GEL 324 Sedimentology

Particle Size Analysis I

Sieve Analysis

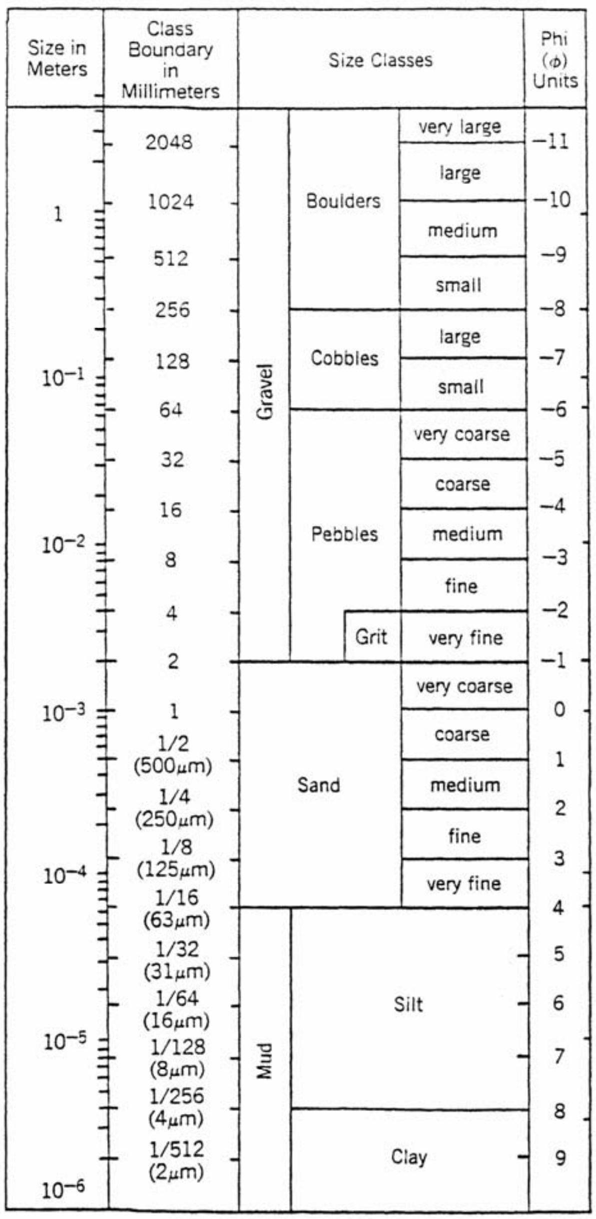

Figure 1. The Wentworth-Udden and Phi size scales (from Fritz, W.J. and Moore, J.N., 1988, Basics of Physical Stratigraphy and Sedimentology, John Wiley and Sons, Inc., New York.

Introduction

Particle-size analysis is an important component of the study of clastic sediments and rocks. It is not practical to actually measure the size of individual particles but sieve analysis allows particles to be grouped into classes according to the Wentworth-Udden or Phi scales (Figure 1), by bracketing the size class with different sized sieves. The number of size classes varies with the purpose of the study. The sieves are arranged in order of decreasing aperture with a collecting pan at the bottom. A sample of known mass is introduced into the top of the sieve stack and shaken in a mechanical sieve shaker for a standard duration.

The particles retained on each sieve have diameters smaller than the upper sieve aperture but smaller than the lower sieve aperture. The sieving process does not provide information on particle shape and thus the particles on any sieve represent those that were able to pass through the upper sieve given the energy of the shaking effort and the shaking time. In larger samples some particles that are capable of passing through a sieve may not because of particle interference or improper orientation with the mesh. Aggregates of particles or particles with coatings of finer material may not pass through the proper sieve.

Data Analysis and Presentation

The mass retained on each sieve is recorded and converted to mass percent of the original dry mass;

$$M\% = (m/M_0)*100$$

where m is the mass retained on each sieve and M_0 is the original dry mass of the sample. Note that the original dry mass commonly differs from the sum of the masses retained by each sieve. The difference arises from weighing errors and other experimental errors in the analysis. The error can be determined as a percentage of the original dry mass from the equation;

$$\%E = (M_0 - \Sigma M)/M_0 * 100$$

where M_0 is the original dry mass and ΣM is the sum of the masses retained on each sieve and the collecting pan. The error should be less than 1 or 2 %. The cumulative mass percent retained on each sieve, or cumulative % coarser, is found by adding the mass percent of material on all coarser sieves. The particle size analysis for sample 533-1 from Bemidji, Minnesota is shown in Table 1.

Table 1. Particle size analysis for sample 533-1, Bemidji, MN.

Dry Mass (M_0) = 61.5 grams % Error = 0.5%

Particle Size Passed ϕ	Particle Size Retained ϕ	Mass (g)	Mass (%)	Cumulative Mass Retained (%)
-3	-2	0.0	0.0	0.0
-2	-1	1.9	3.1	3.1
-1	0	1.6	10.8	13.9
0	1	17.6	28.8	42.6
1	2	13.1	21.4	64.1
2	3	17.3	28.3	92.3
3	4	3.9	6.4	98.7
pan		0.8	1.3	
SUM		61.2	100.0	

The particle size distribution may be displayed graphically as histograms, frequency curves or cumulative frequency curves or may be expressed as numerical moments of the distribution. The cumulative frequency curve is plotted using cumulative mass % coarser on a probability-scale ordinate and particle size in ϕ units on the abscissa (Figure 2). The Method of Moments uses four statistical measures; mean, standard deviation, skewness and kurtosis; to quantify the shape of the particle size distribution. The moment equations are shown in Table 3 (Note: m = phi class midpoint; f = class weight %; n = 100%)

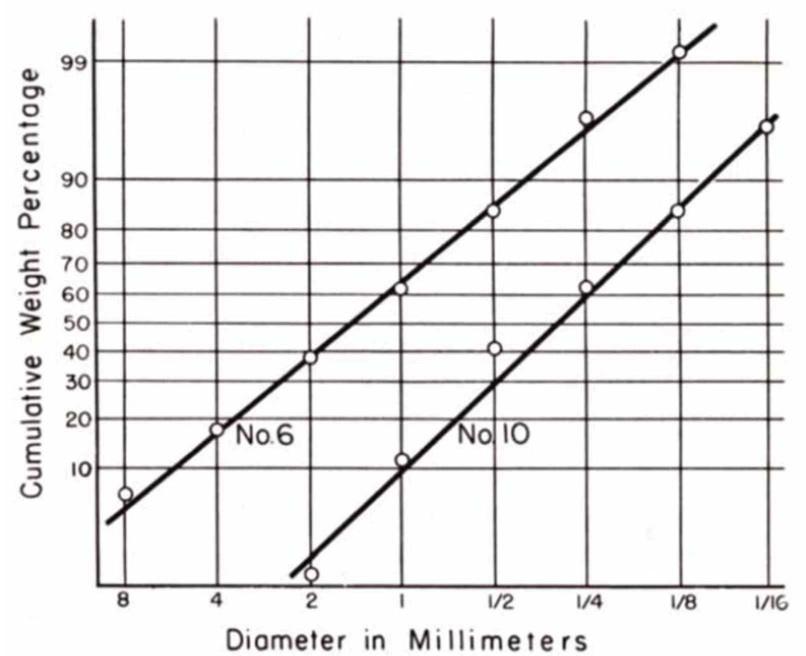

Figure 2. Cumulative frequency curve plotted on log-probability scales (From: Pettijohn, 1975).

Table 3. Numerical moments of the particle size distribution.

Moment 1: Mean

$$\overline{X}_\phi = \frac{\sum fm}{n}$$

Moment 2: Standard Deviation

$$\sigma_\phi = \frac{\sum f(m-\overline{X}_\phi)^2}{n}$$

Moment 3: Skewness

$$Sk_\phi = \frac{\sum f(m-\overline{X}_\phi)^3}{n\sigma_\phi{}^3}$$

Moment 4: Kurtosis

$$K_\phi = \frac{\sum f(m-\overline{X}_\phi)^4}{n\sigma_\phi{}^4}$$

Folk and Ward (1957) devised graphical moments of the distribution based upon ϕ values obtained graphically from the cumulative frequency curve at specific percentile levels. The method generally uses cumulative The Folk and Ward (1957) graphical moments are summarized in Table 4. Descriptive terminology for the Folk and Ward (1957) graphical moment values is presented in Table 5.

Table 4. Folk and Ward (1957) graphical moments of the particle size distribution.

Graphic mean	$M_Z = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$	(1)
Inclusive graphic standard deviation	$\sigma_i = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$	(2)
Inclusive graphic skewness	$SK_i = \frac{(\phi_{84} + \phi_{16} - 2\phi_{50})}{2(\phi_{84} - \phi_{16})} + \frac{(\phi_{95} + \phi_5 - 2\phi_{50})}{2(\phi_{95} - \phi_5)}$	(3)
Graphic kurtosis	$K_G = \frac{(\phi_{95} - \phi_5)}{2.44(\phi_{75} - \phi_{25})}$	(4)

Source: Folk, R. L., and W. C. Ward, 1957, Brazos River bar: A study in the significance of grain-size parameters: *Jour. Sed. Petrology*, v. 27, p. 3–26. Boggs, 2001, Principles of Sedimentology and Stratigraphy, 3rd Edition: Prentice-Hall, 726p.

Table 5. Descriptive terms for Folk and Ward (1957) graphical moments of the particle-size distribution.

Inclusive Graphic Standard Deviation

φ Range	Description
<0.3	Extremely well sorted
0.3 to 0.6	Very well sorted
0.6 to 0.9	Well sorted
0.9 to 1.1	Moderately sorted
1.1 to 1.5	Poorly sorted
1.5 to 3.0	Very poorly sorted
>3.0	Extremely poorly sorted

Graphic Skewness

φ Range	Description
<-0.3	Very coarsely skewed
-0.3 to -0.1	Coarsely skewed
-0.1 to 0.1	Nearly symmetrical
0.1 to 0.3	Finely skewed
>0.3	Very finely skewed

Graphic Kurtosis

φ Range	Description
<0.5	Extremely platykurtic
0.5 to 0.67	Very platykurtic
0.67 to 0.9	Platykurtic
0.9 to 1.1	Mesokurtic
1.1 to 1.5	Leptokurtic
1.5 to 3.0	Very leptokurtic
>3.0	Extremely leptokurtic

Procedure

1. Obtain a representative 30 to 50 gram sample of oven-dried sandy sediment. Inspect the sample to ensure that the particles are thoroughly disaggregated.
2. Weigh the sample and record the mass on your data sheet.
3. Construct a nest of sieves at 0.5ϕ increments and place a collecting pan at the bottom.
4. Pour the sediment sample into the top of the sieve nest and place a cover on the top sieve.
5. Place the sieve nest into the Ro-Tap sieve shaker and set the timer for 10 to 15 minutes.
6. Remove the sieve nest from the Ro-Tap after the shaking is completed. Remove each sieve in turn and carefully pour its contents onto a sheet of paper. Gently brush the bottom of the mesh, being careful to ensure that no particles are lost. NEVER brush the upper surface of the mesh or force particles from the mesh, doing so will damage the mesh. REMEMBER the sieves range from about $40 to $120, depending upon the mesh aperture, so please be careful when removing your sample.
7. Weigh each fraction and record them on your data sheet.
8. Determine the experimental error and calculate the % mass retained and cumulative % mass retained for each sample.
9. Determine the mean, standard deviation, skewness, and kurtosis of the particle size distribution using the Method of Moments.
10. Plot the cumulative frequency curve on the log-probability graph paper provided. Plot cumulative mass % retained (cumulative % coarser) vs. particle size (retained) in ϕ units.
11. Calculate the Folk and Ward graphical moments of the distribution.
12. Write a report of your findings that includes a discussion of your results and a comparison of the results obtained by the Method of Moments and Folk and Ward method.