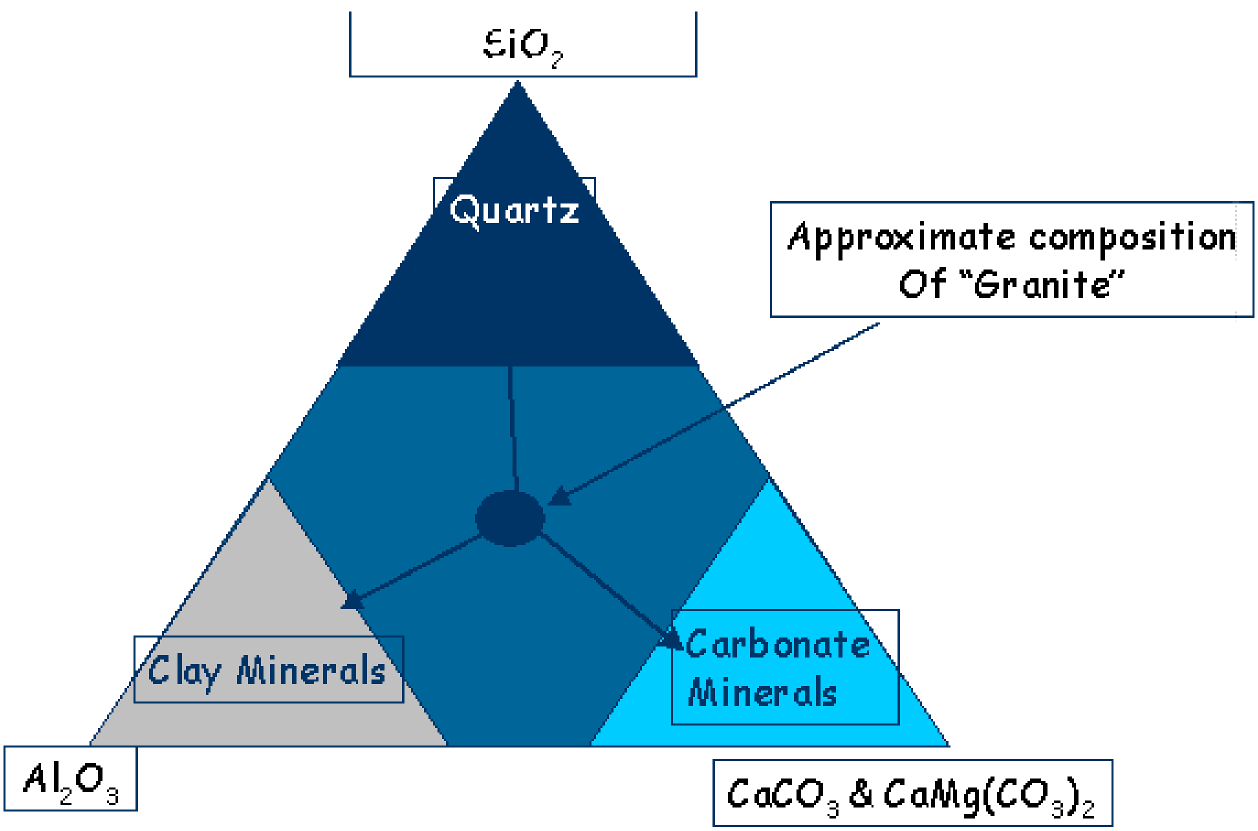
Sedimentary Rocks- Analysis and Classification

Sedimentary rocks are formed by the accumulation of weathering products (Earth materials formed by surface processes that breakdown exposed rocks) that are eventually consolidated into rock layers by compaction and cementation. Sedimentary rocks represent only about 5% of the mass of the earths crust but cover over 70% of the surface area of the land surface. A quick perusal of the geological map of the U.S. will convince anyone that this is a reasonable approximation.

The formation of various sediments is in a way, a geochemical differentiation of the constituents that make up the primary rock composition of the earths crust e.g. granite. The following diagram will illustrate this for the 3 most common sedimentary rock types, shale, limestone-dolostone and sandstone.
Figure 1



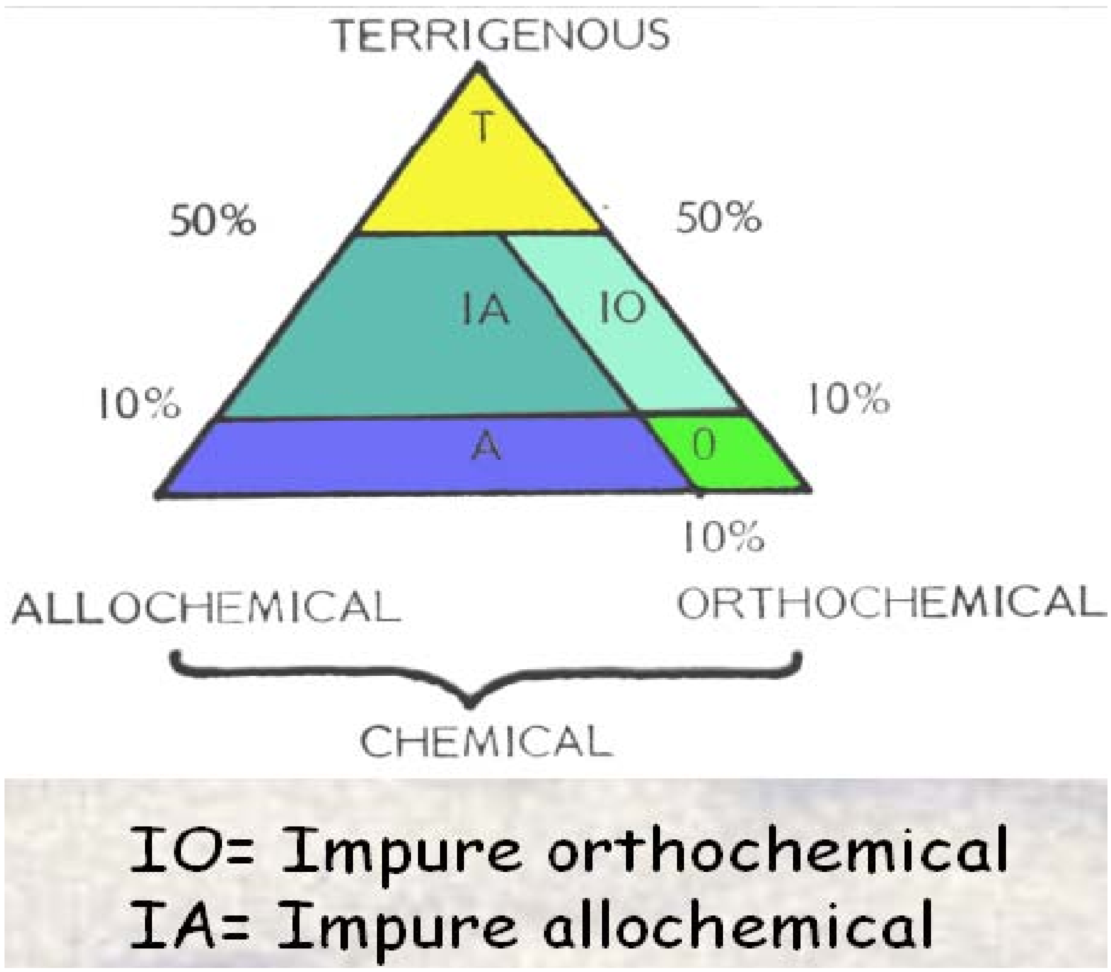
Three Sediment Types:

1. **Terrigenous Clastic** (Detrital) Sediments
a. the residual and secondary particles produced by weathering;
b. shale, sandstone and conglomerate

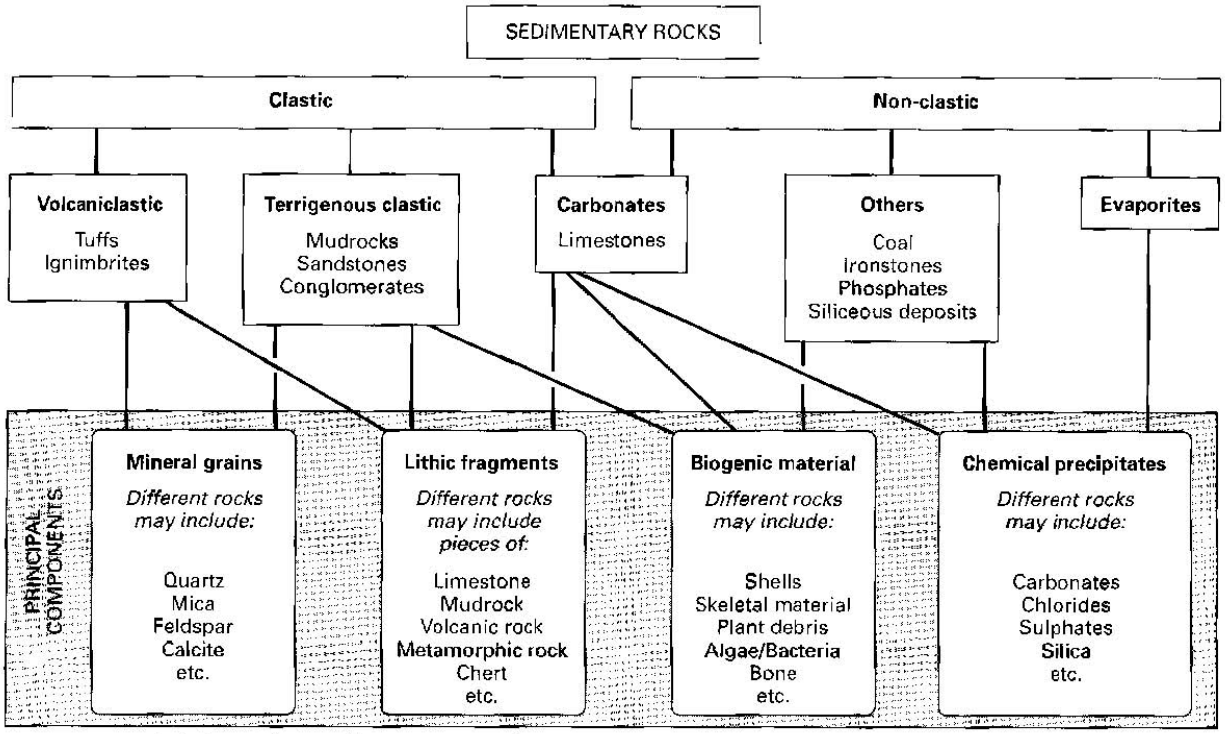
2. **Orthochemical**(Chemical Precipitate) Sediments
a. from the dissolved ions
b. evaporites,

3. **Allochemical**
a. biochemical particles, shell/test fragments
b. most limestone

Figure 2



Sedimentary Petrography/Lithology **Figure 3**



principal conttituents ofssecrmentary rocks

Terrigenous Clastic Sediment (unconsolidated particles) **and Rocks** (lithified; by compaction and cementation)

Figure 4

mm	phi	Name	
		Boulders	Gravel Conglomerate
256	-8		
128	-7		
64	-6	Cobbles	
32	-5		
16	-4		
8	-3	Pebbles	
4	-2		
		Granules	
2	-1	Very coarse sand	Sand Sandstone
1	0	Coarse sand	
0.5	1	Medium sand	
0.25	2	Fine sand	
0.125	3	Very fine sand	
0.063	4	Coarse silt	Mud Mudrock
0.031	5	Medium silt	
0.0156	6	Fine silt	
0.0078	7	Very fine silt	
0.0039	8	Clay	

The Udden–Wentworth scale

Figure 5: **Particle Size; phi (φ) particle size = $-\log_2$(grain diameter in mm)**

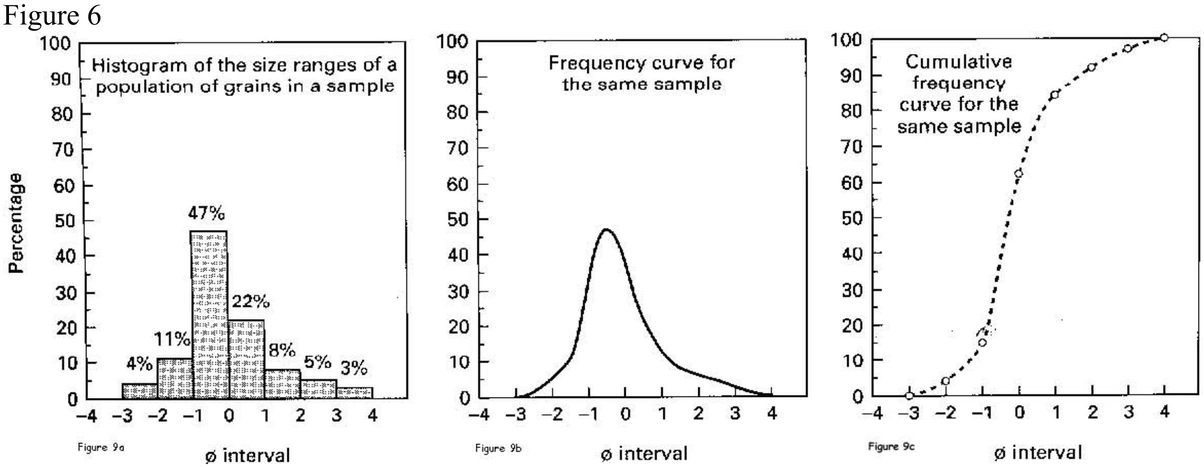
Textural Analysis: Particle Size

One important textural (geometric characteristics of grains) characteristics of detrital sediments is the grain size. It should be obvious that grain size is directly related to the energy of the depositional environment. There are a number of techniques used for completing grain size studies on soils and/or sediments (disaggregated sedimentary particles). Two of the most common are sieving analysis for coarser grained material and sedimentation rate analysis for fine grained material. We shall briefly discuss the two methods below.

Sieving

Sieving is a mechanical method of sorting clastic particles into various size classes or ranges depending on the purpose of the analysis. The sieves are commercially available and consist of 8" diameter. Round screens made with standard mesh wire and listed on the Wentworth table mentioned above. For example, if one were interested in analyzing beach sand, it would be logical to take a stack of sieves including numbers 10, 18, 35, 60, 120 and 230 and have the sample sift through each of the sieves (encouraged by gentle shaking or vibrations) and then the weight percent of each size fraction collected on each screen can be recorded. This in turn would enable one to construct a histogram of the grain size distribution of the sample (Figure 6). An example of a typical histogram is shown below. The grain size analysis may also be shown as a frequency or cumulative frequency curve as illustrated in fig. 6b and c above.

Figure 6



Sieving is a very common technique but is only applicable for medium to coarse grained material; other techniques must be used for very fine grained material.

Sedimentation Rate Method

Sedimentary particles settle in a liquid medium according to Stokes' Law:

$$V_s = \frac{r^2(\rho_s - \rho_l)g}{18\mu}$$

Where V_S is the settling velocity, d is the particle diameter, ρ_s is the grain density, ρ_l is the liquid density, g is the gravitational acceleration and μ is the viscosity of the liquid. A simplified version of the relationship is given by $V = Cr^2$ where C is a constant and r is the radius of the grain. Obviously large grains settle quickly and small ones settle slowly. This technique is very useful for separating clay from other (coarse) minerals when an x-ray diffraction study is required to identify the specific type of clay minerals in the bulk sample.

In practice, a small (25 gram) sample is introduced into a 1000 ml graduated cylinder full of water with some deflocculant (disputant) compound such as calgon to make sure the clay particles will settle as individual grains. The mixture is well mixed and then the settling times are noted. The following table gives the settling times for different size fractions that can be sampled at various depths in the cylinder.

Table 1

Phi	mm	um	Depth(cm)	h	min	s
4.0	0.063	63	20			58
4.5			20		1	56
5.0	0.0312	31.2	10		1	56
5.5			10		3	52
6.0	0.0156	15.6 silt	10		7	42
6.5			10		15	
7.0	0.0078	7.8	10		31	
7.5			10	1	1	
8.0	0.0039	3.9	10	2	3	
8.5			10	4	5	
9.0	0.00195	1.95	10	8	10	
9.5		-- clay	10	16	21	
10.0	0.00098	0.98	10	32	42	
10.5			5	32	42	
11.0	0.00049	0.49	5	65	25	

Texture: *Grain Shape, Sorting and Textural Maturity*
Other aspects of texture, in addition to particle size are useful in the study of clastic sediment (this includes allochemical sediments, see below).

Grain shape, the degree of irregularity of grain boundaries, and

Particle Size Sorting, the range of particle sizes present in a sample, are also useful criteria for the classification of clastic particles.

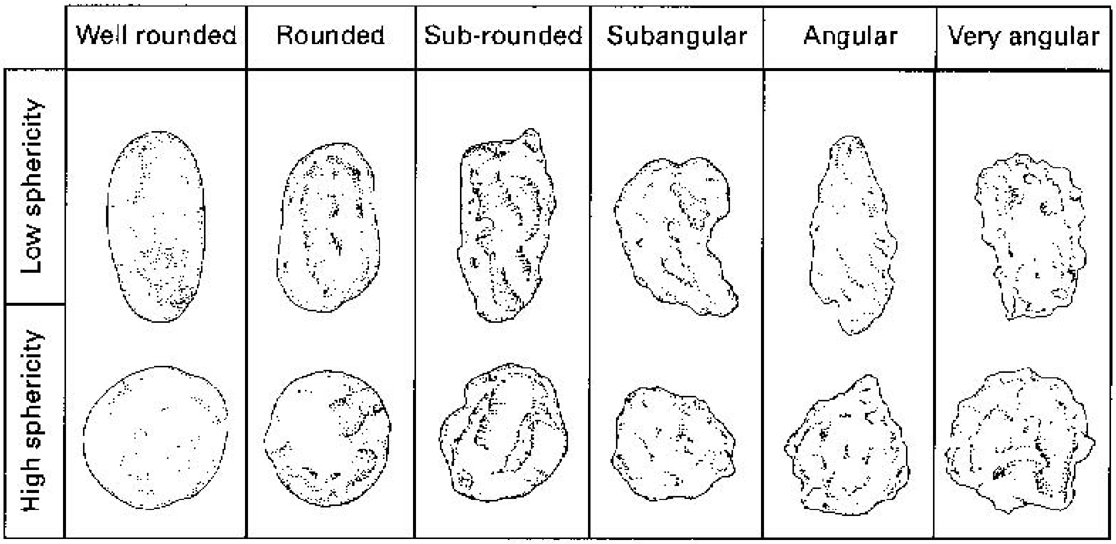
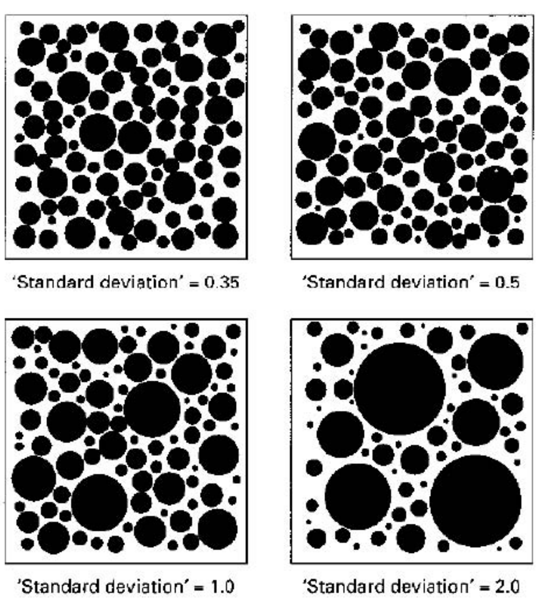


Figure 7: Verbal scale for rounding

The sorting verbal scale qualitatively represents the diversity of particle size. Numerical values of sorting can be calculated using particle size distribution data (see above). The numerical value for sorting is really a representation of statistical range of size variation (standard deviation of particle size). The larger the value the greater the range of particle size.

Figure 8: Numerical and verbal scale for sorting

Very well sorted 'Standard deviation'	< 0.35
Well sorted	=0.35–0.5
Moderately well sorted	=0.5–0.71
Moderately sorted	=0.71–1.0
Poorly sorted	=1.0–2.0
Very poorly sorted	>2.0



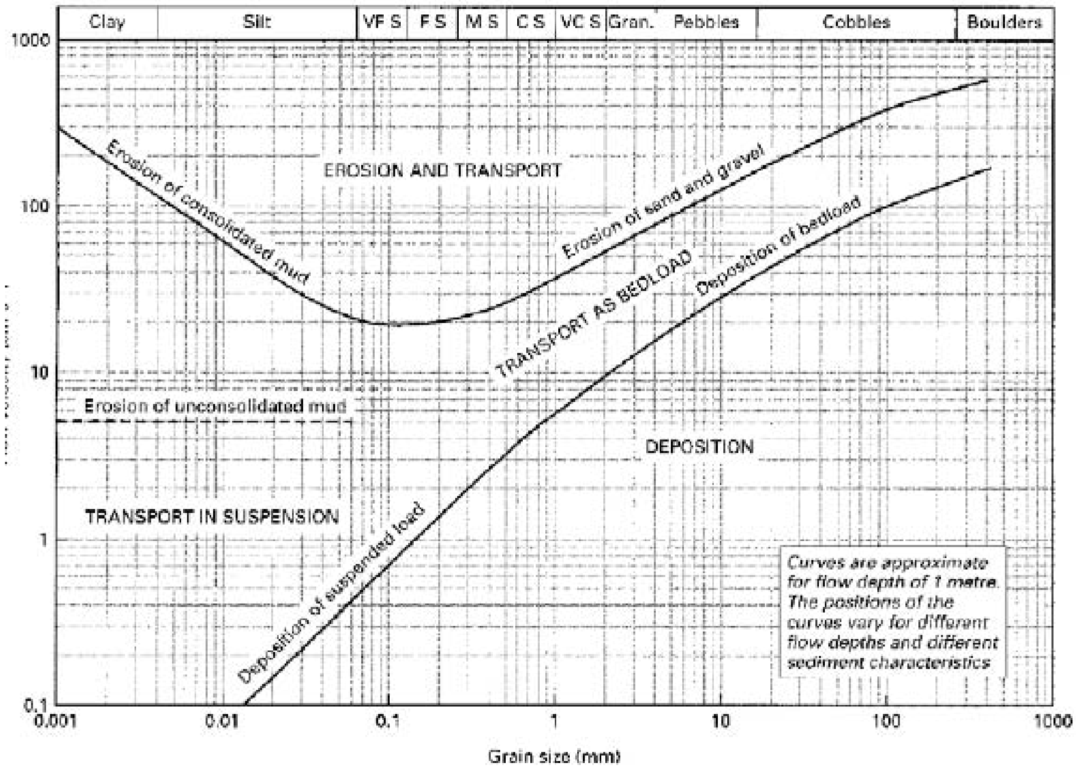
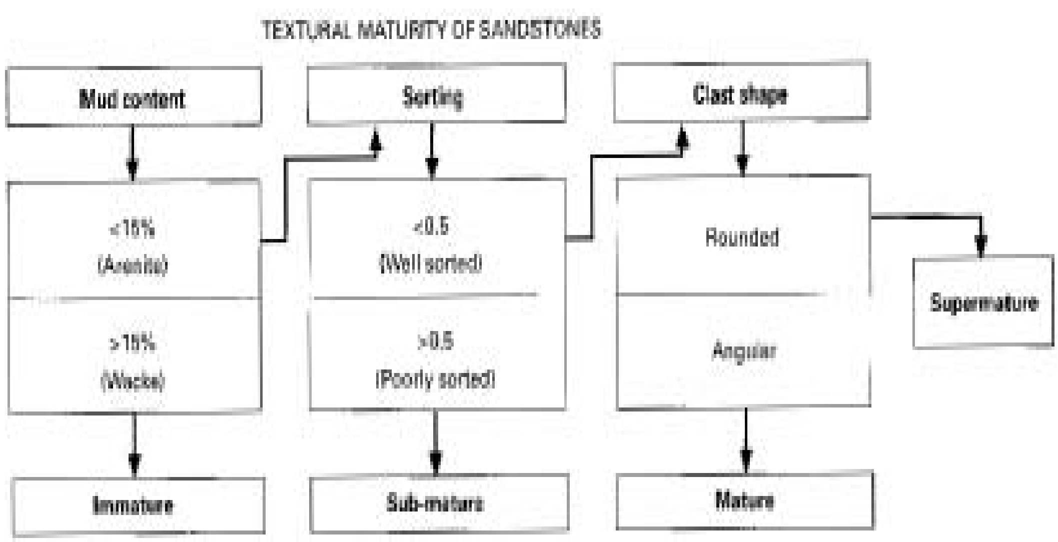


Figure 9: Hjulstrom Diagram

Textural Maturity is a statement of how the degree terrigenous clastic particles have enjoyed the processes of erosion, transport and depositional reworking. Figure 10 shows the verbal scale for and the general idea of textural maturity.

Figure 10



Controls on the Mineralogical Occurrence and Properties of Terrigenous Clastic Particles

Goldich Weathering Stability Series (relative stability in surface weathering environment)

Olivine	***Ca Plagioclase***	*Least Stable*
Pyroxene		
Amphibole		
Biotite		
K-Feldspar	***Na Plagioclase***	
Muscovite		
Quartz		*Most Stable*

- Predicts relative abundance of particulate residues produced in a weathering environment.
  - What are the Assumptions? (Standard surface conditions)
- Results in relative abundance of particulate residues including consideration of
  - Mechanical stability ; Calcite is mineralogically stable but **labile** (mechanically unstable)
  - Abundance: Rock forming Minerals that are abundant (like Plagioclase feldspar) are common sedimentary grains because they are so abundant

Ions in solution

Na+, Ca++	*Most Soluble*	
Mg++, K+		
		(In Natural Waters)
Si+4, Fe++		
Al+++, Fe	*Least Soluble*	

Insitu Minerals: formed in place

- **Clay Minerals** : hydrous Alumino-silicate minerals (phyllosilicates)

Clay Mineral	Additional Cations	Eh/pH Sensitivity	Common Occurrence
Kaolinite (7Ao)	none	low pH	Strong Chemical Weathering
Mica/illite (10 Ao)	K	mod to elevated pH	Alteration of pre-existing clay
Smectite Clays; Montmorillonite (9.5Ao to 17Ao)	K, Na, Ca, Mg, Fe	high pH	volcanogenic protolith: Bentonite; **Swelling Clay**