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BOOK REVIEWS

Crystal Growth & Development: Interpreted From a Mineral's Present Form. By Boris Z. Kantor. Mineralogical Almanac, Volume 6, Association Ecost, Moscow, Russia, and Ocean Pictures Ltd., Littleton, Colorado, U.S.A., 2003, 136 pages, softbound, US$45, including shipping and handling. Available from Terry Huizing, 5341 Thrasher Drive, Cincinnati, Ohio 45247, U.S.A. ISBN 5–900395–46–4.

The growth of crystals and crystal aggregates often gets cursory treatment in mineralogical textbooks published in the so-called western world. A notable exception is the late John Sinkankas's *Mineralogy for Amateurs*. Mineral ontogeny, as it is termed, has received much more attention in Russia, where entire textbooks have been published on the subject. An early example is D.P. Grigoriev's *Ontogeny of Minerals*, which was reviewed in this journal in 1967 [*Can. Mineral.* **9**(1), 136-138]. Boris Kantor, the author of *Crystal Growth & Development*, is a mineral collector and amateur mineralogist with a special interest in mineral ontogeny. His collection was featured in an earlier volume of the Mineralogical Almanac, *Mineral Collections of Russia, Part 1* (reviewed in *Can. Mineral.* **38**, 773-774).

Crystal Growth & Development is structured as a series of twenty-two talks written in an informal, conversational style. The author's thesis is that by carefully looking at crystals and crystal aggregates, much can be learned about how they might have formed. His own enthusiasm for the subject is summed up by his quotation from the German geneticist, B. Müller-Hill: "comprehending how nature works brings an enormous pleasure, and to realize a beautiful detail in its construction, which no one realized before you, arouses the sense of delight." Scattered throughout the text are other quotations and asides from the work of historical and modern mineralogists and other scientists.

At first glance, the titles of some of the talks seem odd, *e.g.*, "The willful hemimorphite. And on twisted and other quartzes once again," but they are really a play on the subjects of the talks. These include: parallel intergrowths and epitaxy; corroded crystals; regenerated, fractured crystals; skeletal and dendritic crystals; twinned crystals; crystal groups (and the difference between "druse" and the Russian term "druza"); spherulites and spherocrystals; crystal rosettes, sheaf-like forms, and curved and twisted crystals; hemimorphic crystals; pseudostalactites; agates; and, stalactites and helictites. The final talk is a summation, ending with an invitation to the reader to look at a final series of mineral photographs: "scrutinize them attentively. Sort out [the] types of mineral formations. Try to imagine their history....Meditate upon causes and conditions."

Integral to the text are 142 excellent color photographs of minerals, and 72 line drawings. The photographs are well chosen to illustrate the topics under discussion, and in some cases they are also rendered as line drawings to emphasize certain features.

The interpretations of crystal growth presented by the author are absorbing, and for the most part, credible. A problem here is that except for a few specific citations to the literature, it is not obvious which interpretations are solely those of the author and which are drawn from the works listed in a short bibliography. One of the more interesting notions is that many aggregates and intergrowths of crystals are in fact single crystals that have developed into multiple individuals because of imperfections in a nucleating crystallite. They are "split crystals," a term that often appears in Russian mineralogical literature. Examples given include okenite spherulites, smithsonite botryoids, stilbite "wheat sheaves", hematite "roses", dolomite "saddle" crystals, and even quartz "gwindels". An intriguing idea is that the orientation of hemimorphic crystals on matrix can be attributed to their electrical polarity and their interaction with a charged matrix. An example is the common occurrence of tourmaline crystals all with their pedion ends projecting into a cavity. More speculative is an explanation of the growth of chalcedony pseudostalactites involving the formation of a semipermeable membrane of silica.

Unfortunately, *Crystal Growth & Development* is not an easy read. In a foreword, the editor of the Mineralogical Almanac series states that "there is always the risk [that in] editing any publication the original feeling by the author is stained [*sic*] and discolored [*sic*]" and that "editing was reduced to a minimum, even Russian–English translations." The result is a rather cumbersome text, despite the author's breezy style.

Like previous volumes in the Mineralogical Almanac series, *Crystal Growth & Development* is printed on high-quality paper, with excellent graphics. The few typographical errors found are outside the main body of the text, suggesting the use of a spell-check. However, a spell-check does nothing for incorrect word forms or sentence construction.

Crystal Growth & Development is clearly aimed at amateurs. Mineral collectors and amateur mineralogists would all benefit from reading this book. Hopefully, they would come to look at their mineral specimens in a new light. With its many illustrations of crystal growth, the book could also be used as supplementary material in teaching introductory mineralogy.

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Natural Mineral Forms. Exhibit in Fersman Mineralogical Museum, Russian Academy of Science. By A.A. Godovikov and V.I. Stepanov; Margarita I. Novgorodova, ed.). Ocean Pictures Ltd., Box 368, Moscow 103009, Russia, 2003, 64 pages, softbound, US$30 including shipping and handling. Available from Terry Huizing, 5341 Thrasher Drive, Cincinnati, Ohio 45247, U.S.A. ISBN 5–900395–47–2.

Natural Mineral Forms is essentially an illustrated guide to an exhibit by the same name at the famous Fersman Mineralogical Museum. The exhibit is organized according to a classification system ("taxon system") based on mineral morphology, devised by the authors, the late Alexander A. Godovikov and the late Victor I. Stepanov, both prominent Russian mineralogists.

The classification system is the framework of *Natural Mineral Forms*. It covers all crystallized mineral forms that are bounded by natural surfaces, and which range in size up to a few decimeters ("small bodies"). The system has two major divisions, or "taxons", each comprising a chapter in the guide: mineral forms that crystallize in low-viscosity media, such as solutions and gases, and mineral forms that crystallize in viscous and solid media, such as molten and solid rocks, and sediments. Within each division, there is a hierarchy of forms, from the simple at the highest level, to the complex at the lowest. For example, at the highest level of the first division (numbered 1.1) there are "individs", essentially single crystals. At the next level (1.2), we find mineral aggregates, and at the lowest level (1.3), "small mineral bodies." Section 1.1 is in turn divided into "crystals" (1.1.1), "partially crystallized mineral individs" (1.1.2), and something called "globular individs" (1.1.3). Then under "crystals", we have "fully faced crystals" (1.1.1.1), "skeletal crystals" (1.1.1.2), "fibrous crystals" (1.1.1.3), and "spherical crystals" (1.1.1.4). Twinned crystals are considered aggregates and are in section 1.2. Many seemingly unnecessary terms have been coined for the kinds of aggregates that are typically described in mineralogy textbooks. Examples include: "heteroepitaxite" for epitactic rutile on hematite, "anthodite" for "ram's horn" gypsum, and "simplectites" for graphic intergrowths. Calcite crystals containing inclusions of sand are classified as "poikilites", which is certainly a misuse of the term poikilitic. In another departure from the conventional, included as mineral forms under "small mineral bodies", are such things as veins, concretions, septaria, lithophysae, and even orbicular structures in igneous rocks. A very brief, final chapter of the *Natural Mineral Forms* deals with the destruction of mineral forms by such processes as deformation and dissolution. In conclusion, the authors discuss their approach to the classification system. As they seem to admit, the system involved some rather arbitrary criteria. It is difficult to see its practical application beyond the present exhibit at the Fersman Museum.

The strength of *Natural Mineral Forms* is the description of the various mineral forms. Included are derivations of the terms used, examples of the forms, comments on their genesis, and literature references. The descriptions are well written, in good English. Most of the mineral forms are illustrated by excellent photographs (154 in color, four black-and-white) of specimens in the Fersman exhibit. The captions include locality information, specimen size and the Fersman catalog number.

Natural Mineral Forms is printed on high-quality glossy paper, with excellent graphics. The names of the various mineral forms appear in bold font, making it easy to search the text in the absence of an index. Ignoring such unfortunate spellings as "individs", there are very few typographical errors.

Natural Mineral Forms is the next best thing to actually seeing what surely must be a fascinating exhibit. It should appeal to anyone interested in mineral forms. The illustrations alone make it a worthwhile addition to library shelves. *Natural Mineral Forms* would make an ideal supplement to standard mineralogy textbooks in teaching introductory mineralogy. A reference copy might be particularly useful in mineralogy laboratory sessions.

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Structural Classification of Minerals. Volume **2**. *Minerals with ApBqCrDs to ApBqCrDsExFyGz... general chemical formulas*. By José Lima-de-Faria (2003). Kluwer Academic Publishers, 101 Philip Drive, Norwell, Massachusetts 02061, U.S.A. 151 pages. US$58 (hardcover). ISBN 1–4020–1119–9; 0–7923–6893–2 (set of three volumes).

The first volume was reviewed in *Canadian Mineralogist* **40**, 1236 (2002). This volume continues on from the first volume with more complicated structures. The systematic tables contain mineral name, chemical formula, structural formula, space group, unit-cell dimensions, equivalent positions, structure-type, and abbreviated references (101 pages). The structure-type tables list minerals under the headings of close-packed, group, chain, sheet, and framework structures (36 pages). The book concludes with an index of mineral names (13 pages). There is a one-page introduction and a page providing details of the structural notation. One needs to look at volume 1 for the references and abbreviations. Because the layers are more complex, the corresponding condensed model sheets are not included.

The classification challenges primary classifications based on structure, with a quotation from William Lawrence Bragg: "The important thing in Science is not so much to obtain new facts as to discover new ways of thinking about them." This classification is structural plus chemical and not structural plus alphabetical, as might appear. The alphabetical order is provisional and not important, so it will tend to disappear. Sanidine $K[(Si,Al)_4O_8]$ is in volume 1, whereas microcline $K[AlSi_3O_8]$ is in volume 2.

Mineral nomenclature follows Nickel & Nichols (1991), so that the book does not incorporate recent changes. For instance, andrewsite has been discredited as a mixture of hentschelite + rockbridgeite ± chalcosiderite [*American Mineralogist* **75**, 1197 (1990)]. The IMA Amphibole Subcommittee has renamed dannemorite manganogrunerite. The IMA polytype subcommittee has decided to use *O* and *A* (in italics) for orthorhombic and triclinic (anorthic) respectively, rather than Or and Tc.

The only typographical errors in mineral names involve accents, occasionally omitted from mineral names in the mineral index, but not in the tables. The unit-cell dimensions and Z for a few minerals could have been obtained from the Mineral Powder Diffraction File.

The great strength of this book lies in the information in the tables. The book is printed on good-quality paper with clear type. Compared to other mineralogical books, the price is reasonable. Earth Science libraries will find a copy useful as a reference text, and the price may be low enough to justify a personal copy. I look forward to the production of volume three of this series, which the author states is practically finished.

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Phosphates – Geochemical, Geobiological and Materials Importance. Edited by Matthew J. Kohn, John Rakovan and John M. Hughes. Reviews in Mineralogy and Geochemistry, Vol. 48 (2002). Mineralogical Society of America, 1015 Eighteenth Street, Washington, D.C. 20036, U.S.A. US$40, $30 to MSA, GS, CMS members (ISBN 0–939950–60–X).

The phosphate minerals apatite, monazite and xenotime are easily recognizable phases found in an extraordinarily wide range of geological environments. They have become important source-materials for geochemical investigations. Trace or accessory minerals in high-temperature igneous, and metamorphic terranes, they form relatively stable crystals that harbor elements useful in dating and in investigations of the reaction history of rocks. On the other end of the temperature spectrum is the apatitic mineral matter in the bones and teeth of vertebrates, and the phosphate biochemical pathways that are basic to the energy system essential for life. With such diverse facets, it is not surprising that phosphates are a focus of attention, and an appropriate topic for coverage in the *Reviews in Mineralogy and Geochemistry* series. This 742-page volume attests to the chemical attributes and variations of several of the phases, and attempts to encompass the diverse occurrences, and some applications unique to phosphates.

Distinctive morphology of the oft-times reasonably sized (>0.2 μm) crystallites, with high indices of refraction (N_{lowest}1.63, apatite, 1.77 monazite, and 1.72 xenotime), mean that these minerals are relatively easily identified within an aggregate or thin section by standard petrographic techniques. In addition, the distinctive composition, phosphate and elevated REE content make these minerals obvious during examination by scanning electron microscopy coupled with energy-dispersion X-ray elemental analysis or by the high-resolution techniques now possible with laser-coupled mass spectroscopy. Relatively resistant to destruction, they may remain virtually unchanged during weathering, transport into sedimentary environments, and survive prograde metamorphism, or hydrothermal alteration, to elevated temperatures, all of which makes them advantageous mineral materials for petrological, geochemical and mineralogical examination. Also, low-temperature, indeed body-temperature "bioapatites", have been the topic of investigation for hundreds of years.

There is nowhere that humans can avoid being confronted with phosphates, but as this volume illustrates, it is difficult to encompass the mineralogy and materials science of a group with such diverse occurrences. It is a tall order to summarize and put into perspective the vast amount of information that distinguishes even a few of the mineral species and their applications in geological, biological, medical, and industrial activities; consequently, the coverage is idiosyncratic. However, this volume is perhaps the only source where mineralogists and geochemists can relatively effortlessly obtain such a range of information. Not since the two-volume work by Van Wazer (1958) has there been a comprehensive compilation on phosphorus and its compounds. There are more restricted and specific works on phosphate minerals (*e.g.*, Nriagu & Moore 1984), and the most recent efforts of Corbridge (2000) address chemistry, biochemistry and technology; my brief overview compares both ends of the apatite spectrum (Skinner *et al.* 2003). This present volume, therefore, is truly a "review" of the current status of physical and compositional data on selected phosphorus-bearing minerals, and some synthetic materials. For information on the traditional areas such as soils, agriculture and biochemistry, where phosphates are of tantamount importance, the reader will have to resort to on-line library search-routines of a vast literature.

The nineteen chapters are grouped under five subheadings: mineralogy and crystal chemistry, petrology, biomineralization, geochronology and materials applications. In traditional fashion, the volume starts with chapters on the basic crystal-chemical and crystallographic mineral attributes of phosphates. These atomic level considerations are background for the geochemical – petrological – biochemical chapters that follow.

Integration of the mineral data from igneous and metamorphic terranes can delineate temperature, pressure, and compositional boundaries essential to geological interpretations, and phosphate minerals are primary sources for dating these phosphate rocks. The compositional range of biogenic apatite-bearing sediments raises other questions that may be more readily appreciated after the review of the global phosphorus cycle, the chemical distinctions of "bioapatite", and some of the health-related applications. One of the main contributions of a collection of such diverse topics is the extensive bibliographies that accompany each chapter. The inaugural chapter on crystal structure of the apatite series (Hughes and Rakovan) is followed by an overview of the composition range of apatite-group minerals and mechanisms of substitution (Pan & Fleet). These papers facilitate a broader understanding of the entire group of phosphate-containing minerals, not just the orthophosphates (Huminicki & Hawthorne). With this background, the natural appearance and growth of apatite (Rakovan), or the growth, synthesis and properties of monazite, xenotime, and the recently defined mineral species pretulite, $Sc(PO_4)$ (Boatner), lay the groundwork for an appreciation of the chemical variety observed and documented from high-temperature rocks.

Piccoli & Candela offer caveats for interpretations of apatite data from igneous rocks (including carbonatite), whereas Spear & Pyle describe the composition and zoning of apatite, monazite, and xenotime in metamorphic rocks, and consider the partitioning of elements between apatite and a fluid phase, or apatite and biotite, before discussing paragenesis.

The practical side of REE and U analyses by Oyle *et al.* includes a discussion of detection limits and analytical precision. An overview of the Phosphoria Formation is presented as an example of sedimentary phosphorites (Knudsen & Gunter). This section on petrology concludes with the chapter on the global phosphorus cycle (Filippelli).

The biomineralization subset of papers commences with an overview of the calcium phosphate biominerals (Elliot), followed by a discussion of the stable isotope (O, C, and Sr) compositions of bones, teeth (Kohn & Cerling) and the trace elements (Ba, Sr, Pb, La, Sm, Yb, U) in fossil bone (Trueman & Tuross). Geochronology dating of phosphate minerals includes chapters on the U–Th method by Harrison *et al.*, whereas Farley & Stokli describe the (U–Th)He technique, and Gleadow *et al.* discuss fission-track analysis, a method that relates to the thermochronology of apatite.

Applications are covered in the final section. There is a chapter on the biomedical aspects of apatite (Gross & Berndt), another on the application of phosphates in sequestering nuclear waste (Ewing & Wang), and in the last chapter a presentation on apatite luminescence (Waychunas) illuminates (!) the varying emission colors and zoning found in apatites from some famous mineral localities. Spectacular color photographs from this chapter and the Rakovan article are included in a section of Plates.

Considering the range of topics covered, a reader will, at the very least, appreciate some of the investigative efforts distinctive to phosphate minerals. The volume provides appropriate background, summarizes some research results, and presents a remarkable overview of the diversity that characterizes phosphates. The juxtaposition of interdisciplinary papers suggests many potential research opportunities in both basic and applied areas. The volume is an excellent springboard for mineralogists and geochemists into the challenging world of phosphate minerals and their reactions.

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The Cambridge Encyclopedia of Meteorites. By O. Richard Norton. Cambridge University Press, 40 West 20th Street, New York, N.Y., 2002, 354 pages, eight appendices. US$50, hard cover (ISBN 0521621437).

Although titled an encyclopedia, this book is more like an introductory level textbook, written in a popular style. Indeed the organization is textbook-like, and definitely not like an encyclopedia. Norton explains that the model for this type of encyclopedia was provided by Aristotle.

This book is not a thorough description of the petrography of meteorites and impactites, such as provided by Dodd (1981), an essential volume now badly out of date. Nor is Norton's book a thorough technical exploration of the study of meteorites (meteoritics) and the numerous theories regarding their parent planets and asteroids. Serviceable books by T.F. Wasson fill this niche. Nor is this a completely popularized summary of meteoritical results, such as have been penned by Hap McSween. Rather, Norton's book lies between popular books and highly technical ones. It is a college-level introduction to the study of meteorites, interplanetary dust, and impactites. The book presents the basic characteristics of these materials, including results as recent as 2000. Topics are presented as short papers, usually including interesting historical perspectives.

The author brings a very personal touch to this book, for he is a true meteorite afficionado. A major attribute is an unparalleled collection of spectacular photographs and figures illustrating all major aspects of meteoritics. For such a reasonably priced book, this was a real surprise.

Interplanetary dust particles (IDPs), predominantly small grains shed by asteroids and comets, are the first things dealt with in this book – the author starts small. Yet, these diminutive samples are critical to meteoritics because only such small grains can be derived from every solar system body (excepting the sun), unlike meteorites, which apparently sample only 100–200 asteroids, Mars and Moon. Norton is apparently unaware of IDPs that are not chondritic in composition (that is, not having the composition of the most primitive meteorites as well as the solar photosphere). In fact, IDPs with refractory compositions, which may be very primitive, are not mentioned. These particular particles are admittedly rare, but may be critical to our picture of the early solar system. I am admittedly a little biased in this matter, having studied these special IDPs many years ago. Norton does include a subchapter on the recovery of IDPs from Earth-orbiting spacecraft, which I was very happy to see. Also mentioned are stardust and interstellar dust grains that are being recovered from meteorites, and which are now shedding light on the origin of atoms and presolar molecules.

Alongside the discussion of meteor showers, which actually originate from comets, Norton describes NASA's current Stardust mission of comet sample return. Incorrectly, he states that the spacecraft samples dust from the comet's tail, whereas the collection will actually be made from the coma – a rather minor difference. The book covers well the topic of meteor showers; however, these phenomena derive from cometary, not asteroidal, dust entering Earth's atmosphere. Next come major aspects concerning the fall of meteorites to Earth. This topic is generally of more interest to amateur meteoriticists than to professionals. The latter are generally more interested in data provided by meteorites than information on how they arrived at the lab. However, many of us seriously ponder unusual aspects of meteorite falls, including their possible sources and the dynamic processes operating on small bodies in the solar system.

Included are detailed descriptions of the outer morphology of meteorites, the changes that occur to them during atmospheric passage, and the weathering processes that further modify them at Earth's surface. These are examples of topics that are usually given only a few paragraphs in most advanced meteorite textbooks, but which are of considerable interest to amateur meteorite collectors.

There follows a classification of meteorites, a rather confusing topic for neophytes and, for that matter, many professionals. This is done in a historical manner, so that the student can appreciate how our perception of meteorites has changed. This material is important because so many popular publications on meteorites seem bound and determined to perpetuate rather outdated schemes of classification.

A chapter is dedicated to the enigmatic chondrules, common components of most chondrite meteorites, which have been partially or totally melted in space. This topic is nicely introduced with many spectacular images, and a fair amount of discussion of their mineralogy and classification. It is a pity that this did not extend to the recent recognition that most chondrules have in fact undergone multiple melting episodes – an important clue to their formation.

Each of the major meteorites groups is then described in turn. A gratifying amount of recent results are included here, although some information is already outdated in this fast-moving field. This topic is clearly the heart of the book. Next is a nice summary of our current view of the origin and early history of the solar system, based on analytical results from meteorite studies. Norton begins by introducing concepts such as use of radioisotopes for dating and for tracking geochemical processes. Of course, entire books are devoted to each of these topics, and so little more than an introduction is possible here.

Our knowledge of asteroids, based upon meteorites and ground-based spectroscopic observation, is summarized next. Fortunately, the fabulous results of the recent NEAR Mission to asteroid Eros were available for inclusion in the book. They give the volume an immediacy not available in other meteorite books.

The final major topic is the important process of impact crater formation on Earth. Again, this chapter provides little more than an introduction. Support for basic research into this subject has been in decline during the last decade, although public interest has not flagged. However, the results of the explosive growth in interest into asteroid and cometary impact on Earth are well summarized here, with one curious exception. I could find no mention of tektites, which is rather odd given their widespread distribution and public interest.

Finally, there are several very useful appendices for amateurs and beginning meteorite students, including data on all known terrestrial impact craters, meteorite statistics, classification, and testing and preparation techniques.

Who should purchase this book? It is not well suited for many professional meteoriticists, whose specialized concerns are largely beyond the scope of the volume, and who (mainly) couldn't care less about detailed descriptions of, say, regmaglypt or fusion-crust formation. Similarly, this is not a book for pure amateurs, who will be unconcerned with the vagaries of meteorite classification, or the statistics of meteorite-fall phenomena. I have used this book successfully for a single semester undergraduate class on meteorites. Thus, an audience probably exists in the middle ground of meteorite enthusiasts, namely those people having some science background, and a more than passing interest in meteorites. There must be a large number of such individuals among this journal's readers. The fall of the Tagish Lake meteorite, in western Canada in 2000, elicited a great deal of interest in meteorites in Canada and the U.S.A. Further, the search for new meteorites and meteor craters in Canada's great northern expanses has served to educate many North Americans about the scientific value of meteorites. Lastly, meteorite prices have dramatically increased in the last decade, making enthusiasts out of many fortune-seekers. This book will find a ready market.

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