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BOOK REVIEWS

THE CAMBRIDGE ENCYCLOPEDIA OF METEORITES. O. Richard Norton. Cambridge University Press, 2002. Hardbound, 354 p. $50 U.S.

METEORITES: A JOURNEY THROUGH SPACE AND TIME. Alex Bevan and John De Laeter. Smithsonian Institution Press, 2002. Hardbound, 215 p.x $35.95 U.S.

Meteorites, like minerals, have become prized collectors' items. Public interest in meteorites has increased markedly, fueled in large measure by the momentum of scientific discovery over the last several decades. The mineralogy of meteorites has been summarized within a recent MSA *Reviews in Mineralogy* (Volume 36, *Planetary Materials*), but that treatment is too technical for most undergraduate students, nongeologists, and amateur enthusiasts. Two new books, *The Cambridge Encyclopedia of Meteorites* (henceforth "*CEM*") and *Meteorites: A Journey through Space and Time* (henceforth "*MET*"), thoroughly describe extraterrestrial materials with a minimum of required background and jargon, while at the same time providing enough astrophysical and petrologic context to make them exciting. The intended audience for both books is the interested layman, but they are appropriate for undergraduate geology students who seek an introduction to meteorites.

Although most of these chunks of rock and iron may not be as visually stunning as colorful, geometric crystals, the ~150 full-color images in both *CEM* and *MET* demonstrate why meteorites are so appealing. The vivid photographs alone are worth the price of these books, although the photomicrographs in *MET* are somewhat out of focus and the color registration is sometimes poor (the surfaces of the Moon and Mars, as well as several iron meteorites, are printed in cobalt blue).

CEM opens by describing the smallest meteorites – cosmic dust particles, some of which once resided in comets, and interstellar grains formed around other stars and laboriously extracted from larger meteorites. Chapter 2 describes the dizzying orbital paths of meteors and what happens as they fall to Earth. This is followed by a discussion of meteorite morphologies, which are molded by melting during atmospheric passage, and how their appearance can be altered by terrestrial weathering. A short chapter then describes the historical (and no longer used) classification strategies for meteorites. Beginning with Chapter 5, the various meteorite groups are described in turn: chondrites, carbonaceous chondrites (awarded their own chapter because of their primitive nature), achondrites (igneous meteorites), primitve achondrites (mostly residues from partial melting), martian and lunar achondrites, irons and stony-irons (mostly asteroidal cores). Various important topics, such as the modern chondrite classification scheme, shock metamorphism, the nature of chondrules, fractional crystallization and differentiation in asteroids, the cooling histories of metallic alloys, the utility of oxygen isotopes in meteorites, are introduced throughout these chapters as appropriate. Chapter 10, describing the role of meteorites in unraveling the mysteries of the early Solar System, includes an introduction to radiometric dating and solar system chronology, a description of the solar nebula, the sequence of condensation to form refractory inclusions, and the melting of chondrules. Chapter 11 introduces asteroid parent bodies, beginning with a description of the main asteroid belt, followed by sections on spectroscopy and physical characteristics of asteroids, and ending with a summary of the NEAR-Shoemaker spacecraft encounter with asteroids Mathilde and Eros. A final chapter describes the impact scars made by meteorites that collide with the Earth and other planets, cratering mechanics, some criteria for recognizing impact structures, and impacts that have apparently been catastrophic for the terrestrial biosphere.

The layout of *MET* is somewhat similar, opening with a chapter on ancient beliefs and the history of meteoritics, followed by descriptions of meteorites and fall phenomena. The asteroid sources and the recovery of meteorites are then explained. *MET* was written by two Australian meteoriticists, and there is an emphasis on Australian meteorites. A chapter on the Earth's anatomy precedes a description of chondrites as planetary building blocks. Then differentiated meteorites (achondrites, irons, and stony irons) are introduced. Chapters on stardust in meteorites and radiometric dating set up an essay on how meteorites can be used to decipher processes and events in the early solar nebula. Discussions on the possible relationships between meteorites and life, and on impact craters then follow. The book ends with a survey of future exploration and analysis of extraterrestrial materials via spacecraft (incomplete because it omits most NASA missions).

Each chapter in *CEM* ends with a list of references, although these are not always (from my perspective) the most appropriate references available and the bibliographies would be more useful had they been annotated. *MET* has a comparable number of references (a more judicious selection of papers but, again, without annotation) ordered by chapter but listed together at the end of the book. Eight very useful appendices in *CEM* describe: meteorite classification, the formation ages of selected meteorites (an uncritical list containing some ages that are suspect or highly controversial), characteristics of the important rock-forming minerals that comprise meteorites, recipes for etching iron meteorites to reveal the Widmanstatten structure and for chemically testing suspected meteorites for nickel, a listing of prominent museum collections and research facilities for meteorites, known terrestrial impact craters, and a compilation of the world's meteorites by classification. Both *CEM*

and *MET* contain a helpful glossary and a comprehensive index.

These books clearly fill a need—they are the best available descriptive references of meteorites for students and interested amateurs. *MET* is more fun to read, as it is less technical and written in a more entertaining style. *CEM* is more comprehensive and thorough in its coverage, although its treatment of petrogenetic processes is simplified and its presentation of cosmochemistry is not very complete. The beautiful color illustrations make leafing through both of these volumes the equivalent of viewing a good museum collection, and the appendices in *CEM* are a useful resource. Anyone interested in minerals that formed on other worlds, that are sometimes exotic beyond our experience and imagination, that occasionally fall from the sky, should try one of these books.

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NATURAL ZEOLITES: OCCURRENCE, PROPERTIES, APPLICATIONS. David L. Bish and Douglas W. Ming, Editors, Reviews in Mineralogy and Geochemistry, 2001, Vol. 45, 662 p. Mineralogical Society of America and the Geochemical Society, Washington, D.C. $32 ($24 for MSA members).

Natural Zeolites: Occurrence, Properties, Applications is the latest book reviewing various aspects of this important family of industrial materials and rock-forming minerals. Unlike many volumes of the *Reviews in Mineralogy and Geochemistry* (nee *Reviews in Mineralogy*) series, this book was not associated with a short course. It was designed by the editors to combine and synthesize the ever-expanding volume of information about natural zeolites that has accumulated since the publication of Volume 4 of *Reviews in Mineralogy* (*Mineralogy and Geology of Natural Zeolites*, published in 1977 and now out of print). The new book is comprised of 18 chapters, grouped into four sections: Mineralogy (chapters 1 to 5), Occurrence (chapters 6 to 12), Physicochemical Properties (chapters 13 and 14), and Applications (chapters 15 to 18). The breadth of topics covered in this volume make it stand out among its peers in the natural zeolite literature in that it is the most comprehensive treatment of natural zeolites compiled to date.

The first section, Mineralogy, contains five chapters covering various aspects of the mineralogy and chemistry of natural zeolites. The first two chapters on zeolite crystal structures (T. Armbruster and M. Gunter) and crystal chemistry (E. Passaglia and R. Sheppard) take on the difficult task of providing brief yet comprehensive reviews of these topics that have alone been the subject of several books over the last 15 years (Gottardi and Galli 1985; Tschernich 1992; Meier et al. 2001). While the "laundry-list" approach that was necessarily used in organizing these chapters does not make for captivating reading, the authors have created very useful references. Chapter 3 on the stability of natural zeolites (S. Chipera and J. Apps) is an interesting review of Chipera's modeling efforts and closes with a heuristically enlightening discussion of the problems encountered in trying to reconcile experimental observations of zeolite stability. Chapter 4 on the isotope geochemistry of natural zeolites (H. Karlsson) is easily one of the best in the whole volume. It is not only the first review that I am aware of on this subject, but provides a comprehensive review of work on both the stable and radiogenic isotope geochemistry of zeolites along with thoughtful commentary and interpretations of the reviewed studies. The section closes with Chapter 5 on heulandite-clinoptilolite nomenclature (D. Bish and J. Boak) that provides a comprehensive review of the confusing topic of distinguishing between these isostructural phases.

The discussion in Chapter 5 reflects current issues in natural zeolite designations. Recent International Mineralogical Association (IMA) recommendations for zeolite nomenclature (Coombs et al. 1997) have unwittingly created considerable confusion in designation of zeolite species. These issues are addressed and variously dealt with in Chapters 1 and 2 as well. The strict (and perhaps arbitrary) IMA recommendations are not consistently obeyed in the book, which may further the confusion that currently surrounds zeolite nomenclature. Inclusion of the IMA recommendations in the volume would have been useful for context.

The second section of the volume, Occurrence, consists of seven chapters dealing with the presence of zeolites in a variety of natural environments. As a whole, this section provides a useful and updated compilation of information on zeolites in sediments and sedimentary rocks. Several important types of zeolite occurrence are afforded less coverage than sedimentary and volcaniclastic occurrences, namely pegmatitic and magmatic zeolites and zeolites in mafic lavas. Chapters 6 (R. Hay and R. Sheppard), 7 (A. Langella, P. Cappelletti, and M. de' Gennaro) and 8 (R. Sheppard and R. Hay) include a wealth of references and general descriptions of various zeolite deposits in sedimentary and volcaniclastic rocks. Chapters 9 and 10 by M. Utada on zeolites in regional metamorphic and hydrothermal environments provide numerous examples of the distribution of zeolites in various thermal regimes but ignore much of the recent work on large igneous provinces. Particularly noteworthy are chapters 11 and 12 on zeolites in soils (Ming and Boettinger) and petroleum reservoirs (A. Iijima) that provide well-researched reviews of the occurrence and implications of zeolites in these systems. Unfortunately, little attention is given by any of the chapters in this section to explaining the factors that control zeolite distribution in geologic systems (save a few, almost perfunctory lists of variables affecting zeolite formation that are not developed further).

The third section on Physicochemical Properties consists of Chapter 13 on the thermal behavior of zeolites (D. Bish and J. Carey) and Chapter 14 on their ion exchange properties (R. Pabalan and F. Bertetti). Both chapters present useful reviews of the general behavior of zeolites along with fairly exhaustive references to primary data sources. Each chapter closes with a section describing applications of the thermodynamic models developed earlier within the chapter. The authors of these two chapters did not provide readers with much in the way of an evaluation of the quality and consistency of the referenced data on zeolite dehydration and ion exchange, but duly note the need

to carefully evaluate these factors when applying data. Also missing from these chapters was the development or consideration of thermodynamic frameworks other than those adopted by the authors in their previous work. This is perhaps a bigger problem in Chapter 14 that ignores changes in hydration state that accompany many ion exchange reactions in zeolites (a point noted in the preceding chapter).

The book closes with a section on applications of natural zeolites. The uses of zeolites covered range from building materials (Chapter 16; C. Colella, M. de' Gennaro, and R. Aiello) to water treatment (Chapter 15; D. Kalló), solar engineering (Chapter 17; D. Tchernev), and agriculture (Chapter 18; D. Ming and E. Allen). Taken as a whole, these chapters offer a fascinating glimpse into the multifarious applications of natural zeolites. All four chapters provide relevant discussions of the properties that make zeolites useful in these applications along with case studies.

This book is destined to be a classic reference for those interested in natural zeolites. The level of writing is easily accessible for those who are not specialists in this field as well, including graduate students and non-mineralogy-oriented geologists who encounter zeolites during their work. These users should be aware that the book has an unfortunately long list of errata (available by download from the MSA website), some of which are fairly important (errors in formulas, etc.). Nonetheless, it is apparent that Bish and Ming did a Herculean task in editing this volume and producing a well-formatted and informative text. As with all of the *RIM* and *RIMG* volumes, it is quite reasonably priced. The most comprehensive recent resource on natural zeolites (and an excellent one), it belongs in all research libraries and on the bookshelves of workers in this field.

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FOURTH HUTTON SYMPOSIUM ON THE ORIGIN OF GRANITES AND RELATED ROCKS, edited by Bernard Barbarin, William Edryd Stephens, Bernard Bonin, Jean-Luc Bouchez, David Barrie Clarke, Michel Cuney, and Hervé Martin, GSA Special Paper 350, 2001, 321 p. (originally published as Transactions of The Royal Society of Edinburgh: Earth Sciences, v. 91, parts 1 & 2)

This volume is the fourth in a series, published jointly by GSA and the Royal Society of Edinburgh, in which selected contributions from the quadrennial Hutton symposia are published. The twenty-three papers reflect the flavor of the meeting, which in turns reflects the status of research on problems related to granitic rocks at the close of the 20th century. This continuing series of symposia was conceived in the 1980's and first held in Edinburgh in 1987 to commemorate James Hutton and his initial address to the Royal Society concerning the initially fluid, or magmatic, state of granite. Though titled "The Origin of Granites and Related Rocks," the symposia have been from the beginning much more wide-ranging than that. Granites are treated very *sensu lato* and other very different rocks that bear upon granites, notably basalts, receive considerable coverage. Furthermore, not just origins of magmas but essentially all geological aspects of granitic rocks receive scrutiny, e.g., melt segregation, ascent, and emplacement; magma chamber and volcanic processes; ore deposits; and tectonic implications of felsic magmatism.

The four symposia have been held in Edinburgh; Canberra, Australia, in 1991; College Park, USA, in 1995; and Clermont-Ferrand, France, in 1999. As might be expected with the passage of time and locations on three different continents, the general emphases and the distribution of subjects of papers has varied considerably from conference to conference, as has the geographical distribution of participants. The first volume, whose authorship was dominated by Britain, the USA, and other English-speaking nations (17 of 19 first authors), really did emphasize the origin, or petrogenesis, of granites. Subsequent volumes have greatly expanded the range of subjects and the origins of authors. The fourth volume is the first to include first authors from all continents (except Antarctica!), and what I would call petrogenesis is downplayed and regional studies, mineral deposits, and emplacement receive more attention.

The fourth symposium carries on the tradition of presenting an excellent snapshot of the status of research at the time of the meeting—in this case, the very end of the twentieth century. Insofar as it represents the greatest geographic diversity yet—first authors of the 23 papers come from 14 countries and 6 continents—it could be said to present the best of the four granite research snapshots. By my arbitrary classification, two papers deal with petrogenetic processes; three with physical processes within magmas (from field, experimental, and theoretical perspectives); five with magma segregation, ascent, and emplacement; three with accessory minerals and geochronology; and seven with regional problems. Thought I'm not sure that any single paper stands out as certain to be a classic, all are solid and as a compilation the book is very strong.

A personal perspective/gripe: I am bit concerned that questions concerning the generation of granitic magmas appear to be considered solved. That is to say, in many cases once a descriptor has been applied to a rock (I-type, S-type, H-type, calc-alkaline, high-K calc-alkaline, adakitic, etc.), often based on a limited number of characteristics, or a few samples are plotted on a particular diagram, the petrogenetic question is solved: the source material and tectonic setting are firmly established. Such treatment has become very common, though not the rule, in current literature, and it creeps into a number of the papers in this volume. They tend to jump directly from descriptive data about granites into interpretation of regional geologic his-

tory without pausing to critically evaluate the constraints that the data actually impose on petrogenesis, and then the constraints that petrogenesis imposes upon regional geologic processes. No classification scheme provides a unique solution to the puzzle of magma genesis, and magma genesis only provides constraints on tectonic setting. I should note that papers in this volume that are guilty of this sort of simplification have plenty of other data and ideas that make them worthwhile contributions.

It would be impractical to comment specifically on all of the papers, but I will mention just a few that exemplify the breadth of the volume. An imaginative contribution by Collins, Richards, Healy, and Ellison combines field and geochemical evidence with considerations about material properties to develop a model for hybridization in solidifying, intermittently replenished magma systems. Although the paper deals with a single example from Australia, the implications are intriguing and potentially wide-ranging. Koyaguchi and Kaneko likewise address mafic replenishments and the evolving physical characteristics of silicic magma chambers, but they evaluate thermal and mechanical evolution first, through a conceptual model of waxing and waning partially molten (mechanically solid), mush, and liquid zones above mafic injections and their cumulates; then, through quantitative thermal modelling; and finally, by preliminary analogue experiments. They provide a distinctive perspective on magma dynamics that is both clear and testable by granite petrologists and kindred volcanic petrologists. A paper by Benn, Odonne, Lee, and Darcovich presents the results of cleverly conceived analogue experiments of pluton emplacement in deforming brittle and ductile crust. It suggests that plutons play a major role in localizing compressional structures, that depth of emplacement (with respect to the brittle-ductile transition) is an important control of shapes and structural relations of plutons, and that apparent shapes and map relations of plutons will vary depending upon depth of exposure within the pluton. In their discussion of Ordovician plutonism in northwestern Argentina, Pankhurst, Rapela, and Fanning venture a bit into the "petrogenetic typology" that I disparaged in the previous paragraph, but for the most part this is a good example of regional petrogenetic study, with thoughtful evaluation of a wide range of field, geochronological, elemental, and isotopic data of several distinct but roughly coeval intrusive suites. The authors conclude that trondhjemites, metaluminous and peraluminous granitoids, and gabbros were all generated within the lithosphere, with varying contributions from subcontinental mantle and mafic and sedimentary crustal sources. A welcome contribution for Anglo geologists is provided by Jean-Pierre Pupin, on the petrogenetic interpretation of zircon compositions. Pupin's papers on zircon morphology have established a classification that ostensibly characterizes T, fluid activity, and melt composition of magmas from which zircon crystallized, and by implication tectonic setting. This work, almost entirely in French, is widely accepted and heavily cited by petrologists from the European continent but almost entirely neglected by those of us whose primary language is English. The Hutton Volume paper takes a similar approach to that of the morphological studies, classifying zircons by Hf and Y concentrations and relating this classification to petrogenesis. Zircon potentially preserves the best permanent record available of otherwise obscured ancient environments. It is to be hoped that this paper will help to stimulate a close look at Pupin's work in this regard. Finally, Robb, Freeman, and Armstrong's paper on hydrothermal modification of Bushveld granites exemplifies the application of a combination of traditional and newer methods to verify and begin to elucidate complex and protracted histories. Field, petrographic, and fluid inclusion work demonstrate sequential mineralization at decreasing T; previous (Rb-Sr, zircon Pb-Pb evaporation, whole rock Pb-Pb) and new (SHRIMP zircon) dating reveals that this mineralization was not a consequence of internally-derived magmatic fluids but rather occurred during discrete, unrelated events that spanned almost a billion years.

Those who wish to be fully abreast of the evolution and status of granite studies (in a broad sense) should own a copy of this volume, as well as the other Hutton volumes. For others with occasional but less intense interest, I strongly recommend making sure that library copies are accessible and that mental or concrete notes are made that these resources are available. There is a lot of useful material in this series for faculty and other professionals and graduate students interested in crustal evolution, structural geology and tectonics, volcanology, and mineral deposits.

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