 1) sediment **grain size**, 2) **grain rounding** and 3) **sorting** (Figure 3.1). The term grain size refers to the average particle size within a sedimentary rock. It is usually determined by measuring the dimensions of many sediment particles (in millimetres), and calculating the average or mean of these data (Figure 3.1a). Grain size is one of the fundamental ways in which siliciclastic sedimentary rocks are named and provides vital information about the manner in which the sediment was transported and deposited. The degree of rounding of sedimentary particles also provides information about sediment transport. Grains that have been transported a long distance have had ample time in which to become abraded by contact with other grains. In effect, the further a grain is transported, the fewer sharp edges it retains (and the more rounded the grains appear; Figure 3.1b). **Well-rounded** grains have usually been transported a long distance from their source. **Angular** grains generally have not.

Sorting refers to the degree of uniformity of particle size within a sediment or sedimentary rock (Figure 3.1c). **Well-sorted** sediment is dominated by particles very similar in size. **Poorly-sorted** sediment contains a range of particle sizes. As with grain size and rounding, the relative sorting of sediment provides useful information about the transport history of siliciclastic sedimentary rocks.

3.1-3. Classification of Siliciclastic Sedimentary Rocks

As discussed earlier, sediment grain size is one of the primary ways by which to name siliciclastic sediment and sedimentary rocks. Coarse-grained siliciclastics are composed of sediment particles greater than 2 mm in size. Unconsolidated sediment of this size is generally called **gravel**, but some sedimentologists subdivide this size fraction into pebbles, cobbles and boulders (see Table 3.1). A sedimentary rock composed of gravel would be called a **conglomerate** if the grains are rounded, or a **breccia** if the grains are angular.

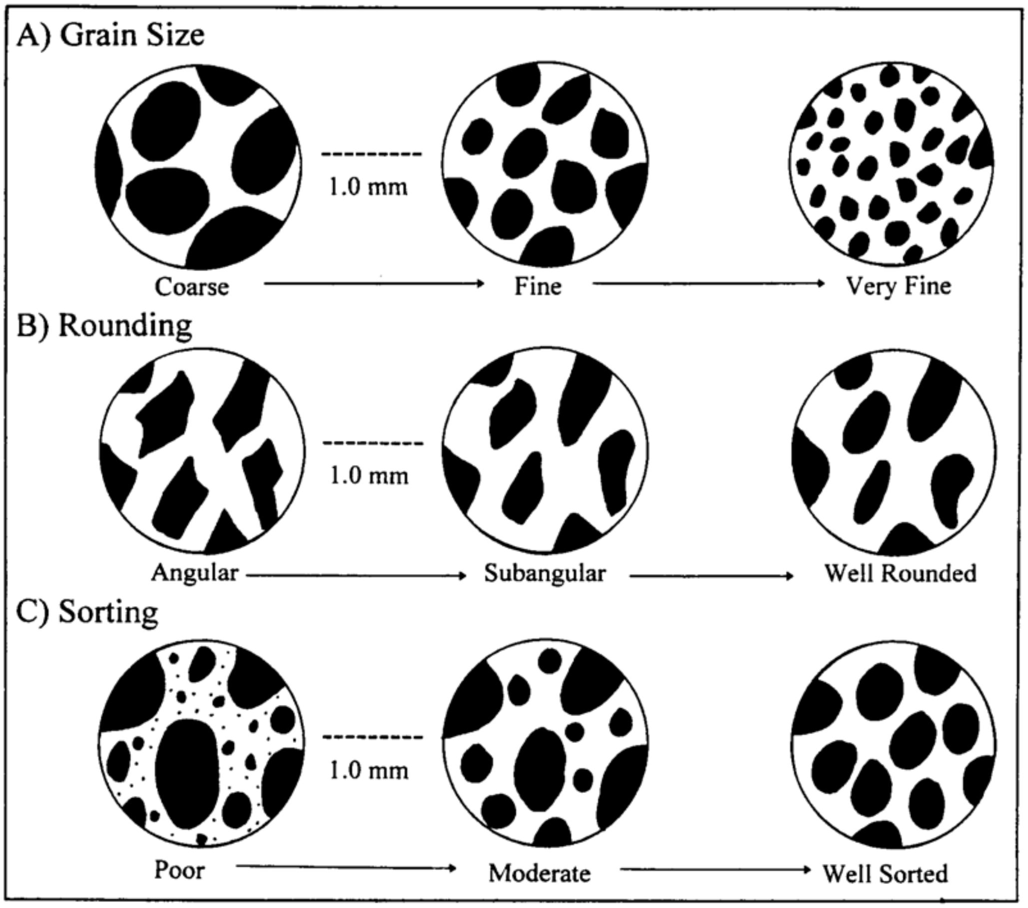

Figure 3-1: Variations in (A) grain size, (B) rounding and (C) sorting for particles in sedimentary rocks

Medium-grained siliciclastic sediment (grain size between 0.063mm and 2mm) is called **sand** and the rock composed of this material would be called a **sandstone**. Fine-grained siliciclastics are called **silt** (**siltstone** for the rock) if the average grain size is between 0.063 and 0.004 mm, or **clay**[1] (**claystone** for the rock) if the average grain size is less than 0.004 mm. As it is pretty hard to distinguish silt from clay even with a hand lens, the terms **mud** and **mudstone** are often used to name sediment and sedimentary rocks dominated by clay and silt-sized grains. If a mudstone parts along well defined planes, it is called a **shale**.

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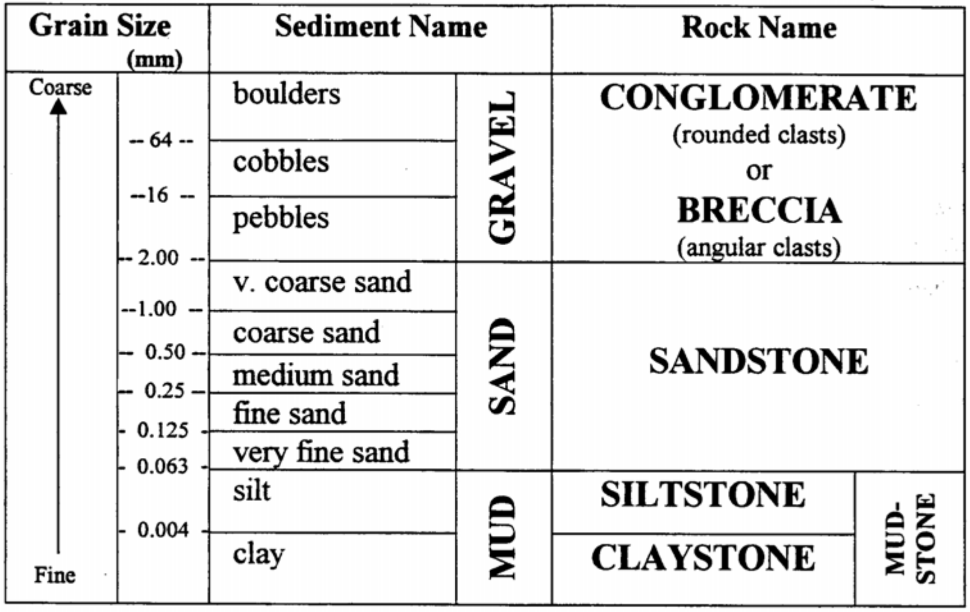
[1] Note: The term clay as used here is not the same as that used in Chapter 1 concerning minerals. Clay in this chapter denotes a particular size fraction rather than mineralogy. Clay-sized sediment can be composed of quartz, feldspar, mica or any other mineral, even the clay mineral kaolinite. It helps that most clay minerals are also clay-sized.

Table 3.1. Grain size characterization of siliciclastic sedimentary and sedimentary rocks



Grain Size (mm)		**Sediment Name**		**Rock Name**	
Coarse ↑		boulders	**GRAVEL**	**CONGLOMERATE** (rounded clasts) or **BRECCIA** (angular clasts)	
	-- 64 --	cobbles			
	--16 --	pebbles			
	-- 2.00 --	v. coarse sand	**SAND**	**SANDSTONE**	
	--1.00 --	coarse sand			
	-- 0.50 --	medium sand			
	-- 0.25 --	fine sand			
	- 0.125 -	very fine sand			
	- 0.063 -	silt	**MUD**	**SILTSTONE**	**MUD-STONE**
Fine	- 0.004 -	clay		**CLAYSTONE**	

Sediment sorting and mineralogy can also be used to name siliciclastic sedimentary rocks, particularly sandstones. If a sandstone contains little silt and clay (e.g., less than 15% by volume), it is said to be an **arenite**. Sandstones containing between 15 and 50% silt and clay are called **wacke** (pronounced wacky), or, more commonly, **greywacke,** owing to their dark grayish-green color. Most geologists regard greywackes as "dirty sandstones." Arenites can be further subdivided in categories reflecting their mineralogical maturity. Mature sandstones are dominated by quartz and are called **quartz arenites**. These rocks are usually well sorted because they were deposited in environments where there was constant sediment movement (e.g., along a beach). Immature sandstones contain either high proportions of feldspar (> 25%) in which they are called **feldspathic arenites** (or **arkose)** or they contain grains that are of mixed origin (quartz, feldspar, mica, broken bits of rock fragments), in which case they . Both varieties are generally less well sorted than their quartz-rich counterparts. Greywackes are the least well sorted of all the sandstones.

Color is a useful means by which to distinguish various sandstones from one another. For example, most quartz arenites are light in color because quartz is generally white. Lithic sandstones are usually light gray and greywackes range from grey to grey-greenish. Most arkose is somewhat pink in color because potassium feldspar is pink. BEWARE: not all pink sandstone is arkose. Iron oxide stains and cements (e.g., hematite) can color quartz arenite pink to red. These "red sandstones" are common in arid regions such as deserts. The moral is make sure that you examine every sandstone with a hand lens before you jump to conclusion about its composition. Try to identify the components that make up the grains in siliciclastic rocks before you try naming them.

Geologists generally do not apply specific names to conglomerates, siltstones or claystones regardless of their sorting or mineralogy. However, it is not unusual to find short descriptions applied to the basic rock name (e.g., well sorted, quartz-conglomerate, glauconitic claystone etc.).

Table 3.2 lists all the sedimentary rocks you are responsible for in GY 111 as well as some of the diagnostic features that allow you to distinguish between them.

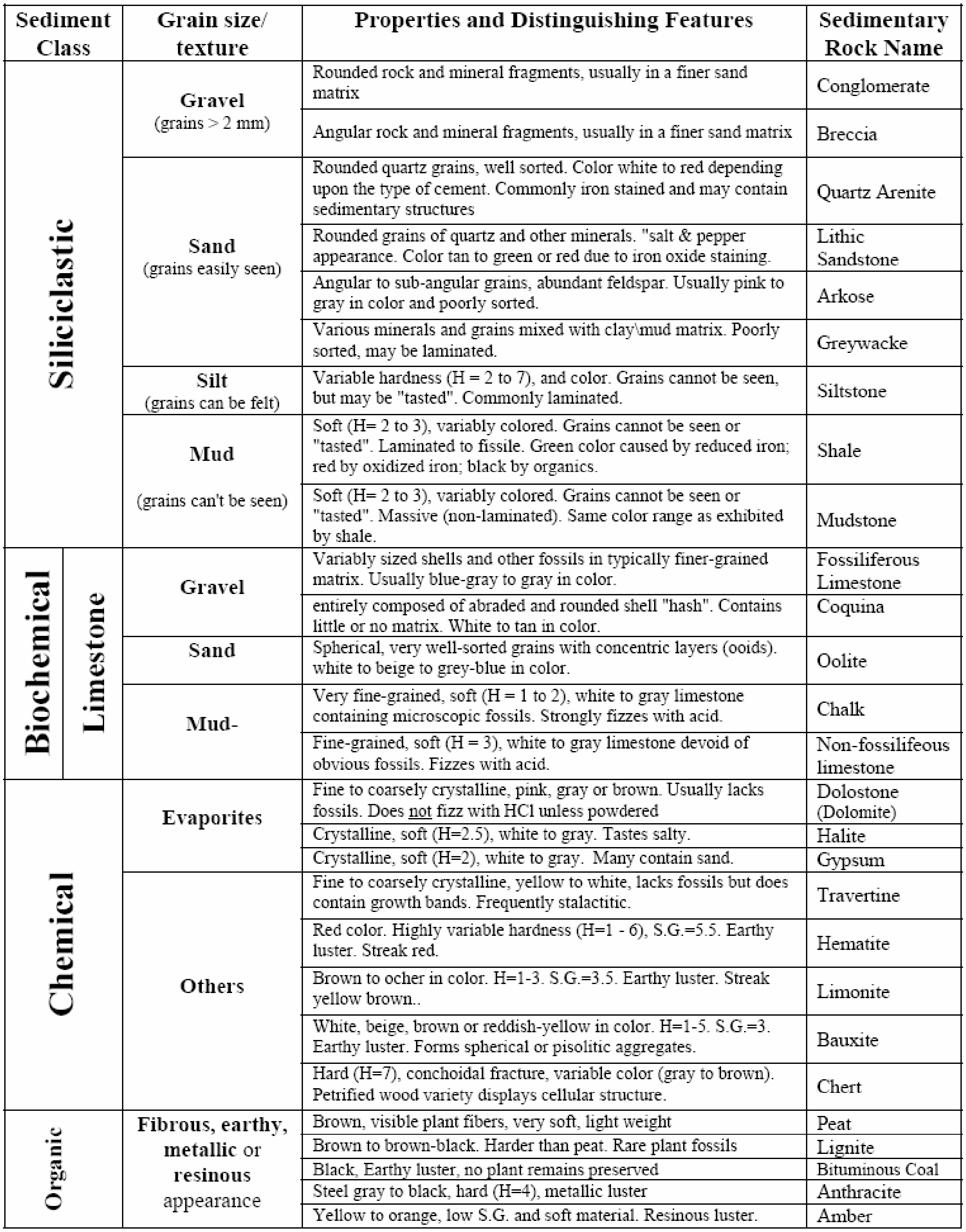
3.2 Chemical and Biochemical Sedimentary Rocks

This group of sedimentary rocks encompasses a diverse variety of materials and minerals that are either produced through biochemical or chemical precipitation. The most volumetrically important are composed of carbonate minerals (limestone and dolostone). Other important sedimentary rocks of this group are chert and the evaporites. Coals are a special variety of biochemical sedimentary rocks which are discussed separately in section 3.3.

3.2-1. Limestone

Limestone is primarily composed of the **carbonate minerals** calcite and aragonite ($CaCO_3$). These minerals occur in two basic forms: 1) fragmented grains of once living organisms such as clams, oysters, corals, starfish etc., and 2) as a chemical cement precipitated between the grains that hold the rock together. It is for these reasons that limestones are classified as "biochemical" sedimentary rocks. Most limestones formed from carbonate sediment that was deposited in marine environments. The types of environments where carbonate sediment is deposited today is highly variable (beaches, reefs, deep sea etc.). Since different organisms live in different environments, the types of shells and other fossils that comprise limestones are diverse. They include corals, barnacles, clams and oyster shells, some trilobites, bryozoans and many others. Fortunately for those of you in GY 111, naming limestones does not involve identifying specific fossils. You get to do this joyful task in GY 112! In GY 111, it is sufficient

Table 3.2. Classification and identification chart for hand specimens of common sedimentary rocks.



Sediment Class	Grain size/ texture	Properties and Distinguishing Features	Sedimentary Rock Name
Siliciclastic	**Gravel** (grains > 2 mm)	Rounded rock and mineral fragments, usually in a finer sand matrix	Conglomerate
		Angular rock and mineral fragments, usually in a finer sand matrix	Breccia
	Sand (grains easily seen)	Rounded quartz grains, well sorted. Color white to red depending upon the type of cement. Commonly iron stained and may contain sedimentary structures	Quartz Arenite
		Rounded grains of quartz and other minerals. "salt & pepper appearance. Color tan to green or red due to iron oxide staining.	Lithic Sandstone
		Angular to sub-angular grains, abundant feldspar. Usually pink to gray in color and poorly sorted.	Arkose
		Various minerals and grains mixed with clay\mud matrix. Poorly sorted, may be laminated.	Greywacke
	Silt (grains can be felt)	Variable hardness (H = 2 to 7), and color. Grains cannot be seen, but may be "tasted". Commonly laminated.	Siltstone
	Mud (grains can't be seen)	Soft (H= 2 to 3), variably colored. Grains cannot be seen or "tasted". Laminated to fissile. Green color caused by reduced iron; red by oxidized iron; black by organics.	Shale
		Soft (H= 2 to 3), variably colored. Grains cannot be seen or "tasted". Massive (non-laminated). Same color range as exhibited by shale.	Mudstone
Biochemical **Limestone**	**Gravel**	Variably sized shells and other fossils in typically finer-grained matrix. Usually blue-gray to gray in color.	Fossiliferous Limestone
		entirely composed of abraded and rounded shell "hash". Contains little or no matrix. White to tan in color.	Coquina
	Sand	Spherical, very well-sorted grains with concentric layers (ooids). white to beige to grey-blue in color.	Oolite
	Mud-	Very fine-grained, soft (H = 1 to 2), white to gray limestone containing microscopic fossils. Strongly fizzes with acid.	Chalk
		Fine-grained, soft (H = 3), white to gray limestone devoid of obvious fossils. Fizzes with acid.	Non-fossilifeous limestone
Chemical	**Evaporites**	Fine to coarsely crystalline, pink, gray or brown. Usually lacks fossils. Does not fizz with HCl unless powdered	Dolostone (Dolomite)
		Crystalline, soft (H=2.5), white to gray. Tastes salty.	Halite
		Crystalline, soft (H=2), white to gray. Many contain sand.	Gypsum
	Others	Fine to coarsely crystalline, yellow to white, lacks fossils but does contain growth bands. Frequently stalactitic.	Travertine
		Red color. Highly variable hardness (H=1 - 6), S.G.=5.5. Earthy luster. Streak red.	Hematite
		Brown to ocher in color. H=1-3. S.G.=3.5. Earthy luster. Streak yellow brown..	Limonite
		White, beige, brown or reddish-yellow in color. H=1-5. S.G.=3. Earthy luster. Forms spherical or pisolitic aggregates.	Bauxite
		Hard (H=7), conchoidal fracture, variable color (gray to brown). Petrified wood variety displays cellular structure.	Chert
Organic	**Fibrous, earthy, metallic** or **resinous** appearance	Brown, visible plant fibers, very soft, light weight	Peat
		Brown to brown-black. Harder than peat. Rare plant fossils	Lignite
		Black, Earthy luster, no plant remains preserved	Bituminous Coal
		Steel gray to black, hard (H=4), metallic luster	Anthracite
		Yellow to orange, low S.G. and soft material. Resinous luster.	Amber

to name a limestone containing obvious organic remains (e.g., shells in a matrix of fine sediment), a **fossiliferous limestone**. Most of these types of limestones are light gray to dark gray, however, glauconitic limestone is green in color because it contains significant amounts of glauconite (a green mineral). Several other limestones composed of fossil remains are listed in Table 3.2. Of these, **coquina** and **chalk** are the most important.

Coquina is a particularly fossiliferous variety of limestone. Its name is derived from a type of bivalve (the coquina shell), that is common on beaches in southern Florida. The shells are so abundant that they alone are the sole ingredient in the fossiliferous limestones that form in this area. The term coquina limestone is today not so restrictive. It is used for any limestone that is primarily composed of shell remains (mostly bivalves). Coquinas are usually readily identifiable by their color (yellow to white), and their very porous nature.

Chalk is also fossiliferous, but the organisms that comprise it are far too small to be identified with a hand lens. Chalks are composed of carbonate microfossils like foraminifera or nannofossils like coccoliths (you will learn more about these beasties in GY 112). The fact that chalks are composed of very small organisms makes their positive identification difficult. Most chalks are white to very light gray in color and are relatively soft (hardness 1 to 2). The materials most commonly confused with chalk are kaolinite and **non-fossiliferous limestone**. Kaolinite is a clay mineral and does not react with HCl (it also sticks more readily to your tongue). Non-fossiliferous limestone is a carbonate rock that is composed of fine-grained particles and reacts with acid. Most of the grains in non-fossiliferous limestone are broken up, minute pieces of other carbonate components so they are distinct from chalks. They are generally harder (hardness 1 to 3) and darker in color (light gray to dark gray) than chalk.

Oolitic limestones (or **oolites**) are an example of a non-fossiliferous limestone. These white to gray limestones are composed of exceptionally well sorted, spherical carbonate grains called **ooids** that are each between 1 and 2 mm in size. Most geologists believe that ooids formed through inorganic precipitation (chemical sedimentation), possibly using organic films as templates, on the sea floor in tropical environments like the Bahamas. In much the same way that a snowball grows larger when you roll it across the snow, ooids are thought to grow larger by rolling back and forth across the sea floor. As a result of this motion, individual ooids build up layer upon layer of carbonate minerals.

In a hand lens, you can frequently see the spherical layering within individual oolites, a diagnostic means by which to identify these particular limestones.

Limestone is chemically susceptible to alteration via pore water and burial. One of the most dramatic changes that can occur is complete recrystallization. Every grain in the limestone (fossils, ooids, etc.) and all of the cement dissolves virtually simultaneously with precipitation resulting in large calcite crystals (greater than 1 or 2 mm each). These **crystalline limestones** are easy to identify as they display crystal faces when examined with a hand lens**.**

3.2-2. Chert

Chert is a rock of variable color that is composed of cryptocrystalline quartz. It forms through either biochemical or chemical sedimentation. Most biochemical chert is formed in much the same way as chalk; through the accumulation of microfossils in a marine environment. The only difference is that the microfossils that produce chert (mostly radiolarians) are composed of silica (SiO_2) rather than carbonate minerals. Like chalk, individual microfossils cannot be distinguished within biochemical chert. Instead, the rock is distinguished on the basis of its hardness (H=7).

Chemical chert forms through the alteration of pre-existing rocks, especially limestone. In some cases, preserved fossils can be identified within the chert. In other cases, alteration is so extensive that all fossils are destroyed. It is frequently impossible to distinguish between biochemical and chemical chert without the aid of a powerful microscope, and you are not expected to do so in GY 111.

Cryptocrystalline quartz also frequently replaces organic material within fossilized wood. The result is **petrified wood**. It can be distinguished from other varieties of chert by its characteristic "wood grain" texture.

3.2-2. Evaporites

Sea water contains an enormous amount of dissolved chemical substances which is the reason why it tastes salty. If sea water is evaporated, the concentration of the ions dissolved in it will increase. Eventually, some of the dissolved chemicals will precipitate out forming **evaporite minerals** (or **evaporites**). Evaporite minerals precipitate in the following order: 1) **calcite,** 2) **dolomite**, 3) **gypsum**, 4) anhydrite**,** 5) **halite** and 6) sylvite. It is important to note that the chemical composition of the water changes with each evaporite mineral precipitated. If new sea water is added to the evaporating brine (a common occurrence that is caused by tidal flooding or waves washing into an arid coastal area), the chemical composition of the water may change significantly enough to change the precipitation order. Cyclic evaporite sedimentation is common in evaporite sedimentation (see discussion on lakes below).

You should already be familiar with the properties of calcite, dolomite, gypsum and halite (if not refer to the first section on minerals). The dolomite that precipitates out in evaporite environments can be much finer than the pink dolomite you had in your mineral tray. In fact, evaporite dolomite can be so fine as to make distinguishing individual crystals within a sample virtually impossible. The proper name for a rock composed of finely-crystalline dolomite is **dolostone**. Most dolostones are light gray to beige in color and can easily be confused with micritic limestones. Fortunately, dolomite does not fizz with hydrochloric acid (unless it is powdered), so a good way to distinguish dolostone from limestone is by dropping a bit of dilute hydrochloric acid on the un-powdered sample.

Sylvite has the chemical composition KCl and is a relative of halite (NaCl). Not surprisingly, the two minerals have similar properties. These include hardness (H = 2.5), luster, specific gravity and a salty taste. So similar are the minerals that sylvite can be used as a salt-substitute for individuals requiring a low sodium diet. Sylvite can be distinguished from halite by its slightly bitter aftertaste, its reddish color and "greasy" feel (caused by its reaction with the humidity in air).

Evaporite minerals can also precipitate from lakes, often seasonally. When conditions are very dry (e.g. during the summer), light colored minerals like gypsum will be precipitated. When conditions are less dry (e.g., winter), darker colored dolomite (or calcite) will be precipitated. The result is a cyclic alteration of light and dark colored minerals which geologists refer to as banded gypsum.

3.2-3 Other Chemical Sedimentary Rocks

There are countless other types of chemical sedimentary rocks that can form on the Earth's surface and just below it where groundwater percolates. All but a few, **hematite, limonite. bauxite** and **travertine,** can be ignored in GY 111.

You are already familiar with the first three chemical sedimentary rocks; however, you were introduced to them as "minerals". Hematite was the heavy mineral (S.G. = 5.6), that produced a red powder on a streak plate. Much of the hematite that we find on the Earth is actually a sedimentary mineral. It forms through chemical precipitation, or through chemical replacement of earlier sedimentary rocks. Red Mountain just outside of Birmingham is a classic example of this type of chemical sedimentary rock. Here, fossiliferous limestone and oolitic limestone have been replaced by hematite (hence the term **hematite-replaced limestone** that some geologists use in place of just hematite).

Hematite, along with limonite and bauxite, are also products of weathering. Limonite you will recall, is the yellow-rust colored earthy material seen during the minerals component of GY 111L. Bauxite is the variably colored (frequently reddish-white) "pisolitic" material in the minerals drawer. All three of these minerals form through the chemical breakdown of other rocks (mostly the siliciclastic class). The iron oxides/hydroxides (hematite and limonite) and aluminum oxide (bauxite) are the only substances left in an extremely chemically weathered soil. Bauxite only forms in tropical regions subjected to the most extreme chemical processes (e.g., northern Australia, Jamaica etc.).

Travertine is likewise an "old friend", albeit in a different form. It is calcite that was chemically precipitated as speleothems (stalactites, stalagmites, flow rock etc.) in caves. Like hematite-replaced limestone, travertine is produced by groundwater flowing beneath the Earth's surface. Because travertine is a form of calcite, it has the same overall mineralogical properties as calcite (e.g. hardness 3, reaction with acid etc.). Travertine is distinguished from calcite (and limestone) by being crystalline. If it came from a stalagmite or a stalactite, it will probably also contain concentric lamellae, a result of the layer by layer addition of $CaCO_3$ during precipitation.

3.3 Organic Sedimentary Rocks

Sedimentary rocks consisting mostly of plant detritus are a special class of biochemical sedimentary rocks. These **organic sedimentary rocks** are formed in anaerobic (low oxygen) environments such as swamps where abundant plant material is produced. In the presence of oxygen, organic material will be oxidized to carbon dioxide (CO_2) and lost from the sediment. Without oxygen, organic material can be retained in the sediment. As more and more plant detritus is produced, compression of the lowest layers begins to occur. The result is a brown, fibrous mass of twigs and leaves called **peat.** Anyone who has ever planted a tree is familiar with peat (as peat moss). You are supposed to put a ball of peat at the base of the roots to retain soil moisture.

As further burial occurs, the organic material comprising peat experiences higher temperature and pressure. With time, peat can be converted into **lignite**, the first true grade of **coal**. Lignite is a dull, very soft, brown-black material that seldom contains any recognizable plant relicts (pressure and temperature tend to homogenize the organic material). Increased pressure and temperature (approaching that which can form metamorphic rocks) will convert lignite first into **bituminous coal** and ultimately into **anthracite**. Anthracite is the highest grade of coal found on the Earth and forms only under conditions so extreme that it is generally considered a metamorphic rock (Ch. 4). Both bituminous coal and anthracite are black in color, but their hardnesses and "lusters" are very different. Bituminous coal (hardness 1 to 3), is softer than anthracite (hardness 3 to 4), and anthracite has a very shiny, nearly metallic luster. The differences between the coals are diagnostic, especially if you examine all grades together at the same time.

Another organic sedimentary rock that you might see in the labs is fossilized tree sap or **amber**. Amber is yellow to orange, very light and frequently contains the remains of insects. It was this latter property that made amber "famous" in the movie *Jurassic Park*.

3.4 Sedimentary Structures

Sediment is generally deposited in discrete horizontal layers called **strata**. These sedimentary packages can be 100's of metres thick. Strata is in turn made up of much smaller-scaled layers called **beds**. The scale of **bedding** is highly variable. Thinly-bedded sedimentary rocks are characterized by 1 to 5 cm thick layers. The layering in medium-bedded sedimentary rocks varies between 5 and 50 cm in thickness. Sedimentary rocks containing beds that are greater than 50 cm in thickness are considered to be thickly-bedded. The term **bedding sequence** is used to describe the pattern of interbedding involving different sedimentary rocks (i.e. sandstone, conglomerate, limestone, coal). sedimentary layers and strata are discussed much more in Chapter 5 of this lab manual.

Some individual sedimentary beds are homogeneous (e.g. a micrite limestone), but many others are characterized by a very fine layering on the order of 1 to 2 mm in thickness. This fine layering is known as **lamination**, and can be either parallel to the bedding (**parallel lamination**) or inclined at an angle to the bedding (**cross-stratification**). All kinds of lamination, as well as other features generated by currents during deposition of sediment are called collectively **sedimentary structures**.

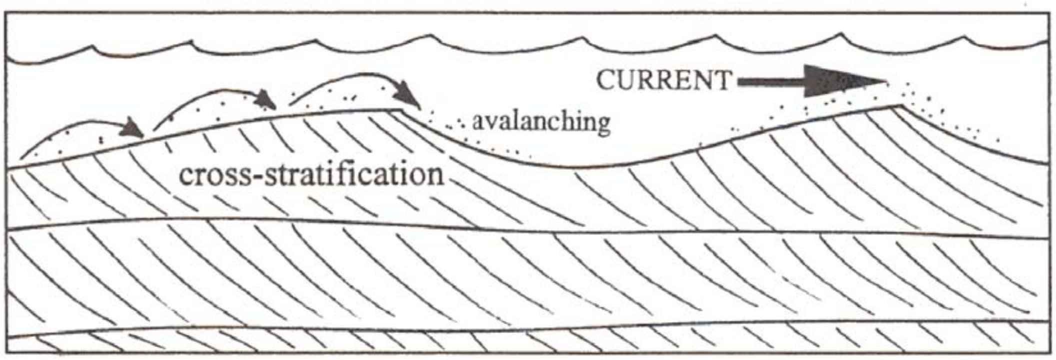


Figure 3-2: Ripples form when currents move sediment along a river bed or the sea floor. Cross-stratification results from the avalanching of sediment down the steep side of the ripple.

Cross-stratification (sometimes called **cross-bedding**) results when sediment migrating along a river bed or sea floor is piled up into **ripples, sand dunes** and other **bedforms** by currents. The inclined lamination results from sediment avalanching down the steeper side of the ripple or dune (Figure 3.2). Parallel lamination is also caused by currents, but faster than the ones than develop ripples or dunes. The best place to find parallel lamination is in the quartz-rich sediment deposited along the surf zone of beaches.

Sedimentary structures reveal much about the processes responsible for deposition. They commonly occur in an orderly succession indicative of increasing or decreasing currents during deposition. There are many other sedimentary structures that are outlined in some detail in physical geology textbooks. Many of them will be discussed during the sedimentology portion of GY 112 and in advanced courses intended for geology majors such as GY 344\444.

3.5 Environments of Deposition

By now, you probably have the feeling that sedimentary rocks can be composed of anything, and that they can form anywhere on the Earth's surface. That is more or less correct. As long as a sediment-making process is operating (e.g., weathering etc.), and as long as the sediment can be deposited in some sedimentary **basin** (a depression on the Earth's surface; Chapter 6), sedimentary rocks can form. Sedimentologists regard areas where sediment is being deposited as **depositional environments**. Table 3.3 and Figure 3.3 summarize the processes and types of sediment that occur in the world's major depositional environments. You will learn more about this material in the lecture component of GY 111. If you can't wait, feel free to read the relevant chapters in your textbook. You may find that understanding depositional environments also helps you understand the sedimentary rocks that you are responsible for in the labs.

3.6 Identifying Sedimentary Rocks: A Survival Guide

Most of the sedimentary rocks that you will encounter in GY 111 are summarized in Table 3.2. As with other rocks, there is a technique to identifying sedimentary rocks. Do not immediately try to name a rock when you first pick it up. Instead, determine if a sedimentary rock is siliciclastic, biochemical\chemical or organic. For example, if you pick a sample from your specimen tray that is light weight, black and contains obvious plant material, it is an organic sedimentary rock. That narrows the rock's identity to one of only four possibilities. If the rock is not black, lightweight and full of plant material, it is unlikely to be organic and you can therefore eliminate the 4 organic varieties. Is the rock siliciclastic (i.e., does it contain quartz or feldspar particles)? If so, use your hand lens and a ruler to estimate the average grain size of the particles. As you know, some sedimentary rocks such as shale and mudstone are very fine grained and you will not be able to see grains. Look for other evidence of a detrital origin such as sedimentary structures. If grains are present, try to identify their mineralogy. A sandstone full of quartz grains is a quartz arenite. One containing obvious feldspar is an arkose. One containing fine matrix material that is gray or green in color is a greywacke, etc. A rock that is not organic and does not appear to be siliciclastic is likely biochemical\chemical. Is the specimen harder than glass (chert), or does it react when a small drop of acid is placed on it (limestone)? Use your hand lens to classify any limestones according to the information provided in Table 3.2. If the rock is soft (less than 4), and no reaction is apparent with acid, you probably have an evaporite mineral on your hands. Halite can be distinguished on the basis of taste, but use caution. The person before you may have just attempted the acid test on the specimen you are about to lick.

Figure 3.3. Schematic representation of some of the major sedimentary environments summarized in Table 3.3. No scale is implied.

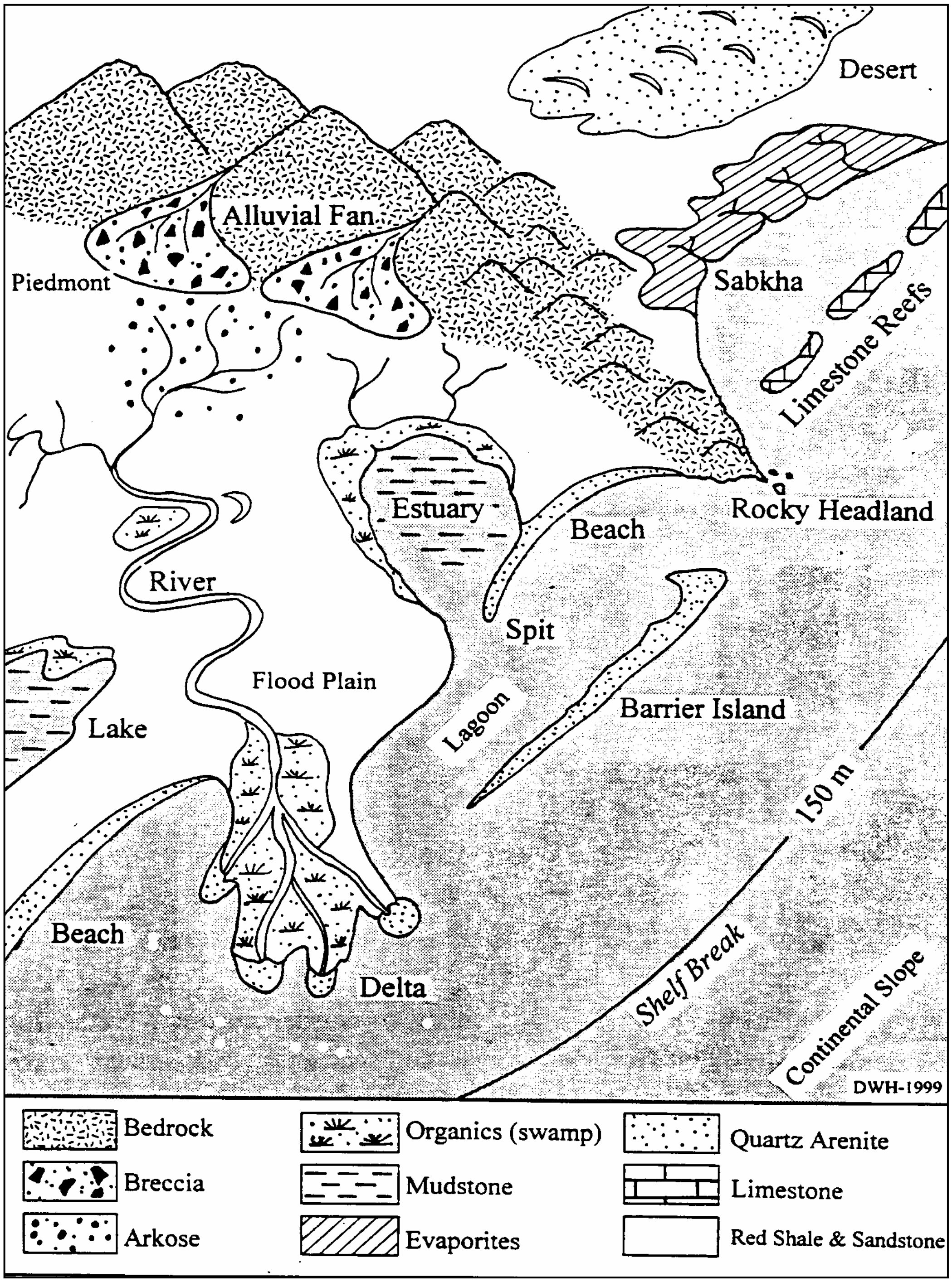


Table 3.3. Names and environments of deposition of sedimentary rocks in GY 111.

GY 111 Rock Name	Environment of Deposition
SILICICLASTIC	
conglomerate	river/stream bed (channel)
breccia	alluvial fan\piedmont
white quartz arenite	beach
red quartz arenite	desert
arkose sandstone	alluvial fan\piedmont
greywacke sandstone	continental slope, deep marine
siltstone	delta/ river (flood plain)
red shale	river/stream flood plain
black shale	swamp or deep marine (depends on fossil content)
green shale	variable (lagoon – marine)
CHEMICAL\BIOCHEMICAL	
limestone (oolitic)	shallow marine (wave zone)
limestone (fossiliferous)	shallow marine
limestone (glauconitic)	shallow marine
limestone (non-fossiliferous)	marine
limestone (chalk)	deep marine
chert	deep marine (deep) or replacement
travertine	cave
evaporite (dolostone)	evaporite basin/sabkha
evaporite (halite)	evaporite basin/sabkha
evaporite (gypsum)	evaporite basin/sabkha
hematite	soil (chemical weathering)
limonite	soil (chemical weathering)
bauxite	soil (chemical weathering)
ORGANIC	
peat	swamp
lignite	
bituminous coal	
anthracite	
amber	

3.7 Exercises

Check with your lab instructor to determine which of the optional exercises (if any) that you are responsible for in this lab component of GY 111. Regardless of these exercises, all students should be able to identify sedimentary rocks and minerals rocks like those provided in the rock tray.

For the exam, you should be able to identify the following attributes of each sedimentary rock specimen:

(a) their texture or class (siliciclastic, chemical\biochemical, organic)
(b) their mineral composition (quartz, carbonate, coal etc.).
(c) particle sorting and degree of rounding (Figure 3.1)
(c) if siliciclastic, their grain size (Table 3.1)
(d) their properties and name (Table 3.2).
(e) their probable environment of deposition (Table 3.3, Figure 3.3)

Optional Exercises

You may wish to refer to your lecture notes and/or textbook for assistance in answering some of these questions.

1) How would the grain size of sediment deposited along a river point bar differ from the sediment deposited on the flood plain? How would the grain size of sediment deposited in a deep ocean trench differ from the sediment deposited near a reef. Why the differences?

2) What kind of sediment would you expect to find deposited in
    a) a lake located in a cool rain forest.
    b) a lake located in a desert.
    c) a lake located on the tundra of Alaska.

3) In what way would the fossil content of quartz arenite sandstone deposited along a beach differ from the fossil content of the same type of sandstone deposited along a river point bar?

4) Explain how and why evaporite minerals precipitate during sea water evaporation. Why do the minerals precipitate in a specific order?

5) In which ways do mature and immature siliciclastic sandstones differ?

6) Southern Alabama is underlain by thick sequences of sedimentary rocks. Refer to the geological map of Alabama in the hallway outside of your classroom. The different colors refer to strata of different ages. Can you explain the stratal patterns in southern Alabama?

7) How is sediment converted into sedimentary rock? In what way(s) might quartz sand on Dauphin Island be converted to quartz arenite?

8) In what way(s) would sediment deposited by a glacier differ from sediment deposited by a river?

9) Why is it better to make tombstones out of quartz arenite than limestone? (Hint: think about mineral stability).

10) The orientation of ripples in a sandstone can give the direction of current flow during the deposition of the sandstone. Geologists refer to this orientation as the **paleocurrent.** How could you distinguish between sediment deposited in a river and sediment deposited in a tidal channel using paleocurrents alone (This isn’t a particularly difficult question, but it does require you to think about how sediment moves in each of these environments).