THE MEASUREMENT OF SIZE,SHAPE AND SPATIAL DISTRIBUTION OF MINERALS IN ROCKS

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Abstract

Accurate information about the size, shape and spatial distribution of minerals is seldom available because of the time and effort required to collect the necessary data.

The automatic measuring devices that are now becoming available can readily collect numbers of mineralogical data and these devices are briefly described and compared with the old manual methods. Examples are given of the manner in which the two-dimensional information that is usually obtained in this way must be stereologically assessed in three-dimensional terms.

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There are many mineralogical parameters which are of enormous potential value to the mineralogist but which are seldom measured and assessed in a reliable manner. The main reasons for this deficiency are the great difficulty and the tedium involved during the manual collection of the necessary data. There is, however, an ever-increasing need to obtain accurate information about the nature, and the size, shape and spatial distribution of minerals in rocks and in mineral treatment plant products. It is also important that such information be obtained cheaply and rapidly.

Consequently, a variety of automatic measuring devices have recently been produced in an attempt to fulfill this need. These instruments can provide rapidly large amounts of data which are subsequently interpreted with the aid of computers and of the new science of stereology.

Although the basic principles have been known for over 100 years the term stereology was only coined in 1961 when the International Society for Stereology was formed. Stereology is the study of the relationships that exist between quantities measured on two-dimensional planes and the features that these quantities represent in three-dimensional space. In other words, stereology is the study of solid rocks by the uniaxial examination of plane surfaces.

Stereology differs from stereoscopy which is the biaxial viewing of a transparent material for the same ultimate purpose. The mineralogist cannot of course, use stereoscopy for the examination of opaque specimens nor can he use it when the internal structures are complex. The term "stereoscopy" is sometimes used in mineralogical circles as the equivalent of stereology but stereometry is defined in the Oxford dictionary as "the art or science of measuring solids; the application of solid geometry to the measurement of solid bodies; or the art of measuring specific gravities with a stereometer". None of these definitions is applicable in our context and it is suggested that the term stereology should be used whenever we mean the interpretation of two-dimensional (planar) information in three-dimensional (solid) terms.

This interpretation can be carried out either with the aid of serial sections or by statistical-geometrical methods. Serial sections are essential for the disjointed but continuous features, such as veins or pores, or for the study of specimens in which only a single feature is present and to which statistical methods cannot be applied. Usually, however, the statistical method is much more useful in mineralogy; it is only strictly applicable to the analysis of features that occur in large numbers in the specimen being examined. These features must either be randomly distributed in the solid under investigation or it must be possible to create a random distribution of any orientated features by suitable sampling methods.

The most readily determinal stereological measurements are the volume fractions of the various components of a solid. The measurements have been manually determined for over a century by a variety of areal, linear and point counting methods.

The sizes of the various features in a rock are more difficult to measure. In the first place, it is extremely difficult to define the "size" of an irregular-shaped feature. Secondly, the "apparent size" of a feature depends on the position of the plane surface that is being examined relative to the "centre" of the feature. Some mineralogical features, for example, equi-axial mineral grains, can be roughly equated to spheres and, in these instances, the definition of, and the determination of " size" are comparatively easy. On the other hand, the platy and acicular grains that are often found in rocks present difficulties of size measurements that are, as yet , incompletely resolved. A number of correction procedures has been developed to convert the apparent size of particles to true size and , despite the problems of definition it is possible to make comparative measurements without using correction procedures.

The shape of mineral grains is a quantitative property of great value to the mineral technologist and to the petrogenetisist e.g. the shape of the constituent grains affects the strength of rocks and also provides some indication of the conditions under which the rocks was formed. Although mineral grains are frequently anisodiametric the shapes are, on the whole, comparatively simple; for example; it is not usual to encounter deeply embayed grains whilst convoluted grains are almost unknown.

The most complex of the commonly-seen mineral shapes are plates and fibres which from some viewpoints cannot be distinguished from each other; however, their true nature can be determined by viewing the specimen from a number of directions. A shape factor can best be determined if the grains show no preferred orientation and if all the grains of a mineral are of similar general shape. In the case of rocks that contain two generations of the same mineral having different shapes (e.g. ilmenite in lunar specimens) it is only possible to determine an average shape factor for the combined generations. The most commonly determined shape factor is the axial ratio of the grain. $Q = \frac{L}{W}$ where L is the caliper diameter and W is the minimum width. This shape factor involves a measurement of size and, again, illustrates the interdependence of the size and shape parameters.

The total number of *grains per unit area* is also an important variable and must be determined in order to calculate the number of grains per unit volume, the mean grain size and other compound factors.*

The *spatial distribution* parameters of rocks are rather more complex than the size and shape measurements. A particular feature, such as a mineral grain, can be described by its nature,

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$NA = N_V D$

N_V = no. per unit vol

N_A = no. per unit area

D = average caliper diameter

with randomly oriented grains

size and orientation and also by its position in space relative to the neighbouring grains. This spatial parameter is qualitatively described by mineralogists in terms of texture. The quantification of textural data is not easy but this information is nowadays being demanded by the mineral technologist. Parameters such as the "mean free path-length" between grains of a specific mineral provide useful data for studies of mineral liberation; free path-length distribution data are even more valuable for mineral process design purposes. Furthermore, the quantitative determination of preferred orientations of mineral grains (or spatial anisotropy) is of great potential value to the mineralogist and petrologist. Other spatial parameters that need to be measured quantitatively include the connectivity and/or continuity of single features such as veinlets but as mentioned earlier, these single features can only be measured by using serial sections.

Most stereological parameters can be determined by a simple microscope equipped with a counting eyepiece. However, in order to make the statistical-geometrical measurements as accurate as possible it is essential that very large numbers of observations be made and, the only effective way to make such measurements is by instrumental methods.

The history of mineralogical measuring devices began in the 1840's with Delesse's experiments with tin foil and scissors. Since that time more sophisticated devices have been slowly developed and these have allowed the mineralogist to collect better information more quickly than was previously possible.The mechanical micrometers of Shand and the so-called "automatic" point counting device by Swift were superseded in the 1960's by semi-automatic optical instruments which included microscopes equipped with moving light beams, moving light-detection devices or moving specimen stages.In these later instruments the individual intercepts made by a light beam across a specified mineral can either be sorted into size groups or added up to measure the proportion of that mineral in the specimen.

All of the instruments that rely on mechanically - moved parts suffer from the inherently slow speeds of mechanical movement.Much greater speeds are possible when electron beams are employed either to illuminate a specimen or to " move " a detecting device. For example, the image analysing computers that have recently become available use an electronically -moved detection device. An optical image of a specimen is focused onto the face of a vidicon tube in a television camera where it produces a pattern of electrical charges that are of similar intensity to the original optical pattern.The electrical pattern is examined by an electron beam which acts,as a detection device. The signal produced by the electron beam is passed to a computer which analyses it (and consequently, the original optical image) in terms of the proportions of various signal levels (i. e. mineral phases),signal lengths (grain sizes), numbers of various signals (numbers of grains),etc.

These instruments are very fast and thirty or more mineral parameters can be measured on a single field of view in one second. The field of view can then be automatically changed and the measurements repeated until a statistically viable number of observations have been made.

The image analysing devices now available still suffer from a number of deficiencies; for example they do not provide the type and degree of mineral discrimination or the pattern-recognition capacity of the skilled mineralogist. Current research aims to improve the discrimination of these optical devices either by more sophisticated electronic cicuitry or by using the traditional mineralogical techniques of etching, staining and choice of illumination.

Another rewarding approach to the problem of mineral discrimination lies in the use of computers to assess the data provided by electron probe analysers. These devices can now provide rapid and detailed information on mineralogical parameters such as the proportions, the sizes and the locations of the various minerals in a rock specimen. The major drawback of electron probe (and similar, non-optical) instruments is their high capital cost. However, the unit cost of the information that they provide is usually lower than of manual examination and comparable with that of automatic optical machines.

The mineralogist is, in general, more familiar with optically-determined parameters than with the effects of electron, ion or proton beams and for him the image analysing computers may, at present, be the most attractive of the automatic measuring techniques. However, the greater flexibility, the improved mineral discrimination and the better spatial resolution of the microanalyser - type equipment may eventually more than balance the drawback of the high capital cost. The use of computers is becoming commonplace in mineralogy and one can expect an ever greater awareness of the value of statistical stereology in the determination of mineralogical parameters. The use of stereology will involve the acceptance by the mineralogist of a number of new techniques and a more mathematical approach to mineralogy than has been common in the past.

The increasing use of automatic, instrumental techniques of measurement will not, in any way, impair the status or reduce the functions and responsibilities of the mineralogist. On the contrary, he will be in some danger of being swamped by large amounts of unaccustomed, but exciting, new information that will be of enormous value in his continuing struggle to understand the minerals and rocks.