Texture

As A Facies Element

The Geometrical aspects of the component particles of a rock.

Includes:
1. Size of particles
2. Shape of particles
3. Fabric (arrangement) of particles

Basic Considerations

In a rock it is important to distinguish among the following:
1. The clastic particles themselves
2. The matrix surrounding the particles
3. Cement which binds the particles together

Also must make adjustments for diagenetic changes which can affect the primary texture properties of the rock.

- ☺ Will bind matrix particles together so that their texture cannot be determined
- ☺ Authigenic minerals (those which grow in the sediment after deposition; e.g. silica, calcite, dolomite, siderite) may be confused for texture particles

An Historical Framework

During the 1950's, 60's, and 70's the study of sedimentation was dominated by the statistical analysis of sediment.

Numerous very sophisticated mathematical techniques were applied to the analysis of sediments.

Entire graduate courses were given over to teaching these techniques and the principles behind them.

Professional journals were filled with papers describing the statistical study of sediments.

On the short term great progress seemed to be being made in our ability to analyze and interpret sediments.

But the final goal of a definitive set of criteria capable of discriminating samples of sediment from different environments seemed to keep always be just beyond our reach.

Finally, in the 1980's some began to seriously question whether sediment size analysis was all it was cracked up to be; whether size analysis could really give us the answers we wanted, definitive separation of sediments from different environments.

Once doubts began to be seriously raised in the open the whole edifice of grain size analysis as a path to truth about the world of depositional environments collapsed quickly.

Today the systematic study of sediment grain size has almost disappeared.

- ☺ No longer do armies of students spend hours sorting and sifting sediment, weighing it, statistically analyzing it, and trying to make sense of the results.

Grain size analysis was an experiment to find a magic bullet to an understanding of depositional environments and depositional processes.

- ☺ The experiment has for the most part failed to produce the desired results.
- ☺ Nonetheless, we have come to a lot of understanding through these decades of research .

It is not essential that you know the complexities of this history.

But it is important that you understand the essential scientific strategies, and conclusions that have come from this research.

The Analysis of Texture as SIZE

Grain size is one of the most obvious properties of a rock.

What we want to know is: "Do the differences in grain size have any meaning in terms of the processes which produced the rock."

- ☺ Differences in energy conditions?
- ☺ Differences in processes of deposition?
- ☺ Differences in depositional environments?

Simplistically, we know that...

- ☺ Large sized particles represent high energy conditions, and
- ☺ Small sized particles represent low energy conditions.

But this is so obvious to be trivial.

Is there any thing more specific, more precise, more explicit, more accurate, or more informative that we can say about grain size???

Practical Problems Studying Grain Size

The practical problem with studying grain size is...

- ☺ First, measuring the grains for size.
  - ➩ Is difficult when studying small grains, less than gravel
- ☺ Second, measuring enough of them to be able to say anything meaningful.
  - ➩ What is required is a statistical sample.

Thus, the only way that this topic can be approached in a systematic manner is statistically.

- ☺ Statistical analysis can provide numerical descriptions of large numbers of particles.
- ☺ Statistical analysis allows comparisons of different samples to determine how similar or different they are.

SOME STATISTIC BASICS

Statistics is a mathematical discipline.

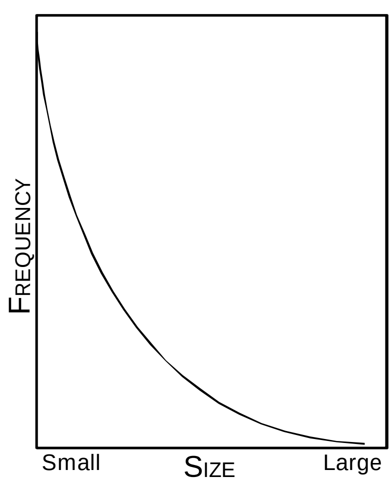
As a result we can define mathematical norms, theoretically ideal conditions or cases which can serve as…

☺ A basis for the description of a sediment
☺ A basis of comparing different sediments.

Theoretical (Mathematical) Descriptions (Distributions) of Variations in Populations

THE POISSON DISTRIBUTION

Take a stick, and break it at random a large number of times (or take a rock a crush it). Measure the length (or size) of each broken segment and plot it on a frequency diagram.



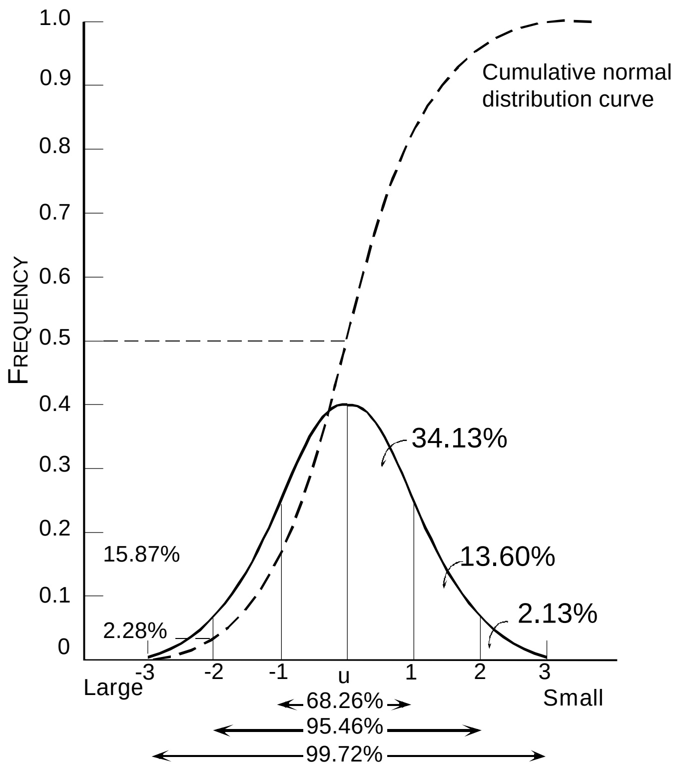
The result is a distribution in which there are a large number of relatively short pieces, with larger pieces becoming progressively more rare.

This is a poisson distribution.

Many natural phenomena posses a poisson distribution.

THE NORMAL DISTRIBUTION

Take a room full of people at random. Measure all their heights and plot them on a frequency diagram.



The result is what is called a normal distribution.

☺ The normal distribution is what results when a sample is the result of random (stochastic) processes

The normal distribution is not only the result of random processes it is also a mathematically defined property

☺ That is, a random processes always results in a distribution which possess the following properties.
  - ☞ There is a mean measurement which divides the distribution into two equal halves - the frequency distribution is the same for areas equal distance above and below the mean.
  - ☞ There is a standard deviation which measures the amount of dispursion in the sample.

Deviations from normal

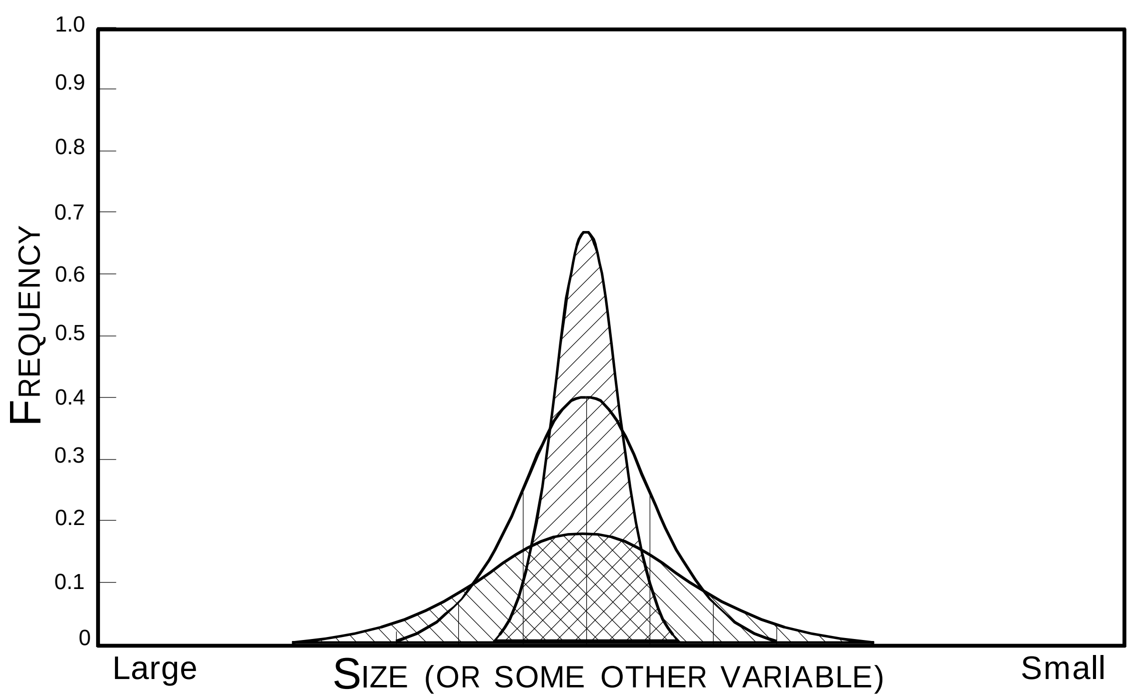
The normal distribution is what results from perfectly random processes…

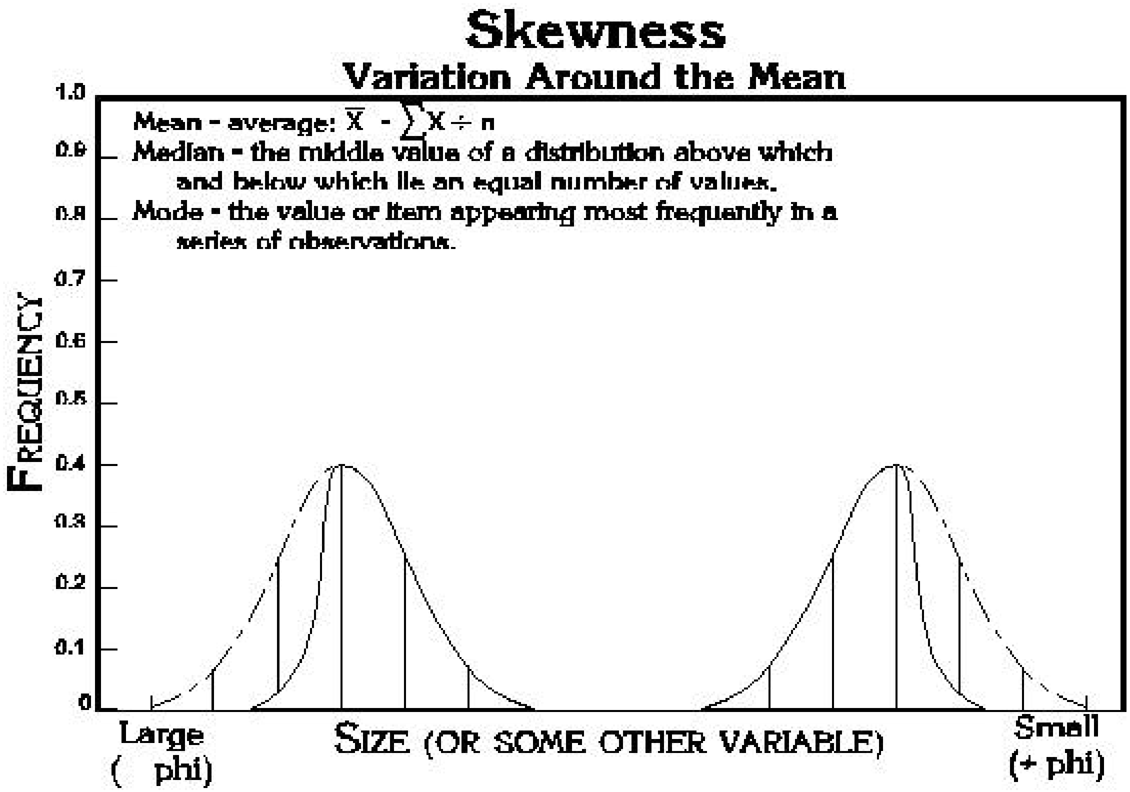
BUT, it is not unusual for sample distributions to not be normal.

- ☞ The meaning of a non-normal distribution is that the processes responsible for the distribution are not random.
- ☞ That there is some other, deterministic, processes operating.
- ☞ The result is one of the two following distributions.
  - ➜ Skewness
  - ➜ Kurtosis

Platykurtic - a flattened curve with a larger standard deviation than normal.

Leptokurtic - a peaked curve with a smaller standard deviation than normal.




Skewness
Variation Around the Mean
Mean - average: $\overline{X}$ - $\sum X \div n$
Median - the middle value of a distribution above which and below which lie an equal number of values.
Mode - the value or item appearing most frequently in a series of observations.
FREQUENCY
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Large
(phi)
SIZE (OR SOME OTHER VARIABLE)
Small
(+ phi)

APPLICATION OF STATISTICS TO THE STUDY OF GRAIN SIZE DISTRIBUTIONS IN SEDIMENTS

In applying statistics to the study of sediments there are two phases.

1. The practical
   - ➜ Gathering the data.
   - ➜ Representing the data once gathered.

2. The theoretical
   - ➜ Determining what all the data means.
   - ➜ Deciding if the data is useful.

THE PRACTICAL - GATHERING THE DATA

Because sediment grains come is such a great range of sizes it is not possible to determine all grain sizes by the same methods.

☺ A variety of methods are in use depending on the sample.

SLIDE - e.g. directing measurement, sieve sets, settling tubes, etc.

SIZE CATEGORIES FOR SEDIMENTS

SLIDE - grade scales

We also need some way of dividing the sediment into size categories.

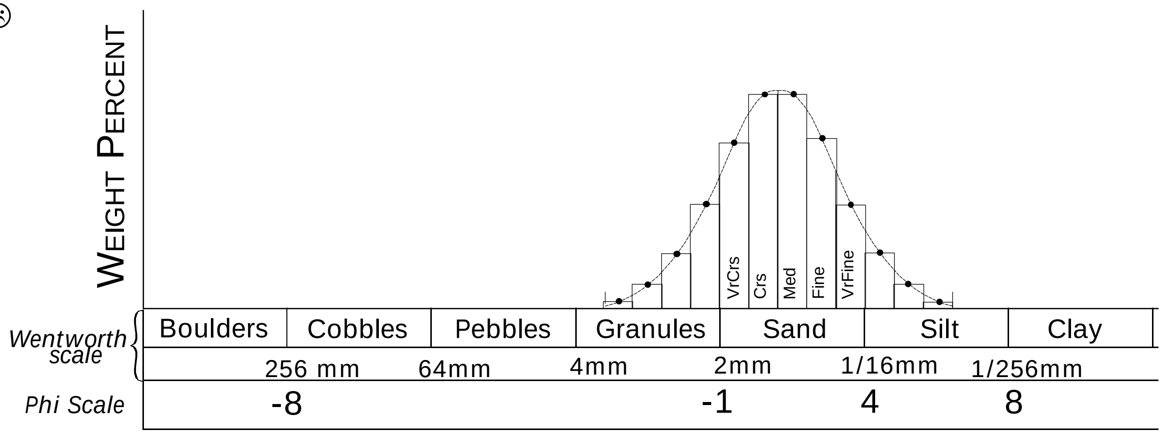
☺ A simple series of categories

Lutite	Clay	
Siltite	Silt	
Arenite	Sand	
Rudite	Gravel	

⇨ But even here we still have the practical problem of knowing what separates once category from another so we know into which category each grain goes.

☺ Udden (1898)-Wentworth (1922) scale - size ranges are based on a logarithmic scale.
- ⇨ Has center of 1 mm, and multiplier or divisor of 2
- ⇨ This scale gathers together sediment sizes which respond roughly equally to transport energy.

☹



A problem with such a logarithmic scale is that if you try to graph it it almost always produces a curved line.
- ☞ Also, it is very difficult to do statistics on logarithmic data

Therefore, in 1934 Krumbein introduced the phi transformation.

$\phi = -\log_2 d$ or $-\log_2 d/d_o$ (standard grain diam, i.e. 1 mm)

Advantages of the phi transformation
1. Main points on Udden-Wentworth scale become whole numbers, which can be statistically analyzed.

ϕ Scale	Wentworth	

-8 to -1 ϕ -1 to 4 ϕ 4 to 8 ϕ > 8 ϕ	Gravel Sand[1] Silt Clay	Negative = large particles 0 = median sand size Positive = small particles

2. Scale is reversed so large particles (conventionally plotted on the left) are plotted on the left as negative ϕ, and smaller sizes become positive and are plotted on the right.

3. Use of ϕ scale permits use of arithmetic rather than logarithmic graph paper and simplifies calculations and representation of descriptive statistics.

4. The grain sizes for which most statistics are done (sand and finer) are positive numbers, and positive numbers are easier to deal with Statistically.

[1] Most sand is around 0 ϕ.

THE PRACTICAL APPLICATION OF STATISTICS: REPRESENTING THE DATA ONCE GATHERED

The most common method of sediment analysis is the sieve set.

☺ Avoids having to individually count hundreds of thousands of sand grains and sort them by size.

☹ But the data gathered by this method consists of piles of sand, each pile containing sand within a certain size range.

☹ And we don't have an actual count of sand grains, but a weight percent of sand in that size range.

- ☞ Thus, we are not analyzing actual counts of sand grains or particular sizes since two samples of the same weight but different sand sizes will have different numbers of grains.
- ☞ But weight percents is the only practical way to handle this type of information.

What we need to do now is find a way to represent this data visually and statistically

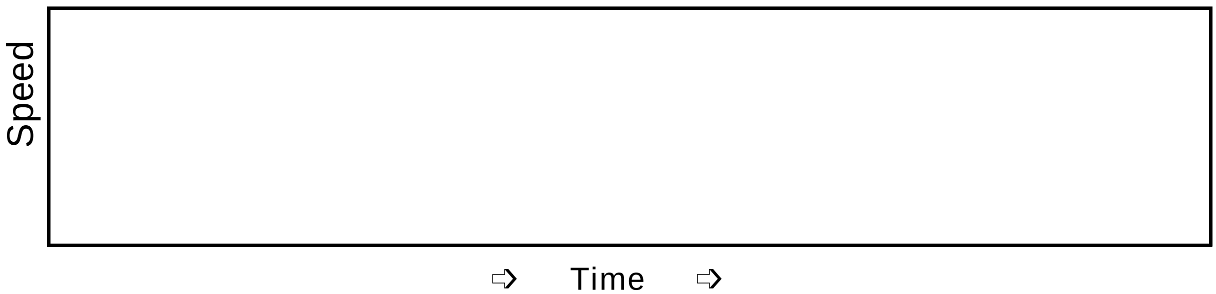
SLIDE

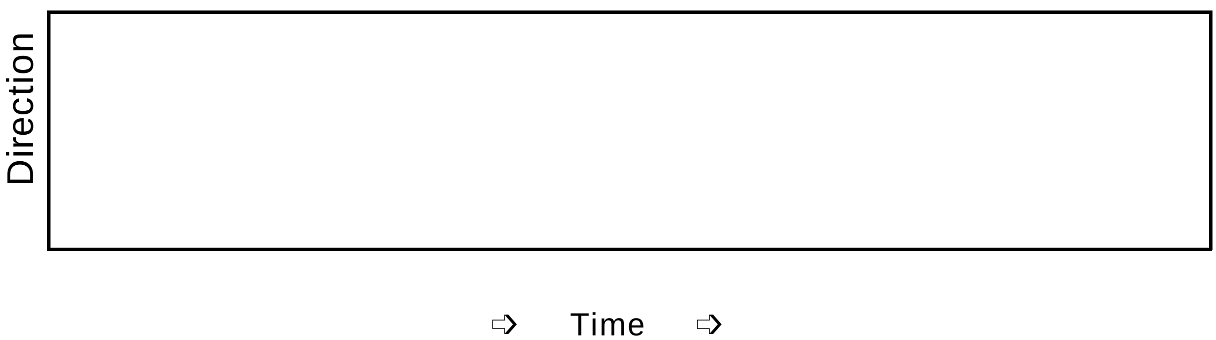
1. Histograms
2. Cumulative curves
3. Scatter diagrams

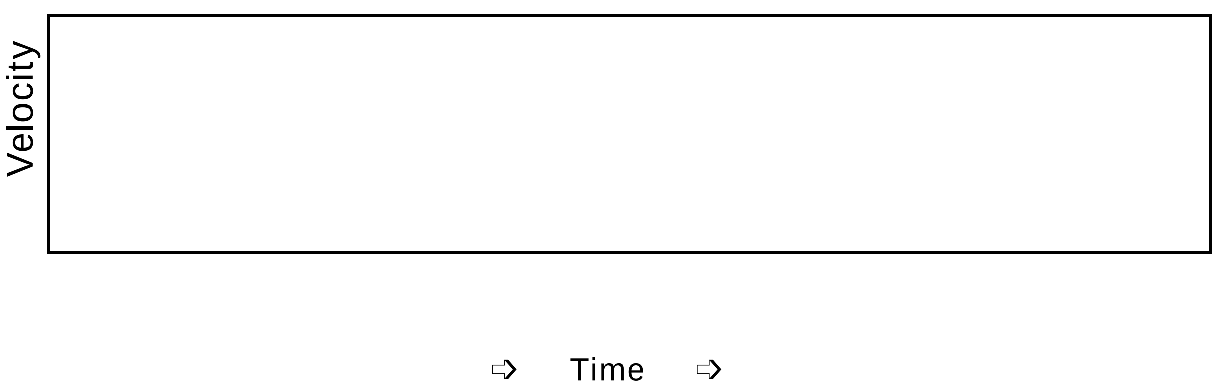
THE THEORETICAL SIDE OF STATISTICAL ANALYSIS: DETERMINING WHAT ALL THE DATA MEANS

☺ Begin with ideal processes operating in a stream of flowing water containing particles of a wide range of sizes.

☺ Make a series of deductive arguments to see what should logically follow.







IF (under the conditions established on the previous page) we assume that the water speed and direction (velocity) fluctuates randomly…

☞ AND IF we assume that the sediments available for transport are randomly distributed in size…

☞ THEN the transportation of the particles is random (because the movement of each particle results from unpredictable fluctuations in the velocity of the water)

The result is we end up with a sample of sediment which is normally distributed.

By extension we can make the following arguments

IF we assume for a long system that gradient decreases steadily downstream:

THEN

1. Gravity component of transport decreases steadily.
2. Competency and capacity of water decreases steadily.

BY EXTENSION a series of samples collected at random points downstream should show systematic changes.

1. Average grain size should decrease from proximal➡distal.
2. For any point of the proximal➡distal axis, if processes are random, the sample of sediment at that point should be randomly distributed.

Proximal ➪ ➪ ➪ ➪ ➪ ➪ ➪ Distal

-

8 - -1 ϕ 0 ϕ > 8 ϕ

Gravel Medium sand Clay

THE THEORETICAL SIDE OF STATISTICAL ANALYSIS: DECIDING IF THE DATA IS USEFUL

The main questions here is:

☺ Can these data of sediment size distrubitons be used to distinguish depositional environments.

In making these arguments it is important to understand the importance of the theoretical models we have just outlined as a baseline.

☞ Assuming randomness and ideal conditions we know what should happen.

☞ Any deviations from that then might contain some meaning about processes in the real world.

BUT FIRST - Can we assume that environmental processes are random??

☞ Theoretically it might seem reasonable,...

☞ BUT Empirically --- NO !
   ➠ What we discover is that when we measure actual sediments many deviations away from normal are found.

1. Processes may not have enough time to operate.
2. Environments may have specific processes that are not random.

But the absence of a normal distribution in real sediments is not bad. In fact it may help us to identify environments.

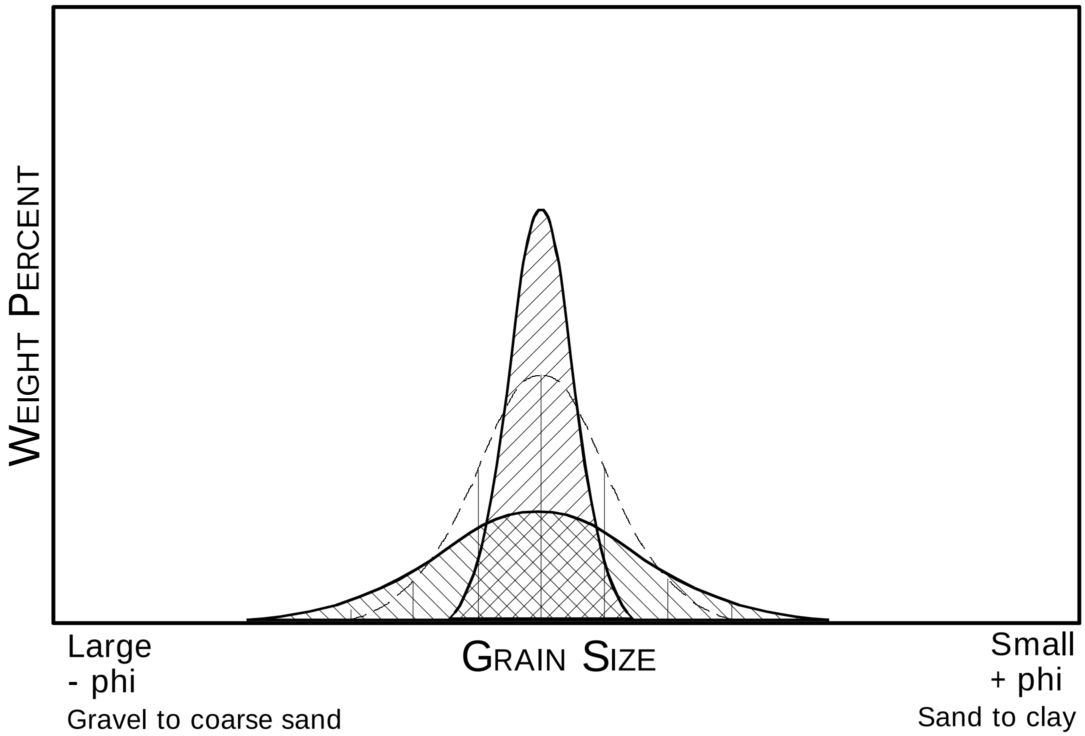
☺ Assumptions of real world grain size studies:
   1. Environmental processes are unique and mold deposits in specific ways diagnostic of the environment.
   2. Therefore grain size analysis should allow identification of those environments.

Additional assumptions:

1. Sediment starts off normal.
2. Processes in environments are normal.
3. Weathering does not take place to transform sediment as it is transported.

But to evaluate the usefulness of this data we need to examine size distributions in more detail.

INTERPRETATIONS OF SEDIMENT SIZE DATA

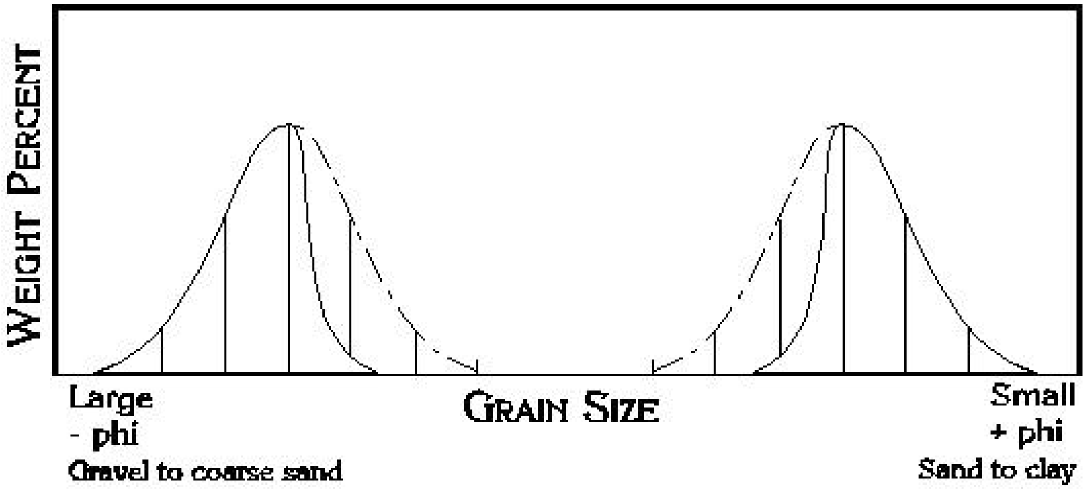


Leptokurtic curves mean the following:

- ⇨ Sediment highly sorted
- ⇨ Turbulence range narrow
- ⇨ Velocity changes narrow
- ⇨ For example, multicyclic, clean, mature sands

Playtkurtic curves mean the following:

- ⇨ Sediment poorly sorted
- ⇨ Turbulence range wide
- ⇨ Velocity changes wide
- ⇨ For example, sediments near source



Positively skewed curves mean the following:

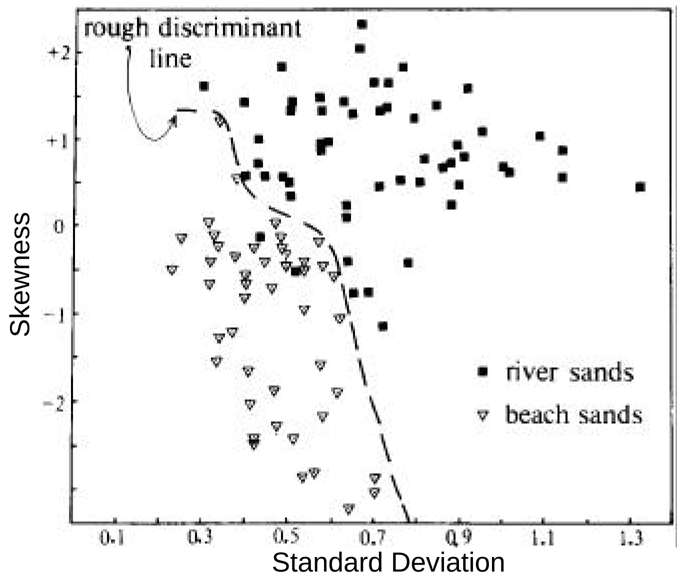
⇨ Tail of fines

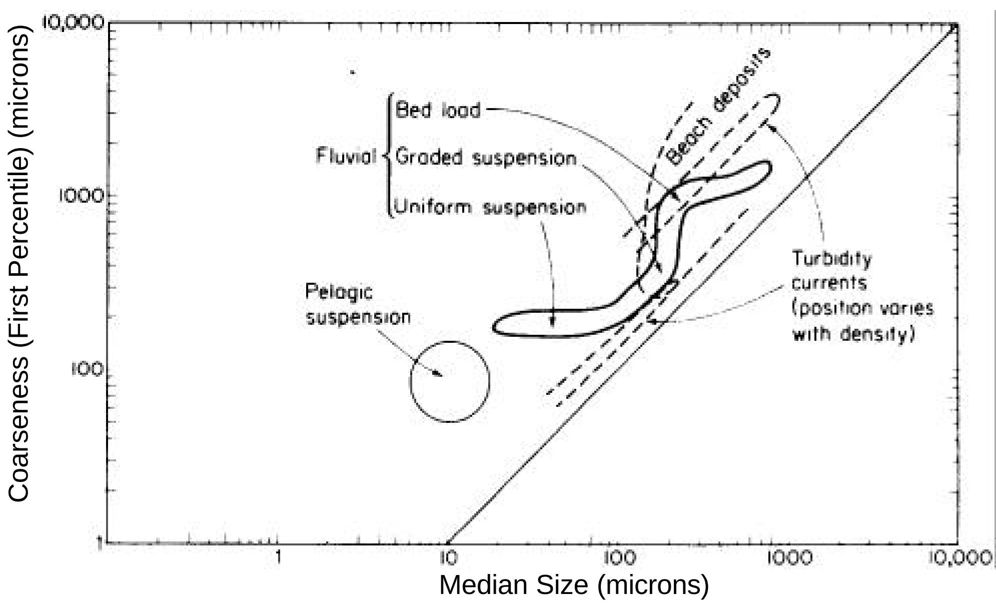
⇨ The range of sizes in the fine fractions are greater than the range of sizes in the coarser fractions.

Negatively skewed curves mean the following:

⇨ Tail of coarse

⇨ The range of sizes in the coarse fractions are greater than the range of sizes in the fine fractions.


rough discriminant line
+2
+1
0
−1
−2
Skewness
river sands
beach sands
0.1
0.3
0.5
0.7
0.9
1.1
1.3
Standard Deviation


Coarseness (First Percentile) (microns)
10,000
1000
100
1
Beach deposits
Fluvial
Bed load
Graded suspension
Uniform suspension
Pelagic suspension
Turbidity currents (position varies with density)
1
10
100
1000
10,000
Median Size (microns)