Moment Measures in Relation to the Depositional Environments of Sands

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With 4 figures in the text

During November and December of 1961 a number of sand samples were collected from four Swiss rivers: the Aare, Landquart, Reuss, and Ticino. This was done in connection with a sedimentological research project concerned with depositional environments such as beaches, dunes, and rivers. All samples were collected within two weeks, taking advantage of the unusually mild weather.

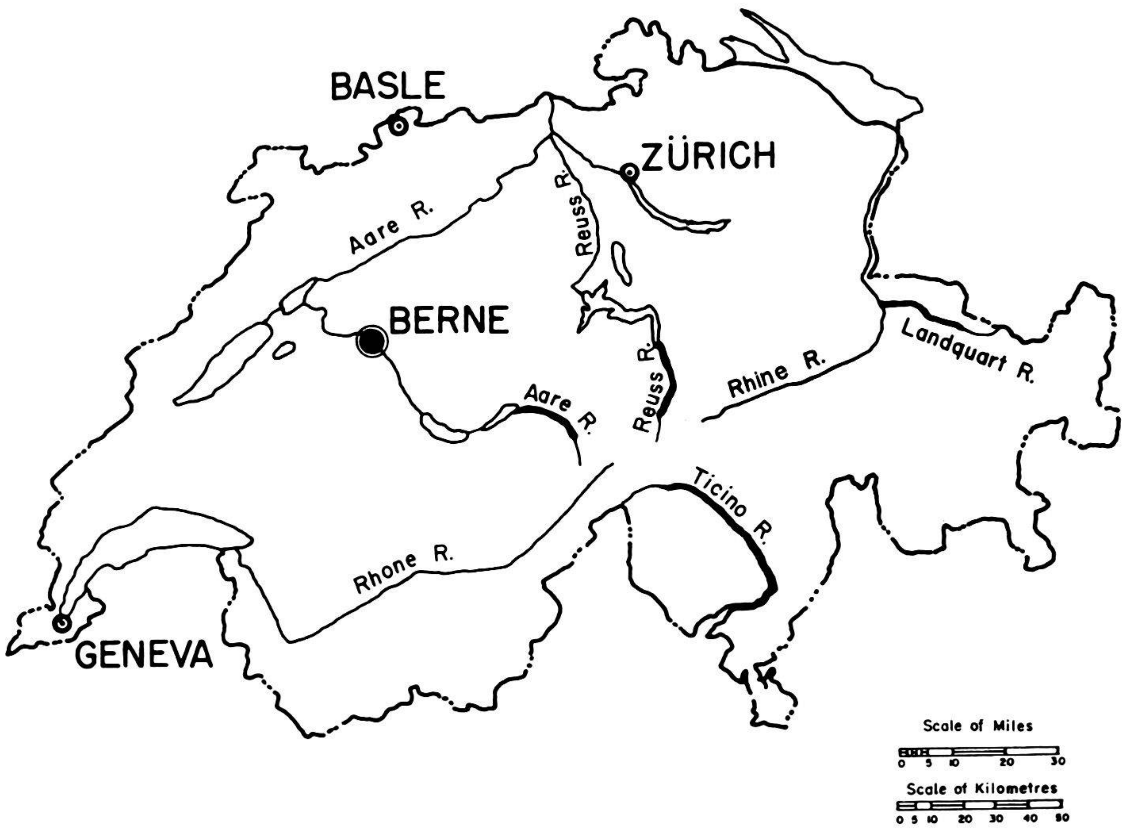

Fig. 1. Map of Switzerland showing the four sampled rivers in heavy lines.

On the map (fig. 1) the sampled areas of the four rivers are indicated by heavy lines. They are, in alphabetical order:

Aare River:	from the town of Guttannen to the Lake of Brienz.
Landquart River:	from the town of Klosters to the Rhine River.
Reuss River:	from the town of Göschenen to the Lake of Lucerne.
Ticino River:	from the town of Airolo to the Lago Maggiore.

The samples were taken at intervals of 5 kilometers whenever possible. Only along the Ticino River were two samples taken at each sampling point. Each sample weighed approximately two pounds. No special care was taken in the sampling procedure, i.e., the samples were taken from the river banks.

In the laboratory, the samples were carefully washed through a U.S.B.S. sieve, No. 230, in order to separate silt and clay from the sand. After drying and splitting to 50 g, the samples were sieved through a set of 3inch sieves, i.e., U.S.B.S. Nos. 16, 20, 30, 40, 50, 70, 100, 140, 200, and 230, for 30 minutes on a Syntron sieving machine.

From the sieve analyses, textural parameters were calculated using an IBM 1620 computer. Parameters of interest are the four moment measures: the mean, the standard deviation, the skewness, and the kurtosis. The following data are all based on the φ scale.

$$\phi = -\log_2 d \quad \text{or} \quad d = 2^{-\phi}$$

where d is the diameter in millimeters.

In a distribution the Nth moment is defined as:

$$M_N(\phi) = \sum_i \phi_i^N f_i$$

where f_i is the weight fraction on the ith screen and ϕ_i is the mean value of ϕ for the ith screen.

The first moment, the mean, μ, is defined as:

$$\mu = M_1(\phi) = \sum_i \phi_i f_i .$$

The second moment measure, the standard deviation, σ, expresses the degree of dispersion and is defined as:

$$\sigma = \sqrt{M_2 (\phi - \mu)} .$$

The third moment measure, the skewness, α_3, indicates the degree of symmetry of the grain size distribution curve and is defined as:

$$\alpha_3 = \frac{M_3 (\phi - \mu)}{\sigma^3} .$$

If the skewness is zero, the distribution is symmetric.

The fourth moment measure, the kurtosis, β_2, measures the degree of peakedness. It is defined as:

$$\beta_2 = \frac{M_4 (\phi - \mu)}{\sigma^4} - 3 .$$

Kurtosis is sometimes defined as:

$$\frac{M_4 (\phi - \mu)}{\sigma^4} .$$

If this definition is used, a normal distribution has a kurtosis of 3. For convenience, it has become customary to subtract 3 from the above expression. This operation results in a kurtosis of zero for a normal distribution.

Moment measures have been used in geology, especially in the field of sedimentology, for many years. Their value, however, has been questioned by several authors at one time or another. In recent years, R. L. FOLK & W. C. WARD (1957), and C. C. MASON & R. L. FOLK (1958) have made extensive studies concerned with the significance and value of measures based on the grain size frequency distributions in sediments from different environments. MASON & FOLK analysed data obtained from samples from the beaches, dunes and aeolian flats of Mustang Island in the vicinity of Corpus Christi, Texas. They conclude from their results that «the best way to identify the environments is by plotting skewness against kurtosis, because these properties reflect the changes in the tails of the distribution and the tails are the most sensitive to transportive mechanisms». It should be pointed out that the parameters used by them are graphical measures, not moment measures.

More recently, G. M. FRIEDMAN (1961) and (1962) has used moment measures to characterize sands and to identify their depositional environments. His studies indicated that moment measures, as well as graphical measures, are useful parameters and suitable tools for the geologist concerned with the identification of depositional environments of sands of the geological past.

Inasmuch as we have accumulated a large amount of statistical data on grain size frequency distributions of sands, it was decided to apply similar testing methods to some of our samples. For this purpose, three graphs were made using an IBM 1620 computer and an on-line automatic Calcomp X-Y plotter.

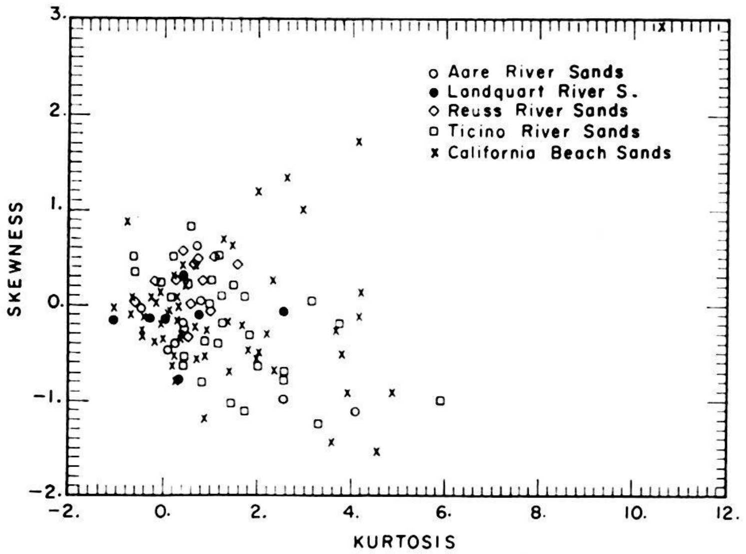

Fig. 2. Plot of the skewness against the kurtosis of Swiss river sands and California beach sands.

In fig. 2, the third moment measure (skewness) is plotted against the fourth moment measure (kurtosis) for 58 river sands from Switzerland and 60 beach sands sampled at intervals of 5 miles along the coast line of California. The graph shows a random distribution of the data points of both depositional environments with no indication of any separation associated with the origin of the samples.

In fig. 3, for the same samples compared in fig. 2, the second moment measure (standard deviation; sorting) was plotted against the third moment measure. The result is similar to that observed in fig. 2, with no apparent separation noted between beach and river sands.

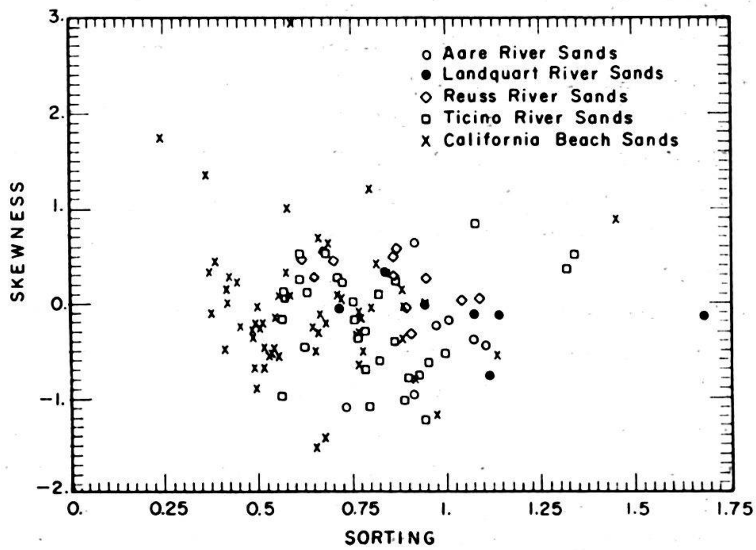

Fig. 3. Plot of the skewness against the sorting of Swiss river sands and California beach sands.

In fig. 4, the first moment (the mean) was plotted against the second moment measure (sorting) for river sands and dune sands. In all, 51 dune sands from California desert areas, i.e., Kelso, Eureka and Death Valley, were compared with 58 river sands from Switzerland. The graph shows some resemblance to a similar graph in G. M. FRIEDMAN's (1961) paper (p. 521). Whereas FRIEDMAN's graph

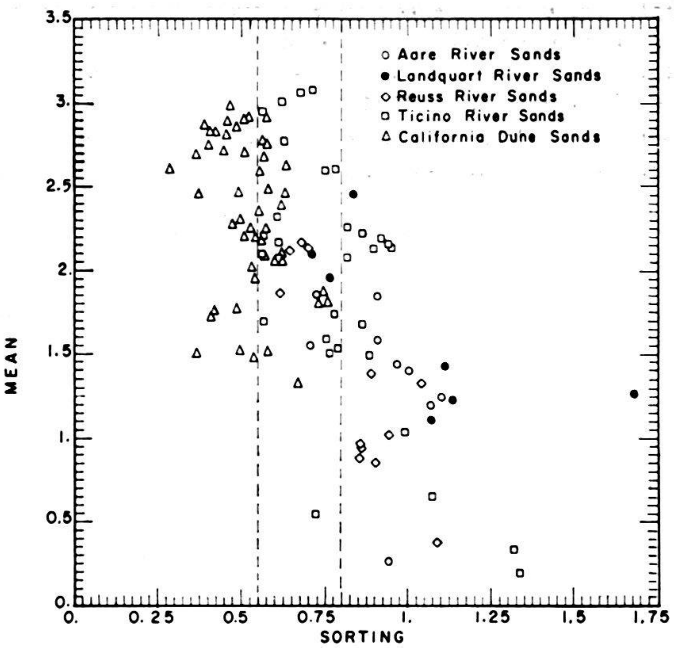

Fig. 4. Plot of the first moment (mean) against the sorting of Swiss river sands and California dune sands.

shows three fields of data points which are separated by complex curved lines, fig. 4 herein has been drawn with a separation of the data points into three fields, i.e., a dune field, a river field and a field where data points of both environments are found. The lines which separate the three fields are straight lines. They were, however, drawn into the graph in a somewhat arbitrary manner. It should be noted that the narrow field of overlap ranging from 0.55 to 0.80 for the sorting value contains 43 samples (22 river sands and 21 dune sands) out of a total of 109 samples. Thirty dune sands fall in the left field (sorting < 0.55), whereas 36 river sands fall in the right field of the graph (sorting > 0.80). Inasmuch as the largest number of data points (43 or 39.5%) fall in the field of overlap, a separation of river and dune sands based on a mean and second moment measure plot does not seem to be very diagnostic.

Summarizing the above results, it appears that moment measures may not be reliable when applied to such problems as determining the nature of the depositional environments of sandy sediments. No immediate explanation for the discrepancies between G. M. FRIEDMAN's (1961) results and our own can be given, except perhaps that moment measures should be applied as diagnostic parameters only to certain relatively small depositional environments such as Mustang Island, Texas. Under these conditions, their application might prove to be «quite successful» as pointed out by C. C. MASON & R. L. FOLK (1958).

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