LECTURE 1
INTRODUCTION TO
SEDIMENTARY ROCKS

REFERENCES:

Hamblin Chapter 5, Clark & Cook Chapter 9, Skinner & Porter Chapter 5

Sedimentology is the study of the processes of formation, transport and deposition of material which accumulates as sediment in continental and marine environments and eventually forms sedimentary rocks.

Study of sediments:

- types (detrital, chemical, organic)
- sedimentary structures - origin and environmental significance
- environments of origin and deposition
  And of sedimentary rocks formed from them:
- including processes of lithification - compaction, cementation and diagenesis

Importance

- **understanding depositional processes**
- **economic**
- **coal, oil, banded iron formations, sediment hosted ores**
- **understand origin to develop exploration strategies**
- **e.g. oil - source rocks, migration, reservoir rocks**

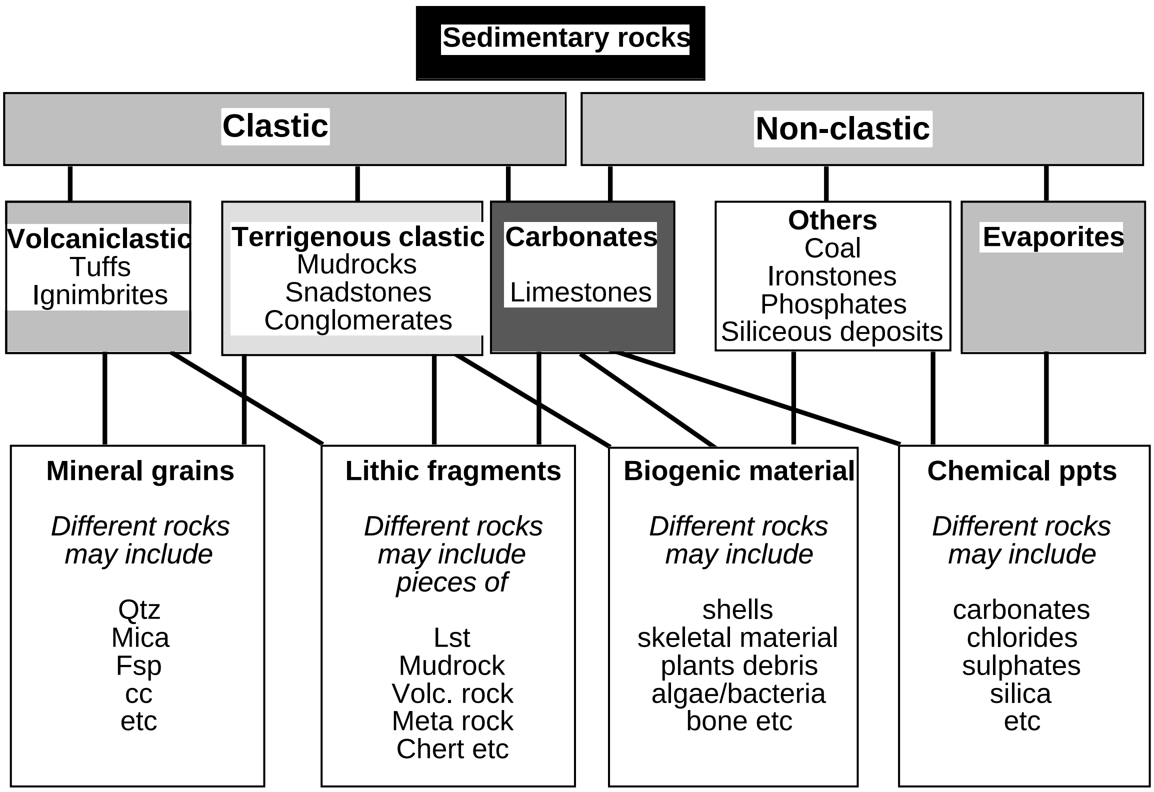
Sediments are primarily formed by the accumulation of grains which are the products of chemical and mechanical breakdown (otherwise known as weathering) of pre-existing rocks. Examples of sediments which you will be familiar with are mud (clay and silt), sand and gravel. **Detritus** is the general term applied to the solid products of weathering which have been removed from their site of origin. Particles produced by mechanical breakdown are called clasts (from the Greek work meaning 'broken').

After deposition sediments usually undergo changes leading to consolidation or lithification into *sedimentary rocks*. This process of change in known as **diagenesis**. Piles of sedimentary rocks have accumulated throughout most of the earth's history and form a significant proportion of the rocks found at the earth's surface today.

Table 1 : *Relative extent of rock types exposed at the earth's surface*

	%
shale	52
sandstone	15
granite	15
limestone	7
basalt	3
others	8

By studying the nature of the material in sedimentary rocks we may obtain information about the source of the sediment, the type and length of transport, and the geological environment in which it was deposited. In this practical, we will be examining some of the properties of sedimentary rocks.



Types of sediments and sedimentary rocks

There are three principle types of sedimentary rocks:

1. Detrital or clastic sedimentary rocks, as described above, consist of aggregates of grains (or

clasts) which have been lithified during diagenesis

2. Biogenic sedimentary rocks result from the accumulation of skeletal remains of plants or animals. The most important types are (1) made up of calcium carbonate (*calcareous*) e.g. limestone, and shelly sandstone; (2) made up of silica (*siliceous*) e.g. chert; and (3) made up of coalified plant remains (*carbonaceous*) e.g. coal.

3. Chemical sedimentary rocks form from precipitation within the environment of deposition, so their composition depends on the chemical composition of the acqueous solution from which they are deposited (e.g. lake, ocean, groundwater) and chemical conditions (e.g. carbon dioxide, oxygen, pH). Common chemical precipitates include siliceous (chert), phosphatic, iron-rich, calcareous and manganiferous varieties. In addition, evaporation of saline water, especially in large marine basins, can produce large volumes of various salts, termed *evaporites*.

CLASSIFICATION OF DETRITAL SEDIMENTARY ROCKS

1. Grain Size

Detrital sedimentary rocks are primarily classified on the basis of their **grain size**. Grain size depends on the grain size of the parent material, the length of transportation and the energy available during transportation.

We can measure grain size by direct measurement, sieving or other analytical techniques. Conventionally, grains of differing diameters are grouped into various size classes, using the **Wentworth Scale** (Table 2 and Fig. 11.2). Note that the scale has a constant ratio of 2 between successive size classes, i.e. the particle diameter assigned to any particular class is twice that of the preceding (smaller) class.

N.B.: It is important that you become familiar with the size classes of the Wentworth Scale so that you can quickly estimate the grain size of sedimentary rocks in the field and laboratory. Remember that clay sized material cannot be seen with the naked eye.

Table 2 : CLASSIFICATION OF SEDIMENTS AND SEDIMENTARY ROCKS BY GRAIN SIZE

Particle name	*Diameter range*	*Unconsolidated*	*Consolidated*
boulder	greater than 256 mm	gravel*	conglomerate*
cobble	64 - 256 mm	gravel	(rounded) or
pebble	4 - 64 mm	gravel	breccia (angular)
granule	2 - 4 mm	gravel	
sand	1/16 (0.0625) - 2 mm	sand	sandstone
silt	1/256 - 1/16 mm	silt)	siltstone)
clay	less than 1/256 (0.0039)mm	clay) mud	claystone) mudstone

* May be prefixed by particle name, e.g. boulder gravel or pebble conglomerate.

These size classes are shown in diagrammatic form below. Note that the sand category is further divided into five size groups for more detailed description.

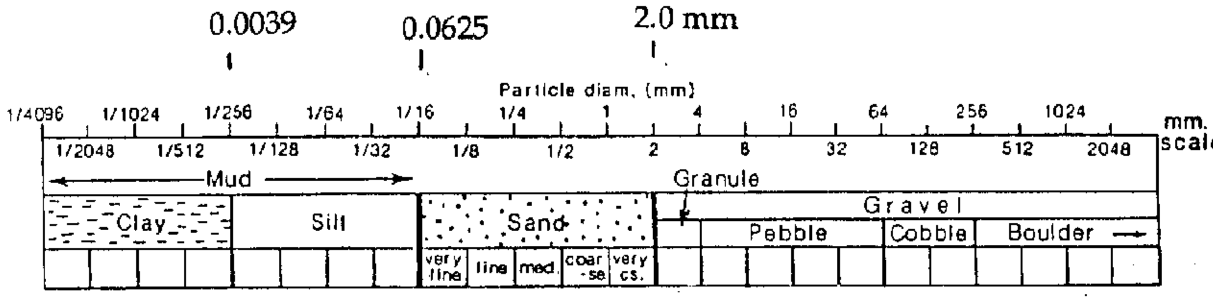
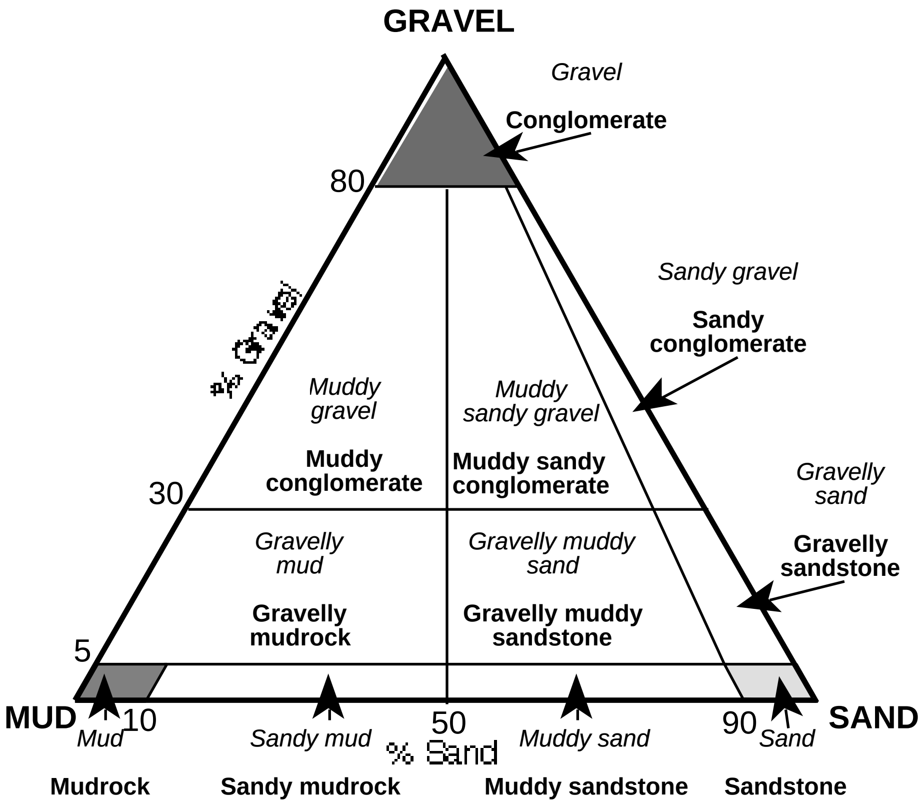


Fig 2 : ***The Wentworth Scale***

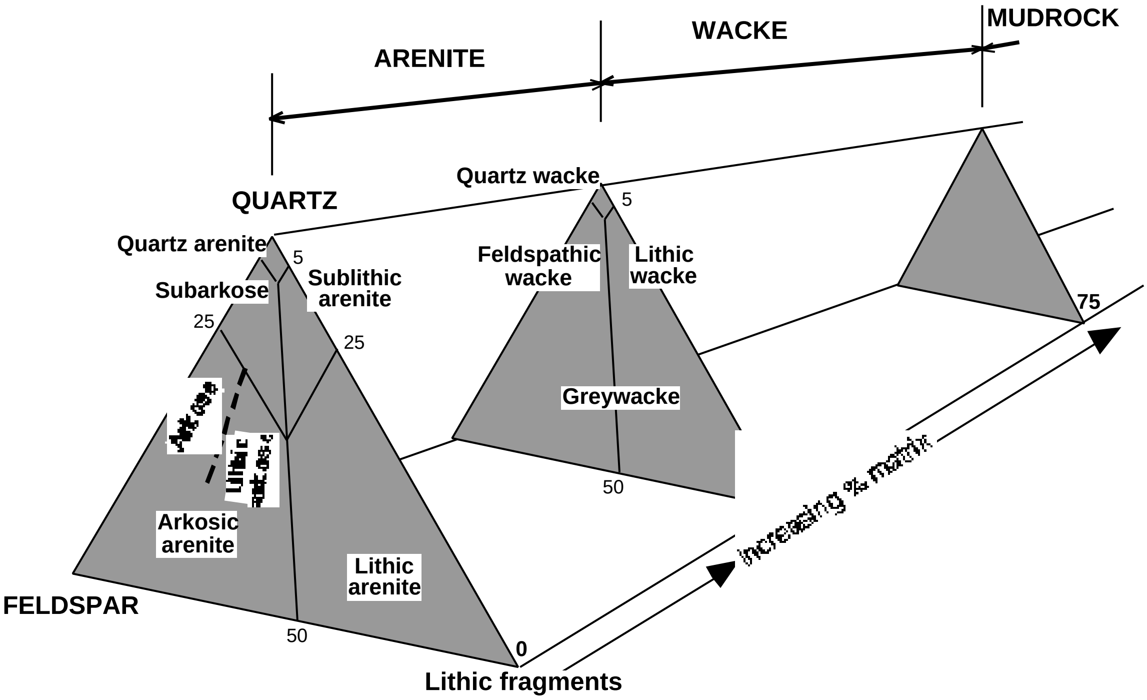


Nomenclature for terrigenous clastic sediments and sedimentary rocks

2. Composition

It is important to identify the **composition** of the detrital grains (framework) which may be individual minerals such as quartz and feldspar, or may be fragments of rock *(lithic fragments).* Similarly, the composition of the matrix (not always possible in hand specimen) and/or cement also needs to be determined. It is then possible to modify the grain size name with some compositional features. For example a sandstone which comprises a high proportion of quartz grains and is cemented with silica, could be called a *silica-cemented quartzose sandstone*, or a sandstone which contains abundant lithic fragments might be called a *lithic sandstone.*

Greywacke



The Pettijohn Classification of sandstones.

Mineralogy

QUARTZ (qtz)– average sandstone contains 65% quartz, some have 100% quartz. Most stable of minerals under sedimentary conditions. Quartz can survive many cycles of erosion and depositon. Most qtz grains are derived from plutonic granitoid rocks, some are derived from vein quartz.

FELDSPARS (fsp)– in sandstones feldspar average between 10 and 15% of the grains. In arkoses this is often over 50%. The mechanical stability of fsp is lower than qtz since fsps have a strong cleavage leading to their destruction after one cycle of erosion and deposition. Fluvial sediments often contain more fsp than beach and aeolian sediments. Fsps are also prone to alteration due to their chemical instability, they break down to clays eventually in the sedimentary environment.

Micas and Clay Minerals – these sheet silicates are common in the matrix of sandstones and are the main component of mudrocks. Due to their flaky nature they tend to get washed out of coarser sediments and accumulate in fine sands or silts, these minerals get blown out of wind-blown sediments.

Heavy Minerals - these accesory grains make up less than 1% in sedimentary rocks. They are particularly resistant to erosion and transportation. Minerals can include zircon, tourmaline, rutile, apatite, garnet etc.

DESCRIPTION OF DETRITAL SEDIMENTARY ROCKS

Some of the important characteristics of detrital sedimentary rocks are described below. *It is important that you clearly understand the meaning of each term, and being able to describe sedimentary rocks using these terms.*

1. Sorting

The **sorting** of a sedimentary rock is a measure of the range of grain sizes present. If the grain size is very restricted then the sedimentary rock is described as *well sorted* (e.g. Fig 1a). If a wide range of grain sizes is present, (e.g. Fig 1b), then the rock is described as *poorly sorted*. Sorting images are presented in Fig 3. below.

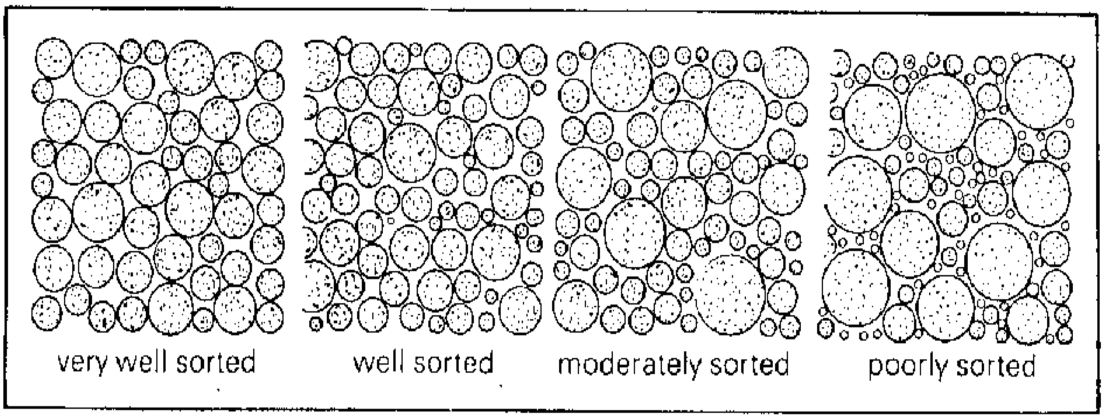


Fig. 3 : Sorting images

The degree of sorting is determined by a number of factors, including the nature of the source material, the transporting medium (i.e. water, wind, ice or gravity), and the depositional environment.

2. Grain shape

Grain shape refers to the geometric form of detrital grains, and is expressed using specific terms. For our purposes, it will be useful to consider the **roundness** of the grains. Grain shape depends on the original shape of the particles, their internal structure (and hardness), and the length of transportation. The longer a particle is transported, the more abrasion it undergoes, and the more round it can become. However, a particle of mica for example, which has a strong layering, is unlikely to ever become round, whereas quartz which is hard and massive, can with sufficient transportation.

Roundness is an expression of the sharpness or the corners and edges of grains. We can describe grains using terms such as angular, sub-angular, rounded and well rounded, shown in Fig. 4. Another aspect of shape is sphericity, that is the degree to which the grain approaches a sphere in shape. The relationship between roundness and sphericity is shown in Fig.4.

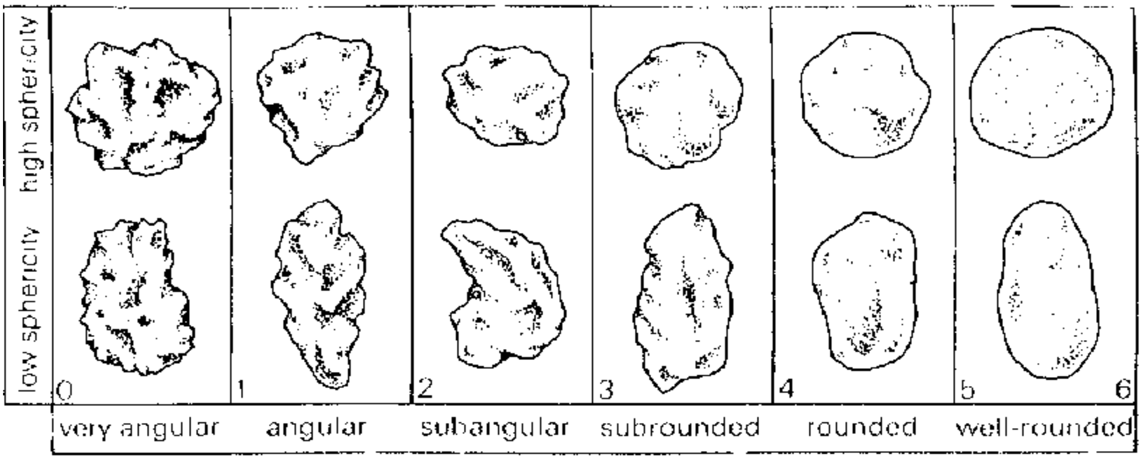
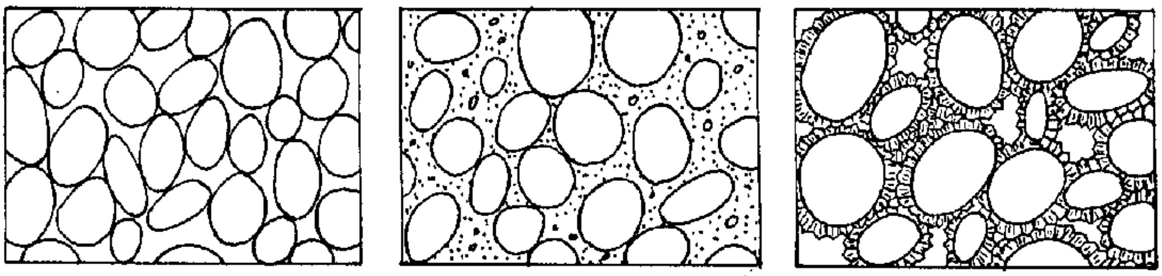


Fig.4 : Images of grains for determination of roundness and sphericity.

3. Framework and Matrix

The dominant clasts or grains in a sand-sized or coarser grained sedimentary rock are known as the framework. (In a finer grained rock it is difficult to distinguish the grains so this type of description is not useful). Typically, these grains are in contact or near contact with each other, and may be surrounded by empty space (**pore space**; e.g. gravel; Fig. 1a), or may be surrounded by finer grained sediment (called **matrix**(with which they were deposited (e.g. pebbly mudstone; Fig. 1b).



a. grains with intergranular pore spaces

b. coarse grains with finer grained matrix

c. grains bound together by chemically precipitated cement. Note pore spaces.

Fig. 1 : *Framework, matrix and cement*

4. Cementation

An important process in the diagenesis of sediments which leads to their consolidation is **cementation** - the process by which a cement is added that acts as a bonding agent between grains (Fig. 1c). The cement is typically a mineral which is chemically precipitated in the pore spaces of the sediment by fluids moving through them. The most common types are quartz (silica cement), calcite (carbonate cement) or iron oxide (ferruginous cement). Cement will bond both framework and matrix grains.

N.B.: The distinction between cement and matrix can be difficult. One thing to remember is that cement is **always secondary**, that it is formed **after** the rock is deposited. Matrix, on the other hand, is often primary, **but** can also be secondary in origin.

5. Sedimentary structures

A variety of structures may be formed in sedimentary rocks during deposition. Sediments are usually deposited in horizontal layers called **beds**, and adjacent beds are separated by **bedding planes**. Thus *bedding* is one of the most important sedimentary structures to recognise. Beds may be very thin (layers less than 1 mm thick - these are usually called **laminae**, and a fine grained sedimentary rock with such layers would be called, for example, a laminated mudstone), or up to thicknesses of many metres. Rocks which exhibit no structures are usually called **massive.**

Sedimentary structures which are observed in sedimentary rocks were formed when the sediment was deposited, or soon after while the sediment was still soft. Structures which we commonly see are produced by the currents responsible for transportation and deposition of the sediment. They are useful because:

(1) they can provide us with information about how the sediment was transported, conditions of current flow (e.g. water depth, direction), and the environment of deposition; and

(2) because we usually know where in a sedimentary bed they occur (e.g. top or bottom), we can determine whether the sedimentary sequence is right way up or upside down. This is important in terrains where rocks are very folded and deformed.

Common sedimentary structures include:

- plane-parallel laminations (mm scale layers parallel to each other and bedding)
- cross-laminations (mm scale layers oriented at an angle to overall bedding)
- wavy laminations (mm scale layers with a wavy appearance)
- graded bedding (a layer which normally has coarser material at the base with grain size becoming finer towards the top)
- dessication cracks (polygonal shrinkage cracks in mudstones infilled with sand)
- ripply marks (symmetrical or asymmetrical ripples formed by current action)
- flute casts (scours formed by current action)
- current lineations (linear grooved produced by current action)
- slump folds (produced because the sediment is full of water and 'unstable')
- load casts (formed where heavy overlying sediments sink into the softer sediments below (e.g. sands overlying muds).

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