SEDIMENTARY ROCKS

INTRODUCTION

Weathering, erosion and deposition

The start of sedimentary rocks is the weathering process of the rock cycle as surface materials are weathered they decay to particles and dissolved material (solutions). The erosion of particles by **water** and **wind** plus the additional force of **gravity** moves the weathered materials. Though these processes happen everywhere on the earth, the most weathering and erosion is in the mountains and along with gravity's help particles and dissolved material are moved inevitably to the lowest elevation that is the ocean basins. Thus sediments are moved to the sea and eventually subducted or moved by plate tectonics. As well, sediments may be dropped, or deposited, not making it to the sea and solidify to solid rock. This happens by cementation of grains and compaction. Sedimentary rocks may spend long times on the continents, perhaps billions of years, before they are weathered again or they may be reverted back to new minerals by igneous and metamorphic processes.

Whatever precious gems and metals were mixed in the weathered rock are also released and moved along. Since gems must be durable (with good tenacity), they last well and are concentrated with the denser sedimentary particles. Much of our gold, diamonds, and other precious substances are mined from sedimentary rocks.

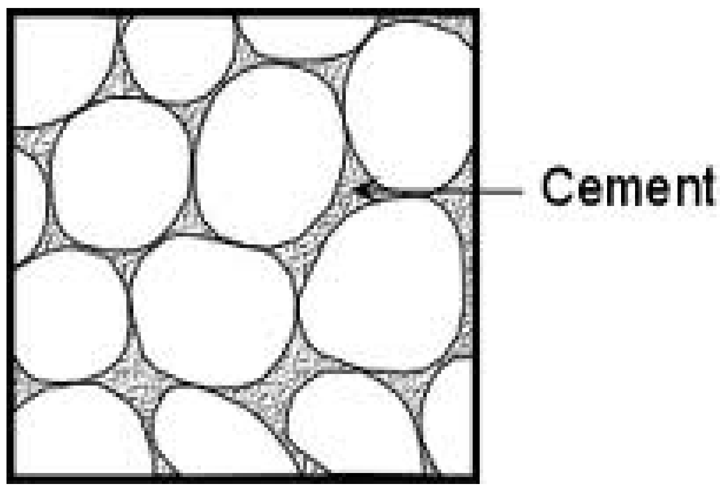

Figure 1. Gray areas are cement deposited inorganically between grains.

Evaporites, sedimentary inorganic chemical deposits, and cement

Many interesting and attractive minerals form in precipitated salts (out of salty water). The rocks formed from the drying out of water include rocks salt, rock gypsum, borates, such as ulexite, and some limestones such as lithographic limestone that is used in printing. Though these rocks and their mineral constituents are attractive, no true gems form in this way.

Cement is an inorganic precipitate, between grains, that binds sedimentary particles together to form a solid rock (Figure 1).

Organic deposits

A few gems form as organic accumulations such as when plant material collects. Both coal and amber form in such deposits. **Coal** is used in the gem **Jet**, a black organic compound that takes a good polish. It is used in mourning jewelry (for funerals, etc).

Amber is fossil tree resin that oozes from trees. When buried it can harden into a transparent gem. In ocean sediments, the shells of ancient mollusks related to present day squid and octopus accumulated to form **ammolite**, a fossilized **mother of pearl**. **Coral**, both living and fossil, is used in jewelry as well. Other organic gems include, mammoth ivory, bones, and shark's teeth.

Few of these organic gems are very durable and they are really better treated in their own lab section as organic gems, which also includes **pearls**. Any of these can be related in their origins to the sedimentary system of the earth and can be obtained from sedimentary deposits. Some certainly are found in sedimentary deposits dating back to at least the age of dinosaurs.

Alluvial and other Detrital Sediments (made of particles)

Mostly gems and precious metals are found in accumulations of sand and gravel, alluvial deposits. **Alluvium** is material moved and deposited by rivers. **Placer** deposits (discussed below) are of particular interest to gem hunters. This is because the gem gravel contained in placer deposits can have the most precious of stones, diamonds, rubies, sapphires, jade, gold nuggets, etc.

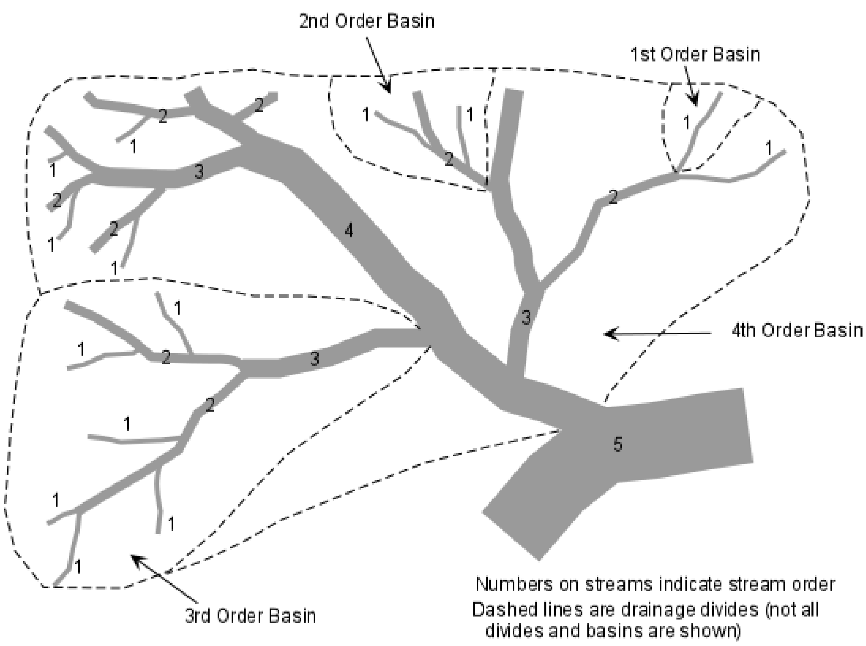

Figure 2. The rivers start in 1st order (1) streams that flow into successively larger stream. An area of many thousand square miles may drain into the largest (5th order streams).

Modern alluvial deposits (those sediments deposited from rivers and streams and still uncemented) are one of the best places to start a search for gems and precious metals, because their drainage basins (see Figure 2) may encompass many square kilometers of area and the sediments derived from weathering of the landscape of the region are then concentrated into a few or single river channels. Rivers are thus followed by **prospectors** (those seeking valuable earth materials) from downstream upstream towards the river's head where it begins. Any branches (**tributaries**) leading into the main stream must also be investigated. The trail of gems or precious metals is followed back to its source. Rivers are both an easy place to travel through rough terrain and pretty easy pickings for gem materials. Devices such a **sluices** (see below) and large dredges (boats that remove and process bottom sediments) are used to concentrate the precious contents. **Dredging** pulls loose sedimentary material off the bottom of the river channel.

However, any modern deposit could also have been formed in the distant past. Over geological time, these **ancient alluvial deposits** will have solidified (been cemented) into hard sedimentary rocks and perhaps climatic conditions have changed so that they are nowhere near a modern stream. To understand these deposits and locate them we need to understand how the **detrital** (made of particles) sedimentary rocks are formed, identified, and classified.

Detrital rocks are formed when accumulated particles (detritus) varying in size from clay and silt to large boulders are deposited. The particles may start their “career’s” in landslided where coarse angular rocks cascade down the side of a mountain. The rock and mineral particles may be transported no further and when cemented form a detrital rock characteristic of this bottom of a cliff or slope environment (**Elluvium** is sometimes used to describe this detritus that is an accumulation of rock debris produced in place by the decomposition or disintegration of rocks that has not been moved by streams). If the particles have been moved primarily by gravity, they will be angular and a rock called **Breccia** (made of angular broken pieces of all sizes) will form. But the particles may also be picked up and rolled down the hill by running water. Fast moving streams start in mountainous areas and may move particles of very large size.

Rounding

When particles are moved by running water they become rounded (Figure 3). The corners hit first and are worn down. The sharp edges are also pounded. The particles may become round boulders or pebbles. Bits of sand move with them. As the water slows the largest particles drop out first, making deposits of round boulders and pebbles called **conglomerate**. The smaller particles are swept away downstream (unless they are trapped between or beneath the large particles).

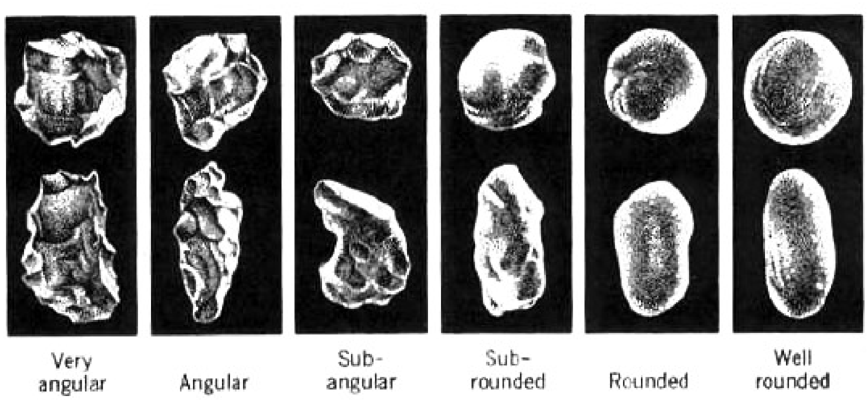

Figure 3. The farther a particle is moved, the more rounded and spherical it should become. Angular particles are deposited close to their source (From Powers, 1959).

Sorting

This sediment moving process of running water sorts particles by size and to a lesser degree by shape. This is called **sorting** (Figure 4). The amount of sorting depending on the conditions and amount of time at which the stream works on the particles. Obviously particles of the same mineral that are more rounded and sorted have traveled further. The sediments **sorting**, **roundness,** and **sphericity** could act as a clue to following either modern or ancient alluvial rocks to their ultimate source. Very well sorted and rounded materials may suggest a source from an older sedimentary rock rather than from igneous rock.

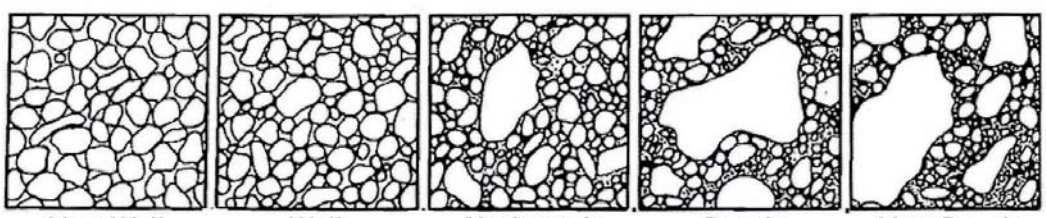

Figure 4. Consider the history of sediment. If the materials are moved long distances they are likely to be well-sorted by size. The closer to a source, the more poorly sorted a sample may be. These are conglomerates to sandstones.

How rocks are sorted by size and density is important. Would a gold pebble (nugget) of ½ inch in diameterbe deposited in a quartz pebble conglomerate with ½ inch pebbles? No. The size of the **gold**
particle would likely be smaller to be deposited with the quartz because gold has a density of 19.3 gm/ml while **quartz** has a density of about 2.65 gm/ml. Gold is about 7 times denser. There must be a **hydraulic equivalency** (water equivalency) of particles for them to be deposited together. In other words, the gold pebbles or sand grains would be about 7 times smaller than the quartz for them to be deposited together. Though there are reasons why this may not be entirely accurate, such as particle shape.

This hydraulic equivalency is dependent on particle size, shape, and density. Suffice it to say that size sorting, shape sorting, and sorting due to density all are at work when a particle is either **entrained** (picked up) or **deposited (**dropped**)** from a fluid.

Mechanical concentration leads to a separation of lighter minerals from heavier minerals and allows particles of approximately the same density and shape to be deposited together. Part of mechanical concentration is **Winnowing.** Winnowing is when materials are drawn off, and it is used to remove the outer husk from wheat. The wheat is tossed into the air and the lighter husks (chaff) are separated from the heavier wheat berries. Such sorting processes happening in a stream tend to concentrate gold, diamonds, etc. into a small volume of rock that makes their mining possible.

Figure 5. Panning.

Deposits

Deposits of particles from a fluid such as wind or water that are likely to hold gold, platinum, or precious gems are mostly tested by **panning** or **sluicing** rock material.

Gold panning involves allowing water to move particles, entrain them in the water, and then settle them (Figure 5). Panning uses settling in water. It tends to allow the densest materials to settle most rapidly in the pan's center. Size and shape would have some effect, but usually are outweighed by density.

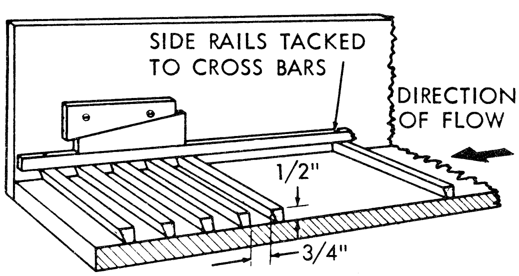

FIGURE 17. – Wooden riffle suitable for use in a sampling sluice.

Figure 6. Inside of a sluice. Riffles are ridges that catch the denser particles, less dense particles are washed away.

Sluicing uses a box like channel with ridges, called **riffles** (Figure 6), on the bottom to trap denser materials, such as gold, in the troughs (bottoms) of the riffles, while less dense particles of material such as quartz are washed over the riffles and out of the sluice box by running water.

In nature, stream bottoms (also called **stream beds**) have natural riffles and **potholes** that tend to concentrate denser materials. Prospectors know to try these spots when looking for precious materials. One wise prospector explained that every crack and crevasse in a dry stream bed needs to be investigated. Careful investigation may lead to success.

One idea that needs to be thoroughly discussed is the idea of **placer deposits** (Figure 7.). Placer is a Spanish word meaning "alluvial sand." It is a deposit of valuable material that has been concentrated in one place by natural actions such as a stream that deposits the heavier material and winnows the lighter material. Dense gems, metal, and coarser-grained detrital material make up the deposits. One ubiquitous (always present), or at least nearly so, mineral in these sands is magnetite. The black magnetite makes "**black sands**." Gold, diamonds, etc. may also be concentrated in blacks sands. Though placers may occur on a beach or due to wind as well, the most common placers are **alluvial placers**.

Alluvial placers are most common where a river makes a turn or curve, called a **meander. Figure 7** shows **meanders**, and because the river turns, water is slowed causing deposition on a point bar. The point bar is on the inside curve of a stream meander. There is more likely to be a concentration here than in a straight stretch of the river.

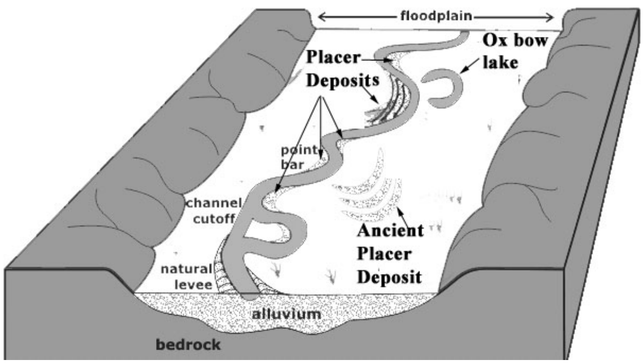

Figure 7. Point bars and placer deposits.

Point bars, and for that matter any bars in a river channel, tend to form layers (beds) of gravel. Coarser bedded deposits of sediment, such as pebbles in gravel, are good places to look for valuable materials, such as gemstones, though gold particles may be of any size

Ancient deposits

Lastly, ancient sedimentary rocks may have a similar origin to present day detritus, but they are cemented together by mineral precipitates (Figure 1). Because they have similar origins, their extent and the way they formed can be modeled based on recent deposits. Though they are harder to work, they may be very significant, such as gold in quartz conglomerate of the Witwatersrand of South Africa that may account for 40% of all gold ever mined (You should see a sample in lab).

Though Brazil is no longer a big producer, it was a major source of alluvial diamonds from about 1730 till around 1870. Diamonds from ancient stream deposits account for much of Brazil's production. The diamonds came from older conglomerate (pebbly rocks) that were weathered into present day streams.

Both gold and diamonds are durable and will last for long times without being destroyed by abrasion or weathering processes.

SEDIMENTARY ROCK EXERCISE

A) Detrital rocks.

For each sample that your instructor assigns make observations and then describe the sample.

Your instructor will tell you whether the samples are detrital or chemical.

Detrital rocks (made of particles)	

For the detrital (made of particles) sedimentary rocks the following table will help. Place sample # next to the rock name.

Grains that compose sample and Common characteristics	**Size of grains**	**Name of detrital rock** **Place sample # in this box**
Angular fragments Often all grains are one color and cement is another color	Particles greater than 2 mm	Breccia
Gravel (rounded pebbles) Often our samples have sand grains as well	Particles greater than 2 mm	Conglomerate
Sand Often white, gray, or tan Feels like sand paper	Particles less than 2 mm	Sandstone
Clay Gray, green, black, red smooth and chip like shape Thin but wide pieces	Particles invisible (clay)	Shale

B) Chemical rocks.

Chemical rocks (made of organic particles or precipitates)	

For Chemical rocks and organic rocks use the following table to name them.

Notice that the chemical and organic rocks tend to be rather soft. Mostly the chemical rocks are salts made by a combination of positive and negatively charged ions or molecules combining. The amount that these dissolve is an indication of which will first precipitate as water begins to evaporate. Some limestones are inorganic salts others contain fossils.

Hardness and Characteristics	**Reaction to acid or other characteristic properties**	**Name** **Place sample # in this box**
Softer than fingernail May be pink, white, or colorless-opaque or transparent	none	Rock Gypsum
Harder than fingernail Often shows cubes usually gray or colorless.	none, but may dissolve	Rock salt (should be translucent)
Harder than fingernail Fine, smooth, no fossils	bubbles, fine-grained	lithographic limestone
Harder than fingernail Broken bits of shell that look like oatmeal	bubbles, but acid may sink in rapidly to the holes	Coquina (little shell) limestone
Harder than fingernail fossils may be bits of shell or coral	bubbles, contains fossils	Fossil limestone (organic)
Softer than fingernail black color may have shiny parches, light weight	brownish-black, flakey	Bituminous coal (organic)

Descriptions of Sedimentary Rocks

Specimen Number	detrital–particle size organic–constituents chemical–minerals	physical properties	rock name

GROUP EXERCISES

Fossils

1) Animal fossils

Fossils are both highly prized as collectors items and as evidence of past life and needed for scientific study. As well the shells of some molluscs retain their mother of pearl luster after complete fossilization and are referred to as **ammolite**, a gemstone.

Of course, the fact that fossils were once living in the area where the rocks formed and are constituents of sedimentary rocks indicates the conditions the sedimentary rocks was forming under. Fossil remains can make very attractive display pieces and are highly collectible. Many of the molluscs (clams, mussels, snails, etc.) once had calcium carbonate shells that were pearly. Do you see any pearly material in your examples of limestone? Only rocks going back to about the age of dinosaurs preserve mother of pearl. Older fossils in rocks tend to lose the mother of pearl. Time, dehydration, and deterioration of organic material change the rock and fossils.

Ammonites were a type of marine mollusk similar to a squid or nautilus that live today. Their shells could be very large and they could produce mother of pearl. This fossil mother of pearl is mined to make jewelry.

Explain some facts about ammolite.

A) What is it? Give a description. Can you find a picture of the animal to project?

B) Where is it mined?

C) What kind of rocks is it in? Did the animals live in a specific place?

D) Is the material hard enough to make a good gem or is it a little soft and delicate?

2) Plant fossils

Rocks of organic nature include the coals, anthracite and bituminous coals both are accumulations of plant matter that was crushed and slowly lost volatile constituents becoming a carbon rich material. Anthracite has undergone more heating and pressure and many geologists consider it a **metamorphic rock**. It is used in carving as well as in mourning jewelry, and as a stocking stuffer for naughty children.

Jet is a related type of coal that takes a good polish and is used in the same manner as anthracite.

A) What is Jet? Where does most jet come from? Country of origin?

B) Explain details of what mourning jewelry is. Is it popular today?

C) Are there substitutes for jet these days that may not have been around in the past?

D) Are there some properties of jet worth mentioning? Hardness, density, etc.

3) Amber

Amber is not itself a true fossil, it is fossilized tree resin, but amber can contain fossils and some pieces are highly collectible.

A) What is amber? Explain a little about the origins of amber.

B) Why are fossils in amber usually different than fossils in rock?

C) What are some important fossils found? Why is amber part of *Jurassic Park* the movie?

D) Explain a little about amber's properties and what fake amber might be.

4) Pebbles of Sapphire from Montana

Pebbles of sapphire have been found in streams and ancient stream deposits of Montana. Some are of excellent color and clarity. Though sapphires are usually thought to be blue they can be almost any color other than red, which is a ruby. Sapphires from Montana come in many colors. Some fine ones are found in basalt (igneous) flows in Yogo Gulch. Do not discuss these igneous ones, stick to the detrital sources (alluvial/river derived).

A) What is sapphire made of? Chemical composition. Give a brief description including Mohs' hardness.

B) What is their source in Montana thought to be? Is there a rather famous river involved?

B) Do the samples you have seem very rounded? Based on the rounding have they traveled far?

C) Do the crystals/grains seem to have any similarity in shape or size? This might in part be due to their processing, but could also be a geologic property. About how big are the largest in diameter compared to the smallest.

Everyone do this as homework

5) Witwatersrand Gold Ore Sample

This rock came from South Africa. It contains gold, but can be classified as “**noseeum”** gold. Sometimes the gold is visible, but mainly one sees larger bits of “**fool’s gold**” that contains the true gold that is microscopic.

1) Look for the pyrite.

2) Look at the rock texture. Can you tell what rock it is? Name it. It is pervasively cemented.

3) Find out about this “ore” and give a little history. What does ore mean? How old is the ore? How did the gold get their?

4) More history, who found this gold? When? What famous city is located near it?

5) How deep are the mines? Try and find comparison to average mines.

6) How much gold is/has been found? Altogether? Per year? Per ton?

7) There appears to be other precious/valuable material in this rocks as well. What?

8) How important a deposit is this? Was it world changing?

Evaluation Questions for Sedimentary Rocks

1) Detrital sedimentary rocks are more likely to contain gems than chemical sedimentary rocks. Why?

2) Chemical sedimentary rocks might make excellent display samples showing crystals, etc., but why are they not generally good for cutting gems? What properties might be missing?

3) A golden looking sample is found in a stream. What test might you run on it to see if it is valuable?

4) Illustrate and explain where a placer forms in a stream.

5) Would a grain of gold generally be the same size as a grain of quartz found in an alluvial deposit? Look at the densities of both and try and explain their hydraulic equivalency (water moving equivalency).

6) Gold is now being found in “noseeum” deposits. But in the past it was found mainly in stream deposits as nuggets. What is a nugget? What is the biggest nugget found?

7) Rounding and sphericity of particles may indicate how far a sample has moved. Explain why the texture of breccia has not moved far, but that the texture of well sorted, rounded sand has. Illustrate both.

8) In general what are the chemical sedimentary rocks (this includes biochemically formed rocks) composed of? So there might be two types. From your experience of the rocks above from lab, do any of them appear to behave as if they had a detrital origin (have particles)?

9) Explain or give your thoughts on how a detrital rock, such as sandstone, conglomerate, or breccia) derived from an older sedimentary rock would look compared to a detrital rock derived from a granite. You may discuss the mineral contents, etc. This is not an easy question to fully answer. But at least try to explain textural differences. If you can think about compositional differences too.