BOOK REVIEWS

STATISTICAL ANALYSIS IN THE GEOLOGICAL SCIENCES, R. L. MILLER AND J. S. KAHN, John Wiley & Sons Ltd., New York, London, xiii + 483 pages, 17 Ch., 7 App. 1962.

Statistical analysis is not yet fully accepted as one of the principal tools of the earth scientist, partly because of the lack of any adequate text written by a geologist working in this field. The book by R. L. Miller and J. S. Kahn attempts to meet this need and will be useful, at least until a better text appears.

A list of chapter headings follows:

The book has a number of excellent features, the chief one being that the authors discuss a very wide variety of statistical topics and original approaches to earth science interpretation: the latter are chiefly evident in the last four chapters.

Scattered through the text are numerous references to published papers, many including a brief summary related to the topic under discussion. These will be valuable to the research worker, and indicate the authors' wide familiarity with the literature (although there are no references to Laffitte, De Wijs, Matheron, Krige and other writers on sampling theory for ore-deposits).

The authors wisely stress in Chapter V the importance of recognition of the different types of error involved in the acceptance or rejection of a hypothesis, and the consequences entailed for inductive reasoning.

There is a useful introduction to probability theory, which is a topic seldom found in statistics texts written by mathematicians and yet is vital to proper understanding of the techniques used so widely by laymen.

However, I find many points to criticise. The principal one concerns the basic problem in any applied statistics text, of how much mathematics to include. The treatment here is very uneven, ranging from a mere two paragraphs of description of the normal law (p. 33) to many pages of algebra in Chapter VII to demonstrate the expectations and the partitioning of sums of squares in variance analysis: almost all of the latter is useless to the geologist, who needs only a reference to a mathematical text. By contrast, hardly any mathematical background is provided for the chapters on multivariate methods, which are treated very largely in an empirical descriptive manner by following, step by step, the computational approach in the examples provided from the literature. No attempt is made to explain the vectorial approach to multivariate analysis, which can not be assumed as common knowledge, yet this does not prevent the appearance of statements such as ". . . this involves finding a suitable rotation of axes that carries the convariance matrix to diagonal form" (p. 246).

It is, in fact, never quite clear in this text what degree of statistical sophistication is expected of the reader (although it is specifically stated on p. x that it is for research workers and graduate students). For example, the terms "heuristically" (p. 12) and "stochastic" (p. 17) are used in the elementary discussions without prior definition.

Presumably these defects are a consequence of there being two authors who have adopted different approaches and have not synthesised their writing. This may for example explain the extraordinarily confused and obscure two pages introducing Multivariate Analysis (pp. 245–6), which attempt to indicate where different topics will be discussed. Perhaps this also explains the unsatisfactory treatment of simple two-variable correlation. The parameter l is introduced for a bivariate normal distribution on p. 39, but the sampling statistic r first appears in a problem-example in the section concerned with Bartlett's test for equal variances (Chapter VI, p. 112). It is next discussed in the introduction to regression analysis (p. 184–5) where ratio correlation is the topic. Nowhere is to be found any systematic treatment of correlation ratios, and there is very little discussion concerning the relationship between correlation and various types of linear curve-fitting as a function of different kinds of geological assumptions regarding dependence of variables (however, see p. 204). References

made in later chapters (p. 213, 239) to correlation studies in Chapter VI appear to be wrong.

The treatment of analysis of variance is adequate as far as it goes. The distinction between nested (hierarchical) and factorial designs is not, however, made clear, although this is important both conceptually and in regard to computations. Also there is no treatment of models involving more than 2 factors. A minor but irritating point is the use of $x_{.j}$ to represent $_i\sum x_{ij}$ (rather than e.g. $T_{.j}$): since $\bar{x}_{.j}$ is used for the mean of x_{ij} over all values of i, some confusion can arise.

Throughout the book there are many typographic errors in mathematical statements, and an inexcusable number of mistakes in grammar, spelling and punctuation. The prose style is regrettable and the manner of presentation frequently confusing (e.g. text and diagrams on pp. 30–31; text on pp. 63–66).

In spite of the wide choice of subject material, several important topics have been omitted or treated too briefly. These include:

(a) sampling theory and population types;
(b) properties and estimators of the lognormal function;
(c) Fisher's g-statistics for deviations from normality;
(d) models for distribution laws of various kinds;
(e) sampling theory for ore-deposits;
(f) interpretation of closed array data.

The major contribution of Miller & Kahn is to summarize and describe much of the earth science literature in applied statistics, and to suggest fruitful methods for future application. The reader whose knowledge of formal statistics is thin should follow the advice of the authors and (p. 247)—"turn to suitable statistics textbooks and the advice of professional statisticians".

DENIS M. SHAW

STUDIES IN ANALYTICAL GEOCHEMISTRY, DENIS M. SHAW, EDITOR (Royal Society of Canada. Special Publications Series No. 6) University of Toronto Press, 139 pages, 1963. $6.95.

This collection of six articles edited by Denis Shaw on the treatment and physicochemical implications of trace element, major element and stable isotope distribution is of interest to both the general geologist and the geochemist. Each of the papers reviews a particular area of analytical geochemistry, presents new data and suggests additional areas that might profit from the same techniques.

The aim of the first article as stated by the author, K. K. Turekian is, "to present a critique of some attempted uses of trace elements to solve specific geologic problems," and to show how trace elements may be used to provide some limiting conditions for models of the history of the earth's crust. Some of the geologic problems involving trace element distribution which the author discusses are: parental material of amphibolite, mechanisms involved in the formation of granite, equilibrium between coexisting phases, mode of origin of basaltic rocks, ancient sedimentary environments, statigraphic correlation and geochemical cycles. Although a critical appraisal of efforts in these fields is indeed useful the reviewer feels that twenty pages is not sufficient to do justice to these important areas of geochemical research.

The second and third articles review the exciting and relatively new field of stable isotope distribution and its application to many geochemical problems. H. G. Thode in his article on Sulphur Isotope Geochemistry first discusses the general variation of the S^{32}/S^{34} ratio in many different rock types and environments. The author then compares the remarkably constant S^{32}/S^{34} ratio in meteorites with the weighted mean ratios for four large basic and ultrabasic sills and from the close correspondence concludes that the earth's mantle (parent material of the intrusives) is genetically related to meteorites. Many granitic bodies on the other hand show a marked enrichment in S^{34} and the S^{32}/S^{34} ratio of these granites overlap the range in the ratio found in sedimentary rocks. The sulphur isotope ratio in sedimentary rocks can be related to the reduction of $SO_4^=$ to H_2S. The fractionation on reduction depends on the equilibrium fractionation of S^{32} and S^{34} between $SO_4^=$ and H_2S and also on the rate of reduction ($S^{32}O_4^=$ is reduced to H_2S faster than $S^{34}O_4^=$). Both the inorganic and the bacterial reduction are considered. The author concludes this excellent review article with suggestions for future research in this field.

Examples of how the stable oxygen isotope distribution between coexisting phases can be used as a geologic thermometer are discussed in the third paper by R. N. Clayton. After describing the underlying theory and experimental methods used in determining the O^{18}/O^{16} ratios, Clayton reviews the use of these ratios as indicators of recent and past ocean temperatures. As with all thermometric techniques a major problem is that of calibration. The variation of the isotopic equilibrium constant as a function of temperature is considered for a number of simple coexisting pairs (calcite-water, quartz-water, magnetite-water). The isotopically determined temperatures using the quartz-calcite pair in a number of recrystallized Leadville limestone localities in Colorado and the quartz-magnetite pair in a number of metamorphic zones in the iron formations

of the Lake Superior region give some idea of the tremendous potential of this geologic thermometer. Thode's and Clayton's excellent review articles on the implications of stable isotope distribution complement one another very well; the first paper being concerned with chemical and genetic implications and the second paper with geologic thermometry.

"Some Problems of the Geochemistry of Fluorine" by Michael Fleischer and W. O. Robinson is a review of the analytical data on the fluorine content of sedimentary, metamorphic and igneous rocks and the affect of rock type on the fluoride content of groundwater. The authors point out the difficulty in selecting analyses and in trying to make general statements about the distribution of fluorine. The section on the variation in fluoride content of ground and surface waters should be of particular interest to those concerned with fluoridation of communal water supplies. This article is typical of the careful and critical examination of analytical data being carried out by Fleischer and his coworkers at the U.S.G.S. in the continuing process of revising Clarke's, "Data of Geochemistry."

The last two articles consider the often neglected problem of sampling and the statistical significance of geochemical data. E. H. Timothy Whitten in "Application of Quantitative Methods in the Geochemical Study of Granite Massifs," stresses the idea that, in order to use the variability of chemical, mineralogical and physical parameters as a guide to the petrogenesis of a geologic feature, the nature and scale of this variability must first be understood. Using a number of examples ("older granite" of Donegal, Malsburg granite in Germany, Climax granodiorite stock in Nevada, Monte Capanne granodiorite in Italy, etc.) the author points out the spatial variability (geographical and elevation coordinates) of a number of parameters using trend surface analysis. The parameters which were used included both open (those not of constant sum such as specific gravity) and closed parameters (those of constant sum such as chemical and modal analyses). This article, with its extensive bibliography, is an excellent review of recent efforts to provide a more rigorous basis for judging the significance of parameter variability in granite massifs.

The problem of discerning the functional relationship between variables or groups of variables, especially those which do not lend themselves to the usual graphical analysis, is discussed by G. V. Middleton in the last article. In this nonmathematical review the author indicates by example the type of geochemical problem which might profit from a number of multivariate statistical methods. Some of the examples cited are: the regression of the ω refractive index of scapolite on the ten major oxide components assuming the independence of these oxide variables, factor analysis of deep ocean muds in order to find from a larger number of

intercorrelated variables the relatively few mutually independent factors, the use of the discriminant function in discerning significant differences in composition between rock types, individual rock masses or tectonic environments. The article is concise and informative, and gives insight into the usefulness of the many statistical techniques open to the geochemist.

One thing lacking in this volume is an introductory or concluding article linking the different areas of geochemistry covered by the six articles. A separate article on the physicochemical and crystal chemical control of element and isotope distribution, and on the chemical significance as compared to the statistical significance of parameter variability would have helped to serve this purpose. Apart from the minor criticisms noted, this volume is highly recommended for those who are interested in the new techniques being developed to tackle petrologic problems.

P. L. ROEDER

PROCEEDINGS OF THE NINTH ANNUAL MEETING OF THE MINERALOGICAL ASSOCIATION OF CANADA

The Ninth Annual Meeting of the Mineralogical Association of Canada was held on May 18–19, 1964 in the Royal York Hotel, Toronto, Ontario, in conjunction with the annual meetings of The American Association of Petroleum Geologists, the Society of Economic Paleontologists and Mineralogists, and the Geological Association of Canada.

The general business meeting of the Association was held on Tuesday, May 19 and was chaired by the President, Dr. D. M. Shaw. The Secretary, S. Kaiman, reported that in the election of officers for 1964, 227 ballots were cast and the following slate was elected:

President	D. M. Shaw
Vice-President	W. W. Moorhouse
Secretary	S. Kaiman
Treasurer	H. R. Steacy
Committee Members	J. R. Smith (3 years)
	K. L. Currie (3 years)
	W. E. Hale (2 years)
	A. J. Frueh, Jr. (2 years)
	E. H. G. Cornford (1 year)
	J. P. GIRAULT (1 year)
	D. H. Gorman

Membership as of May 11, 1964 numbered 755, made up of 503 ordinary and associate members, 241 corporate members and 11 student members.