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GEOL3010L. Earth Materials II
Mechanical Size Analysis of Sediments by Dry Sieving

I. Introduction

The study of sediments is concerned with

1. the physical conditions of a sediment, whether glacial, fluvial, marine, etc;
2. the time of formation or age of the deposits and;
3. the provenance, or area of denudation that furnished the material composing the sediment.

It was recognized in the second half of the nineteenth century that the median size, and distribution of sizes around the median, of sedimentary materials could be useful in defining the physical conditions of sedimentation. Numerous methods have been developed for size analysis, in part as a function of the range of grain sizes. In this laboratory exercise we shall confine our attention to dry sieving of sand sized material.

II. Grade Scales

Although the texture of sediments involves a variety of characteristics, by far the most important is grain size. There is a tremendous range in particle size with diameters ranging from microns to meters, and some system must therefore be used to describe grain size. A *grade scale* may be defined as an arbitrary division of a continuous scale of sizes, such that each scale unit or *grade* may serve as a convenient class interval for conducting an analysis or for expressing the results of an analysis. Because of the tremendous range in sizes, it is not practical to establish uniform intervals (an arithmetic scale) since we would have literally hundreds of such intervals. A logarithmic (geometric) scale was proposed in 1922 by William Wentworth. In this scale each successive size interval is 1/2 of its predecessor. W. C. Krumbien proposed a phi (φ) scale which reduced the fractional values of the Wentworth scale to whole numbers. By definition

$$1\varphi \text{ unit} = -\log_2$$

1 millimeter corresponds to 0φ . Sizes greater than 1 mm have negative values while those less than 1 mm have positive values. The Wentworth and Krumbein scales follow (also see attachment for more details).

Table 1. Grade Scales

			mm	µm
Boulder		-8	256	
Cobble		-7	128	
		-6	64	
Pebble		-5	32	
		-4	16	
		-3	8	
Granule		-2	4	4000
Sand	Very coarse	-1	2	2000
	Coarse	0	1	1000
	Medium	+1	1/2	500
	Fine	+2	1/4	250
	Very fine	+3	1/8	125

Silt	Coarse	+4	1/16	62.5
	Medium	+5	1/32	31.3
	Fine	+6	1/64	15.6
	Very fine	+7	1/128	
Clay	Coarse	+8	1/256	
	Medium	+9	1/512	
	Fine	+10	1/1024	
	Very fine	+11	1/2048	
Colloid		+12, <+12	1/4096	

III. Plotting of Size Analysis Data

One of the common methods of plotting size analysis data is the histogram. For this purpose the results of the analysis are compiled into a frequency table, which shows the class intervals in millimeters or any other convenient units (we will use φ), and the frequencies of each class or grade, usually as a percentage of the total weight. In general, the class intervals are plotted along the horizontal X-axis, and above each of the classes a vertical rectangle is drawn with a width equal to the class interval and a height proportional to the frequency of the class. For the purpose of statistical analysis, which we will discuss in the next section, we will also draw a cumulative curve. This curve is constructed from the histogram by summing the percentage of material in each class to obtain the successive ordinates of the cumulative curve. It can be shown that the cumulative curve is the integral of the corresponding frequency curve and is, therefore, a more reliable index of the continuous nature of the sediment distribution than the histogram.

As an example, a hypothetical 100 gram sample is collected from a sedimentary environment. We take this sediment into the laboratory and pass it through a set of screens on a sieve shaker. The following masses of sediment were captured on each screen (Table 2).

Table 2. Size Analysis Data for Example Plot

Screen Size (mm)	Unit	Mass of Sed. (g)	% of Total Mass
4	-2	0	0
2	-1	10	10
1	0	20	20
1/2	+1	40	40
1/4	+2	20	20
1/8	+3	10	10
1/16	+4	0	0

The histogram and cumulative curve for these data are shown in Figure 1. The wise and clever student will immediately recognize that a histogram can be plotted using a spreadsheet. Drawing a cumulative curve is a bit more difficult, but still readily doable on a spreadsheet. And even better, the resulting graphical image can be captured electronically and used in an electronic document or a printed document. How cool is that!

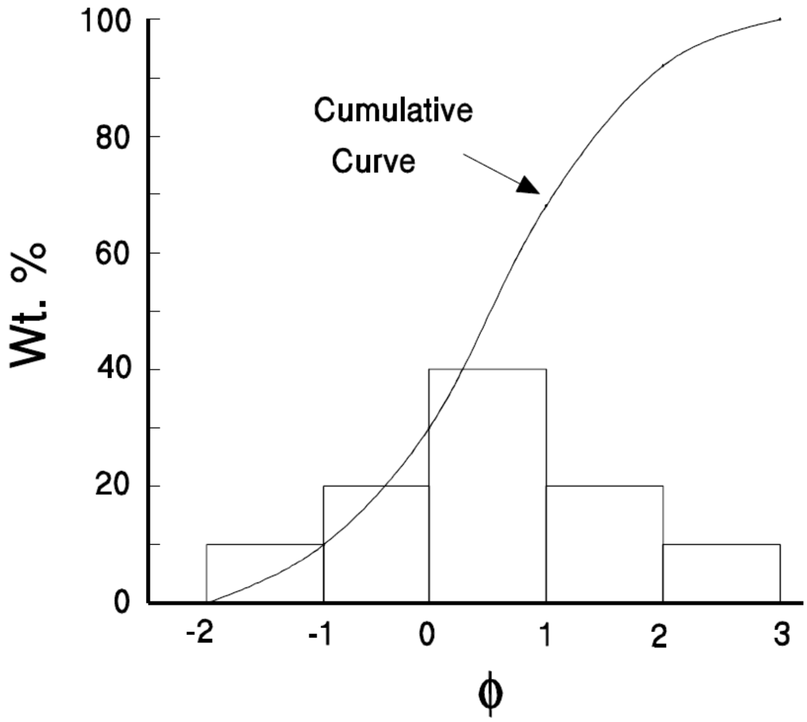


Figure 1. Histogram and cumulative curve constructed using the data in Table 2.

One of the major sources of errors in this laboratory exercise is the plotting of the histograms and cumulative curves. If you do not understand the illustration above (Figure 1), **ask questions!**

IV. Statistical Analysis

1. Quartile measures

A number of statistical measures have been proposed for treating size analysis data. In this laboratory we will use quartile measures and moment measures. The advantage of quartile measures is the ease with which they are determined from the analytical data. The quartile values can be obtained directly from the cumulative curve.

Definition of symbols:

Q_1 = sediment size at the 25% point on the cumulative curve.

Q_3 = sediment size at the 75% point on the cumulative curve.

Md = sediment size at the 50% point on the cumulative curve.

P_{10} = sediment size at the 10% point on the cumulative curve.

P_{90} = sediment size at the 90% point on the cumulative curve.

The *median value* is defined as the middlemost member of the distribution. It is that diameter which is large than 50% of the diameters in the distribution, and smaller than the other 50%. For its graphic determination it is only necessary to draw a cumulative curve for the sediment size distribution, and then read the diameter value which corresponds to the point where the 50% line crosses the cumulative curve. For the example we are using,

$$Md = 0.5$$

The *quartile deviation* (also known as sorting) is a measure of the dispersion of the grain sizes around the median. This measure is confined to the central 50% of the distribution. The simplest form of the quartile deviation is the arithmetic quartile deviation, QD_a, which is a measure of half the spread between the two quartiles. Mathematically,

$$Qd_a = (Q_3 - Q_1)/2$$

For the example we are using,

$$Qd_a = [(1.25)-(-0.25)]/2 = 0.75$$

The *quartile skewness* is a measure of the departure of the arithmetic mean of the sample from the median. Mathematically,

$$Sk_a = 1/2[(Q_1 + Q_3) - 2Md]$$

For the example we are using,

$$Sk_a = 1/2[(-0.25 + 1.25) - 2(0.5)] = 0$$

Skewness can be either positive or negative. The significance of the sign is shown by the graphs plotted in Figures 2 and 3.

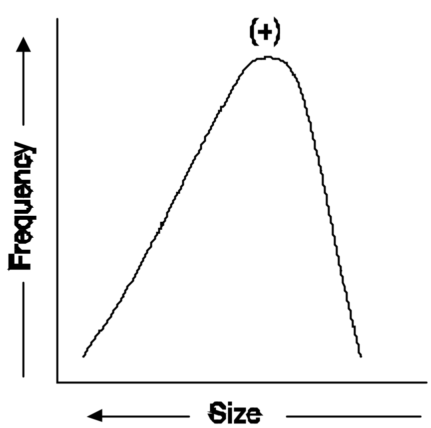


Figure 2. Graph showing positive quartile skewness.

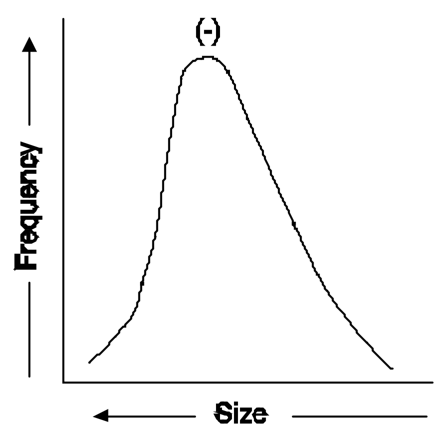


Figure 3. Graph showing negative quartile skewness.

The *quartile kurtosis* is a measure of the degree of peakedness of a curve. It essentially involves a comparison of the spread of the central position of the curve to the spread of the curve as a whole. Mathematically,

$$K_{qa} = (Q_3 - Q_1)/2(P_{90} - P_{10})$$

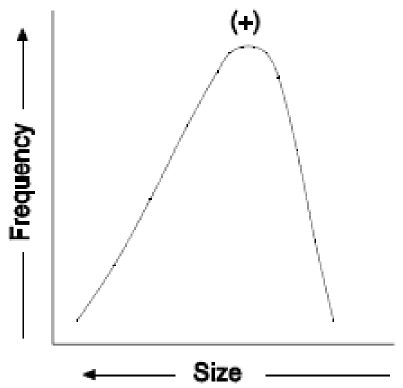


Figure 4. Graph showing high quartile kurtosis.

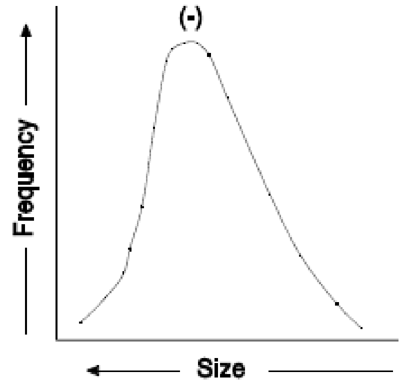


Figure 5. Graph showing low quartile kurtosis.

For the example we are using,

$$K_{qa} = [1.25 - (-0.25)]/2[2 - (-1)] = 0.25$$

The kurtosis as defined above yields values which decrease with increasing peakedness. As the cluster of values in the central part of the curve become more pronounced, without a corresponding decrease in the total spread of the curve, the kurtosis values also decreases. This is graphically illustrated in Figures 4 and 5.

2. Moment measures

Grain size statistical parameters can be calculated directly without reference to graphical plots by the mathematical method of moments. The formulas are shown below (*Table 3.4*) and an example calculation is shown in *Table 3.5*. As above, the wise and clever student will immediately recognize that a spreadsheet is the way to do these calculations. You may also note that there is an Excel template for doing this calculation available on the course web site.

Table 3.4 Formulas for calculating grain-size parameters by the moment method

Mean (1st moment)	$\bar{x}_\phi = \dfrac{\Sigma fm}{n}$
Standard deviation (2nd moment)	$\sigma_\phi = \sqrt{\dfrac{\Sigma f(m - \bar{x}_\phi)^2}{100}}$
Skewness (3rd moment)	$Sk_\phi = \dfrac{\Sigma f(m - \bar{x}_\phi)^3}{100\sigma_\phi^3}$
Kurtosis (4th moment)	$K_\phi = \dfrac{\Sigma f(m - \bar{x}_\phi)^4}{100\sigma_\phi^4}$

where f = weight percent (frequency) in each grain-size grade present
m = midpoint of each grain-size grade in phi values
n = total number in sample; 100 when f is in percent

Table 3.5 Samle form for computing moment statistics using 1/2 ϕ classes

Class interval (ϕ)	m Midpoint (ϕ)	f Weight %	fm Product	$m - \bar{x}$ Deviation	$(m - \bar{x})^2$ Deviation squared	$f(m - \bar{x})^2$ Product	$(m - \bar{x})^3$ Deviation cubed	$f(m - \bar{x})^4$ Product	$(m - \bar{x})^4$ Deviation quadrupled	$f(m - \bar{x})^4$ Product
0–0.5	0.25	0.9	0.2	–2.13	4.54	4.09	–9.67	–8.70	20.60	18.54
0.5–1.0	0.75	2.9	2.2	–1.63	2.66	7.71	–4.34	–12.59	7.07	20.50
1.0–1.5	1.25	12.2	15.3	–1.13	1.28	15.62	–1.45	–17.69	1.63	19.89
1.5–2.0	1.75	13.7	24.0	–0.63	0.40	5.48	–0.25	–3.43	0.16	2.19
2.0–2.5	2.25	23.7	53.3	–0.13	0.02	0.47	0.00	0.00	0.00	0.00
2.5–3.0	2.75	26.8	73.7	0.37	0.13	3.48	0.05	1.34	0.02	0.54
3.0–3.5	3.25	12.2	39.7	0.87	0.76	9.27	0.66	8.05	0.57	6.95
3.5–4.0	3.75	5.6	21.0	1.37	1.88	10.53	2.57	14.39	3.52	19.71
>4.0	4.25	2.0	8.5	1.87	3.50	7.00	6.55	13.10	12.25	24.50
Total		100.0	237.9			63.65		–5.53		112.82

Source: McBride, E. F., Mathematical treatment of size distribution data, *in* R. E. Carver (ed.), *Procedures in sedimentary petrology*. © 1971 by John Wiley & Sons, Inc. Table 2, p. 119, reprinted by permission of John Wiley & Sons, Inc., New York.

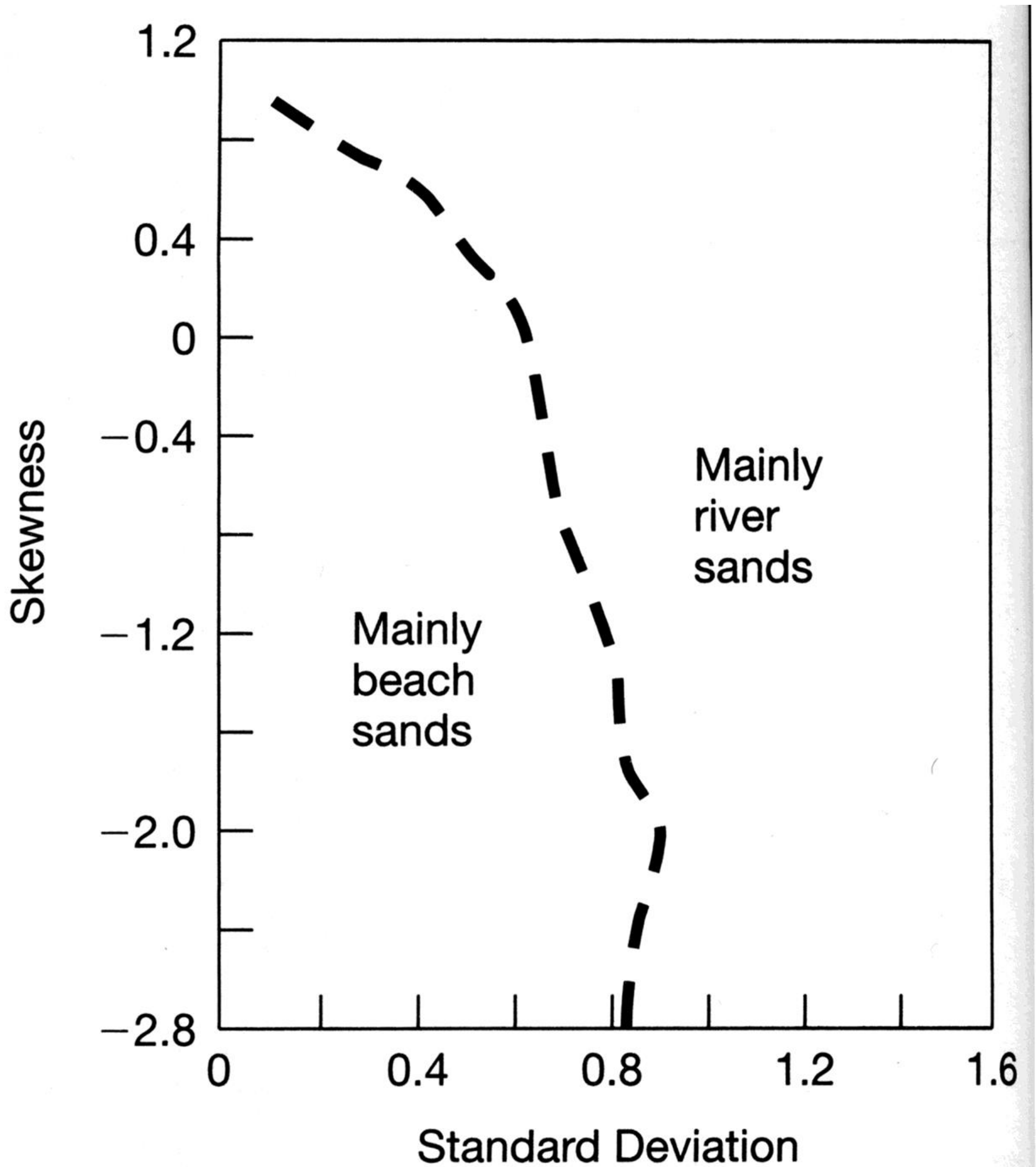
V. Mechanical Analysis by Dry Sieving

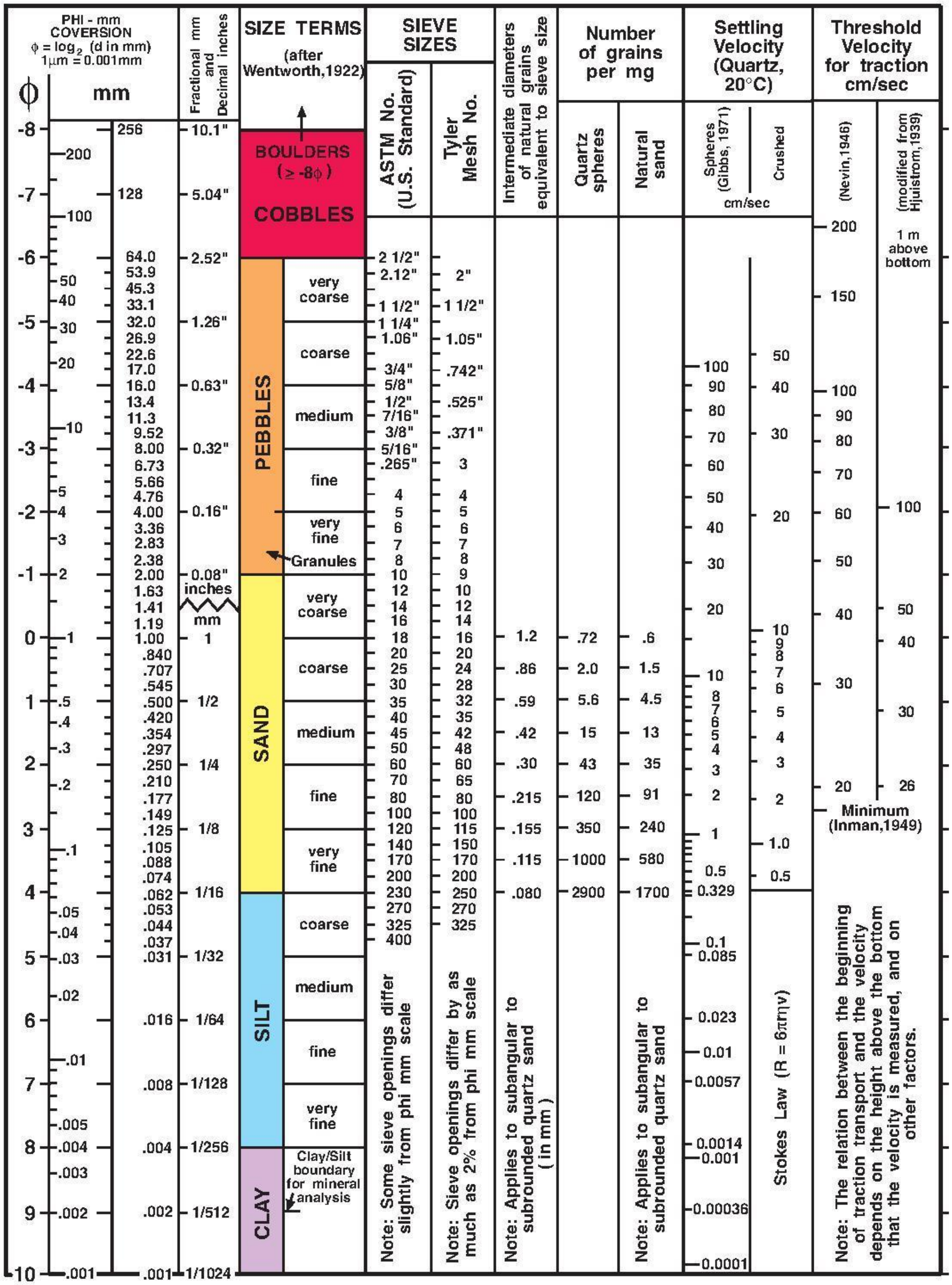
Size analysis by dry sieving is a straightforward procedure. The details are outlined below.

1. Weigh out approximately 100 grams of sample.
2. Set up the sieve rack from coarse at the top to fine at the bottom. Attach the pan to the bottom of the sieve rack.
3. Dump the sample into the top of the rack and cover.
4. Place the sieve rack on the sieve shaker, securely fasten, and run the shaker for 10 minutes.
5. Remove the sieve rack and weigh the amount of sediment collected on each sieve and in the pan.
6. Add these values and compare the sum to the original weight. The difference should not be greater than 1%.
7. Thoroughly clean the sieves using the soft-bristle brushes. **Never bang the sieves on any object or with your hand. Do not run sharp objects over the mesh.**

Draw a histogram and a cumulative curve and calculate the various quartile statistics using the equations given above.

Calculate the various moment statistics using the equations the spreadsheet provided. **Be sure to put the number of your sample on the spreadsheet and on your lab hand-in.** No number, no credit. Plot your sample on the Moment Skewness - Standard deviation diagram (below). Using this plot, what do you think was the source of your sand sample? Explain.


1.2
0.4
0
−0.4
−1.2
−2.0
−2.8
Skewness
Mainly river sands
Mainly beach sands
0
0.4
0.8
1.2
1.6
Standard Deviation


PHI - mm COVERSION
φ = log2 (d in mm)
1μm = 0.001mm
φ
mm
Fractional mm and Decimal inches
SIZE TERMS
(after Wentworth,1922)
SIEVE SIZES
ASTM No. (U.S. Standard)
Tyler Mesh No.
Intermediate diameters of natural grains equivalent to sieve size
Number of grains per mg
Quartz spheres
Natural sand
Settling Velocity (Quartz, 20°C)
Spheres (Gibbs, 1971)
Crushed
cm/sec
Threshold Velocity for traction cm/sec
(Nevin,1946)
(modified from Hjulstrom,1939)
1 m above bottom
BOULDERS (≥ -8φ)
COBBLES
PEBBLES
very coarse
coarse
medium
fine
very fine
Granules
SAND
SILT
CLAY
Clay/Silt boundary for mineral analysis
inches
mm
Minimum (Inman,1949)
Note: Some sieve openings differ slightly from phi mm scale
Note: Sieve openings differ by as much as 2% from phi mm scale
Note: Applies to subangular to subrounded quartz sand (in mm)
Note: Applies to subangular to subrounded quartz sand
Stokes Law (R = 6πηv)
Note: The relation between the beginning of traction transport and the velocity depends on the height above the bottom that the velocity is measured, and on other factors.