CLASTIC SEDIMENTARY ROCKS and SEDIMENTS

Clastic sedimentary rocks - Rocks composed of fragments of pre-existing rocks. Sandstones, siltstones, mudstones, conglomerates, and breccias are all clastic rocks.

Background:
- Mechanical and Chemical Weathering
- Production of Clastic Sediment
- Classification of Sediment according to size: Gravel, Sand, Silt, Clay
- Erosion, Transportation and Deposition of Sediment
- Lithification of Sediment: Burial, Compaction, and Cementation
- Clastic Rocks Classification:
  - from gravel, either breccia or conglomerate
  - from sand, different kinds of sandstones, or arenites (i.e.: quartz sandstone, arkose sandstone, graywacke sandstone, lithic sandstone)
  - from silt: siltstone
  - from mixtures of silt and clay: mudstone
  - from clay: claystone and shale
- Textural Components of a clastic sediment: grains, matrix, cement, pores
  (remember that clay grains, or particles, are always flat crystals)
- Rounding
- Sorting
- Maturity
- Different sediments in different sedimentary environments
- Sedimentary Bodies
- Sedimentary Structures
- Preparation and Use of Thin Sections and Acetate Peels

In this lab we will learn to identify several different types of clastic sedimentary rocks, including mudstones, siltstones, sandstones, conglomerates, and breccias. I have set aside the rocks that we will study. You will be working in teams.

Classification of Sediments and Sedimentary Rocks

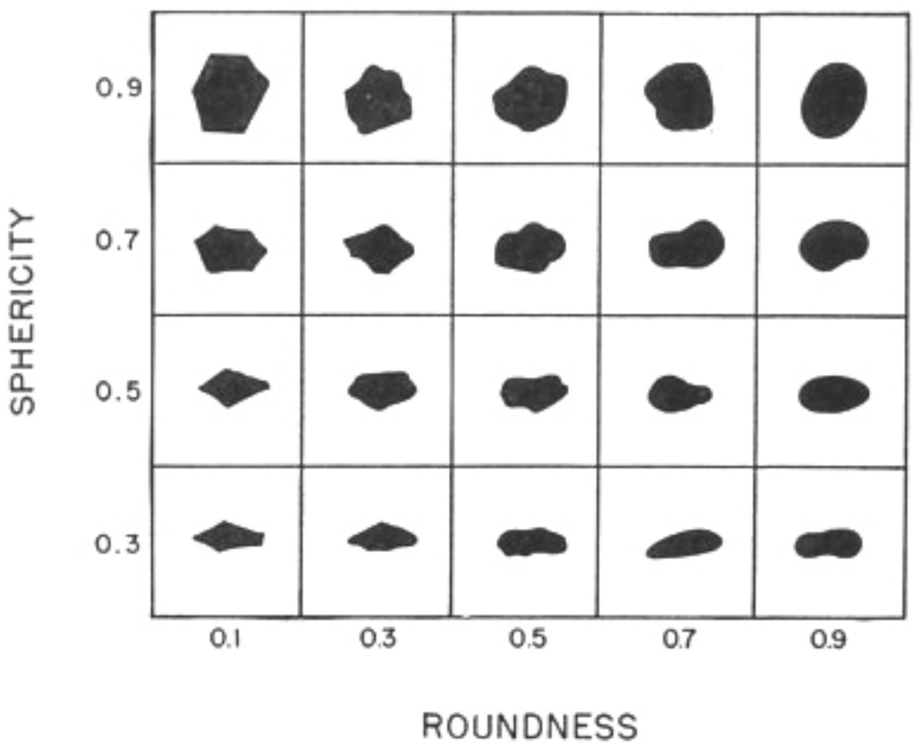
Clastic sediments (and derived sedimentary rocks) are first classified according to texture (grain size). For example, sandstone is a rock comprised of grains ranging from .062 to 2 mm. A rock composed mostly of grains greater than 2mm is either a breccia or a conglomerate, depending on the rounding of the grains. Make sure that you understand that the classification of clastic rocks as conglomerate, sandstone, siltstone, mudstone, and claystone is based on texture.

Millimeters		µm	Phi (φ)	Wentworth size class	
			-20		
	4096		-12	Boulder (-8 to -12φ)	
	1024		-10		
	256		-8		
	64		-6	Pebble (-6 to -8φ)	
	16		-4	Pebble (-2 to -6φ)	
	4		-2		
	3.36		-1.75		
	2.83		-1.50	Gravel	Gravel
	2.38		-1.25		
	2.00		-1.00		
	1.68		-0.75		
	1.41		-0.50	Very coarse sand	
	1.19		-0.25		
	1.00		-0.00		
	0.84		0.25		
	0.71		0.50	Coarse sand	
	0.59		0.75		
1/2	0.50	500	1.00		
	0.42	420	1.25		
	0.35	350	1.50	Medium sand	Sand
	0.30	300	1.75		
1/4	0.25	250	2.00		
	0.210	210	2.25		
	0.177	177	2.50	Fine sand	
	0.149	149	2.75		
1/8	0.125	125	3.00		
	0.105	105	3.25		
	0.088	88	3.50	Very fine sand	
	0.074	74	3.75		
1/16	0.0625	63	4.00		
	0.0530	53	4.25		
	0.0440	44	4.50	Coarse silt	
	0.0370	37	4.75		
1/32	0.0310	31	5	Medium silt	
1/64	0.0156	15.6	6	Fine silt	
1/128	0.0078	7.8	7	Very fine silt	
1/256	0.0039	3.9	8		Mud
	0.0020	2.0	9		
	0.00098	0.98	10		
	0.00049	0.49	11	Clay	
	0.00024	0.24	12		
	0.00012	0.12	13		
	0.00006	0.06	14		

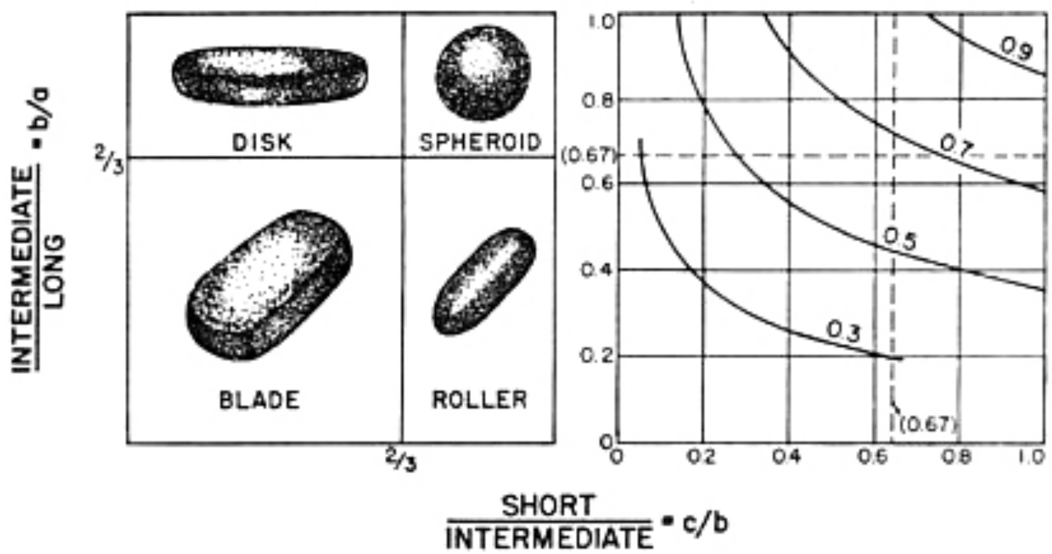
Rounding

Rounding, or roundness, refers to the degree to which sharp corners and edges of rocks or minerals have been worn away. It is a measure of the intensity and degree of transport and wear. A rounded grain has been subject to a long history of transport and wear, while an angular clast was virtually never transported, but rather buried right after formation.

Rounding should not be confused with **sphericity**, which is a measure of how closely a particle approaches the shape of a sphere. Sphericity has no relevance in geologic interpretations. Ideally, a cubic grain is angular (not rounded), but also spherical, since the three axis, x, y, and z, are of the same length



*This visual chart can be used for estimating the roundness and sphericity of sand grains (from Krumbein, W.C., and Sloss, L.L., **Stratigraphy and Sedimentation**, 1956, Freeman and Company, San Francisco CA)*



This figure shows Zingg's classification of pebble shapes, based on ratios of intercepts.
*(from Krumbein, W.C., and Sloss, L.L., **Stratigraphy and Sedimentation**, 1956, Freeman and Company, San Francisco CA)*

Sorting
Sorting is a measure of the uniformity (or lack of uniformity) of particles in a sediment. A well sorted sediment is one where all particles have approximately the same size. A poorly sorted sediment is one where particles have a wide range of sizes

Maturity
Maturity is defined by three parameters: rounding, sorting, and abundance of quartz in your sand (or sandstone).
A mature sediment has good sorting and good rounding, and is rich in quartz.
An immature sediment instead has poor sorting, is angular, and contains a variety of different lithologies.

Textures of Sandstones
The textural components of a sand are the **grains** that give it its framework and the pores between them. The pores can host smaller size grains (the **matrix**) and eventually become filled with **cement**. A well cemented sandstone would have no pores or partially filled pores. Matrix can also fill pores (in that case, the sand is not sorted) but more commonly cement would be found (if there is no matrix, the sediment would probably be well sorted).

Since we are specifically talking about sandstones, the grains would always be sand-size. The matrix, if and when present, consists of smaller grains that fill the pores between the sand clasts, and as a consequence must be either silt or clay, or a combination of the two.
Cement is a chemical precipitate that originates from groundwater during diagenesis (a series of changes that occur during the transformation of a sediment into a sedimentary rock). Because of this, cement could consist of any chemical substance or

mineral precipitated from groundwater, but the most common cements are usually silica (SiO_2), calcite ($CaCO_3$), and hematite (Fe_2O_3).
Some sandstones can be held together by a combination of matrix, cement and **pressure solution** of the grains. Pressure solution occurs when the constituent mineral grains are pressed together under sufficient pressure that chemical reactions occur at grain boundaries. At the contact, the grains might start to dissolve, and this process cements the grains together.

Classification of Clastic Sedimentary Rocks (sandstones and conglomerates) Based on Composition

Sandstones (and, when possible, conglomerates) are also classified according to mineralogy or composition of the rock. The sandstones that you are working with will fall into one of the following classifications based on the composition of the rock:

1. Arkose Sandstones: these sandstones are usually reddish or pinkish, contains greater than 25% feldspar, usually contains rock fragments, micas and clays. The high percentage of unstable feldspars and lithic fragments usually indicates that the grains forming the rock have not been transported great distances. The sediment was deposited close to the source area, and the source area would contain K-feldspar minerals. These would be typical of batholiths, which would indicate an active margin.
For example, an arkosic sediment would be found at the foot of a granitic mountain chain, such as our own Sierra Nevada.

2. Quartz Sandstones, or Arenites: these sandstones contain more than 95% quartz. May contain heavy minerals, which are more resistant to abrasion. To form a quartz-rich rock such as a quartz arenite requires special conditions. A quartz arenite implies several cycles of erosion, transport, and deposition to form. That is, a very long history that would allow unstable mineral grains such as the feldspars to be removed. A quartz arenite can also indicate transport over long distances, as it would happen in a river that drains a craton (the stable part of a continent).
A good example of quartz sand can be found in the beaches of the Gulf of Mexico, in Texas and Louisiana, where the Missouri/Mississippi rivers system drains a huge area and sediment has been carried for thousands of miles

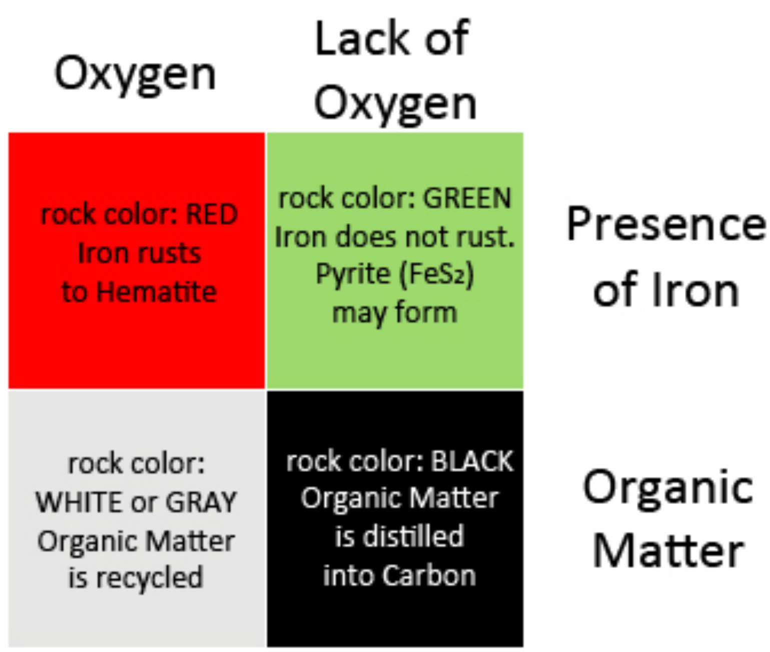
3. Graywacke Sandstones: these sandstones are usually gray or darker in general, because they contain abundant clay, together with rock fragments, feldspar and quartz (remember that clay minerals have cohesive properties that would allow organic matter to remain attached to the grains; organic matter, being essential carbon, is dark in color). The presence of feldspars and rock fragments suggest that the sediment forming the greywacke was not transported great distances. The presence of clay in the sandstone makes the rock very immature and indicates closeness to the source area or mixing of already sorted kinds of sediment, which could happen in case of turbiditic deposition.
For example, graywacke sandstones are currently being deposited in Santa Monica Basin (and in many other parts of the world, at the foot of the continental slope, constituting the continental rise)

4. Lithic Sandstones: these sandstones contain an abundance of rock fragments. Lithic sandstones are usually deposited close to the source area and present angular fragments.

Color of Sediments

Color of sediment is sometimes useful in the identification of either the original environment of sedimentation or in the processes that followed lithification. That is, the original color of our rock may have changed since the time it was buried, or the color might have changed because of weathering.
Often, the color of shale is more diagnostic than that of a sandstone (or a limestone). The main inferences can be done concerning the abundance of oxygen and /or iron in the environment of deposition.

- "Normal" conditions would lead to a light-colored sediment, **light gray, cream**, **tan**, or **white**.
- If iron is present, even in minimal amounts, it will react with oxygen to form hematite, limonite, goethite, which will turn the rock **red**, **yellow**, **brown**, even **purple**. That is possible at the scale of particles (in a red mud, or red clay) but also at the level of cement (for instance the red rocks of Arizona and Utah have red cement, but the grains are quartz, that can not be oxidized; in this case oxidation – and coloration – are secondary, having occurred after lithification).
- If iron is present but there is no oxygen, mudstones can acquire **green**, **greenish**, or **grayish** colorations. Still, iron is commonly found in most environments.
- If oxygen is absent and there is organic matter, this will be preserved (see discussion on graywacke sandstones), and as a consequence our rock will look **dark gray** or **black** (for instance, black shales from global anoxic events).



If Organic Matter and Iron are both present in the sediment and there is Oxygen, the Organic Matter is recycled and the rock is either white or red, depending on the amount of Iron. If there is no Oxygen, the rock is likely going to be black, and crystals of pyrite are also likely to form