

## BOOK REVIEWS

During the last few months, three books on mineral data that are similar in both price and content have been published. Rather than write three separate reviews, it is more appropriate to write one review in which these books are compared and contrasted. The *Glossary*, which until recently was the sole book in this discipline, has now been challenged by two new books: the *Manual* and *Lapis*.

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*Glossary of Mineral Species* (sixth edition). By M. Fleischer & J.A. Mandarino. Mineralogical Record, P.O. Box 35565, Tucson, Arizona 85740, 1990, vi + 256 pages. US\$15 (no ISBN number given).

*Mineral Reference Manual*. By E.H. Nickel & M.C. Nichols. Van Nostrand Reinhold, New York, N.Y. (distributed in Canada by Nelson Canada, 1120 Birchmount Road, Scarborough, Ontario M1K 5G4), 1991, 250 pages. CDN\$21.95 (ISBN 0-442-00344-7).

*Das grosse Lapis Mineralienverzeichnis*. By S. Weisse & R. Hochleitner. Christian Weise Verlag, Oberanger 6, D-8000 München 2, Germany, 1990, 304 pages. DM29.80 (ISBN 3-921656-17-6).

All three books have in common an alphabetical listing of mineral names, along with chemical formula, crystal system, and color for each of the minerals. Each book contains about the same small number of selected well-known chemical varieties and recently discredited mineral names.

The *Glossary* generally contains a single reference, which is usually in the *American Mineralogist*, to the mineral description, whereas the *Manual* contains up to three references (first description, mineral description, and crystal structure), and there are no references in *Lapis*. The *Glossary* gives mineral groups and isostructural minerals and polymorphs, whereas both the *Manual* and *Lapis* give a numerical numbering system based upon the chemical-structural classification of Strunz.

The *Manual* gives some additional physical properties such as hardness, luster, measured density and calculated density. In addition, it gives the type locality and the status ruling of the International Mineralogical Association. *Lapis* gives many additional physical properties such as hardness, streak, cleavage, maximum size recorded, and a qualitative indication of rarity. This means

that *Lapis* is aimed more at the mineral collector, who can quickly compare these properties with a hand specimen identification. Although *Lapis* is written in German, an English-only reader will be able to understand the tabulated data. In general, the international method of mineral nomenclature is followed (e.g., Sphalerit instead of Zinkblend, Tennantit instead of Arsenfahlerz).

The treatment of polytypes in the *Glossary* is inconsistent. For example, molybdenite-2H and molybdenite-3R are given separate listings; however, wurtzite is merely noted to contain polytypes, and the mica polytypes are completely ignored. (The *Manual*, on the other hand, consistently lists all polytypes, whereas *Lapis* consistently ignores them.) The symbol for argon again is given incorrectly as A instead of Ar on page v of the *Glossary*. The mineral chalcophyllite has been omitted, although it is in the fifth edition, 1986. The general formula for the montgomeryite group is incorrectly given as  $\text{Ca}_4\text{A}^{+2}\text{B}^{+3}_3(\text{PO}_4)_6 \cdot 12\text{H}_2\text{O}$  instead of  $\text{Ca}_4\text{A}^{2+}\text{B}^{3+}_4(\text{PO}_4)_6(\text{OH})_4 \cdot 12\text{H}_2\text{O}$  (four minor errors). The use of B here is unfortunate since it can be taken as boron. *Lapis* incorrectly accords species status to argentite, which is unstable below 179°C. The *Manual* gives species status to both endellite and halloysite-10A, although the International Clay Minerals Association has accepted halloysite-10A as the correct name and equivalent to endellite.

Both the *Glossary* and *Lapis* incorrectly treat gersdorffite. Only the *Manual* gives the three polymorphs and hence three distinct mineral species as gersdorffite-Pa3, gersdorffite-P2<sub>1</sub>3, and gersdorffite-Pca2<sub>1</sub>. Aluminum has been accepted by the Commission of New Minerals and Mineral Names of the International Mineralogical Association (CNMMN) as a mineral species. The *Manual* gives it species status. *Lapis* leaves it out. The *Glossary* lists it but does not give it species status. Notwithstanding the above, all three books have few errors and, clearly, were prepared with exceptional care and effort.

Both the *Glossary* and *Lapis* have a spiral binding, which allows the book to be left open on a desk, in contrast to the normal binding for the *Manual*. Both the *Glossary* and *Lapis* have abundant blank areas in which the owner may write other information in the book; in the *Manual*, crystal drawings are printed at the end of those chapters where space permits, apparently for aesthetic reasons. *Lapis* is printed in tabulated form, which allows the data to be found more easily, compared to the free-flow form of the *Manual* and *Glossary*. Each book is clearly printed

on high-quality paper.

Science libraries will need to purchase all three books. Although each book has some distinct advantages, I predict that the choice of most individual professional scientists will be the *Manual*, primarily because it contains more references and data. The mineralogical community should extend its thanks to all three groups of researchers for their efforts, which will save us all untold hours in searching the literature.

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*The Al<sub>2</sub>SiO<sub>5</sub> Polymorphs*. By Derrill M. Kerrick. Reviews in Mineralogy, volume 22, edited by Paul H. Ribbe. Mineralogical Society of America, 406 p., US\$25.

Determination of the phase relations among the three minerals *andalusite*, *kyanite* and *sillimanite* has been the object of more experimental and theoretical effort than any other problem in petrology. The discussion long ago passed beyond straightforward determination of a potentially very useful geological thermometer and barometer, and has become a sort of measure of the state of petrology as a whole. As this excellent new book points out, there remain significant uncertainties about many aspects of relations among the aluminosilicates. Kerrick begins with a rapid review of the history of the problem, and then briefly discusses the crystal structure, optical and physical properties of the polymorphs. This material is all sound enough, but readily available elsewhere. The really valuable material starts with a discussion of the work on phase equilibria. Kerrick critically reviews all modern experimental work. Although he has preferences, his review is remarkably dispassionate and thorough, and he concludes that on the basis of experimental work alone, one cannot at present decide between competing phase-diagrams. Remarkably enough, the missing key piece of data is a reliable determination of the room-pressure transition from andalusite to sillimanite, which at first sight looks like one of the easiest experiments. Kerrick goes on to puncture some old and new myths, showing convincingly that lattice defects, Al-Si disorder, and the fibrolite problem cannot reasonably account for the discrepancy among phase diagrams. Non-stoichiometry (*i.e.*, content of trace elements such as Fe and Mn), and interfacial energies of very fine-grained products may account for part or all of the discrepancy in some cases. It is noteworthy that modern methods such as magic-angle-spin nuclear magnetic resonance give results only marginally better than older methods, and still

leave significant uncertainty about the possibility of small degrees of Al-Si disorder. Since experimental data are insufficient to accurately fix the phase diagram, Kerrick reviews field studies bearing on stability relations. This section forms a quick review in modern methods of metamorphic petrology. Finally, the book reviews reaction kinetics and crystal-growth mechanisms relevant to aluminosilicates, evidence for Al metasomatism, and anatexis in pelitic rocks. These final three chapters are full of insight, but less satisfying than the preceding chapters, largely because experimental data and theoretical underpinnings are largely nonexistent. Kerrick makes the point that evidence for major Al metasomatism is overwhelming in many instances, and the common assumption of Al immobility is simply invalid. The book ends with an extensive bibliography (43 pages). Kerrick states that this bibliography is intended to bring together all significant information on the subject.

The book is commendably lucid and well organized, and the style wonderfully easy to read. I read it for pleasure as well as instruction. Illustrations are numerous, well selected and well reproduced. Production has been carefully monitored. I found very few typographical errors. At the bargain price of US\$25, no geologist with the slightest interest in metamorphic rocks can afford to be without this book. For the student, it will serve as a valuable supplement to courses on mineralogy and metamorphic petrology; for the professional geologist and researcher, it will surely be an often-consulted, authoritative reference.

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*Deformation Processes in Minerals, Ceramics and Rocks*. Edited by D.J. Barber and P.G. Meredith. The Mineralogical Society Series, Volume 1. Unwin Hyman, London, 1990, 423 + xviii pages. CDN\$72.00 (ISBN 0-04-445088-5).

The Mineralogical Society is to be commended for sponsoring what might be construed as a structural geology volume. In doing so, it explicitly recognizes the ever-increasing need to eliminate classical subdisciplinary boundaries within the earth sciences. This volume comprises 16 contributions arising from a two-day conference held in 1987 to review the state of the art in the field of deformation "microprocesses and micromechanisms". The emphasis on cross-disciplinary, parallel developments in science is reflected by an array of contributors whose professional pigeonholes include, in addition to structural geology, ceramics, materials science and engineering,

geophysics, metallurgy, physics, metamorphic petrology, ..... and mineralogy.

Contributions are grouped into "brittle" and "ductile" sections, although the often-inappropriate nature of such a division at the process-mechanism level is rightly noted. In expectation of readers unfamiliar with the literature, the editors have made reference to other source compendia in their contributions. Papers in the "brittle" section are all substantially reviews or collations of data. Topics include fracture mechanics, dynamic and quasi-static growth of cracks (Meredith, Gueguen *et al.*, Freeman & Swanson), statistical approaches to fracture (Gueguen *et al.*), *in situ* observations of fracture propagation (Freeman & Swanson), construction of maps portraying deformation-failure mechanisms (Hallam & Ashby), and crystal-defect control of brittle-plastic transitions (Murrell). The attempt by several contributors to clarify behavior during the brittle-ductile transition of materials is significant in light of the concentration of interdependent geological phenomena at analogous crustal levels, *e.g.*, focused flow of fluid, ore-mineral concentration, hydration reactions, strain localization, and seismicity.

The bulk of the volume addresses non-brittle deformation. The absolute need to address the interdependence of chemomechanical processes is exemplified by the integration of deformation microstructures into P-T-t-mechanism paths (Knipe) and the elucidation of metamorphic reaction-enhanced ductility (Rubie). Reviews of non-brittle deformation processes (Barber) and deformation experiments (Tullis) are buttressed by considerations of the thermodynamics and experimental replication of pressure solution (Lehner, Spiers & Schutjens), stress-sensitive microstructures (Derby), crystallographic fabric simulation (Takeshita *et al.*), crystal-chemical analysis of dislocation glide (Heuer *et al.*) and TEM observations of dislocations in chalcopyrite (Hennig-Michaeli & Couderc). The paper by Poirier *et al.* is of a type that should be required reading for field-based researchers in order that we appreciate the origin of experimentally determined relationships such as laws of constitutive flow. The contribution by Spiers & Schutjens is noteworthy for the specificity of its experimental method and underlying theoretical assumptions, the absence of which can otherwise lead to unconstructive discussion of ambiguities.

This volume succeeds best as a review document, being to a large extent a prisoner of the publishing process; authors continue to publish, and journals are produced more quickly. The trade-off is a generally high-quality presentation. Type, tables

and line diagrams are excellent. Micrographs have lost resolution during reproduction, although not to the point of detraction. To me, the cover photo typifies the excitement inherent in these studies. Pricing of the book is commensurate with current rates and is better value than many. This volume should be most useful to researchers unfamiliar with the field and for graduate students requiring a crash course on theory, methods and application of materials-science approaches to deformation of the Earth.

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*Principles and Applications of Inorganic Geochemistry.* By Gunter Faure. MacMillan Publishing Co., New York, 1991, 626 + xiii pages, US\$58 hardbound. (ISBN 0-02-336441-6).

It is the stated intention of the author to produce an introductory textbook on the principles of geochemistry; it is also his intention to aim the book at senior and graduate students. The construction and presentation of the subject matter, in three distinct sections, reflect on the author's long experience as a teacher of fundamentals of inorganic geochemistry. The book is generally uniform in its treatment of each section, *viz.*, geochemistry of the universe, Earth and planets; chemical reactions and the stability of minerals; and applications of geochemistry to the solution of global problems. Altogether, it forms an interesting sandwich, with the meat most definitely in the middle. Although primarily directed at students, those of us who are a few years past those days of compulsory learning also can benefit from a very succinct and readable refresher course that is also liberally sprinkled with excellent figures and tables of useful information.

The *first* section starts with the Big Bang and rapidly brings us down to Earth with patient, and often entertaining expositions of the nature and history of geochemistry, stellar evolution, nucleosynthesis and the origins of the elements, radioactivity, atomic structure, nature of chemical bonds and ionic properties, and their various applications in radiometric dating. The tenth and final chapter of this section deals with chemical differentiation of the earth and provides a particularly clear focal point for the preceding chapters, as well as a formal introduction to the geochemistry of the elements.

The *second* section is largely confined to the details of low-temperature chemical processes that form, weather and alter crustal and mantle materials, and comprise the mechanics of "the Earth as a giant machine that processes rocks....".

Since we are dealing with basic principles of chemistry, illustrated with examples appropriate to geochemical problems, there is little the author can do to brighten the parade of chapters: acids and bases, salts and thermodynamics, mineral stability, clay minerals, redox reactions, rates of chemical reactions. Nonetheless, each chapter is very easy to read and is supplemented with numerous examples of worked-out calculations. Each chapter ends with a concise summary and a set of problems designed to enhance the reader's comprehension. In particular, the mysteries of calculating mineral-stability diagrams and Eh - pH plots are laid low as the reader is led carefully through a well-laid-out procedure. As one might expect of the author, the chapter on isotope fractionation (H, C, O, S, Sr) is especially well written. There are a few deficiencies, particularly for a book that emphasizes low-temperature processes. The pages that deal with colloidal processes and ion-exchange reactions are few (3), and there is nothing at all on chemisorption or physical adsorption isotherms, catalysis or surface reactions in general. Moreover, the chemical principles behind studies of fluid inclusions should have been included in a book such as this.

The *third* and final section contains a chapter on consequences of chemical weathering of rocks and minerals (including a useful page or two on placer deposits), and introduces us to the nature and classification of soils, and necessarily, to geomicrobiology. Other chapters include definitions and descriptions of geochemical cycles, environmental geochemistry and radioactive waste-disposal technology, and chemistry of surface waters (but not groundwaters). Each chapter ends with the usual set of problems to be worked out, and also with a discourse on problems of a different kind. These are global in scope and are largely due to human activities related to exploration for nonrenewable natural resources, contamination of food and water supplies, and generation of energy. The role of geochemistry in recognizing and monitoring these problems is emphasized.

Overall, the book is an excellent one and is thoroughly recommended to geochemists and geologists alike. It is up-to-date and topical, clearly illustrated and concise, well-referenced, and replete with extensive tables of thermodynamic data to facilitate problem solving. Altogether, it is well worth the price of purchase.

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*Theory and Applications of Pearce Element Ratios to Geochemical Data Analysis.* Edited by

J.K. Russell and C.R. Stanley. Geological Association of Canada, Short Course Notes, volume 8, 1990, 315 pages. \$30 (soft cover). ISBN 0-919216-41-2.

This book represents a collection of 12 papers presented at a two-day short course at the joint annual meeting of the Geological Association of Canada and Mineralogical Association of Canada in Vancouver in May 1990, plus a chapter of collected "homework problems", selected to illustrate the methodology and variety of Pearce Element Ratio (PER) application in the interpretation of geochemical data.

As noted in the Preface by the first editor, it has been more than two decades since Pearce developed the basic methodology of using molecular proportion ratio plots in the form  $X/Z$  versus  $Y/Z$  to analyze variations in fractional crystallization in the Palisades Sill of New Jersey. In view of the resistance and criticism of the PER methodology, particularly in recent years, this book is long overdue.

In the first chapter, Russell & Nicholls set the stage for subsequent chapters by reminding the reader of the scientific basis for the rigorous testing of a hypothesis: try to *disprove* the validity of a hypothesis through simple consideration of underlying principles of scientific methodology, which they note "are not common in the literature of geology". Through an example they illustrate the use of PER in a hypothetical test for plagioclase fractionation. Unfortunately, the uninitiated reader might find the lack of explanation for their choice of axis variables somewhat puzzling.

This problem is overcome in the second chapter, by Nicholls & Russell, which presents an overview of PER methodology as applied to fractionation in igneous systems. Of particular interest is their choice and concise explanation of the principles by which X, Y and Z constituents are selected in testing for fractionation of various phases. These authors also include a substantive bibliography of relevant publications since Pearce's original paper in 1968.

The third chapter, by Russell & Stanley, reviews the theoretical basis for the graphical analysis of material-transfer processes in general, and specifically addresses the application of variation diagrams (including PER plots) to the study of igneous rocks. The authors' systematic examination of the variations to be expected on different types of plots leads them to the justifiable conclusion "that Pearce element ratios offer the best opportunity for determining the stoichiometry of mass transfer processes from chemical data" .... and that PER "remain the most effective means of discriminating between petrologic hypotheses". A brief appendix examines the variations on logarithmic

mic PER plots, which typically show curvilinear trends. From comparisons with the linear relations displayed on standard PER plots, they suggest that the use of chemical variation diagrams composed of logarithms of ratios is ill-advised. Whereas this is generally true if fractionation processes are being examined, logarithmic ratio plots have been used to advantage in studies of chemical alteration by Beswick & Soucie (1978) and, more recently, by DePangher (1988).

Chapters 4 and 12 by Russell & Halleran represent a two-part examination of trace-element variations on PER plots, the former in the context of magmatic differentiation, and the latter in the recognition of open-system behavior. In chapter 4, Russell & Halleran use PER to examine trace-element variations in the 1959 Kilauea Iki picrites and basaltic lavas, specifically "to test the idea that the Kilauea Iki data result from fractionation and sorting in a chemically closed system" rather than through magma mixing. Using ratios involving fourteen different trace-elements, they demonstrate that only V, Cr, Co and Ni are not conserved, *i.e.*, they are involved in the differentiation process. They conclude that the variation is consistent with sorting of phenocrystic olivine that has inclusions of chromite and sulfide. They find no evidence to support the magma-mixing hypothesis.

Halleran & Russell pursue further their examination of analytical data on Kilauea lava in Chapter 12, where they demonstrate that the 1970 and 1971 Mauna Ulu lavas were derived from separate magma-batches. A similar examination of the 1983 Phase 1, Puu Oo lavas identifies three spatially, temporally and chemically distinct groups, one of which appears to be the result of mixing of the other two.

Chapter 5, by Jim Nicholls, examines the constraints imposed by process stoichiometry on variations in PER. In response to earlier criticisms of PER analysis and the problem of induced correlation, Nicholls uses an amusing analogy of jelly bean thieves (mineral phases) who steal only particular colors (atoms) in particular proportions (stoichiometric) from shipments (samples) dispatched from various factories (magmas), to demonstrate the basis of the methodology. The skeptic and uninitiated alike will surely become believers in the power of PER from this simple and clear analogy, as Nicholls then applies it to an analysis of the variations displayed in the 1968 picrites and basalts of Kilauea. In the second half of this chapter, Nicholls examines the problem of analytical error using complex numbers to represent the coordinates of samples on PER plots and to define error ellipses about the data points.

In Chapter 6, Pearce demonstrates how to

extract "the most possible information" from a data set using PER analysis for simulated basalt-andesite liquids, as well as for natural data from the Toliman volcano, Guatemala, and from Kilauea. The rigor of this methodology, as contrasted with Harker diagrams, for the testing of hypotheses is well explained in the text and further amplified in a brief appendix.

In Chapter 7, Stanley & Russell demonstrate the use of matrix algebra in the development of PER diagrams for use in various types of tests of petrological hypotheses. In particular, they illustrate in detail a matrix methodology to determine appropriate axis-coefficients to test and identify various systems of multiphase fractionation and to discriminate between rival hypotheses by optimizing the most powerful and sensitive sets of axis coefficients for the problem at hand.

In Chapter 8, Roger Nielsen examines the sensitivity of PER analysis for a range of igneous processes through computer modeling of simulated data-sets, including both major oxide and trace-element variations. Processes examined include fractional crystallization, recharge (self mixing), assimilation, eruption and periodic mixing for mafic to intermediate magma-systems. The basis for the underlying algorithms and the choice of parameters used in the various modeling software are outlined in the text (copies of the software are available from the author, having been published elsewhere earlier). Comparisons of modeled and natural data-sets lead Nielsen to several conclusions and cautions regarding the power of PER analysis for the identification and evaluation of the various natural processes.

Chapter 9, on error propagation and regression analysis in PER diagrams, is not for those, such as this reviewer, who have a poor intestinal fortitude for digesting things mathematical. However, for the more mathematically literate readers, Cliff Stanley's presentation will be much appreciated, as it represents a truly rigorous approach to the analysis of error propagation and regression in the statistical testing of petrological hypotheses. The analysis of effects due to induced correlation should lay to rest any criticisms aimed at this aspect of the PER approach.

A similarly mathematical presentation is given by Richard Ernst in Chapter 10, on the sensitivity of Pearce Element Ratio Analysis to non-conserved behavior of the denominator element (which is normally selected to be the conserved component Z where PER axes are expressed as X/Z versus Y/Z). Following his mathematical analysis of this problem in natural systems, such as those involving assimilation and other open-system processes, Ernst concludes that non-conservation of Z will

cause an error in Pearce element ratios, normalized Pearce element ratios, and the slope and intercept on PER diagrams. The impact of this chapter would have been greatly enhanced had specific natural examples been used to contrast the effect on PER diagrams of selecting conserved *versus* non-conserved denominator components, e.g., olivine fractionation trends with Z as  $\text{Al}_2\text{O}_3$  (conserved) *versus* Ni (non-conserved) or plagioclase trend with Z as  $\text{TiO}_2$  (conserved) *versus* Sr (non-conserved).

In Chapter 11, Tony Fowler undertakes a brief but thorough review of several approaches, including PER applications, to the quantification of processes of rock alteration. Using metavolcanic compositions from the Abitibi greenstone belt of the Superior Province as examples, Fowler demonstrates how PER diagrams can be used to identify conserved and mobile components in processes of rock alteration. Although the analysis falls short on the quantification aspects of the problem, this chapter should be very thought-provoking for those with an interest in processes of rock-fluid interaction. Fowler's presentation clearly indicates that the PER methodology has the potential to reveal mass ratios of rock and fluid, and element distribution-coefficients between rock and fluid, and could therefore become the basis for a new and quantitative examination of metamorphic and metasomatic processes and of systems of hydrothermal mineralization.

The final chapter of this book is a collection of "Homework Problems and Annotated Solutions". Those readers involved in teaching senior undergraduate and graduate courses in petrology, geochemistry or economic geology will find this chapter particularly useful as a source for lecture and lab materials alike. Researchers in these fields who have resisted the PER analysis approach will find the time taken to work through these problems most worthwhile in terms of the new insights they will experience into the power and rigor of PER analysis.

Because of the diverse applications of PER analysis, this book should be on the shelf of every petrologist with a teaching or research interest in problems related to fractional crystallization, magma recharge, assimilation, partial melting and alteration geochemistry, as addressed by the various contributors. The methodology is equally applicable to many other geological problems in which mass-transfer processes may have been involved. All the tools required to tackle such problems are clearly laid out, and a considerable amount of software has already been developed by the contributors to facilitate their application. This

book should go a long way in convincing petrologists and geochemists that there is a better way to analyze their chemical data.

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*Meteorites and the Early Solar System.* Edited by John F. Kerridge and Mildred S. Mathews. The University of Arizona Press, Tucson, Arizona. 1988. 1269 + xvi pages. US\$65. ISBN 0-8165-1063-6.

The book, conceived with the graduate-student population in mind, is an exhaustive compilation of papers by 69 collaborating authors. An excellent Overview and Classification of Meteorites is followed by chapters on Source regions, Irradiation effects, Solar System chronology, Chemistry of chondrites, Nucleosynthesis, *etc.* A succinct Summary by J.F. Kerridge and E. Anders, a Glossary of some terms, and five appendixes also are included. All the topics are quite coherent and self-contained, with copious bibliographic references. This book will also be welcome by astrophysicists, exobiologists, and planetologists, besides geologists and geochemists. As the editors admit, there is a noticeable sharp transition in style from one chapter to the next in many cases; however, a good consistency is achieved in the use of units, symbols, and notations.

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*Marine Geochemistry.* By Roy Chester. Harper Collins, 1995 Markham Road, Scarborough, Ontario M1B 5M8. 1990. 698 + xviii pages. CDN\$71.95 (softbound). ISBN 0-0455-1109-8.

The book is a fully comprehensive and integrated treatment of the chemistry of the oceans, their sediments, and biota. It treats seawater, sediment, and rock reservoir as a single unified system. A process-oriented framework has been adopted, with an emphasis on the identification of key processes operating within the "unified ocean". The four major parts (Material Sources, the Ocean Reservoir, Material Sinks, and Synthesis) are divided into sixteen chapters. Particular attention is paid to making the text accessible to students from all disciplines, including chemical oceanography and marine geochemistry. This well-choreographed publication would have benefitted from a more exhaustive index.

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