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BOOK REVIEWS

STABILITY OF HEAVY MINERALS. Volume 1, *Contributions to Sedimentology.* Edited by H. Füchtbauer, A. P. Lisitzyn, J. D. Milliman, and E. Seibold. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 1973. 125 pages, 67 figures, 42 tables. DM 52.

According to the editors, the purpose of their new international journal is to publish monographs in sedimentology, papers containing more pages of detailed documentation than standard journals will allow. The editors suggest articles in the range of 50–200 pages as being suitable for their format. (Curiously, only one of the three papers in volume 1 exceeds 40 pages). For my part, I question the practicality of such an effort, costs being as high as they are. On the other hand, I have been told that cost is irrelevant to publishers of such journals because libraries around the world are now so numerous and voracious in their appetites for everything published, that the publisher is guaranteed a profit even if no scientist buys a personal copy.

Leaving philosophy to comment on the journal content from the viewpoint of a sedimentologist, I think most of us will like this issue. I think this for three reasons. First, it consists of three quality papers illustrating some of the work currently being done with heavy minerals in Germany. Second, all the papers are in English, a fact that will relieve most English-speaking natives. Few of us feel fluent in the German language we "learned" as students. Third, each of the papers illustrates a different approach to the study of heavy minerals. Nickel uses experimental geochemistry. Dietz revives the use of mechanical abrasion in a tumbling apparatus. And finally, Grimm examines the change in heavy mineral content with depth in a residual quartz gravel in an Upper Miocene Bavarian molasse.

Nickel's paper, "Experimental Dissolution of Light and Heavy Minerals in Comparison with Weathering and Intrastratal Solution" is by far the longest (168 pages) of the three articles and represents the essence of his doctoral dissertation at Bochum. The question asked is the effect of different pH values on dissolution of minerals in an open system. The method used was to allow solutions ranging in pH from 0.2 to 10.6 to flow over twelve minerals ranging in stability from zircon, tourmaline, and rutile on the one hand to epidote, apatite, and hornblende on the other. Some of the results were to be expected. Dissolution was incongruent. Alkali and alkaline earth elements were removed from mineral surfaces faster and in greater amounts at acid pH values; silica at the highest pH value used (10.6); aluminum is amphoteric and therefore was removed most effectively at pH extremes. Of much new interest, however, are the different mineral stability series arrived at experimentally under different pH conditions. At an experimental pH of 5.6 the sequence matches well with the sequence often reported from weathering profiles. It is, no doubt, more than coincidental that this is about the pH value of rain in equilibrium with the partial pressure of carbon dioxide in the atmosphere. The stability sequence obtained by Nickel at pH 8 is a good match with the "intrastratal solution sequence" reported earlier by Füchtbauer. Given the abundance and solubility of carbonate rocks in the subsurface, it seems quite reasonable that diagenetic aqueous solutions should be buffered near this pH value. Reported values of subsurface pH as measured in the field are notoriously suspect, so it is particularly pleasing to have the sedimentologists' "guesstimate" confirmed by experiment.
and the structure of buddingtonite.

Volker Dietz' paper is a dissertation from Saarbrücken and concerns changes in elongation ratio and roundness of nine heavy mineral species and quartz during experimental transport in water and air ("Experiments on the Influence of Transport on Shape and Roundness of Heavy Minerals"). This 33 page paper I found less convincing than the chemical study described above. My impression is that the level of "background noise" was too high for many sedimentologic signals to penetrate. Dietz is well aware of many causes of the "noise" and tried to tone them down but was not as successful as might have been hoped. After giving his experimental results, he is forced to conclude (page 94) that many factors played a part in producing these results—hardness, tenacity, cleavage, crystal structure, brittleness, and density—and that it is necessary to use an *ad hoc* selection process among these variables to explain his results. At least that is my interpretation of his conclusions. In short, much effort but small yield.

The final paper (22 pages) is by Wolf-Dieter Grimm in Munich and is titled "Stepwise Heavy Weathering in the Residual Quartz Gravel, Bavarian Molasse (Germany)." The gravel contains intercalated clay layers and, after deposition of the gravel, weathering and kaolinization took place with decreasing intensity downwards. This altered the mineral ratios in the deposit and permitted establishment of a weathering stability series for the heavy minerals originally present in the deposit. The series is strikingly like that obtained in Nickel's experiments at pH 5.6 and reported in field studies by many previous workers. Grimm attributes the mineral alteration to humic acids, and this seems quite reasonable.

Summarizing, the three papers in this volume deserve to be read by all sedimentologists. The fact that some of the studies were more successful than others reflects more the inherent complexity of the problems tackled rather than defective approaches.

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THE FELDSPARS. Proceedings of a NATO Advanced Study Institute, Manchester, 11–21 July 1972. Edited by W. S. MacKenzie and J. Zussman. Manchester University Press, Manchester, Great Britain, 1974. xi + 717 pages. £9, $27.50.

This book is a collection of 28 research and 3 review papers representing a portion of those given at the second NATO Advanced Study Institute on Feldspars convened at The University of Manchester in July of 1972. The papers, many of which are highly significant, define the 1972 frontier of our knowledge of feldspar geochemistry and crystal chemistry. The book is divided into four parts, each consisting of 6–10 papers.

Part I (182 pp) contains 10 papers devoted to research on "Structure, Bonding, and Order-Disorder." Following a brief review of the feldspar structures and site nomenclature are a series of research papers dealing primarily with cation occupancy and configuration of the tetrahedral sites and their relationship to optical properties, lattice parameters, and bond distances. Results are also presented on alkali ion diffusion in alkali feldspars, evaluation of tetrahedral bond length and angle variations in terms of a covalent model

In Part II (192 pp), "Phase Equilibria and Thermochemistry," the emphasis is on the alkali feldspars with 6 of the 8 contributions representing this series. Three of the papers report on the effect of pressure on the alkali feldspar solvus, while two deal with certain aspects (nucleation, growth rate, and zoning) of crystal growth from a melt. Other contributions lie in the areas of feldspar chemical interaction with aqueous solutions, the effects of certain physical and chemical parameters on the degree of Si/Al ordering, and the relationship of some thermodynamic properties to ordering.

Part III (174 pp), "Electron Microscopy" opens with a review paper discussing the technique, some observations, and future application to feldspar research. Here the emphasis, as it reflects the general tenor of feldspar research, is on problems in the plagioclase series. Five of the seven papers examine the lamellar structures of peristerites, labradorites, and/or bytownites, focusing on such aspects as size, orientation, composition, schiller, relationships to subsidiary maxima, and antiphase domains. Each of the papers is illustrated with high quality electron micrographs. Conclusions regarding the thermal and compositional extent of the solvi are presented. The two remaining papers deal with the mechanism of unmixing and the orientation of exsolution lamellae in the alkali feldspars.

Part IV (120 pp), "Minor Elements and Natural Occurrences" is the shortest in terms of both the number of pages and contributions (6). It is also the "catch all" portion of the book containing papers of greater subject diversity than found in the other parts. The topics discussed include trace element behavior in feldspars under hydrothermal conditions; cation substitutions and their effects on lattice parameters, structural variations, and stability; the relationship between $2V$ and obliquity in the potassium feldspars; potassium feldspar petrology in two unusual pegmatites; the effects of the crystallization history of plagioclase on the Ca zoning in coexisting almandine; and the stability of feldspars in the metamorphic environment.

The remainder of the book (45 pp) contains an extensive bibliography, a list of participants in the symposium, and an author index. It does not contain a subject index, however, and while one is not an absolute necessity in a book of this type, it would be a convenience to the reader. The book as a whole is quite free of typographical errors and is well illustrated with both photographs and line drawings.

The title, *The Feldspars,* is somewhat misleading since it gives the impression that this is a comprehensive text and not one dealing merely with recent research into specific areas of feldspar chemistry. If, as the authors claim, the book is to serve as an update of the feldspar section in Deer, Howie, and Zussman, *Rock Forming Minerals,* then each of the four sections should conclude with a paper summarizing not only the results of the papers presented in the book, but also those of other contributions to the symposium as well as recent journal articles. The book belongs on the bookshelf of every mineralogist, petrologist and geochemist interested in feldspar research or related problems in other mineral groups.

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MICROPROBE ANALYSIS. Edited by C. A. Andersen. Wiley Interscience Publications, John Wiley & Sons, New York, 1973. xi + 571 pages. $24.95.

The theme of this book is to review microprobe (electron, laser, and ion) instrumentation and applications to the "analysis and characterization of the microstructures of heterogeneous materials" to "delineate the special advantages and areas of application of each of the techniques and instruments." To accomplish this, Andersen has assembled an impressive list of scientists to write on their specific areas of interest. In this, he has been quite successful; however, any effort to assemble a collection of papers by a variety of scientists is bound to suffer somewhat from the differing abilities of the authors, and this book is no exception.

Nearly two-thirds of the book is devoted to electron probe instrumentation and analytical procedures—a clear reflection of the dominance of electron microprobe usage relative to laser and ion probes. Fitzgerald's review of microprobe instrumentation (Chapter One) is written for someone with a basic knowledge of physics and chemistry and, as such, forms an excellent introduction to electron probe analytical methods. Both energy dispersive and wavelength dispersive analysis are dealt with in detail, and comparisons of the resolution obtained by both techniques are made. However, there is no discussion of available instrumentation, nor is there any reference to microprobe automation, an aspect of microprobe analysis that has expanded enormously in recent years. The treatment of analytical modes is perfunctory and serves only to introduce the second chapter by S. J. B. Reed on X-ray generation and quantitative analysis.

Reed's discussion of quantitative analysis is very good, considering the length limitations imposed by the book, and contains an excellent, but dated (1968) set of references. Mineralogists will find this chapter particularly valuable as it includes discussions of, and references to, quantitative analytical procedures, matrix effects in quantitative analysis, analytical accuracy, counting statistics, trace element analysis, and chemical effects in X-ray spectra (somewhat dated). Considering the chapter title, it is not clear to this reviewer why there is no discussion of some of the widely used computer programs for quantitative analysis. Brief comparison of some of these programs, (*e.g.*, Colby's MAGIC IV, Sweatman and Long, and Rucklidge's EMPADR VII) for example, is warranted. In spite of its obvious shortcomings, the chapter is an excellent introduction to basic quantitative microprobe analysis.

Chapter Three, on the high resolution scanning electron microscopy of surfaces (Broers), is of limited value to most mineralogists and is written strictly for those with a working knowledge of electron optics and electron detection. It contains a discussion of gun selection, electron optics, instrument design, *etc*, all factors which effect the quality of high resolution scanning. For those interested in setting up an S.E.M. laboratory for high resolution work, this chapter provides assistance in the selection of a system and outlines potential problems that should be anticipated.

The application of electron microprobes to the study of solid-state devices (Wittry, Chapter Four), will again be of limited interest to most mineralogists. However, it contains a brief but valuable review of the various signals generated by electron beam bombardment. Furthermore, it contains a wealth of appropriate references for investigators with specific problems. Of particular interest are the sections on studies of the distribution of impurities in materials, chemical bonding effects on X-ray spectra, cathodluminescence, crystal structure and crystal orientation.

Geological applications (Chapter Five, Keil), is a good introduction to mineral analysis and contains an excellent set of references (to 1968). Most of the chapter is devoted to applications, but there is a good section on sample preparation and an all-too-brief discussion of quantitative analytical methods. Not withstanding the more-than-adequate treatment of the Bence-Albee method and the low Eo method of Frazier *et al*, this reviewer believes that a discussion of other widely used data reduction procedures in mineral analysis (*e.g.*, Rucklidge's EMPADR VII, Sweatman and Long, *etc*) is called for. Abbreviated, but useful, discussions of bulk rock analysis, using both the broad beam and fusion methods, are contained in this chapter.

The application of the microprobe in ceramics and glass technology (Kane) contains a good discussion of the preparation of insulators for microprobe studies, the sodium diffusion problem, and the preparation of glass standards—all important to the mineralogist. The reader will find that many of the statements made by the author are not documented by references.

Biological applications (Robison) are well-covered in Chapter Seven. Items considered include sample preparation (to minimize damage and element redistribution), operating conditions, and the problems of quantitative analysis—particularly the problem of obtaining reliable standards. This includes an evaluation of biological molecules and macromolecules, and gelatin solutions with dissolved ions as standards. A literature review includes studies of metal tracers in biology, tin and asbestos particles in lung tissue and teeth. The author must be commended for venturing to look forward and discuss areas of possible future advancement.

The most advanced techniques of electron probe studies of free particulate studies are discussed in Chapter Eight. This includes discussions of sample handling techniques, quantitative analysis and, most importantly, computer controlled automation to the study of small particles. The author describes a program that involves the measurement of particle length and width, average $\bar{Z}$ (through sample current measurement), and X-ray emission characterization through wavelength or energy dispensive techniques. Unfortunately, the chapter is severely compromised by the author's neglect to reference other work.

Chemical bonding studies by soft X-ray spectroscopy are covered by White (Chapter Nine). This is the most up-to-date (1970) of all the papers in the book. It contains good sections on the principles of soft X-ray studies and the effects of chemical bonding on X-ray spectra. Mineralogists will find this chapter particularly useful, as it includes discussions of peak-shifts with bonding changes (*e.g.*, Al$K\beta$ λ-shifts with mean Al-O distances and Si$K\beta_1$ shifts with oxidation) and valence state studies using $L\beta/L\alpha$ ratios.

Cathodluminescence (Chapter Ten, Kniseley and Laabs), is a science largely ignored in mineral studies, because of its qualitative nature. Yet it has enormous potential, particularly in the area of trace element studies. This chapter contains a brief discussion of cathodluminescence, theory, instrumentation, and application.

Kossel X-ray diffraction techniques (Chapter Eleven, Yakowitz), are of limited mineralogical interest, but of great interest to the crystallographer. In his indomitable style, Yakowitz deals perfunctorily with the theory of the technique and then dives straight into detailed discussions of regressive analysis of the conic equation (RACE) as applied to lattice spacing studies and internal strain analysis (KISS). Within two pages the average mineralogist is far over his head. Crystallographers will have a ball!

Four chapters of the book are devoted to the laser microprobe. Chapter Twelve (Harding-Barlow, Snetsinger, and Keil) discuss instrumentation theory. The three types of analytical systems—emission spectroscopy, mass spectroscopy, and atomic absorption—are described. Gas chromatography is mentioned briefly. Geological applications are described by Keil and Snetsinger (Chapter Thirteen) where the advantages of the techniques and analytical procedures are covered (with a good list of references). The authors put their finger on the primary reason laser microprobes are not widely used—the difficulty of obtaining quantitative analytical data. Furthermore, the availability of electron microprobes with their better spatial resolution has slowed down the acceptance of laser probes as an analytical tool. Future acceptance of the laser microprobe in mineralogical analysis may be the result of the instrument's ability to discriminate isotopes when the analytical device is a mass spectrometer.

Biological applications are discussed in Chapter Fourteen (Harding-Barlow and Rosan). Laser-beam surgery is now a well recognized practice; however, biological analysis has not fared as well—a consequence of its not-yet-quantitative state, which again is due largely to the standardization problem. The authors describe sample preparation and current techniques of biological analysis. The application of the laser microprobe to metallurgy (Chapter Fifteen, Margoshes), has been as successful as the geological and biological studies. Again, the basic problem is one of standardization.

However, qualitative use of the instrument has been more fruitful. A number of successful applications are discussed.

The last two chapters of the book are devoted to the infant of the microanalytical instruments, the ion microprobe or secondary ion mass analyzer. Robinson (Chapter Sixteen) presents a very good discussion of instruments commercially available (at the time of writing). In addition, he deals briefly with the basic ideas behind the use of a primary ion beam in the production of secondary ions.

Chapter Seventeen (Anderson), is largely a review of his approach to quantitative ion probe analysis and includes discussions of surface chemistry effects, the necessity of the judicious selection of a primary beam (which depends upon the target), the thermodynamic equilibrium model of secondary ion production (application of the Saha-Eggert ionization equation), and the CARISMA program for quantitative analysis. This analytical procedure, which is largely empirical and requires an internal normalization, has been the subject of considerable controversy, primarily because of its lack of a strong theoretical foundation. However, comparisons of ion probe results with those obtained by other methods have been strikingly good. Verification of these results by other laboratories is called for. In addition to elemental abundance studies, the ion probe has been used successfully to measure U, Th, and P isotopic abundances in lunar minerals, for the purpose of obtaining radiometric ages.

As an overall evaluation, the book is a good one and is a valuable addition to a mineralogist's library. However, like all books, it was dated before it was published. Furthermore, it suffers enormously from the uneven technical quality of the papers. Many of the chapters are state-of-the-art, concise reviews, written both for the novice and the expert. Others are written strictly for readers with significant prior knowledge of the topic and a few are strictly of laboratory manual quality.

Most petrologists-mineralogists familiar with quantitative electron microprobe analysis will be disappointed by the complete absence of any discussion of computer controlled instrumentation and on-line data reduction, since on-line systems are being used routinely in many geological laboratories. The omission of this topic is not entirely justified by the rapid rise in computer-controlled instrumentation over the past two years, since pioneers in the field were active in the late 1960's.

For whom was the book intended? In this reviewer's opinion, the book contains few chapters of sufficient depth to be of any aid in the teaching of graduate students. However, as a reference text, it is a valuable addition to a geology, biology, or materials science library.

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THE CHEMISTRY OF IMPERFECT CRYSTALS, Volume 1, PREPARATION, PURIFICATION, CRYSTAL GROWTH AND PHASE THEORY. By F. A. Kroger. 2nd Revised Edition, North Holland/American, Elsevier, Amsterdam, London and New York, 1974. xiii + 313 pages. $25.50.

The first edition of this book appeared in 1964, and it was readily accepted as an important reference in the field of crystal growth and characterization. This acceptance is evidenced by the need to reprint the work within 10 years. Its usefulness was also apparent to this reviewer when our library copy of the first edition was examined and found exceptionally well worn from heavy usage. Instead of merely reprinting the original version, the author has taken the opportunity to update the text with much new information. The original work was published under one cover. This edition has been divided into three volumes.

Volume 1 emphasizes three main topics. The first chapter is devoted to the preparation of materials and comprises over half of the book. Part two is concerned with graphical representation of phase theory and part three with thermodynamic theory. The basic theme of the book is to present a large amount of reference material in a background of theory. This approach is very effective.

Although the first chapter is concerned with the preparation of materials, its main emphasis is on the preparation of single crystals. Subjects covered include purification, methods of analysis, crystal growth, and doping. Most of the special methods of crystal growth which involve a purification or controlled composition step are described and examplified by systems in which they have been applied. This chapter contains several tables, each completely referenced. One table on "Methods employed for growing crystals of various substances" lists over 750 compounds and 1500 references. Including the references with the tables permits the reader to find pertinent material readily. The compounds considered are mostly binary and ternary. The main text, which also includes information on specific phases, includes another 450 references.

Chapter two deals with phase diagrams and their interpretation with respect to growing crystals. Binary systems and their compounds are considered most thoroughly, in part because of their ease of representation. Topics are primarily concerned with solid-melt, solid-melt-vapor, and solid-vapor equilibria. Much attention is given to the role of the vapor both as a reactant and carrier in crystal growth. The diagrams are both hypothetical, with references to systems or compounds which follow the indicated behavior, and real. Examples are abundant.

The last third of this book considers the thermodynamic theory of phase relations on both a general and a molecular scale. Reactions involving vapors and liquids with solid phases and the use of such reactions to control vapor pressures and compositions of solid products are extensively treated. Decomposition, dissociation, and partitioning of species between coexisting phases in PTX space are discussed, using many examples to illustrate the theory. The treatment is mostly classical in nature.

With the emphasis of this book on crystal preparation, it is surprising that the subjects of nucleation and growth mechanisms receive no direct discussion. There is much literature on crystal growth theory and a chapter devoted specifically to its many ramifications would be a useful addition to this otherwise comprehensive compilation.

One pet complaint of this reviewer which is not directed at this book alone but at the entire physical and chemical literature is the omission of titles in the references. The title conveys the main theme of any paper and provides useful information to the reader. Cost of printing is not an adequate excuse to exclude such information. Fortunately, the geological community is more open-minded.

Because this book is mostly concerned with the preparation of crystals of binary and ternary compounds, it will be most useful to the materials scientist. Mineralogists and others concerned with experimental preparation of compounds will also find it very useful. The text is presented in a readable style, the index is good, and errors are few. Although the advanced student and researcher alike will gain much from the text, the extensive bibliography inclusive through 1972 and keyed so well through both the text and tables is probably the most valuable contribution of this book. It provides an excellent entry into the vast literature of the field of crystal preparation. It will be a valuable addition to many private libraries.

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MAN-MADE CRYSTALS. By Joel E. Arem. Smithsonian Institution Press, Washington, D.C., 1973. 112 pages. Hardcover, \$15.00; softcover, \$5.95. Also available from Recess Industries, Inc., P.O. Box 2563, Hyattsville, Maryland 20784.

This is an interesting presentation of one aspect of technology in a rapidly developing society. As pointed out by the author, crystal growing is an art as well as a science, and most of the major advances have been made in the last fifty years. The book is beautifully and profusely illustrated, including a number of plates in full color. It is unfortunate, however, that scales were not provided for photographs of crystals. The text is written for the layman, yet is a useful summary for the mineralogist and geologist not acquainted with the field of synthetic crystals. Such specialists, and many laymen as well, will be frustrated by the absence of a bibliography, or even a list of suggested readings. Certainly, if this book appears in a second edition, such a list should be provided.

Topics covered include a brief history of the crystal-growing art; a summary of the techniques used in industry for growing crystals; a section on man-made gems such as synthetic diamond, ruby, and spinel; a discussion of transistors, lasers and "bubble technology"; and several interesting case histories describing the development of the technology used for growing crystals of silicon carbide, quartz, garnets, and many other substances, some of which do not occur in nature. The latter section also has brief discussions of the effects of element substitution on crystal properties, *e.g.*, yttrium aluminum garnet (YAG) *vs* yttrium iron garnet (YIG).

The book has an index, useful appendices of acronyms and trade names, and an excellent glossary. A final section entitled "How to Grow Crystals at Home" is good, but very brief—persons interested in this topic will find more information in *Crystals and Crystal Growing* by Alan Holden and Phyllis Singer (Anchor Books, Doubleday and Company, Inc., 1960).

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STRONTIUM ISOTOPE GEOLOGY. By G. Faure and J. L. Powell. Vol. 5, Minerals, Rocks, and Inorganic Materials Series. Springer-Verlag, New York, 1972. ix + 189 pages. \$15.30.

It is often maintained that warfare is a prime mover for man's technological advances. The phenomenal growth of isotope geology since the closing of World War II is one more example of the profound, lasting effect that wartime breakthroughs may have on scientific development long after the war effort is over. Today, isotope geology is not only a major field of the earth sciences, but is in itself divided into specialties having little affinity with each other. Among the more significant branches of isotope geology is that based on strontium isotopes. Of the four stable isotopes of strontium, one, Sr^{87}, is in part radiogenic, being produced from Rb^{87} by beta minus decay. Since most rocks contain small, but measurable, amounts of both Rb and Sr, the amount of Sr^{87} per unit Rb is a function of time alone (if the system has remained closed), and can be used for absolute dating. Furthermore, the ratio $Sr^{87/86}$ can be used to study many petrological and geochemical processes because the small mass difference minimizes fractionation.

Faure and Powell, in their timely book, summarize most of the current knowledge in strontium isotope geology. The book is divided into 12 chapters as follows:

The Geochemistry of Rubidium and Strontium, Measurement of Geologic Time by the Rubidium-Strontium Method, Uses of Strontium Isotopes in Petrogenesis, Volcanic Rocks, Granitic Rocks, Alkalic Rocks and Carbonatites, Ultramafic and Related Rocks, Sedimentary Rocks and the Oceans, Isotopic Homogenization of Strontium in Open Systems, Meteorites, The Moon, and The Evolution of the Isotopic Composition of Terrestrial Strontium.

An appendix lists initial $Sr^{87/86}$ ratios and ages for about 130 samples of granitic rocks from all six continents, compiled from about 80 source papers dating from 1961 to 1971. The bibliography includes close to 500 references.

There is no question that this book is a most invaluable addition to the textbook literature. The subject matter represents, a coherent, significant field eminently suited for textbook treatment.

The book is clearly written and illustrated. The major systematic topics (ch. 4-11) are treated fairly evenly (10-15 pages each) and with sufficient detail. The specialist will find, of course, something missing here and there, but a book of this type is not directed to the specialist at all; it is service to the modern geologist at large and to students, both graduate and undergraduate. All of them, we are sure, will greatly benefit from Faure and Powell's book.

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MODERN MINERALOGY. By Keith Frye. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1974, ix + 325 pages. \$12.50.

The avowed purpose of this introductory text in mineralogy is to "introduce the reader first to topics with which he already has some cognizance, and then to use them as a logical basis for the remainder of the discipline." The author sets upon achieving this goal in Chapter 1 entitled

"Principles of Crystal Architecture" by discussing topics ranging from the structure of the atom to the fundamentals of crystal chemistry. This leads the reader to the second chapter which is devoted to describing some of the simple ionic and the more common silicate structures. Crystal symmetry is deferred to Chapter 3 followed by a short discussion of the physical properties of minerals in Chapter 4. Chapter 5, entitled "Radiant Energy and Crystalline Matter" deals mostly with the interaction of visible light and X-rays with matter. The phase rule and phase diagrams are discussed in Chapter 6 followed by the final chapter on mineral genesis.

This text is distinctly different from other texts in mineralogy in that the discussion on crystal structures of minerals precedes the discussion on crystallography. By reversing these two topics in order of their usual presentation the author has himself in the inevitable predicament of having to use undefined crystallographic terms to describe the crystal structures. For example, in reading Chapter 2 on the descriptions of various crystal structures a first year mineralogy student will come across terms such as unit cell, site occupancy, prismatic cleavage, *etc*, which are not discussed until Chapters 3 and 4. Chapter 3 on crystal symmetry is probably the weakest part of the book. The sections on symmetry operations and point groups are bound to be confusing to the beginner. As an example, the author does not mention and the figures do not illustrate the enantiomorphic relationship between objects related by mirror and inversion symmetry. To add to the confusion, Figures 3–9a and 3–9c illustrating rotoreflection and screw-axis symmetry are inaccurate as are Figures 3–31c and 3–33c depicting 32 and 3*m* symmetry, respectively.

The entry on interpretation of binary and ternary phase diagrams is *more* than adequate and the author has made a noteworthy effort to combine the rudiments of phase equilibria with mineral genesis.

The author has compressed a multitude of topics which touch on most facets of mineralogy into the book's 325 pages. As a result, some topics may be treated with greater brevity than students will appreciate for an introductory text. Overall, the illustrations are adequate in their quantity and quality, the book is easy to read, and the number of typographical errors is minimal. The appendix contains a fairly comprehensive table of mineral data which is useful as a quick reference for the reader. The text will probably be most useful for those looking for a compendium of modern mineralogy at the elementary level.

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HETEROGENEOUS PROCESSES OF GEOCHEMICAL MIGRATION. By V. S. Golubev and A. A. Garibyants. Translated by J. P. Fitzsimmons. Consultant Bureau, New York, 1971. 150 pages. $22.50.

Now that granitization is no longer a hot potato, it is again possible to use the word metasomatism without being laughed at. Although equilibrium thermodynamics of closed systems has served very well indeed, most geological systems were open at one time or another, and evidence for disequilibrium is abundant. Theoretical and experimental work related to kinetic and transport problems is now under way in the western hemisphere, but Russian scientists, led by D. S. Korzhinskii, have contributed much to set up a theoretical framework for the discussion of geochemical migration. Korzhinskii, beginning in the 30's, has discussed both the thermodynamics of metasomatic systems and the transport equations for infiltration and diffusion. His interest was primarily in deriving the general properties of metasomatic systems (sequence of zones, general compositional variations within zones, phase rule for open systems) rather than in specific solutions of the transport equations. Golubev and Garibyants take a different approach. They start out (chapter 1) by formulating general material balance and transport equations for the two-phase system (porous rock and fluid) where diffusion, convection, and chemical reactions take place. This is followed by a general discussion of the assumptions that are commonly introduced to simplify the mathematics. Considering multicomponent systems the authors assume that each component behaves independently, so that the problem is equivalent to the one-component case. Although this assumption can be justified only in special cases (*e.g.*, for transport of trace elements), the one-component case generally treated in this book is nevertheless the best starting point. Also, Gupta and Cooper (*Physica,* **54,** 39–59) have recently shown how the description of true multi-component diffusion can be reduced to the simple solutions of Fick's laws for binary diffusion. This first chapter, though brief, is well written and clearly developed.

Much of the remainder of the book is devoted to solutions of the partial differential equations for particular initial and boundary conditions. Throughout, an effort is made to proceed from the general to the particular, but the reader should be warned that the treatment is in no way comprehensive. For example, the discussion is (with one exception) restricted to a simple migrating species; thermodynamics is not discussed; problems involving heterogeneous solids and solid-state processes are neglected. The book is heavy on equations (460 in all) and light on derivations, explanations, and illustrations (42 figures). Given its limited scope it contains a useful collection of solutions to specific boundary value problems and a description of a number of diffusion and infiltration experiments in soils and sediments. The main emphasis is on theory, despite the often exasperating detail of the experimental parts: "The soil was placed in a can of galvanized iron 10 cm tall and 4.5 cm in diameter. The can was filled with two layers of soil, each 5 cm thick. The soil containing the lithium chloride was placed in the lower part of the can. The upper part of the can had five slits, through which, at the end of the experiment, a special plate-like layer of soil was cut into small individual cylinders 1 cm tall."

Diffusion in rocks is discussed in Chapter 2. The solutions to Fick's law given here can be found in any standard text and most of the space is given to the trivial cases (diffusion in a sphere, plate, cylinder, semiinfinite medium, *etc*) rather than the interesting ones such as multilayered media. Also there is no discussion of diffusion with moving boundaries, which must occur whenever the diffusing component(s) cause a new mineral phase to appear (or disappear). The last ten pages of this chapter contain experimental methods (see the above-quoted sample) and results. The authors are well aware of the fact that these data have little meaning because the experimenters made no effort to separate the effects of diffusion from those of adsorption and ion exchange. It would have been helpful to use the wasted space for illustrations and fuller explanations of the mathematics.

This also goes for the rest of the book. Chapter 3 is an extremely brief (13 pages) account of adsorption and ion exchange, including experimental data on such things as sorption of benzene in agglomeratic tuff. Chapter 4 covers the "basic aspects of formal kinetics" which turn out to be the standard first and second order rate laws for *homogeneous* reactions which would seem to be of little interest in the context of the book (which deals with heterogeneous systems). This discussion is preceded by the following statement: "Chemical reactions may be divided into reversible and irreversible . . . Reversible reactions tend toward establishment of chemical equilibrium, at which condition the rates of forward and reverse reactions become adjusted. Irreversible reactions proceed to the end, *i.e.*, to complete loss of the original substances. All chemical reactions are reversible. However, under certain conditions the reactions may proceed in only one direction, *i.e.*, be irreversible." It is perhaps just as well that, for the most part, the authors stay away from thermodynamics. The section on kinetics of heterogeneous processes uses the terminology of external-diffusion kinetics *versus* internal-diffusion kinetics which I find very confusing, despite the translator's efforts to clarify things in a footnote. The reader must also watch out for the difference between a "rectilinear" adsorption isotherm, which is a straight line parallel to the fluid-concentration axis, and a "linear" isotherm, which goes through the origin.

In chapters 5 and 6, cases of combined infiltration and diffusion are considered. Unfortunately, the description of the processes to be analyzed is often so confusing that it is difficult to know what problem is being solved. Some of the most important assumptions are defended in the most casual manner, *e.g.*, "the ion-exchange isotherms for rocks ordinarily differ little from linearity." This statement may hold true for trace elements, but it becomes highly unrealistic for major-element isotherms in hydrothermal systems. In chapter 7 the authors make an interesting attempt to apply the theory developed in the preceding chapters to the formation of hydrothermal deposits and geochemical aureoles. Again, the choice of simplifying assumptions is unusual. The problem is formulated for an infinite macrofracture, through which a one-component solution flows, and an adjacent country rock with an isotropic system of microfractures. Transport in the microfractures occurs by diffusion only and "filtration in the microfractures may be neglected, since a large pressure gradient is necessary for this, the existence of which is unlikely in nature." Perhaps so, but some assessment of this assumption would be in order. Depending on the permeability of the rock, fluids will flow under the influence of small pressure gradients. The authors then simplify the problem further by the additional assumption that the substance penetrates "but an inappreciable distance into the walls." It is hard to see how, under these circumstances, the fluid in the macrofissure interacts with the wall rock at all.

The book is fairly expensive ($22.50 for 150 pages of text), poorly illustrated, and difficult to read. Solutions to many boundary value problems involving convective diffusion and kinetics are presented, generally without derivation. In most cases, the motivation for giving a particular solution is not apparent, and the link to realistic problems is tenuous. It is clear that in order to solve the more complex and realistic geochemical transport problems it is necessary to use numerical solutions. The alternative used in this book is to restrict the discussion to those problems for which exact approximate solutions can be found in closed forms. The authors wish to present "an introduction to the theory of heterogeneous processes of geochemical migration." However, with the exception of the first chapter, the book is simply too difficult to read and too specialized in its approach to be useful as an introduction. It may be useful to students looking for solutions to certain boundary value problems involving chemical transport of a single species in a two-phase medium.

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CHEMICAL BONDS IN SOLIDS. Edited by N. N. Sirota. Consultants Bureau, New York and London, 1972. 4 volumes, 164, 133, 200, and 165 pages, respectively. Each volume $37.50; set of four volumes $120.

These four volumes are a translation of two Russian books published in 1969. These in turn contained the papers presented at a Conference on Chemical Bonds held in Minsk in 1967, plus eight other papers, five of them by the editor and his co-workers. It is stated that the articles were revised by the editor for the present translation, author of the first paper in Volume 1. Most of the authors are from Eastern European countries, if I am correct in assuming that the many for whom no affiliation is given are all Russian. The very good translation is by the editor of *Soviet Physics—Semiconductors*, and the format is that familiar to readers of this and other American Institute of Physics translations.

Volume 1 has the subtitle *General Problems and Electron Structure of Crystals;* Volume 2, *Crystal Structure, Lattice Properties, and Chemical Bonds;* Volume 3, *X-Ray and Thermodynamic Investigations;* and Volume 4, *Semiconductor Crystals, Glasses, and Liquids.* Altogether there are 117 papers. It would be fair to say that there are few which a chemist would immediately accept as dealing with chemical bonds. However, the articles do mostly adopt a recognizably chemical approach, for example in investigating the electron distribution and how the properties of solids depend on composition, and interpreting them in terms of orbitals. The many materials dealt with span the whole range from ionic to covalent, with a predominance of semiconductors. Few minerals are discussed, but there are some crystallographic papers.

It is a long time since these papers were written, and I suspect that few of them are so comprehensive or definitive that they will not have been largely superseded. These volumes must therefore serve mainly as a view of the subject in 1967, together with detailed information on specific substances. This, coupled with the high cost, makes it difficult to recommend these books except perhaps to wealthier institutions with a high concentration of solid-state specialists. Mineralogists should be able to manage without.

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COMPOSITION OF FLUID INCLUSIONS. By Edwin Roedder. Chapter JJ, DATA OF GEOCHEMISTRY, 6th ed., Technical Editor Michael Fleischer. Geological Survey Professional Paper 440-JJ. U. S. Government Printing Office, Washington, D. C., 1972. x + 164 pages, 12 plates. $2.75.

Frank Wigglesworth Clark's classic, *The Data of Geochemistry,* U.S.G.S. Bulletin **770**, 1924, became the Survey's all-time best seller and continues its popularity because it is precisely that—the *data* of geochemistry undiluted by descriptions of analytical techniques or atempts to show how useful the data can be for geologic interpretations. Techniques were left to the text-books; interpretations, to the geologists and mineralogists who used the *Data*.

The new (6th) edition of *The Data of Geochemistry* is following, by and large, Clarke's original plan. The chapters that have appeared thus far are succinct summaries of the data in the several fields. There are explanations of how the data were chosen and discussions and evaluations of them but, again, no descriptions of analytical techniques or detailed or extensive interpretations based on the data presented.

The chapter under review is an exception; the techniques for studying fluid inclusions and analyzing their contents have not yet reached the text-books and proper use of the data is hedged about by conditions so esoteric and numerous that it requires a real expert to outline the *sine qua non* for sound interpretation. Roedder is uniquely equipped, so far as the U.S.A. is concerned, to do these things as well as to summarize the pertinent data; he has worked for years with the techniques he describes and has a knowledge of the literature probably not matched outside the U.S.S.R.

Roedder has not only given us an excellent summary of the burgeoning information from fluid inclusion studies and keys to its evaluation and use, but also a compact textbook on the theory of the formation of such inclusions and outlines of the latest techniques for studying them and analyzing their contents. Geologists and mineralogists should be very grateful to him for the tremendous job he has done of assembling and organizing what will undoubtedly be the definitive reference work for the Western world on fluid inclusions for many years to come and will also find a good deal of interest and use even in the U.S.S.R.

Mineralogists will be interested in the astonishing variety and number of minerals in which inclusions have been described. Listed in the tables are at least the following: sphalerite, galena, pyrite, chalcopyrite, arsenopyrite, pyrrhotite, molybdenite, cinnabar and metacinnabar, realgar, cosalite; halite, sylvite, carnallite, fluorite, villiaumite; quartz, tridymite, cassiterite, magnetite, hematite, sapphire, spinel, davidite, ice; calcite, dolomite, magnesite, ankerite, rhodochrosite, witherite, northupite; albite, adularia, microcline, amazonite, plagioclase, nepheline, pseudoleucite; beryl (including aquamarine and emerald), chkalovite, topaz, spodumene; garnet, kyanite, monazite, scapolite, epidote, diopside, hornblende, olivine, monticellite, zircon; tourmaline, danburite, axinite, datolite, borax, inderite; analcite, natrolite, apophyllite; "mica", muscovite, biotite, phlogopite; barite, celestite, anhydrite, gypsum, melanterite; huebnerite, wolframite, scheelite; amber, diamond, sulfur, gold, and apatite.

Only four of these minerals are listed in the index; the references are not to information in the tables but to plates or incidental mention in the text. Nor does one get a better idea of the minerals involved by looking at the table of contents. Many, but by no means all, are mentioned in the text, but they are not arranged so that one can find a mineral he is looking for.

Chapter JJ covers the literature admirably. There is a page of references for each 2 3/4 pages of text, tables, and illustrations, but only one page of index for each *110* pages of other material. In other words the volume is woefully under-indexed. There are at least forty principal kinds of materials listed in the tables in which inclusions and/or minerals with inclusions occur; seven are listed in the index. There are scores of components of the inclusions in the tables; fifteen in the index.

The index is hardly more than slightly amplified list of the subjects in the table of contents. The tables contain more than 2,000 entries with tens of thousands of "data bits," but all of the index references (10) are to entire tables; *no* information *in* any table is indexed. Admittedly, there is no point to indexing each mention of quartz, calcite, or fluorite, but most of the minerals and types of material are mentioned only once to a few times and all of these *should* be indexed. No localities and no authors are mentioned in the index.

It is most unfortunate to have such an attractive and useful volume with information so difficult to retrieve. In studying the tables the reviewer found a very interesting item and jotted it down, but neglected to record the page number. Later it was necessary to go back through all of the tables again and part of them a third time to find the reference. A one line entry in the index would have allowed the item to be located in a few seconds by anyone interested; it has been completely missed by at least two interested workers.

It might be worthwhile, even at this late date, to prepare an adequate index that could be fastened into the back of the volume, where an index properly belongs anyway.

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