89.215 FORENSIC GEOLOGY
SAND SIZE-DISTRIBUTIONS AS INDICATORS OF CRIME SCENE LOCATIONS

I. Introduction

If you think about the world around you sand, and other sediments, occur in many environments. For example we find sand on beaches, in stream channels and banks, and in deserts. If you look closely at a beach, you will see that the size of the sand grains varies from place to place. As you might expect, where wave action is greatest you have the coarsest material and where wave action is least, the finest material. Dune lines are found behind many beaches, and in the case of dunes the sand is moved and deposited under the action of the wind. Hence, we might expect that dunes would be composed of finer-grained material (because air is significantly less dense than water) compared to the beach. Streams have variable current velocities and the size of the material they deposit varies as a function of current velocity. In addition to the *mean size* (the size of the average sand grain), another important parameter is sorting (the range of grain sizes). Decades of work by geoscientists has revealed that the size and distribution of sedimentary particles can be used to distinguish different sedimentary environments. In this crime scene investigation exercise we will use sedimentary material associated with a body to determine the location of the crime.

II. Grade scales

Sedimentary material exhibits a wide range of grain sizes, from the mud of lake bottoms to the large boulders that can be found in glacial deposits. 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 of sedimentary material, 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 φ values while those less than 1 mm have positive φ values. The Wentworth and Krumbein scales follow.

Table 1. Grade Scales

	φ	mm	µm
Boulder	-8	256	
Cobble	-7	128	
	-6	64	
Pebble	-5	32	
	-4	16	
	-3	8	
Granule	-2	4	4000

		φ	mm	µm
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. Evidence collection and analysis

In this investigation we will collect sand from the wrapping material around a body. The body was dumped here at UML, but the murder took place somewhere else. A criteria we can use to determine the location of the crime is the size distribution of the sedimentary (sand) particles.

As a class we will collect the sand from the wrapping material. We will then do a size analysis of this material and we will also do size analyses for other sands that will serve as comparative samples. These other sands were collected from five locations: Sand Beach, Bar Harbor, Maine; Crane Beach beach sands; Crane Beach dune sands; Plum Island beach sands; and sand from a stream in Burlington. The murder occurred at one of these locations.

Geoscientists use a variety of techniques to determine the size of sedimentary particles. The most common way to determine the size of sand-sized particles is dry sieving. Size analysis by dry sieving is a straightforward procedure.

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.**

IV. Data analysis

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 scaled off 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. The histogram is a graphical (visual) representation of the size distribution for a particular sediment sample. The cumulative 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)	φ 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.

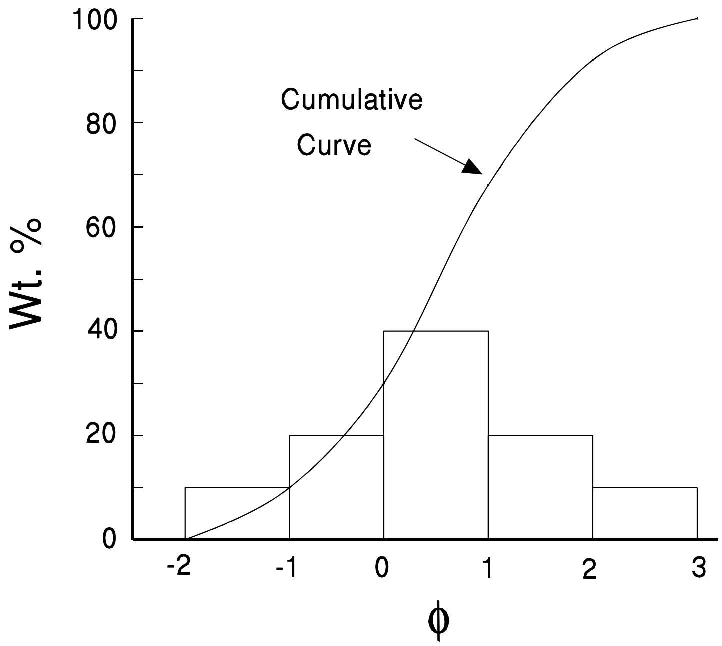

Figure 1. Histogram and cumulative curve constructed using the data in Table 2.

A number of statistical techniques can be used for data comparison. We will use *moment measures*. The calculations are mathematically laborious, but fortunately we have these things called spreadsheets which greatly simplify such calculations. Once you have obtained your size analysis data, enter the data into the spreadsheet program. The program will generate both graphical (frequency curve and histogram + cumulative curve) and numerical parameters for the size distributions. The numerical parameters, and their significance, are listed below.

The *median value* is defined as the middlemost member of the distribution. It is that diameter which is larger than 50% of the diameters in the distribution, and smaller than the other 50%.

Standard deviation (also known as sorting) is a measure of the dispersion of the grain sizes around the median. A sample with a small value is well sorted while a sample with a large value is poorly sorted.

Skewness is a measure of the departure of the geometric mean of the sample from the median. Skewness can be either positive or negative. The significance of the sign is shown by the graphs plotted in Figures 2 and 3.

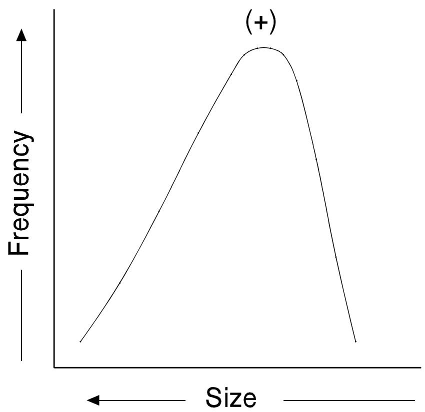

Figure 2. Graph showing positive skewness.

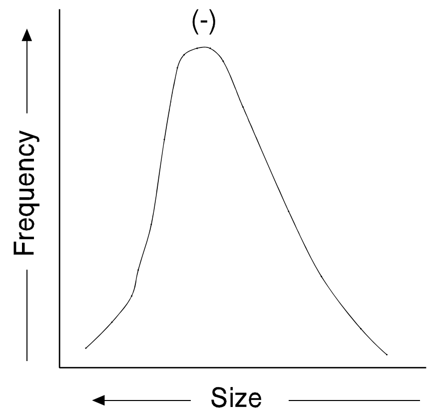

Figure 3. Graph showing negative skewness.

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. Kurtosis values decrease with increasing peakedness. This is graphically illustrated in Figures 4 and 5.

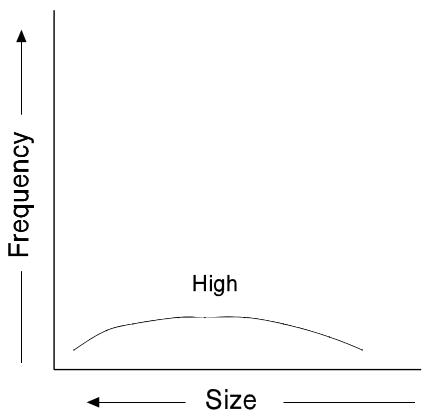

Figure 4. Graph showing high kurtosis.

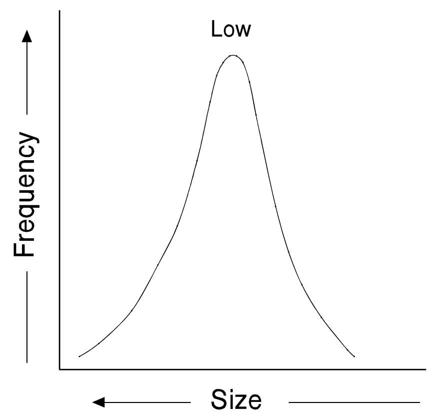

Figure 5. Graph showing low kurtosis.

V. Report

After you have acquired the data for the crime scene sample and the comparative samples, compare the graphical and mathematical values for each comparative sample to the crime scene sample. Which comparative sample(s) best match the crime scene sample? Prepare a brief report that includes your data, the mathematical values for the comparative samples and the crime scene sample, and the conclusions you've drawn from the comparisons. Be as precise as you can about your conclusions because you may be called to testify in court as an expert witness. The defense attorney will do his/her best to discredit your conclusions.

NAME_______________________________

Size Analysis Data

Sand sample -			
Starting weight (g) =			
Screen Size		Mass of Sed. (g)	% of Total Mass
φ	mm		
-2	4000		
-1	2000		
0	1000		
1	500		
2	250		
3	125		
4	62.5		
Final weight (total of all screens in g) =			

Size Distribution Statistics (φ units)

Median grain size =	
Standard deviation (sorting) =	
Skewness =	
Kurtosis =	

NAME___________________________

Size Statistics for Crime Scene and Comparative Sand Samples

Sample	Median Size (φ)	Sorting	Skewness	Kurtosis
Crime Scene				