GEOCHEMISTRY

Negatively Skewed Distributions of Silica and Potassium in Igneous Rocks

PROF. L. H. AHRENS[1] has proposed that the frequency distribution of silica from 440 granitic rocks of Japan can be described in terms of two distributions. This conclusion implies that Japanese rocks are made up of two distinct population types, each having different silica content characteristics. Prof. Ahrens also states that "no specific statistical type has yet been assigned to these negatively skewed distributions".

This communication points out first that a specific statistical type has, in fact, been proposed for the negatively skewed distribution of the type described by Prof. Ahrens, and secondly that the presence of two distributions is by no means established with Prof. Ahrens's argument.

A few years ago[2] I proposed that a distribution described by Johnson[3] as S_B is the type of distribution that one would expect to find in Nature. An examination of the properties of this distribution readily shows that the transformation:

$$y = \log x/(100 - x) = \log x - \log (100 - x)$$

where x is percentage composition leads to a normal distribution in y. In particular, for rare elements the quantity $\log (100 - x)$ is essentially constant and, therefore, frequency distributions of rare elements should be log normally distributed.

So far as Prof. Ahrens's argument suggesting two distributions, it is based on a change in slope in the graph of cumulative frequency of silica from 440 granitic rocks from Japan (ref. 1, Fig. 1). I have recomputed the percentage silica content (x) into the transformed variable (y) and replotted on a cumulative graph (Fig. 1). (The data for my Fig. 1 were obtained from Fig. 2a by Hatton *et al.*[4].) To be sure, there still is a small deviation at the high silica content in the same direction, but it is not so pronounced, since the transformed variable (y) is changing in such a way as to reduce the effect.

It is not my contention here to dispute Prof. Ahrens's hypothesis of two distributions. My contention is that the data and the analysis of that data are entirely inadequate. The conclusion or even the suggestion made by Prof. Ahrens that the silica distribution represents two populations is not justified from the available data. Furthermore, the plotting of cumulative frequencies as a function of percentage for abundant components (50–99 per cent) should by common sense lead to negatively skewed distributions. A simple qualitative argument to show this goes something as follows. If a component is very abundant, then all the other components are essentially trace elements with log normal distribution. Since all trace elements and the abundant elements have to add up to 100 per cent, it follows that the two frequencies should be symmetrical about a point at 50 per cent. Prof. Ahrens's evidence is a consequence of trying to force fit a frequency function with range $(-\infty, +\infty)$ to a random variable inherently restricted to a range (0, 100).

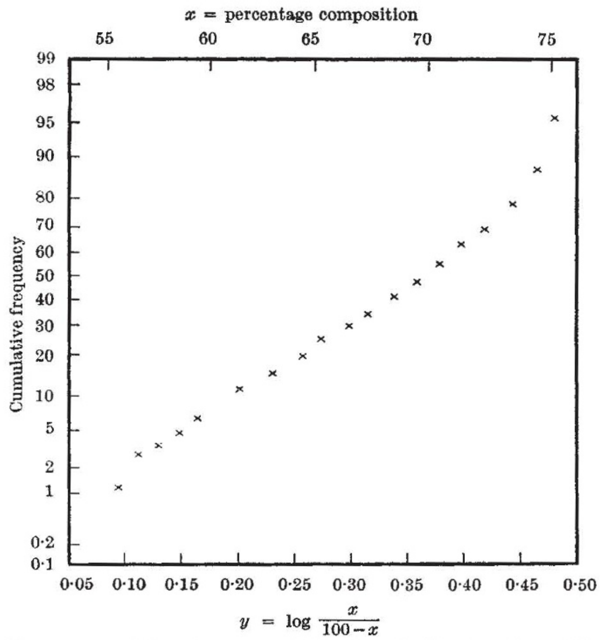

Fig. 1. Cumulative frequency distribution of silica in 428 granitic rocks of Japan plotted against $y = \log (x/100-x)$, where x is silica content per cent

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[1] Ahrens, L. H., *Nature*, **198**, 373 (1963).
[2] Jizba, Z. V., *Geochim. et Cosmochim.*, **16**, 79 (1959).
[3] Johnson, N. L., *Biometrika*, **36**, 149 (1949).
[4] Hatton, H., Nozawa, R., and Saito, M., *Int. Geophys. Cong., Proc. Sect.* 14, 40 (1960).

I THANK Mr. Jizba for directing my attention to the fact that a negatively skewed distribution which "one would expect to find in Nature" has been suggested. There are other statistical types of negatively skewed distributions, but whether any of these or that proposed by Jizba describes the data under consideration better than the 'double-normal' description proposed by me[1] has yet to be ascertained. It has been my experience, both with respect to the data under consideration (silica in Japanese granitic rocks) and to several sets of other data[2,3] (silica in basalt + diabase; potassium in granites, and in potassium-feldspar from granites and gneisses from southern Norway), that the observations are very satisfactorily described by the 'double-normal' procedure.

It is contended that if two straight-line segments (or close approximations to straight-line segments) of distinctly different slope are obtained when the raw data are examined on cumulative frequency paper, the distribution of the raw data may be satisfactorily described in terms of parts of two normal distributions, truncated and juxtaposed (see also Green[4]).

It has been maintained by Jizba that "... the plotting of cumulative frequencies as a function of percentage for abundant components (50–99 per cent) should by common sense lead to negatively skewed distributions". This 'common sense' rule is by no means generally valid. Thus, for example, whereas the distributions of silica in granitic rocks of Japan and in granites of the world are negatively skewed[2,3], silica in rhyolites appears to be normally distributed[3], although its average concentration is very high (73 per cent). In the basaltic rocks, basalt, dolerite and gabbro, silica follows distinctly different distributions[3] in each case, despite the fact that the silica abundance magnitude (≈ 50 per cent) is the same. Moreover, a constituent having a concentration distinctly less than 50 per cent may also show negative skewness; for example, potassium in the examples mentioned above[3], where the concentration magnitude may be as low as about 5 per cent.

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[3] Ahrens, L. H., *Geochim. Cosmochim. Acta* (submitted for publication).
[4] Green, E. J., *Geochim. Cosmochim. Acta* (in the press).