Sedimentary Rocks

So far, you learned that igneous rocks form when molten rock cools, but rocks can form in other ways, too. Sedimentary rocks form when rock fragments, organic materials, or minerals that have fallen (precipitated) out of solution are compacted and/or cemented together. Metamorphic rocks (meaning to "change form") form when heat and/or pressure change existing rocks without melting them.

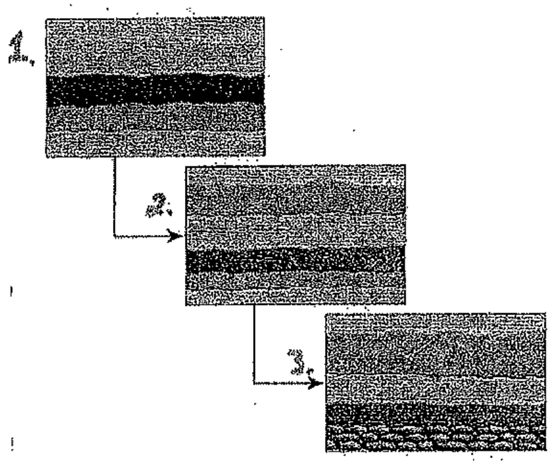
The formation of a sedimentary rock requires several processes. First, rocks of any type are weathered and eroded, and their fragments are deposited as sediments. **Sediment** is loose material composes of small rock fragments, mineral grains, and bits and pieces of plant & animal remains. The word sediment "sedere" is a Latin word meaning "to settle". These sediments are buried under additional layers of sediment, causing the sediments to compact and cement together to form a sedimentary rock. **Weathering** is the chemical or mechanical process of breaking down of any type of rock into smaller pieces called fragments or sediments. **Erosion** is the process by which weathered particles are transported to a new location. **Deposition** occurs when particles are deposited or dropped in a new location. Additional information on weathering, erosion, and deposition can be discussed later.

The *Agents of Erosion* which include, *gravity, wind, glaciers, waves, or running water* may move fragments of weathered rock over great distances. While floating in or being pushed by running water or another agent of erosion, the fragments may become smoother and rounder. When they are finally deposited (often in layers) they may form into a detrital sedimentary rock, by the process of lithification. **Lithification** is the process by which loose sediments are transformed (converted) into sedimentary rocks; this process is further explained later. If the transported particles are very small and water soluble, they may get dissolved in water and eventually could become part of a chemical sedimentary rock. If the fragments are organic (made from or by organisms), they can form a biochemical sedimentary rock. The processes that change sediments into sedimentary rocks include compaction, cementation, chemical processes, and organic processes. Conditions that existed when a rock formed can be inferred from the rock's mineral content and texture.

Although the majority of the rocks in Earth's crust are igneous or metamorphic, many rocks exposed on Earth's surface are sedimentary. Sedimentary rocks are usually found on the surface because the processes that form them occur closer to the surface than the processes that form most igneous and metamorphic rocks. Rocks are classified by their origin, mineral content, and texture.

Compaction

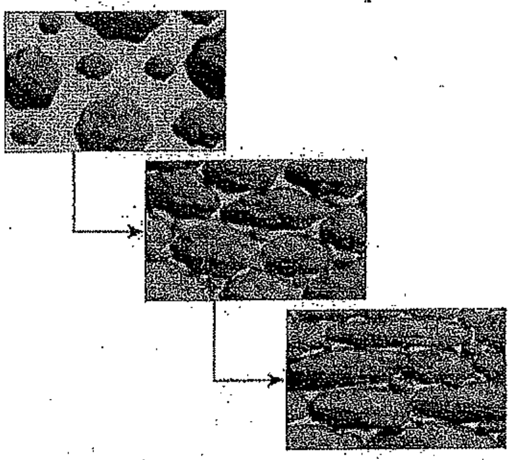
As layers of sediment is deposited one on top of the other, the weight of the overlying layers of sediment and water compresses these particles together. This



process is called compaction. **Compaction** is the process which smaller sediment is pressed together to form a rock. Rocks made of sticky sediments such as mud or clay may form purely by compaction, but most rocks also require cementation to "glue" their particles together. Compaction forces sediments closer together and squeezes water out of the spaces between sediments. Some sediment, such as sand, is resistant to compaction and retains their pore spaces. These spaces can then hold water or other fluids in the future.

Cementation

When water gets between sediments as they are forming into a rock, cementation usually follows. Most water on Earth contains dissolved minerals, so as water evaporates or is squeezed out of the sediments, the minerals it was carrying may be left behind. These minerals then serve as a glue or cement that holds the sediments together to form a clastic rock. The cements in most sedimentary rocks are either calcite



or quartz cements. **Cementation** is the process which sediment is "glued" together by dissolved minerals. Quartz and Calcite are the most common forms of natural cement.

Chemical Processes

Sometimes entire rocks form by a method similar to the way the cement of clastic rocks forms. Chemical sedimentary rocks form when water containing dissolved minerals evaporates, leaving the minerals behind. These minerals then get compacted together by the weight of overlying sediments to form rock.

Dissolved minerals precipitate out of solution when water is saturated with minerals. Saturated water contains as many dissolved minerals as it possibly can hold. When water is saturated, the addition of any more minerals will cause some of the minerals currently dissolved in the water to fall out of the solution and settle on the bottom.

Another situation in which chemical sedimentary rocks can form happens when the temperature of or pressure on a body of water changes. This makes the water unable to hold all of its dissolved minerals, forcing some of them to settle out of the water. Rocks formed when the minerals in water come out of solution, or precipitate, are called evaporites. Notice how evaporites looks like evaporate. This should help you remember how chemical sedimentary rocks (also known as evaporites) form.

Biochemical (Organic) Processes

Substances that are or once were alive, or that were created naturally by living things are called organic. Sedimentary rocks consisting of organic materials are called **Biochemical sedimentary rocks.** Limestone and biochemical (organic) sedimentary rock forms when animal skeletal or shell remains are compacted and cemented together. Bituminous coal, another biochemical (organic) rock, forms in hot, moist areas such as swamps and tropical coastlines with a high concentration of life. The hot, moist climate that speeds up decay, combined with the large quantity of life, results in thick layers of decaying organic material that gets compacted together to form coal.

There are two distinctive types of sedimentary rocks: **detrital and chemical.** They are classified based on how they formed. **Detrital rocks** form by compaction and/or cementation of sediments or **Detritus. Chemical Rocks** form by chemical processes (such as evaporation), and biochemical rocks form by organic processes (such as the compaction of decayed plant remains).

Detrital (clastic) Rocks

Most sedimentary rocks are detrital. This type of sedimentary rock is made of mainly inorganic, land-derived sediments or fragments called **Detritus.** The detritus fragments of other rocks that was compacted and cemented together to make a clastic rock texture that is often visible to the naked eye. The clastic (detrital class) rocks are those composed of weathered, transported, and deposited fragmental mineral material (detritus). The resulting texture (clastic) is one characterized by coarser fragments (framework) It may or may not lie in direct contact with one another; surrounded by finer fragmental debris (matrix); The entire mass ground together by substances that have been chemically precipitated (cement).

Characteristics of Detrital Rocks

When fragments of other rocks or minerals are seen in a rock that means the rock is identified as detrital. Some detrital sedimentary rocks exhibit **bedding** or **Strata** (parallel layers of sediments in rocks). Bedding or **Strata** is sometimes the result of the vertical sorting that happens when sediments settle in quiet (non-flowing or slowly flowing) water. Because larger, denser particles settle more rapidly than smaller particles, the bottom layer of a sedimentary rock that formed in quiet water will generally consist of larger particles. The next layer will contain smaller particles. These layers often alternate in sedimentary rocks. This division of particles creates a type of bedding (called **graded bedding)** that can be used to identify some clastic rocks. **Graded bedding** is when heavier & coarser particles are towards the bottom of the stream. **Cross-beading** may occur as a result of repeated depositional events. **Ripple marks** form when sediment is moved into smaller ridges, by wind, or wave action when sediment is moved into small

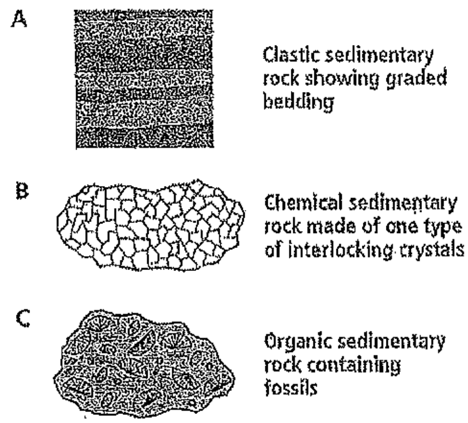


Figure 12-1 Diagrams of clastic, chemical, and organic, sedimentary rocks. Notice the graded bedding of the clastic rock, the mineral crystals in the chemical rock, and the fossils in the organic rock.

ridges. If a stream floods periodically, resulting in the deposition of a layer of sediments in the surrounding area, these layers may be visible in the rocks that form. Figure 12-1A shows an example of graded bedding in a clastic rock.

It was James Hutton in 1785, who studied the layers of strata and noted several ideas that we still use today. He came up with several important theories that we still use today. The first is the ***Principle of Uniformity***. This theory simply says that there is uniformity in natural law through time and space. In other words, the physical, chemical, and biological laws that operate today have operated throughout Earth's history. Understanding natural laws and their effect on the processes operating on Earth today is a guide to the past Earth events as well as future ones. It does not mean that today's world is an exact replica of either the past or the future, but only a sampling of each.

The second theory is the ***Principle of Horizontality.*** This means that all sediment wants to lay horizontal. The third is the ***Law of Superposition.*** This means the oldest layer of rock (strata) is located on the bottom & the youngest layer is located on the top. This is important when talking about **relative dating.** Relative dating is the placing of geologic events in their roper sequence or order. It does not tell how long ago something occurred; only that it preceded one event and followed another.

Identifying Detrital Rocks

All detrital rocks are made mostly of quartz, feldspar, and clay minerals. There are three (3) types of SCALES used to identify the grain size; the MILLIMETER, the WENTWORTH, and the PHI (Φ).

Charles Wentworth in 1922 designed a size classification for sediment, which is the most commonly used today.

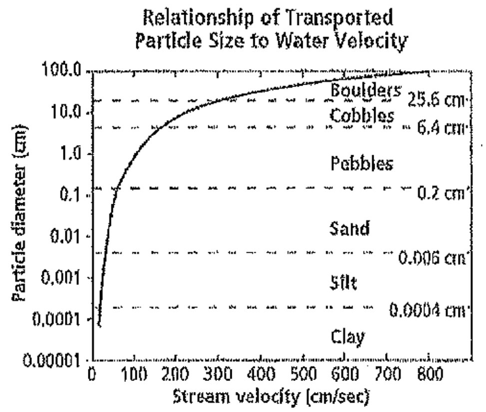
Sometimes the millimeter (centimeter) scale is used, since the metric scale is used worldwide in the scientific community. Particles that make up detrital rocks can range in size from less than 0.0004 cm in diameter (clay) to more than 25.6 cm in diameter (boulders). Therefore, detrital rocks are named based on their grain size and shape.

The PHI (Φ) scale is another size scale used devised by Krumbein. The formula is:

$$\Phi = -\log^{2}$$

Since some sedimentary rocks are made up of pieces of broken rocks fragments, they do not fit together tightly. The space between the fragments is the rocks **porosity. Porosity** is the percentage of open spaces between grains in a rock. Loose sand grains can have a porosity of up to 40%. The incomplete cementation of mineral grains can result in porosities as high as 30%. And lastly when pore spaces are connected to one another, fluids can move through sandstone. This feature makes sandstone layers valuable as underground reservoirs of oil, natural gas, & groundwater. Fine-grained sedimentary rock has very low porosity.

Conglomerate and Breccia have the same composition and range of fragment sizes (0.2 cm to 25.6 cm in diameter), so they are differentiated by their particle shape. Conglomerate is made up of rounded fragments, while Breccia is made up of angular fragments. Because particles become rounder the longer they are transported, the rounded particles found in conglomerate indicate that these particles were carried great distances before being deposited. On the other hand, the angular fragments of Breccia indicate a very short period of transport. Sand-sized particles (0.006 cm to 0.2 cm in diameter) make up sandstone, which looks and feels like sand and may exhibit bedding. Clay-sized particles (less than 0.0004 cm in diameter) make up shale, which tends to be very smooth and is easily split into flat layers.



*This generalized graph shows the water velocity needed to maintain, but not start, movement. Variations occur due to differences in particle density and shape.

Figure 12-2 Graph relating particle diameter to stream velocity, found in the *Earth Science Tables and Charts.*

The chart can be used to determine particle size and thus the name of detrital rocks. The ruler on the edge of the first page of the tables and charts can be used to measure the diameter of particles in a sample or diagram drawn to scale (except for those particles that are extremely small). In addition, the Relationship of Transported Particle Size to Water Velocity shows ranges of particle sizes on the right side. This graph, which is duplicated in Figure 12-2, shows that cobbles range in diameter from 6.4 cm to 25.6 cm. You can use this graph to determine the particle size of a particular type of sediment (such as cobble, pebble, or silt) and to determine the name of a type of sediment based on its particle size.

Chemical Rocks

When minerals dissolved in water precipitate and are then compacted and cemented together, the result is a chemical sedimentary rock.

Characteristics of Chemical Rocks

Chemical sedimentary rocks, formed by chemical processes, have a crystalline texture and can be recognized because they are usually monomineralic (consisting of only one mineral) and consist of interconnected mineral crystals. Refer to Figure 12-1B for an example of this texture. Some chemical sedimentary rocks are soft enough to be scratched with a fingernail

Identifying Chemical Rocks

Chemical sedimentary rocks are named based on their common composition. Because chemical rocks are commonly comprised of a single compound, they can often be identified using mineral tests. For example, rock salt is made entirely of the mineral halite, so it tastes salty and forms cubic crystals. CAUTION: Never taste any rocks or minerals in the lab. Rock gypsum is made of the mineral gypsum. Rock salt and rock gypsum are also known as evaporites. Limestone formed by chemical processes is made of calcite, which fizzes in the presence of a weak acid. Calcite is usually tested with diluted hydrochloric acid.

Biochemical (Organic) Rocks

Biochemical (organic) rocks tend to be monomineralic and have a bioclastic texture. Most bioclastic rocks are made of compacted and cemented organic material, such as animal shells or decayed plant remains. Biological processes contribute to the formation of organic rocks.

Characteristics of Biochemical Rocks

Recall that the fragments that make up detrital sedimentary rocks are often visible with the naked eye. If the visible fragments appear to be organic, such as bones or shells, then the texture is said to be bioclastic, and the rock is organic. Also, any rock containing a fossil is most likely a biochemical (organic) sedimentary rock. However, fossils can also be found in clastic sedimentary rocks, such as shale and sandstone. A fossil is any evidence of previous life preserved in a rock. See Figure 12-1C for an example of a biochemical (organic) sedimentary rock.

Identifying Biochemical (Organic) Rocks

A biochemical (organic) rock consisting of visible shell fragments is a type of limestone, sometimes called coquina or fossiliferous limestone. Bituminous Coal is a biochemical (organic) rock composed of carbon that is made from decayed plant and animal remains. Coal can be recognized by its black color and fine-grained texture.

Using the Scheme for Sedimentary Rock Identification

The Scheme for Sedimentary Rock Identification in Figure 12-3 can be used to name, classify, and describe sedimentary

Name Date: Class Pd:

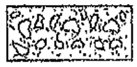
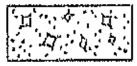
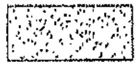
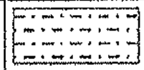
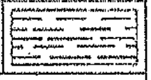
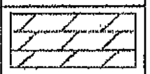
Scheme for Sedimentary Rock Identification					
Inorganic Land-Derived Sedimentary Rocks					
Texture	**Grain size**	**Composition**	**Comments**	**Rock name**	**Map symbol**
Clastic (fragmental)	Pebbles, cobbles, and/or boulders embedded in sand, silt, and/or clay	Mostly quartz, feldspar, and clay minerals; may contain fragments of other rocks and minerals	Rounded fragments	Conglomerate	
			Angular fragments	Breccia	
	Sand (0.2 to 0.006 cm)		Fine to coarse	Sandstone	
	Silt (0.006 to 0.0004 cm)		Very fine grain	Siltstone	
	Clay (less than 0.0004 cm)		Compact; may split easily	Shale	
Chemically and/or Organically Formed Sedimentary Rocks					
Texture	**Grain size**	**Composition**	**Comments**	**Rock name**	**Map symbol**
Crystalline	Varied	Halite	Crystals from chemical precipitates and evaporites	Rock salt	
	Varied	Gypsum		Rock gypsum	
	Varied	Dolomite		Dolostone	
Bioclastic	Microscopic to coarse	Calcite	Cemented shell fragments or precipitates of biologic origin	Limestone	
	Varied	Carbon	From plant remains	Coal	

Figure 12-3 Scheme for identifying sedimentary rocks.

rocks. This chart is divided into two sections. The top section lists detrital sedimentary rocks and is titled "Inorganic Land-Derived Sedimentary Rocks". This title should help you remember that detrital rocks do not contain organic materials (they are inorganic), and that they are formed from sediments found on land (they are land-derived).

The bottom section of the chart lists chemical and organic sedimentary rocks. The left most column of this chart indicates texture. This column should help remind you that all land-derived sedimentary rocks have a clastic (fragmental) texture. On the other hand, chemically formed rocks have a crystalline texture, and biochemically formed rocks have a bioclastic texture.

The next column lists Grain Size, which is very important for classifying detrital rocks. Because grain size is usually variable for chemical and biochemical rocks, it is less useful for classifying those types of rocks. The Composition column tells you what makes up the various sedimentary rocks. Notice that the composition of all detrital rocks is roughly the same (mostly quartz, feldspar, and clay minerals).

Composition is not as useful for classifying detrital rocks as it is for classifying chemical and biochemical (organic) sedimentary rocks. Because most chemical and biochemical (organic) rocks are made of only one mineral, composition is very useful for classifying those kinds of rocks. Detrital rocks are polymineralic, consisting of more than one type of mineral, and chemical and biochemical (organic) rocks are monomineralic, consisting of only one type of mineral.

The Comments column gives additional information about the texture of detrital rocks and the formation of chemical and biochemical (organic) rocks. The symbols for each rock type given in the last column are standard symbols and are used consistently by both geologists and test-makers.

Uses of Sedimentary Rocks

Sedimentary rocks such as sandstone, limestone, and conglomerate are used as building stones. Limestone is also used for making cement, sidewalks, and concrete. Chemical sedimentary rocks such as rock gypsum, limestone, and rock salt are often mined for the minerals they contain. The halite found in rock salt, for example, is used for making table salt as well as the salt that is spread on icy roads. Bituminous coal is another useful biochemical sedimentary rock. It is mined for the heat energy it releases when burned.

Shale weathers easily, so regions where shale forms the bedrock often have a topography consisting of low rolling hills that are easy to build on. Limestone is made of calcite (calcium carbonate), which is chemically a base (pH>7), so it serves as a good buffer to counteract the effects of acid precipitation. Acid precipitation tends to acidify soil, making it unfit for growing crops, but the presence of limestone in the bedrock allows areas that would normally be unable to support farming due to acidic soil to be used for growing crops. However, because calcite dissolves with even a weak acid, areas with limestone bedrock also tend to experience a great deal of erosion.

Detrital sedimentary rocks are especially valuable to geologists because of the fossils, imprints of raindrops, certain types of bedding, and ripple marks they may contain. These features provide scientists with information about surface conditions, life-forms, and climates of the distant past. In addition, some geologists work to locate deposits of groundwater, oil, and natural gas found in the pores of sedimentary rocks such as sandstone.

Name Date: Class Pd:

Sedimentary Rock

TEXTURE	PARTICLE TYPE	COMPOSITION	COMMENTS		ROCK NAME	
Relatively coarse Detrital Grains (Can be seen with naked eye)	Detrital Grains > 2 mm	Any rock type (quartz, chert, or quartzite most common)	Rounded particles		Conglomerate	
			Angular particles		Breccia	
	Detrital Grains 1/16 to 2 mm (sand sized)	Rock fragments, mica, clay, quartz	Dirty" looking, dark colored; sandpapery feel		Graywacke	SANDSTONE
		Quartz, with at least 25% potash feldspar	Often reddish because of potash feldspar; sandpapery feel		Arkose	
		Quartz with minor accessory minerals	White, tan, brown; sandpapery feel		orthoquartzite Quartz Sandstone	
Relatively fine Detrital Grains (Cannot be seen with naked eye)	Detrital grains or interlocking crystals	Quartz and clay minerals	Gritty, 1/16-1/256 mm; some grains can be seen with hand lens		Siltstone	
		Predominantly clay sized particles	Smooth, < 1/256 mm; non-laminated		Claystone, Mudstone	
		Predominantly clay minerals	Smooth, < 1/256 mm; laminated		Shale	
		Calcite ($CaCO_3$)	Consolidated; fizzes rapidly with dilute HCl		Limestone	
		Calcite ($CaCO_3$)	Powdery; shells of microscopic animals; fizzes with HCl		Chalk (Kaolin)	
		Dolomite (Ca,Mg) $(CO_3)_2$	Consolidated; fizzes with dilute HCl when powdered		Dolostone	
		Chalcedony (SiO_2)	Light colored, hardness of 7		Chert	
		Chalcedony (SiO_2)	Dark colored, hardness of 7		Flint	
		Carbonaceous Material	Plant remains	Brown, soft, porous	Peat	
				Brown	Lignite	
				Black, sooty, blocky	Bituminous Coal	
Chemical or Biochemical Grains (Crystals or other grains can be seen with naked eye)	Interlocking Crystals, Ooids, or Biochemical Grains	Calcite ($CaCO_3$)	Fizzes rapidly with dilute HCl	Medium to coarse grained	Crystalline Limestone	
				Abundant fossils, consolidated	Fossiliferous Limestone	
				Ooids (tiny spheres)	Oolitic Limestone	
				Banded	Travertine	
				Fossils & fossil fragments loosely cemented	Coquina	
		Dolomite (Ca,Mg) $(CO_3)_2$	Fizzes with dilute HCl when powdered		Dolostone	
		Halite (NaCl)	Evaporite, tastes salty		Rock Salt	
		Gypsum ($CaSO_4$ $2H_20$)	Evaporite, hardness of 2		Rock Gypsum	