minor errors have escaped detection. For example, the captions of fig. 3 and 4 have been interchanged, at least one photograph is incorrectly oriented and in a few places references are made to non-existent insets or other items omitted when the illustration was taken from its original source. The reproduction of the black and white photographs is clear and sharp, but it is regrettable that none of the photographs of fire-fountaining or lava lakes are in color, for even the best black-and-white prints fail to do justice to these spectacular displays.

The volume will certainly be welcomed not only by volcanologists but by geologists in general and will find an important place in reference libraries of all sizes.

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STATISTICS

George S. Koch Jr. and Richard F. Link, 1971. *Statistical Analysis of Geological Data*, Vol. 2. Wiley, New York, N.Y., 438 pp., £7.75.

This book represents the second of two volumes by the authors. Its purpose is to present some methods of statistical analysis of geological data which are more advanced than those presented in the first volume. The authors assume that the reader is acquainted with univariate statistical analysis, the principles of sampling, and the methods of geological sampling. The mathematics presented is relatively simple and requires only an understanding of elementary algebra, geometry, and some matrix algebra. Examples of applications in geology, mining engineering, petrology, geochemistry and mineral economics are given.

Trend surface analysis is introduced in Chapter 9 (the first chapter of this volume). Multiple regression, discriminant analysis, factor analysis, and the analysis of directional data are introduced in Chapter 10. Chapter 11 includes a discussion of ratios and variables of constant sum. The theory of search, response surface applications, and exploration on a grid are some of the topics covered in Chapter 12. Some of the techniques and problems of ore deposit evaluation are discussed in Chapter 13. Chapter 14 is concerned with operations research, and such topics as linear programming, critical-path scheduling, queuing, and the stages of mining are discussed. Some aspects of geological sampling are reviewed in Chapter 15, while "Gold and the Lognormal Distribution" is the title of Chapter 16. Chapter 17 concludes the second volume and includes a brief discussion of computers and geology.

Although the authors provide few new insights into the problems of applying statistics and operations research to geology, they do bring together many of the recent papers in this area, which is an accomplishment in itself. The large number of topics covered precludes detailed discussions. Practitioners in this area may be dissatisfied with the book since many of the examples violate the assumptions of the particular technique which they are supposed to illustrate. For instance, no mention is made of the dangers of poorly-distributed sample points in trend surface analysis, even after an example is presented (fig. 9.1). The authors often use heteroscedastic data in their parametric examples and say that taking logarithms of the observations would lead to new problems which are never explained. The drawbacks of the book probably are not serious for those readers who are relatively new to statistical analysis in geology. This book should prove useful to those who are familiar with some aspect of geology and want to find out what statistics can do to help them. If the reader is interested in applying some of the techniques, he should pursue the references, since this is not a textbook, and the statistical properties of the data used in the examples could often be improved upon.

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GEOTHERMAL PROBLEMS *

S. Uyeda and A.M. Jessop, Editors, 1970. *Geothermal Problems*. Special Issue of *Tectonophysics*, 10 (1–3). Elsevier, Amsterdam, 390 pp., Dfl. 54.00.

Geothermal Problems by Uyeda and Jessop (The September 1970 issue of *Tecto-*

nophysics) contains 25 papers on terrestrial heat flow presented at the IASPEI/IAGA Symposium, Madrid, 1969. Only highlights can be mentioned in a short review.

In Part I, dealing with geothermal areas, Kozo Yuhara estimates that annually $2 \cdot 10^{23}$ erg/year are released by all the geothermal areas of Japan. Volcanic activity amounts to about $7 \cdot 10^{23}$ and common hot springs $11 \cdot 10^{23}$ erg/year. The normal heat flow in nonvolcanic areas is $73 \cdot 10^{23}$. Exclusive of earthquakes, the total heat energy released is thus $9 \cdot 10^{24}$ erg/year. Since one kWh/year = $3.1 \cdot 10^{17}$ erg/year industrial utilization of geothermal energy would be negligibly small. Experimental methods of measuring geothermal heat flow are described in detail.

Part II contains papers on measurement of thermal conductivity. The outstanding one is by Dorogonitskaja and Moiseenko in which thermal conductivity is obtained indirectly by correlation with other physical properties like diffusion—absorption activity, electrical resistivity, acoustic velocity and density, which are quantities normally logged in oil wells. Temperature gradients can be gotten from well temperatures routinely measured in oil fields (see for instance the article by Uyeda and Watanabe in Part III), but conductivity determinations are lacking and average values are difficult to get from a few core specimens. For 68% of the samples on which the method was tested the value of thermal conductivity calculated from comparison of other physical properties agreed within 10% with the directly measured one.

Part III, "Regional Heat Flow Measurements", consists of 10 articles giving data in Siberia, Italy, France, India, Korea, South America, and the Philippine Sea.

In the western Siberian lowland and the Altai—Sayan region to the west, heat flow shows the expected correlation with the geologic age of the rocks.

In Italy, seven measurements were made in the sediments of the Fossa Bradanica. The holes were less than 100 m deep, which may account for the scatter of the values.

Five measurements in France averaged 2.15 μcal cm^{-2} sec^{-1} (h.f.u.). They were taken in rocks of various ages under mostly unfavorable field conditions.

Four heat flow values in the Cenozoic Cambay Basin in India averaged 2.1. h.f.u. Differences between the individual regions can be explained by the assumed presence of an igneous intrusion of Pliocene—Miocene age.

Additional careful measurement in the Gondwana Basin in India give values that would be expected from local geology and rock ages with the exception of two anomalously high values which are attributed to the circulation of geothermal water.

In South Korea, 12 new heat flow values averaging 1.5 h.f.u. taken mostly in mines are reported. The higher values are in the area of Tertiary volcanism.

Heat flow in the Philippine Sea is variable, reflecting a complex situation requiring more data for interpretation. Heat flow is high in the northern part of it where the station density is adequate immediately to the west of the Bonin Islands between 134° and 139° W longitude. This may be the result of subduction at the Bonin Trench. The new data in the Okinawa Trough appear as the natural extension of the high heat flow belt in the marginal seas of the western Pacific.

Part IV discusses tectonophysical interpretation. It opens with a review by Lubimova and Feldman of new heat flow measurements in the U.S.S.R. and eastern Europe in relation to electrical conductivity versus depth profiles obtained from magnetotelluric and geomagnetic depth sounding. Reasonable theories in the two approaches lead to substantially different estimates of temperature with depth above 400 km. Electrical conductivity between 60—100 km depth gives only about half the temperature calculated from geothermal data.

A compilation of heat flow values from all over the world mostly since 1966 have been plotted against geologic age by Verma et al. They found a decay constant of 4.31 = ±.0.7 · 10^{-10} h.f.u./year, which, they note, is very close to the decay rate of ^{40}K.

A connection between the phase velocities of Rayleigh waves and heat flow across the East Pacific Rise at the mouth of the Gulf of California is reported by Knopoff et al. They found an abnormally low velocity channel under the rise which they attribute to the hot rock under it.

The book ends with three papers on subduction of the lithosphere at island arcs. D.P. McKenzie calculates analytic solutions for the temperature structure of a sinking slab by using the concept of potential temperature in a convecting liquid.

A finite difference scheme is used by Minear and Toksöz for calculating the temperature distribution in models of a downgoing slab. They find that shear strain heating is necessary for producing lava in island arcs. In addition to conductive transfer, contributions of radiative heating (37%), adiabatic compression (16%) and phase changes (12%) have been included. The models show a narrow minimum in the surface heat flow at trenches and fail to yield the high values found behind island arcs, such as in the Sea of Japan. This problem is taken up by Hasebe et al., who calculate the volume of molten basalt that has to rise from the sinking slab under the Sea of Japan to account for the high heat flow there. Under reasonable assumptions, magma has to rise at the rate of 0.3 cm/year thus, accumulating a thickness of 300 km in 100 million years. One way of accommodating this volume is by expansion of the floor of the marginal sea, but the authors say that this requires most of the material of the sinking slab to rise again by penetrative convection. Fortunately for the authors' thesis, I made a rough calculation according to which less than 1/5 of the subducting material needs to rise to give the observed heat flow in the Japan Sea.

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LUNAR ROCK MATERIALS

A.A. Levinson and S.R. Taylor, 1971. *Moon Rocks and Minerals*. Pergamon, Oxford – New York, N.Y., 222 pp., 8 colour plates, 110 text-fig., 33 tables, U.S. $11.50.

This is the second textbook designed as a short summary of the information obtained from a study by scientists of the first rock materials to be returned to Earth from the Moon. The first book (*The Lunar Rocks*, by B. Mason and W.G. Melson, 1970) covers a similar field, but is shorter and gives less detailed rock data and more on the pre-Apollo and Apollo lunar-surface observations.

Levinson and Taylor have produced an excellent, thoughtful and stimulating book. Fellow-scientists involved in lunar investigations may be critical of the concept that lunar processes can safely be summarized at such an early stage in the research programme, based primarily on the Apollo 11 suite of rocks. Subsequent work on the more variable Apollo 12, 14 and 15 suites has provided much new information. However, it is safe to say that few of the major, first-stage conclusions have required modification except in minor detail. Also it is probable that few authors in the near future will have the courage to write a short, comprehensive textbook covering all aspects of the scientific work. As the data multiply, from hundreds of laboratories throughout the world, the tendency will be for texts to be written on specialized topics involving either the petrology, mineralogy, chemistry, geochronology, physics or evolution of the Moon. For this reason it is likely that *Moon Rocks and Minerals* will remain a classic reference source, chiefly for students and non-specialist teachers, for several years.

After a very brief introduction, the eight main chapters are: (1) rocks and soils (classification into basalts, breccias, soils, glasses etc.); (2) minerals; (3) chemistry; (4) organic matter; (5) experimental petrology and lava origins; (6) isotopic studies, ages, cosmic and solar wind effects; (7) physical properties; (8) origin of the Moon. There is a useful Appendix with a glossary of terms, conversion factors, physical properties of the whole Moon, and a list of the chemical elements. The index is comprehensive, but in view of the prohibitive size, a bibliography is replaced by references in the text only to a few principal investigator names and their institutions.

The information is accurate, presented in a logical sequence, and lavishly illustrated by a large number of photographs, diagrams and tables. The two major sections are on the mineralogy and chemistry of the samples. The 28 minerals are described and illustrated separately, with appropriate reservations regarding tin, mica and aragonite, which are still of doubtful origin. Data from subsequent studies have confirmed the presence and significance of amphibole, baddeleyite, zircon, pentlandite and whitlockite (mentioned only tentatively by the authors), have established the presence of at least 4 more new minerals (rich in Zr and rare-earth elements), and have