EARTH AND SPACE SCIENCES 212

CLASTIC SEDIMENTARY ROCKS

Clastic sedimentary rocks are composed of transported fragments derived from the weathering of pre-existing igneous, sedimentary, or metamorphic rocks. Almost all characteristics of these rocks (in particular their composition, texture, color, structural features and fossil content) are useful clues to paleo-conditions of climate, sediment source, relief, ecology and the depositional environment in which the rocks were formed.

Description and classification is a vital first step toward understanding the origin and history of clastic sedimentary rocks. As with igneous rocks, a complete description and classification must be based on both ***mineral content and texture***. The relative abundance of mineralogical and non-mineralogical constituents in clastic rocks is determined largely by the nature of the source of the sedimentary material and the type of weathering which prevailed. The texture (size, shape, sorting, and arrangement of grains) reflects the processes and duration of transportation and deposition of sediment particles.

SAMPLE DESCRIPTION

The following megascopic characteristics are important to observe in clastic sedimentary rocks:

1. Grain size (range and dominant).
2. Grain shape (rounding and sphericity).
3. Degree of sorting (including percent clay matrix vs. percent framework grains).
4. Fabric (grain packing and orientation).
5. Constituent grains (identification and relative abundance).
6. Induration.
7. Cement (amount and type).
8. Color.
9. Fossil components (identification and abundance).
10. Sedimentary structures.

1. Grain Size

It is important to record the range of grain sizes that occurs in the rock (minimum-maximum) and to specify which size dominates. The first and most basic classification of clastic sedimentary rocks is based on the dominant grain size. Figure 1 lists the arbitrary, but widely accepted, divisions between conglomerate, sandstone, siltstone and claystone. Grain sizes of sand and coarser can be determined by visual comparison (see Figure 2). Grain sizes of mudrocks should be determined by microscopic examination, but a field estimate may be made by rubbing a fragment of the rock against your teeth (see Figure 3).

The sizes of clastic particles in a sedimentary rock are related primarily to the following:

(a) *Original sizes of available clasts.* This is dependent primarily on the nature of the source rock and its response to weathering.

(b) *Transporting medium*. The size of particles deposited depends on the energy of the transport agent (ice, running water, oscillating water, wind). As a general rule, clastic sediments grade from coarse to fine away from their source region.

(c) *Duration of transport.* The longer the period of time a sediment is transported, the smaller its particles become due to wear and solution.

Millimeters (mm)		Micrometers (µm)	Phi (ϕ)	Wentworth size class		Rock type
	4096		-12.0	Boulder	Gravel	Conglomerate/ Breccia
	256		-8.0	Cobble		
	64		-6.0	Pebble		
	4		-2.0	Granule		
	2.00		-1.0	Very coarse sand	Sand	Sandstone
	1.00		0.0	Coarse sand		
1/2	0.50	500	1.0	Medium sand		
1/4	0.25	250	2.0	Fine sand		
1/8	0.125	125	3.0	Very fine sand		
1/16	0.0625	63	4.0	Coarse silt	Silt	Siltstone
1/32	0.031	31	5.0	Medium silt		
1/64	0.0156	15.6	6.0	Fine silt		
1/128	0.0078	7.8	7.0	Very fine silt		
1/256	0.0039	3.9	8.0			
	0.00006	0.06	14.0	Clay	Mud	Claystone

Udden-Wentworth grain-size classification. (source: Wentworth, 1922)

Figure 1. The standard grain size scale for clastic sediments. (Udden and Wentworth)

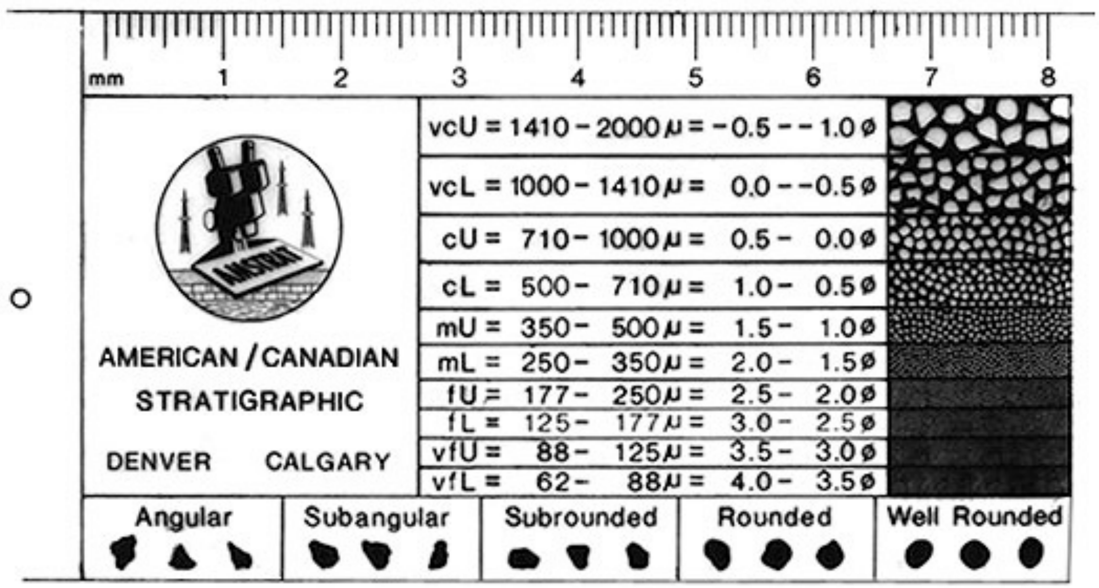

Figure 2. Grain size comparator.

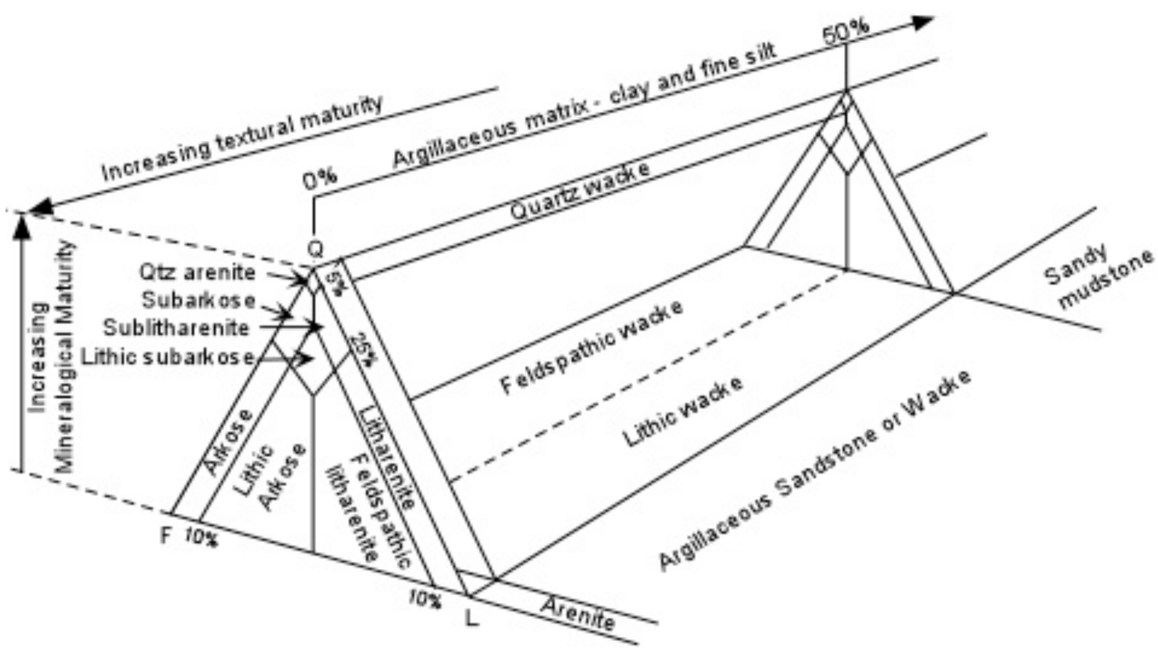

Figure 3. Classification of Mudrocks. (Blatt and co-workers)

2. GRAIN SHAPE.

Shapes of clasts can be described in two ways:

(a) roundness- the smoothing of edges and corners from angular fragments. Roundness serves as an index for duration of transport.

(b) sphericity- approach to spherical form. Sphericity is largely dependent on the original shape of the clasts, but it is increased by rounding.

The easiest way to judge rounding and sphericity is by comparison with reference sketches (see Figure 4). It is important to note consistencies and/or inconsistencies in grain shape within the sample.

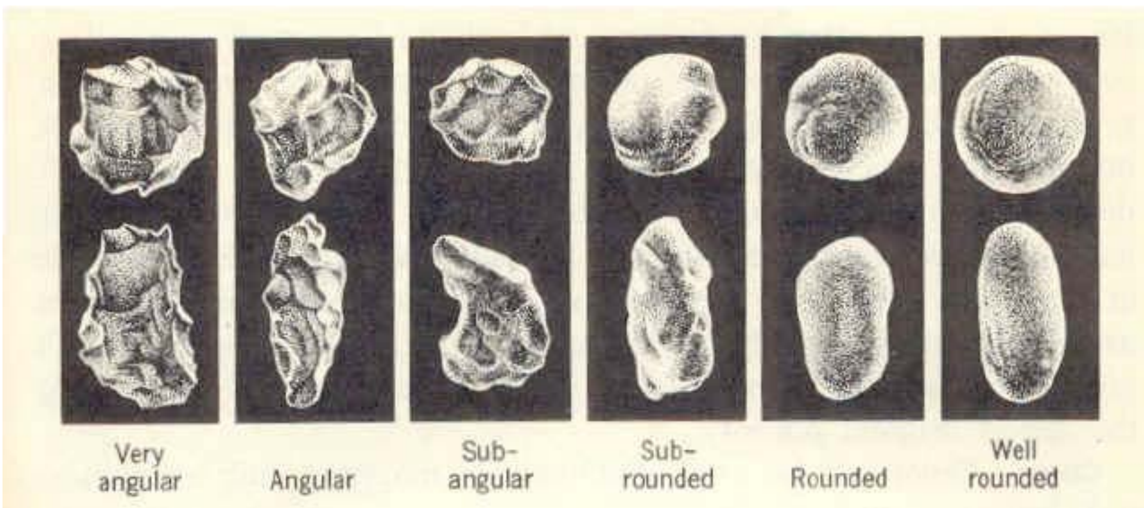

Figure 4. Categories of roundness for grains of low and high sphericity. (after Powers,1933)

3. DEGREE OF SORTING.

Degree of sorting refers to the amount of dispersion around the dominant grain size. Sorting is accomplished by the selection during transport of particles according to their sizes and specific gravities. A well-sorted sediment has a fairly uniform grain size. Figure 5 presents visual estimates of sorting in sandstones. For hand sample descriptions, we generally ignore the degree of sorting in mudrocks due to difficulty associated with their very fine grain size.

Keep in mind that sandstones with a significant percentage of silt or clay matrix are poorly-sorted.

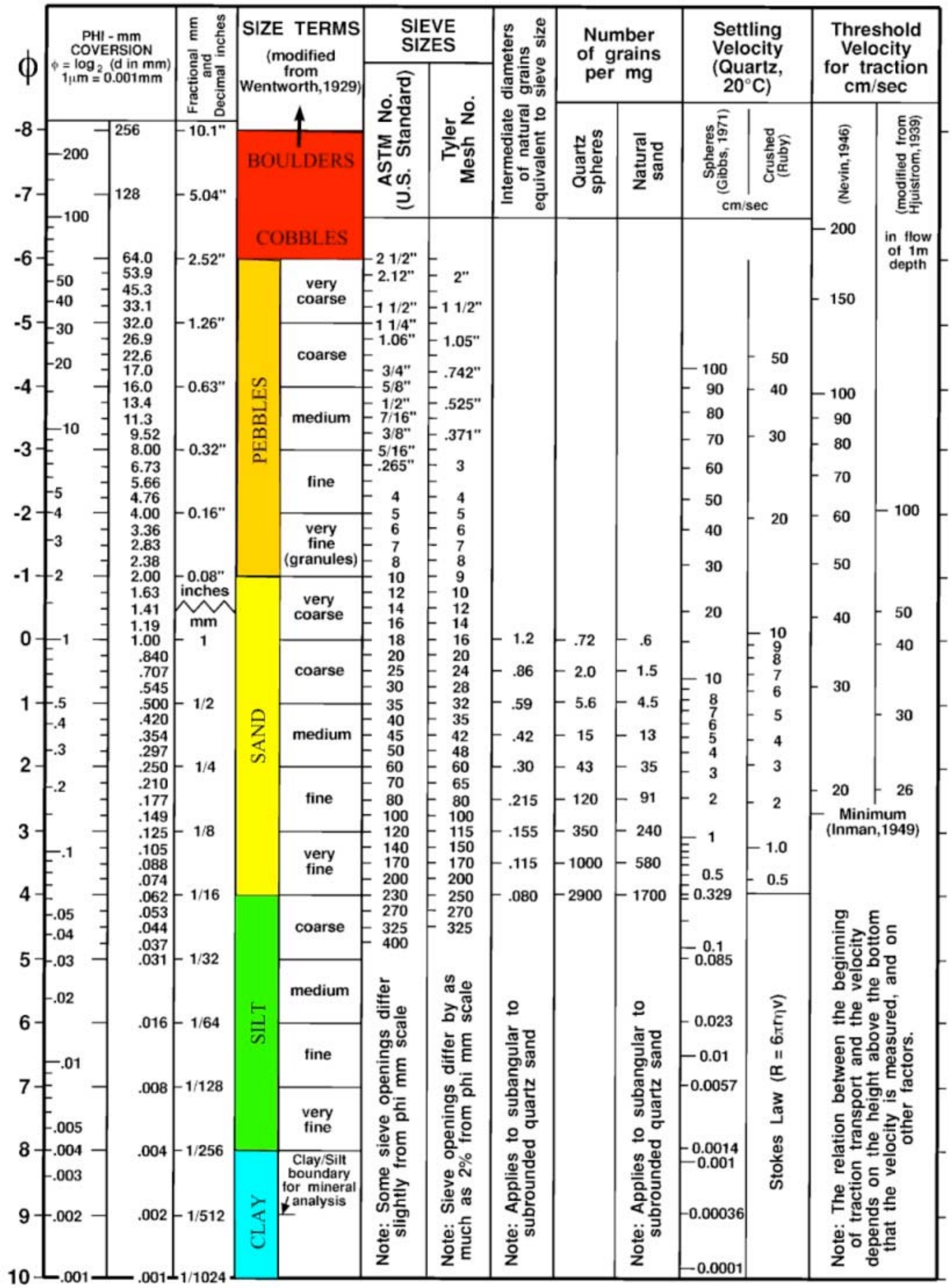

Figure 5. Degrees of sorting

4. FABRIC.

Fabric refers to the orientation (or lack of it) among sediment grains. You can judge by hand sample whether grains show a preferred orientation, i.e. elongate grains are aligned. Packing, crushing, and suturing of grains can be observed in thin section only.

5. CONSTITUENT GRAINS.

It is important to identify the constituent grains that compose clastic sedimentary rocks and to estimate their individual modal abundances. Because we will be working without the aid of thin sections, we will only attempt to identify the individual components of sandstones and coarser-grained clastic sedimentary rocks using a hand lens. Generally these rocks will be composed of varying amounts of **quartz, feldspar, rock fragments, heavy minerals, and micas.**

6. INDURATION.

Induration refers to how well the individual clasts are held together. A well-indurated clastic rock is hard - individual grains are held together very strongly. A poorly-indurated clastic rock is friable. Indicate the degree of induration in your hand sample description. It may help in understanding the extent of certain diagenetic processes (compaction, cementation, etc.).

7. CEMENT.

It is important to determine whether clasts are held together by cement (secondary feature- mineral matter precipitated in pore spaces) or by matrix (primary feature). The most common types of cement include quartz, calcite, and ferric oxides (hematite and limonite). For your descriptions, be sure to estimate what percentage of the rock is composed of cement material.

8. COLOR.

The color of a sedimentary rock relates to its clastic components and also to its cement or matrix and state of oxidation. There are charts used to standardize color designations in the field, but for our purposes it will be sufficient to estimate gross color. You should note hand specimen color on both fresh and weathered surfaces and specify whether the color is due more to the matrix of granular components.

9. FOSSIL COMPONENTS.

Fossils can indicate specific types of depositional environments. If possible, it is important to record the types of fossils, the degree of fragmentation, and any signs of preferred orientation. Trace fossils can also be invaluable indicators of depositional environment.

10. SEDIMENTARY STRUCTURES.

Sedimentary structures are among the most useful features for interpretation of depositional and post-depositional processes. Common sedimentary structures include ***mud cracks*** (shallow water environment), ***ripple marks*** (symmetrical or asymmetrical due to unidirectional or oscillating current), ***cross bedding*** (current action in river channels, sand dunes, etc.), ***laminar bedding*** (quiet water environment, e.g., lakes), ***graded bedding*** (rapid sedimentation from sediment-laden currents, e.g., turbidites), ***current marks (load casts, flute casts, groove casts*** in the basal layer of turbidites), ***cut and fill structures*** (variable velocities in stream channels), ***organic burrows*** (bioturbation).

SEDIMENT MATURITY

There are two types of sediment maturity: textural and compositional. The concept of maturity is extremely important for it may reveal useful information about the processes involved in the formation of the sedimentary rock. You should specify the textural and compositional maturity of the rock in your hand sample description.

<u>Textural Maturity:</u>

The textural maturity of a clastic sediment is increased by the progressive removal of clay- and silt-size particles as well as the sorting and rounding of larger grains. These processes advance at different rates and the stage of textural maturity is determined by the degree to which these processes have approached completion.

The textural maturity of sands is largely a function of input of kinetic energy.

<u>Compositional maturity:</u>

Compositionally mature sediments are those containing a high proportion of the most chemically stable and most physically resistant minerals such as quartz, chert, and ultrastable heavy minerals such as zircon and tourmaline. Compositionally immature sediments contain the less stable grains: feldspars and those rock fragments not consisting principally of quartz.

Clastic sediments are residues of weathering and erosion. The relative stability of their particles is an index of the maturity of the action of these wasting processes. A truly mature sandstone or conglomerate is one subjected to extreme chemical and physical weathering and abrasion (generally for a very long time and possibly at several different locations).

CLASSIFICATION OF SANDSTONES

The two major classes of sandstones, *arenites* and *wackes*, are distinguished according to the amount of matrix present:

$<$ 15% matrix: arenite
$>$ 15% matrix: wacke.

Arenites and wackes can be further sub-classified based on relative proportions of quartz + chert (most stable components), feldspar (both plagioclase and K-feldspar), and unstable lithic fragments (everything else- minerals other than quartz and feldspar, rock fragments, fossils, non-mineralic material). Figures 6 and 7 show two widely used classification diagrams used for arenites and wackes, respectively. Further modifying adjectives can be used to describe additional features such as maturity, general grain size, overall color, type of cement, type of bedding, etc.

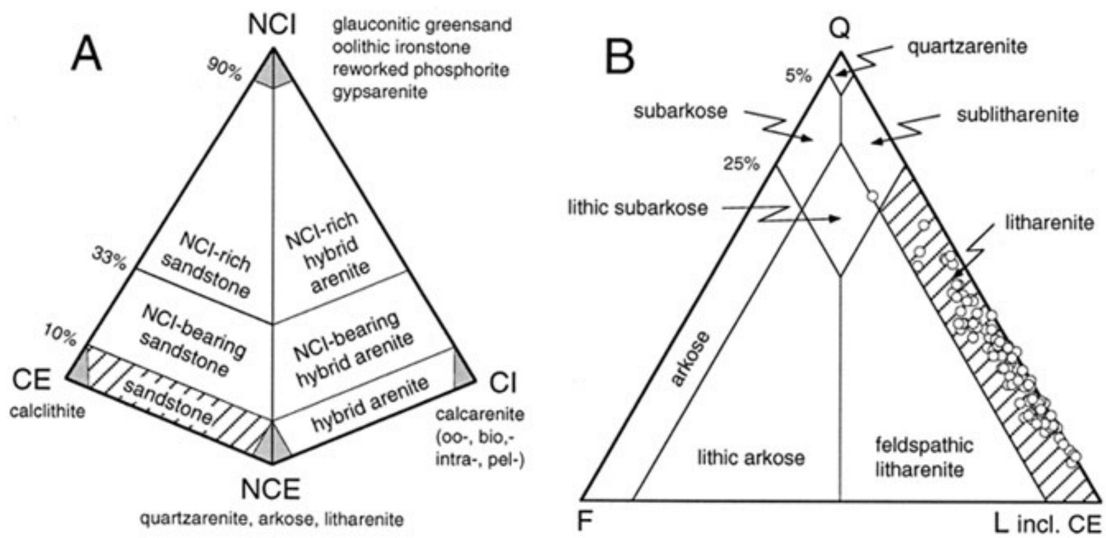

Figure 6. Classification of arenite sandstones. (McBride, 1963)

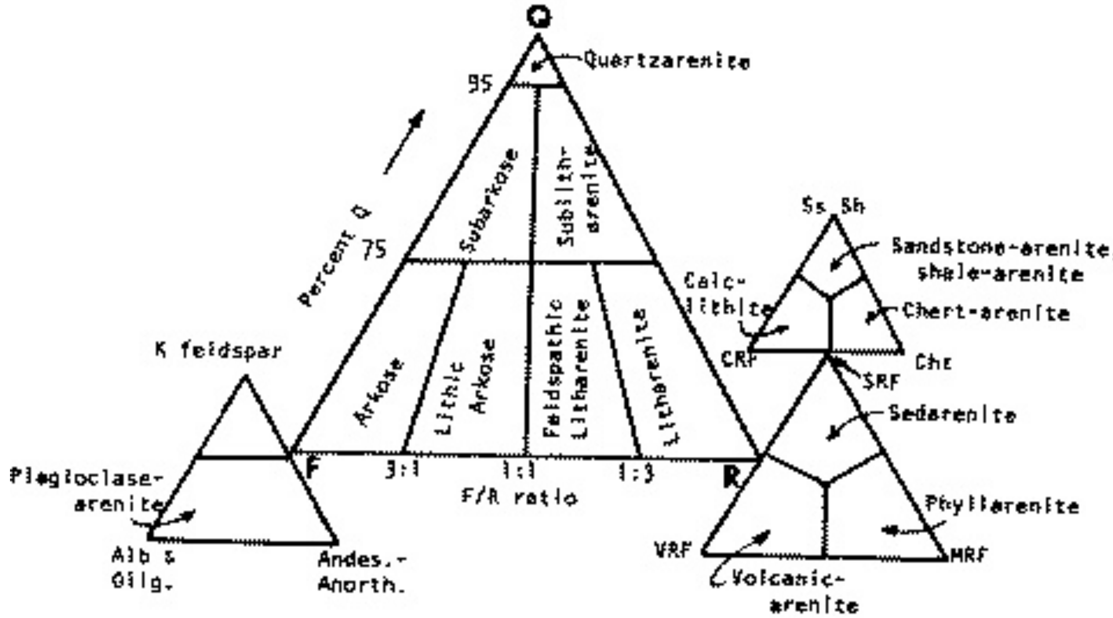

Figure 7. Classification of wacke sandstone. (Folk, 1974)

Earth and Sciences 212: Clastic sedimentary rocks

Assignment: Write up and hand in a complete description of sample 321-49

321-152 Conglomerate (fluvial origin, locality unknown).

The majority of the clasts in this sample are chert, but there are other lithologies. Note the imbrication in some samples.

Question: (1) What lithologies [other than chert] are present?

ARENITES

321-170 Quartzarenite (Berea Grit, Ohio).

This is a nearly pure sandstone**.**

Questions: (1) Comment on the textural and compositional maturity of this sample.

(2) Comment on any diagenetic changes that have occurred.

321-154 Lithic subarkose (locality unknown).

Although the locality and age of this sample are unknown, the color and composition suggest the rock was part of a "continental red bed" in the western U.S. (most likely Triassic in age).

Question: (1) What gives the sandstone its red color?

(2) Is this sandstone well sorted or poorly sorted?

321-199 Subarkose (Wenatchee Formation, Washington).

Note the variations in texture and composition in the different laminae. Some are arkosic in composition and some have been pervasively stained with iron oxides due to a higher porosity.

Questions: (1) What mineral has the feldspar weathered to?

(2) Given the composition and grain size of this sample, suggest a likely parent rock.

321-50 Lithic subarkose (Roslyn Formation, Washington).

Questions: (1) Estimate the relative proportions of detrital components in this rock.

(2) Determine the compositional and textural maturity and suggest a depositional environment.

321-52 Lithic arkose (Swauk Formation, Washington).

Questions: (1) Examine carefully the small (1 to 2 mm) black forms. What are they and what do they indicate about conditions of deposition? (Hint: they are non-mineralic.)

(2) Are your observations consistent with a fluvial origin that has been suggested for these rocks?

<u>321-55 Arkose</u> (location unknown).

Questions: (1) What is the black material? Was it deposited with the other components in the rock (matrix) or introduced during diagenesis (cement)?

(2) What can you say about the porosity and permeability of the sediment which formed this rock?

<u>WACKES</u>

<u>321-258 Lithic wacke</u> (Port Orchard, Oregon).

Note the color of this specimen. This is a good example of the type of rock which is loosely referred to as **"graywacke".**

Questions: (1) Estimate the amount of matrix in this sample.

(2) Comment on the textural and compositional maturity of the sand-sized fraction.

<u>321-144 Lithic wacke</u> (Deception Pass, Washington).

Questions: (1) Why does this graywacke appear green?

(2) Is there textural evidence for a low grade metamorphism?

<u>321-68 Lithic wacke interbedded with siltstone</u> (Naches Formation, Washington).

Note the graded bedding (it is easier to see in the large sample). Graded bedding can be used to determine the “up-direction” in a sedimentary sequence. Convince yourself that you know which direction is “up”.

Question: (1) How does graded bedding form?

<u>MUDROCKS</u>

<u>321-46 Clayey siltstone</u> (locality unknown).

You could use the "taste test" to determine the relative amounts of each component in this rock...but please don't. You can tell by rubbing your thumb across it that the sample is predominantly silt with a significant clay component.

Question: (1) What diagenetic process has occurred to create such a well-indurated siltstone?

<u>321-134 Interbedded mudstone and siltstone</u> (British Columbia).

Question: (1) Compare sedimentary structures and environment of deposition with those of 321-68.

SEDIMENTARY STRUCTURES (single samples)

321-283: Symmetrical ripple marks. These form when currents are oscillating. Unidirectional currents, as in a river environment would produce asymmetrical ripple marks.

Question: What type of depositional environment would have oscillating currents?

321-284: A silt-rich or clay-rich rock is called a shale rather than a mudstone when it has been compacted and shows a feature called “fissility”, meaning that the rock will split along closely spaces planes.

Question: What might be an explanation for the fissility?

321-285: Graded bedding is well developed in this sample. The stratigraphically “up” direction is toward the wide end of the sample. There are also cut-and-fill structures which show the coarser-grained material eroding down into the finer-grained material of a previous depositional event.

Question: What depositional processes might give rise to graded bedding?

321-288: The surface of this sample contains **flute casts** which are indicators of current directions. They are formed on the bottom of the sediments and are commonly associated with the deposits formed by turbidity currents. The flute structures are formed when the head of a turbidity current flows over a recently deposited mud and erodes into it. Subsequently, the tail of the current deposits a fine sand in the depression.

Question: How might one determine current directions from flute casts?

321-290: This mature quartz arenite has preserved delicate raindrop impressions on one surface. This sandstone probably formed in a beach or aeolian environment.

Question: What depositional conditions would be required to preserve raindrop impressions?

321-328: These are “upside down” mud cracks, i.e., impressions of mud cracks.

Question: How do mud cracks form?

Glacial Sediments (single sample)

321-282: This laminated mudrock was deposited in a glacial lake and shows **varves**. Each couplet (one dark and one light layer) represents one year of deposition. Varves can be counted like tree rings. The lighter layers are composed primarily of silt and the darker layers are composed of primarily of clay.

Question: Which layers represent summer deposition and which layers represent winter deposition?