Laboratory 6

Sand Sieve Analysis

John R. Anderson

Department of Geology, Georgia Perimeter College

Dunwoody, GA 30038

The size of sediment particles can be measured by visual estimation or by use by a set of sieves. With experience, most geologists can visually measure grain size within accuracy of the Wentworth grade scale at least down to silt grade. Silt and clay can be differentiated by whether they are crunchy or plastic between one's teeth. Claystones and siltstones are not amenable to size analysis from an optical microscope. Their particle size can be measured individually by electron microscope analysis. Boulder, cobbles, and gravel are best measured manually with a tape measure or ruler.

Sands are most generally measured by sieving. The basic principle of this technique is as follows. A sand sample of known weight is passed through a set of sieves of known mesh sizes. The sieves are arranged in downward decreasing mesh diameters. The sieves are mechanically vibrated for a fixed period of time. The weight of sediment retained on each sieve is measured and converted into a percentage of the total sediment sample. This method is quick and sufficiently accurate for most purposes. Essentially it measures the maximum diameter of a sediment grain. This method is useful in analysis of terrigenous sediment.

Both graphic and statistical methods of data presentation have been developed for the interpretation of sieve data. The percentage of the samples in each class can be shown graphically in bar charts or histogram. Another method of graphic display is the cumulative curve or cumulative arithmetic curve. Cumulative curves are extremely useful because many sample curves can be plotted on the same graph and differences in sorting are at once apparent. The closer a curve approaches the vertical the better sorted it is, as a major percentage of sediment occurs in one class. Significant percentages of coarse and fine end-members show up as horizontal limbs at the ends of the curve.

Sorting can be expressed by various statistical methods. The simplest of these is the measurement of the central tendency of which there are three commonly used parameters: the median, the mode, and the mean. The median grain size is that which separates 50% of the sample from the other; the median is the 50 percentile. The mode is the largest class interval. The mean is variously defined, but a common formula is the average of the 25 and 75 percentile.

A second aspect of sieve analysis is its sorting or the measure of degree of scatter. Sorting is the tendency for the grains to all is of one class of grain size. Several formulae have been used to define this parameter for a sample.

A third property of a grain size frequency curve is termed "kurtosis" or the degree of "peakedness". Curves which are more peaked than the normal distribution curve are termed "leptokurtic"; those which are saggier than the normal are said to be "platykurtic".

The fourth property of a sieve analysis is its skewness, or degree of lop-sidedness. Samples weighted towards the coarse end-member are said to be positively skewed (lop-sided toward the negative phi values), samples weighted towards the fine end are said to be negatively skewed (lop-sided toward the positive phi values).

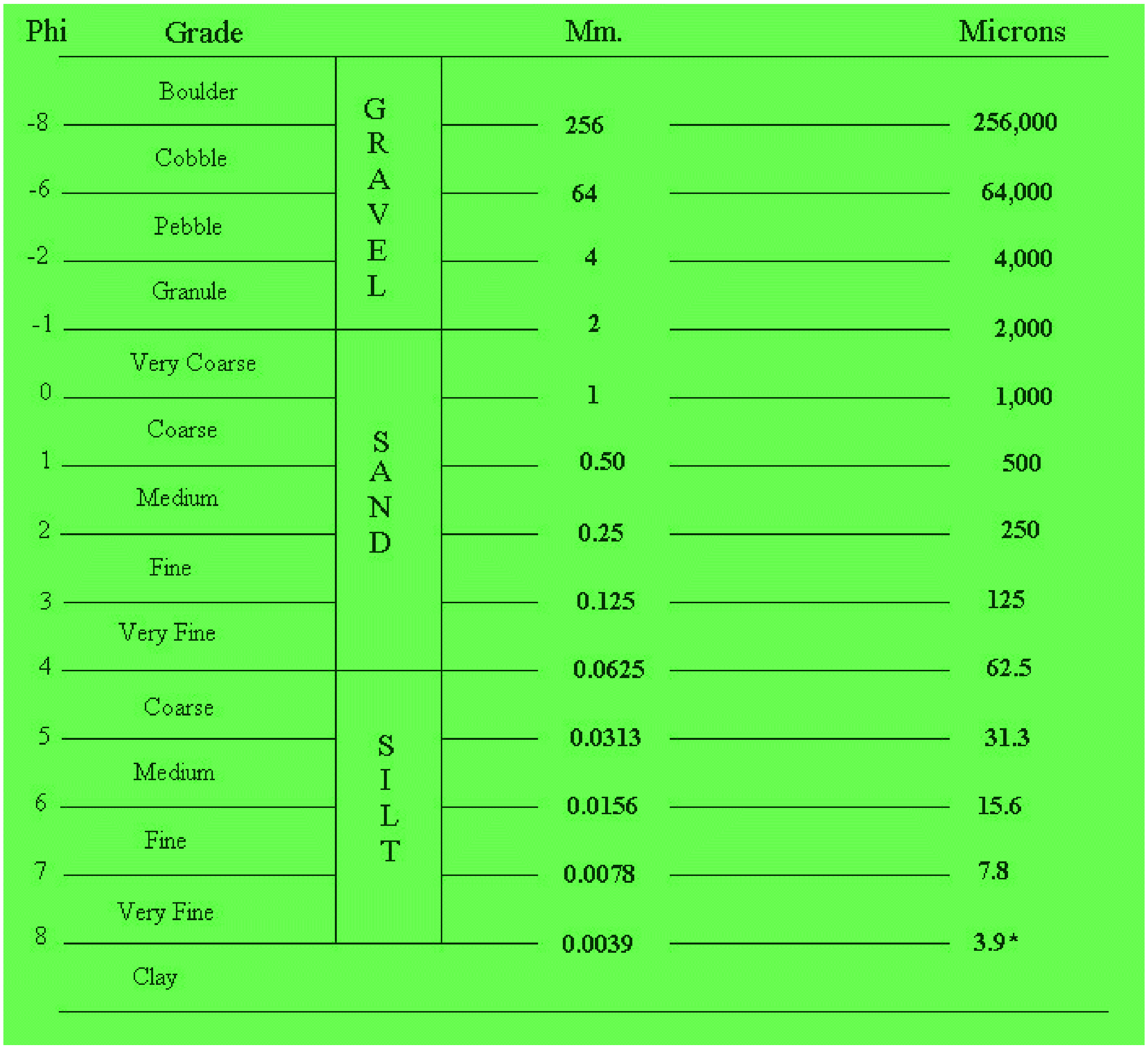
In summary the four statistical measurements for sieved samples consist of a measure of central tendency (including median, mode, and mean); a measure of the degree of scatter or sorting; kurtosis, the degree of peakedness; and skewness, the lop-sidedness of the curve. Various formulae have been defined for these parameters the set of formulae we will use will be Folk and Ward’s (1957).

Within geology accurate sieve analyses are required for petrophysical studies which relate sand texture to porosity and permeability. The distribution of sediment for water wells also requires a detailed knowledge of the sediment of aquifers. Sieve analysis data can be used as an interpretive tool to determine the depositional environment of ancient sediments. The philosophy behind this approach is that modern environments mold the distribution of sediment and these differences can be quantitatively distinguished. Thus, by comparing the sieve analysis data from modern depositional environments with samples from the geologic past the depositional environment for these ancient samples can be determined.

Discussion of Grain Size Parameters

PHI SCALE:

In most research on sediments, grain-size data is given in phi (ϕ) intervals rather than in microns, millimeters, or inches. One phi unit is equal to one Udden-Wentworth grade. Phi diameter is computed by taking the negative log of the diameter in millimeters. Statistical computations and graphic presentations are much simpler when phi diameters are used.



Phi	Grade		Mm.	Microns
	Boulder	GRAVEL		
-8			256	256,000
	Cobble			
-6			64	64,000
	Pebble			
-2			4	4,000
	Granule			
-1			2	2,000
	Very Coarse	SAND		
0			1	1,000
	Coarse			
1			0.50	500
	Medium			
2			0.25	250
	Fine			
3			0.125	125
	Very Fine			
4			0.0625	62.5
	Coarse	SILT		
5			0.0313	31.3
	Medium			
6			0.0156	15.6
	Fine			
7			0.0078	7.8
	Very Fine			
8			0.0039	3.9*
	Clay			

* Some use 2 microns (9ϕ) as the silt-clay boundary

Note that each interval of one phi is equal to one-half the value of the next larger interval measured in mm or microns.

It is much easier to remember that the boundary between sand and silt for example, is 4ϕ than to remember that it is 62.5 microns or 0.00625 mm. or 0.00245 inches.

METHODS OF GRAPHIC PRESENTATION OF DATA:

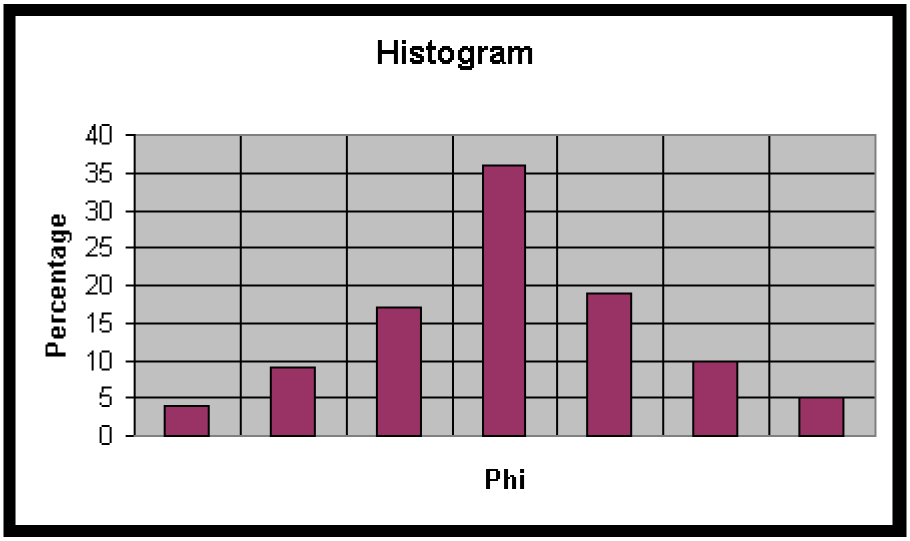
Four types of graphic presentation of grain-size data are used:

1. Histogram
2. Frequency Curve
3. Cumulative Arithmetic Curve
4. Cumulative Probability Curve

In all of these plots, grain size is plotted on the horizontal scale and percentage on the vertical scale. The coarsest grain size is always plotted on the left and finest on the right. The reverse of the usual convention, though in the phi scale the coarsest grain sizes have lower numbers, typically negative numbers where fine grain sizes have higher numbers. Percentages are plotted so as to increase upward on the diagram.

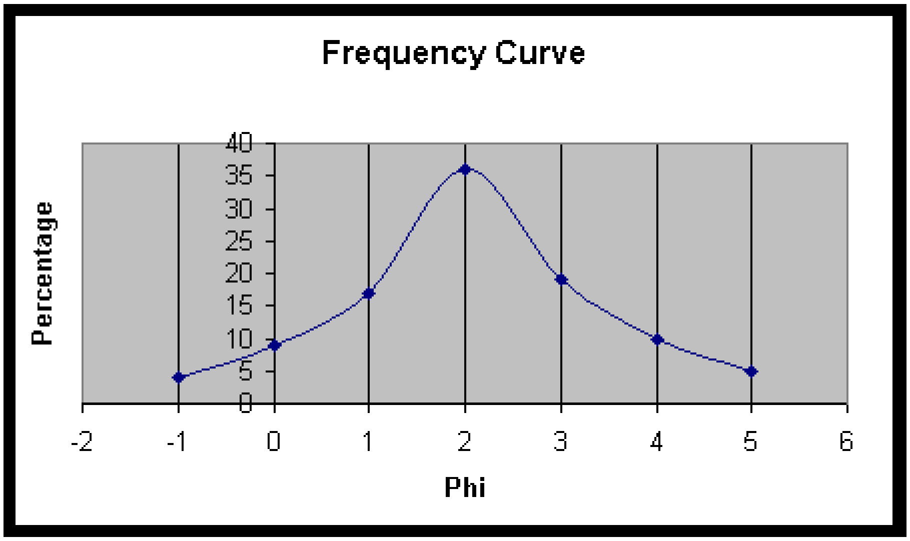
HISTOGRAM – a bar graph

- Good pictorial method
- Shape greatly affected by sieve interval
- Grain-size parameters (sorting, skewness, or kurtosis) cannot be computed from histogram.



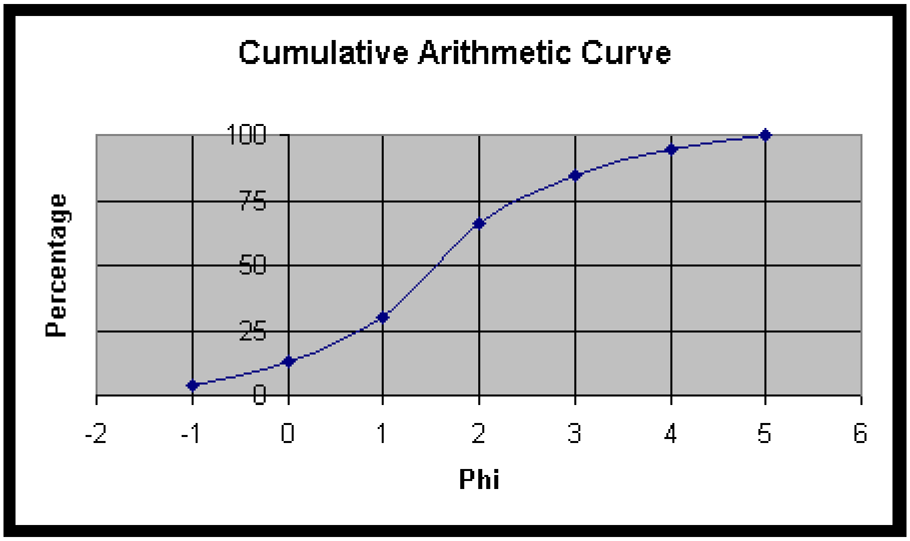
FREQUENCY CURVE – a "smoothed-out" histogram

- Good pictorial method
- Independent of sieve interval
- Grain-size parameters cannot be computed from this curve either.



CUMULATIVE ARITHMETIC CURVE

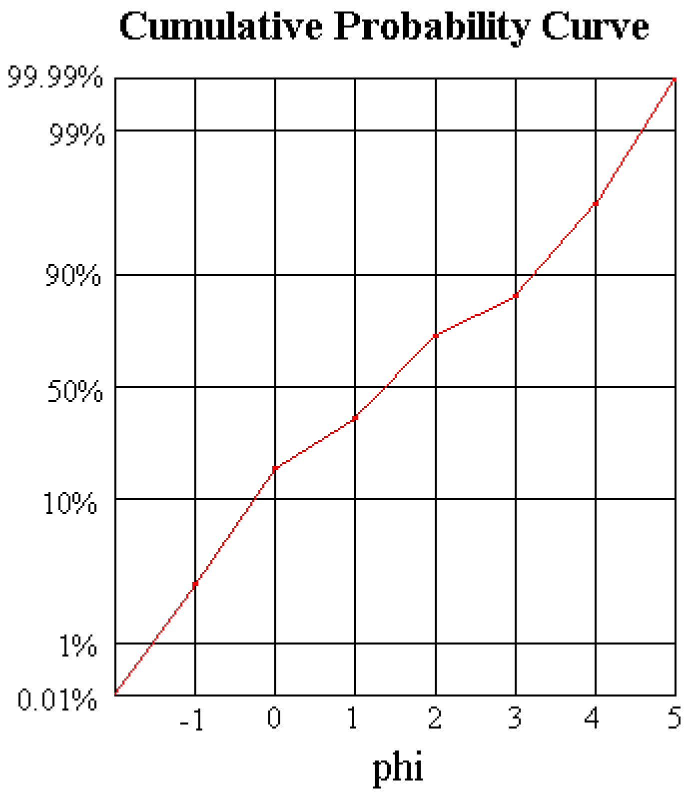
- Plotted on arithmetic scale if phi intervals are used or semi-log paper if millimeters are used.
- More difficult than histogram or frequency curve to interpret at a glance.
- Independent of sieve interval.
- Grain-size parameters can be computed from this curve.



CUMULATIVE PROBABILITY CURVE

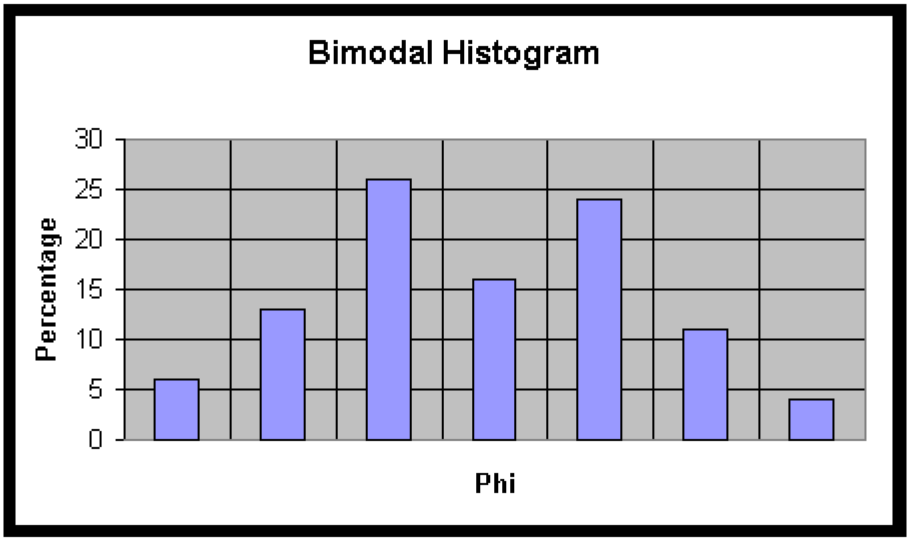
- Plotted on probability paper (condensed scale in middle percentages; expanded scale in low and high percentages).
- Straightens the S-shaped tails of cumulative curve to interpret at a glance.
- Independent of sieve interval.

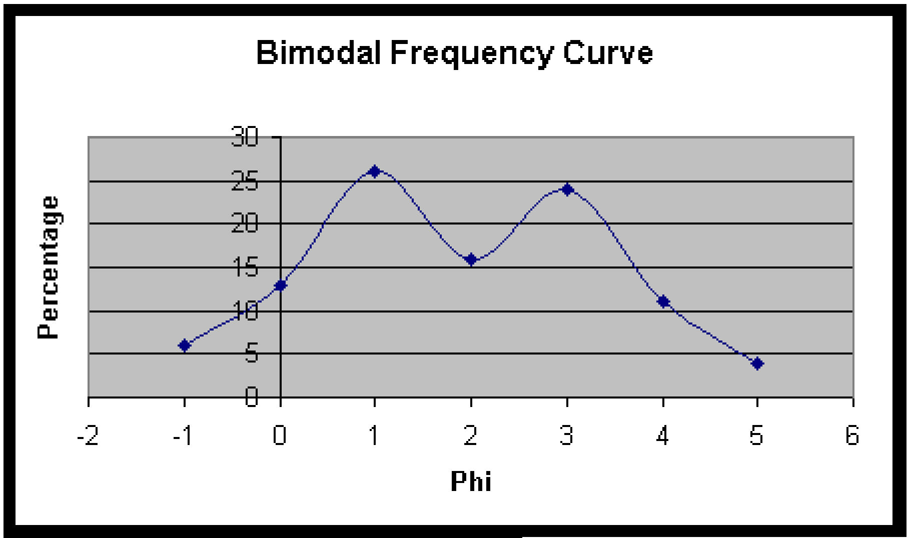
- Grain-size parameters can easily be computed from curve. Sediment with "normal" size distribution plot as a straight line.
- The steeper the slope of the line, the better the sorting.

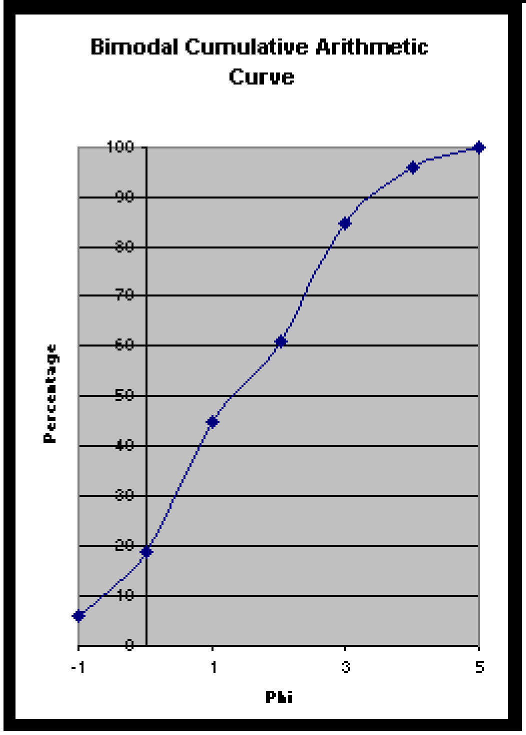


Measures

1. Mode
    - The most frequently occurring particle class.
    - The highest point on the frequency curve.
    - The point of maximum steepness on the cumulative arithmetic curve
    - Determined by trial and error.
    - A valuable measure for the sample.
    - A sample may be bimodal (it has two high points, a primary and secondary mode).

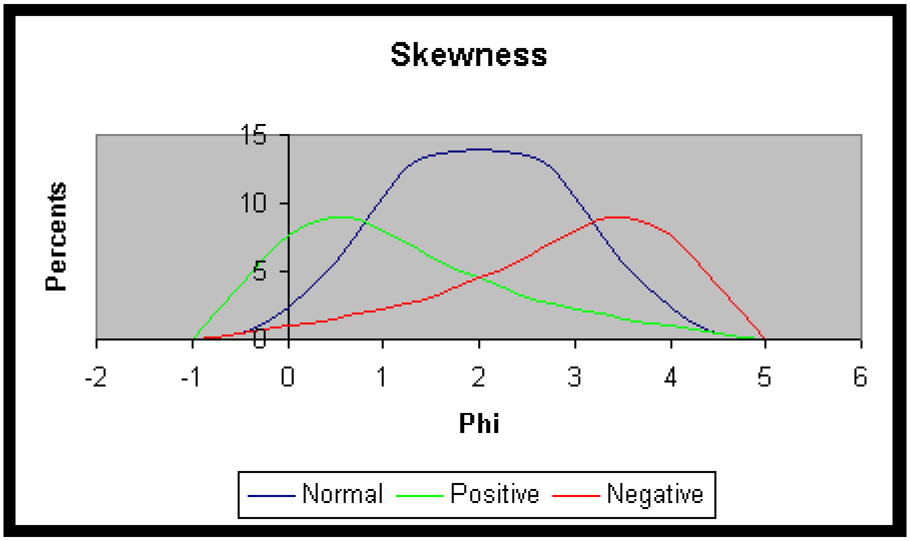

Bimodal Histogram
Percentage
30
25
20
15
10
5
0
Phi



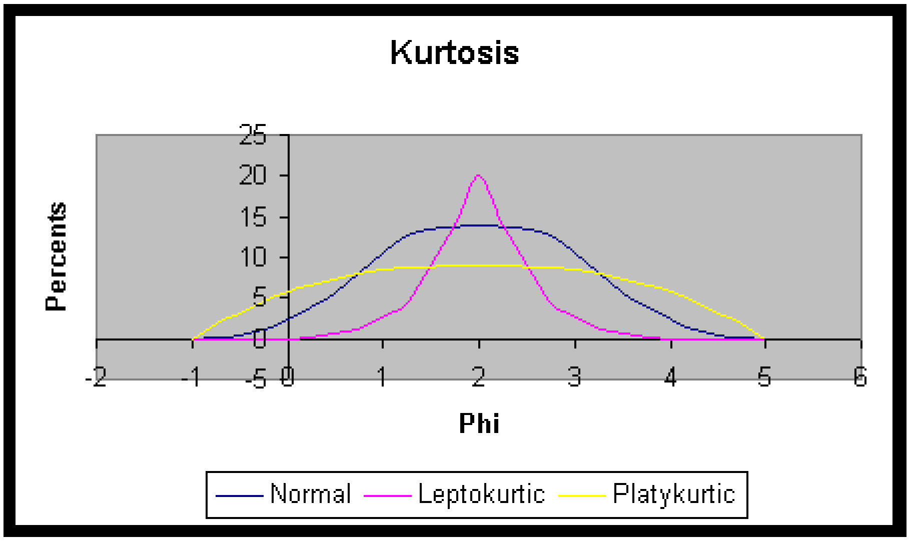


2. Median
   - The diameter at which 50% of the particles are coarser and 50% of the particles are finer.
   - The diameter at which the cumulative curve intersects the 50% line.
   - May not be a very valuable measure for the sample.
3. Mean
   - The average particle size.
   - A very valuable measure for the sample.
4. Standard Deviation
   - A measure of the degree of sorting.
   - A very valuable measure for the sample.
5. Skewness
   - The degree of asymmetry of a frequency or cumulative curve.

- A very valuable measure for the sample.



6. Kurtosis
    - The degree of peakedness or departure from the "normal" frequency or cumulative curve.
    - Leptokurtic curves are excessively peaked (center is better sorted than ends).
    - Platykurtic curves are flat-peaked (ends are better sorted than center).
    - Mesokurtic curves are "normal" (a normal bell shaped curve).
    - Possibly a valuable measure for the sample.



FORMULAE FOR STATISTICAL PARAMETERS OF GRAIN SIZE (Folk & Ward, 1957)

Graphic Mean (M):

$$M = \frac{\phi 16 + \phi 50 + \phi 84}{3}$$

M Values:

Values from	To	Equal
- ∞	–1 ϕ	gravel
-1	0 ϕ	very coarse sand
+0	+1 ϕ	coarse sand
+1	+2 ϕ	medium sand
+2	+3 ϕ	fine sand
+3	+4 ϕ	very fine sand
+4	+8 ϕ	silt
+8	∞ ϕ	clay

Inclusive Graphic Standard Deviation (D):

$$D = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

D Values:

Values from	To	Equal
0.00	0.35 ϕ	very well sorted
0.35	0.50 ϕ	well sorted
0.50	0.71 ϕ	moderately well sorted
0.71	1.00 ϕ	moderately sorted
1.00	2.00 ϕ	poorly sorted
2.00	4.00 ϕ	very poorly sorted
4.00	∞ ϕ	extremely poorly sorted

Inclusive Graphic Skewness (S):

$$S = \frac{\phi 84 + \phi 16 - 2(\phi 50)}{2(\phi 84 - \phi 16)} + \frac{\phi 95 + \phi 5 - 2(\phi 50)}{2(\phi 95 - \phi 5)}$$

S Values:

Values from	To	Mathematically:	Graphically Skewed to the:
+1.00	+0.30	Strongly positive skewed	Very Negative phi values, coarse
+0.30	+0.10	Positive skewed	Negative phi values
+0.10	- 0.10	Near symmetrical	Symmetrical
- 0.10	- 0.30	Negative skewed	Positive phi values
- 0.30	- 1.00	Strongly negative skewed	Very Positive phi values, fine

Graphic Kurtosis (K):

$$K = \frac{\phi 95 - \phi 5}{2.44\,(\phi 75 - \phi 25\,)}$$

K Values:

Values from	**To**	**Equal**
0.41	0.67	very platykurtic
0.67	0.90	platykurtic
0.90	1.11	mesokurtic
1.10	1.50	leptokurtic
1.50	3.00	very leptokurtic
3.00	∞	extremely leptokurtic

Sieve Analysis Laboratory Procedures.

Equipment and Materials Needed:

Equipment:

1. **1 set of sieves = 10, 18, 35, 60, 120, 230, pan (6 sieves and the pan)**
2. **Sieve shaker supplied in lab**
3. **Balance to measure mass of samples**
4. **Computer with a spreadsheet program**

Materials:

1. **Sand sample**
2. **Large sheet of paper**
3. **Smaller sheet of paper - notebook paper will do**
4. **7 containers to place sieved samples in; these can be weighing trays**
5. **Probability graph paper with linear horizontal scale**
6. **3 by 5 index card**
7. **3 ½ inch computer disk**

PROCEDURES:

It is assumed that the sand has already been disaggregated and that the clay and mud, if present in considerable amounts, have been removed. The procedures below should be completed as accurately as you can. Write down any error you notice in your performing of these procedures. This error is not negative, but will assist in your interpretation of the data you acquire from this experiment.

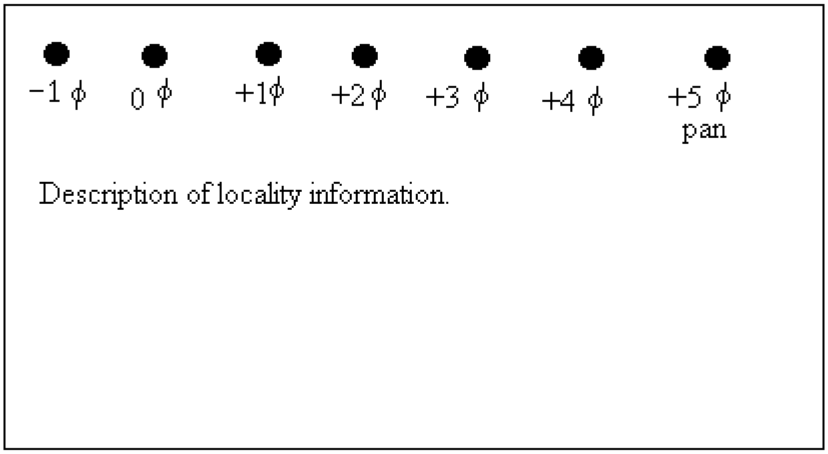
1. **Clean the screens of the sieves CAREFULLY, by turning the sieve face down and STRIKING THE TABLE EVENLY WITH THE RIM. DO NOT TOUCH THE SCREEN WITH YOUR FINGER. YOU MAY USE A SOFT BRISTLE BRUSH TO GENTLY WIPE THE SCREEN.**
2. **Nest the screens in order, coarsest at the top, pan on the bottom. (10, 18, 35, 60, 120, 230, pan)**
3. **Weigh the sample in its packet to 0.01 grams.**
4. **Pour the sample into the top sieve and shake gently by hand. You may remove all the screens that are too coarse to catch any grains. Place the cover on the stack.**
5. **Make sure you weigh the packet and record its weight on your data table.**
6. **Place the stack of sieves on the sieve-shaking machine and shake the sieves for 10 minutes.**
7. **While the sieves are shaking, weigh each container to 0.01 grams, which has been labeled (before you weigh them) as to the sieve size that it will be**

receiving when the sieves are emptied. Make sure you record the mass of each of these containers on your data table.

8. **When the sieves have shaken for 10 minutes, take a large sheet of paper, crease it in the middle, and lay it on the tabletop. Then take a sheet of notebook paper and lay it in the center of the large sheet of paper. Now hold the coarsest screen over the notebook paper and carefully pour out the sand. Pour this sand into its respective weighing container; this container should be placed on another piece of notebook paper to catch any sand that may not get into the container. Then invert the screen and tap it "gently on the table over the paper. Pour the sand into the container.**
9. **Replace the two creased papers as before and now hold the sieve upside down and pound it sharply on the paper,** STRIKING THE TABLE EVENLY WITH THE RIM (otherwise you will bend the screen). **Add the sand thus jarred loose to the container. Make sure all grains end up inside the container. Repeat this process until no more sand is dislodged from the sieves.** DO NOT TOUCH THE SCREEN WITH ANY OBJECT OR LIQUID AT ANY TIME.
10. **Weigh the container with the sample in it to 0.01 grams (this means to two decimal places). Record the weight on your DATA TABLE.**
11. **For each sieve fraction you will place a pinch of the sand on an index card Sediment Slide.**

To make the Sediment Slide:

- a. **An index card is first prepared by typing or printing locality data on it along with comments or other data provided by your instructor or partner who went on the field trip.**
- b. **You will also label spaces for sand samples to be placed, i.e. -1, 0, 1, 2, 3, 4, less than 4 phi (which translate to sieve mesh sizes 10, 18, 35, 60, 120, 230, pan respectively).**
- c. **A hole is punched through the card with a hole punch next to each phi value label. (See example of card below or look at slides already completed by other groups)**
- d. **The bottom of each hole is taped over with transparent tape (not translucent Magic tape). Each hole is to be completed separately.**
- e. **A pinch of sand is drifted onto the exposed sticky side of the tape.**
- f. **Excess sand is shaken off the exposed tape back into the sediment sample. (This is why you only want to place tape over one hole at a time so you don't get the wrong size sand on one of your taped holes.)**
- g. **The top of the slide is then taped over with transparent tape to enclose the sediment.**
- h. **Follow steps a - g for each sand fraction.**
- i. **This slide will be examined by using a microscope or hand lens in procedure 15.**
- j. **Place your completed slide in the file box your instructor provides.**



12. **Repeat procedures 8, 9, 10, and 11 for each of the sieves.**
13. **Now take the data you have gotten and make the calculations (see description of data analysis). If your instructor has provided a template for a spreadsheet, type the data into the spreadsheet data table. After you have typed in your data save your data using the SAVE AS command (not the save command!) in the FILE pull down menu. Give your data a name different than the template name.**
14. **From your data table graph the weight percent on a histogram and frequency curve graph. Graph the cumulative percent data on a cumulative arithmetic curve. On probability graph paper graph the cumulative percent data. The spreadsheet program can generate the histogram, frequency and cumulative graphs, if you know how to graph using a spreadsheet you may do it by this method.**
15. **Examine each sieve fraction from the sediment slide under a binocular microscope or a hand lens and describe the roundness and mineralogy (color of grains use the chart from lab exercise 2, Identifying Minerals in Sands) for each grain size. You will need to do this for the other sand samples. Make a data table for the roundness and mineralogy for the various sand samples.**

WHAT TO DO WITH THE DATA COLLECTED:

1. **You will make (using the weight percent data from your data table) a histogram, frequency curve,and (using the cumulative percent data from your data table) the cumulative arithmetic curve for your data.**
2. **Plot for your sample (using the cumulative percent data from your data table) the cumulative probability curve on probability graph paper. Note the bottom will be phi and the side for percent. The scale on the right not the left increases in percent. The phi scale at the bottom, scale off this axis so there are 10 subdivisions between phi values. Thus you will be able to interpret to 0.01 phi for the various percents. You will draw straight lines from point to point of your data. If you have more than 5% of your sample at –1 phi, you will need to draw a line from the bottom left-hand corner of the graph to your first point so you will be able to interpret the phi value at 5%.**
3. **Using the cumulative probability graph that you plotted compute the mean, standard deviation, skewness, and kurtosis using the graphic formulae of Folk and Ward (1957). The formulae are given above in the discussion section. You will interpret the phi value from your graph for the various percents in the formulae (i.e. phi value at 95%, phi value at 84%, etc). You will need to turn in your calculations. If you don't understand the formulae ask your instructor.**
4. **Construct a data table of the mode grain size, median grain size, mean grain size, sorting, skewness, and kurtosis for the samples analyzed.**
5. **Construct a data table for the observations you have made from the sediment card. You will have roundness of the sediment grains and the percentages of dark minerals compared to light colored minerals. You may be able to differentiate quartz grains from shell fragments in some of the samples you may be given.**

CONCLUSION BUILDING

1. **Compare your calculated data with the data from the known depositional environments. Your lab class may have processed both known depositional environments and unknowns or you will be directed to a known set of data. Briefly comment on the comparison of the mean-median-mode grain size, sorting, skewness, and kurtosis. What depositional environment does your sample appear to be from? How does this data fit? If it differs how do you explain the differences.**
2. **Did you have any error in you laboratory procedures? How did this error affect your results? You will need to take this error into account when you determine the depositional environment for you sample.**
3. **Compare your sample analyzed with the known depositional environment samples as to angularity of sediment grains and the percentage of dark and light colored minerals. Briefly comment on this comparison. How does this data fit? If it differs how do you explain the differences.**

Conclusions are a very important part of science. Conclusions are constructed by interpreting the data you have produced. This exercise synthesizes what we have learned thus far in lab. Weathering, Sedimentary Rocks, Depositional Environments, Relative dating all come into play in producing these conclusions. Depending on the samples given, you may have an historical picture of the changes of environment for a specific locality.