

materials. In total the 19 contributions have only 63 figures and 26 of them are graphic in nature. Geology is a visual science and I would have liked more illustrations. The history comes alive when it is depicted visually. Although the individual contributions stand alone, the editors have provided a common index that I found to be useful. As a bibliophile I enjoy perusing the bibliographies (references in the 19 contributions total 1,245) and I must say that this volume provides the reader with a concise over view of the literature on the subject.

On the whole I found the volume to be well written and tightly edited. Most of the contributions were informative and provided valuable insights on the techniques involved in determining the Age of the Earth. This book would serve well as a textbook for a graduate student seminar course because of its broad coverage of the topic. I think that this volume should be on the shelf of most geologists as it is only through a good understanding of the history of development of a concept that we truly understand it. I am sure that the final page on the quest for determining the age of the earth has not as yet been written and new methodologies will refine our understanding. The concept of deep geologic time will continue to excite future geologists and the quest to determine the Age of the Earth will continue.

## Phosphates: Geochemical, Geobiological and Materials Importance

Edited by **Matthew J. Kohn, John Rakovan, and John M. Hughes**

Mineralogical Society of America and Geochemical Society  
Reviews in Mineralogy and Geochemistry, volume 48  
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Reviewed by **Gerry Ross**

*Kupa'a Farm*  
Box 458  
Kula HI 96790  
U.S.A.

The Mineralogical Society of America has been publishing this series of reviews for nearly 30 years beginning with the initial volume in 1974 on sulfide minerals. They began publishing these reviews in conjunction with the Geochemical Society in 2001 and the series is now up to volume 53. The "phosphates" book was the text for a 2-day short course offered at the annual meeting of Geological Society of America in Denver 2002. The MSA/GS has set high standards with the publication of this series as they invariably offer an excellent snap shot of state-of-the-science in a particular area. This review is no different and offers an incredibly diverse and detailed overview of phosphate minerals.

The phosphates are an important group of minerals in that they have the greatest crossover between areas of traditional geology and mineralogy and nontraditional geoscience areas in such as medical science, materials research, and nuclear waste disposal. The phosphates are considered distinct in that they are able to incorporate more than half of the elements of the periodic table into their atomic structures. Enchanted by this and a myriad of interesting trivia encountered while reading this book, I anxiously await the day when Alex Trebeck (a good Canadian boy who has become "a true American icon" according to the Jeopardy website) and Jeopardy have

"GEOLOGY" as a theme and I can say "I'll take Mineral Facts for \$200".

The book is divided into 5 different sections: mineralogy and crystal chemistry, petrology, biomineralization, geochronology, and materials application. The first few chapters begin with the nuts and bolts of phosphate minerals chiefly the structure (Hughes and Rakovan) and composition (Pan and Fleet). Rakovan then provides a detailed look at the growth and surface properties of apatite followed by a chapter on synthesis by Boatner, who was one of the early researchers into the synthesis of phosphates as a means of using crystalline substances for radioactive waste disposal. Here I learned of a mineral detail for my day on Jeopardy, that being that the scandium phosphate mineral, pretulite is only the sixth mineral known to contain the element scandium as a principal component. I also learned that the mineral monazite, a personal favorite, is derived from the Greek *monazein* meaning "to be solitary"...I am unsure if there is a deeper psychological message here but geochronologists may want to take note. The nuts and bolts section of the book concludes with an exhaustive chapter by Huminicki and Hawthorne on the crystal chemistry of the phosphate minerals.

The section on petrology includes a diverse suite of articles that cover apatite in igneous systems (Piccoli and Candela), apatite, monazite, and xenotime in metamorphic systems (Spear and Pyle), electron microprobe analysis of the aforementioned (Pyle, Spear, Wark), and sedimentary phosphates (Knudsen and Gunter). The final chapter in this section covers the global phosphorous cycle (Filipelli), which I found to be particularly relevant to my current career as a farmer. The section on biomineralization included a chapter by Elliott on calcium phosphate biominerals. Elliot is from the Department of Dental Biophysics at University of London, a new (to me) but very interesting subdiscipline. His chapter is filled with lots of grist to enable you to become much more engaged at a technical level with your

dentist. Subsequent chapters in this section include stable isotopic compositions of biological apatite (Kohn and Cerling) and trace elements in recent and fossil bone (Trueman and Tuross). The chapter on stable isotope composition was particularly enlightening and demonstrated the breadth of applications in this field from dinosaur thermoregulation to the demise of Norse colonies based on the isotopic composition of fossil tooth enamel.

The fourth section of this book covers the broad area of geochronology of phosphate minerals. This area has seen a dramatic increase in activity with recent recognition of the widespread nature and petrogenesis of monazite as well as analytical approaches that allow for spot analyses of small grains or parts of grains. Additionally, understanding the thermal retention of He in apatite led to birth of U-Th-He dating and the blossoming of a new low temperature chronometer. Harrison, Catlos, and Montel provide the opening chapter on U-Th-Pb dating of apatite, monazite and xenotime and provide a good overview. The remaining two chapters cover low temperature geochronology, specifically (U-Th)/He dating of phosphates (Farley and Stockli) and fission track dating (Gleadow, Belton, Kohn, and Brown).

The final section of the book covers materials applications. The chapter on biomedical applications (Gross and Berndt) was a fascinating tour through what is known about apatite in the human body and the challenges of synthesizing remedial materials for bone and teeth. Ewing and Wang present a chapter on phosphates associated with nuclear waste and a concluding article by Waychunas on apatite luminescence, which again returns to the diversity of elements that can be incorporated into apatite and hence activate luminescence.

This book is a real bargain at \$40 (U.S.) and is a nice contrast to the rising prices commanded for geoscience publications by other publishers. I was impressed with the diversity of authorship as well as topic and found individual articles gave you an excellent overview of the state of research in a

particular area complete with extensive references. I would recommend this book to anyone interested in phosphate minerals and tip a hat to MSA/GS who continue to provide outstanding, affordable publications to the earth sciences world.

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