

BOOK REVIEWS

SCANNING PROBE MICROSCOPY OF CLAY MINERALS.

Edited by K.L. Nagy and A.E. Blum. Clay Minerals Society, Boulder, Colorado, 239 pages. \$26.00

The edited volume is actually the proceedings of the Clay Mineral Society Workshop Lecture Series held at the University of Saskatchewan, Canada, in August of 1994. The volume provides a more tutorial approach than is often found in journal publications and provides many helpful suggestions for researchers contemplating the application of SPM to a particular problem. The stated purpose of the volume is to introduce the theory and operation of scanning probe microscopy (SPM) to clay mineralogists, summarizing previous work that uses scanning tunneling microscopy (STM) and scanning force microscopy (SFM) in mineralogy.

In Chapter 1, C. Eggleston presents the necessary background to understand the tip-surface interaction for both STM and atomic force microscopy (AFM). This chapter also discusses the common artifacts encountered in SPM resulting from rough tips, multiple tips, variable tipshape, vibration, drift, and image processing. The chapter concludes with selected applications of SPM used to study surface microtopography, crystal dissolution and growth, and the structure and dynamics of adsorbates. A parallel treatment of the theory and application of AFM and STM to the study of mineral interfaces is presented. In Chapter 2, F.J. Wicks and co-authors discuss the use of AFM to study the atomic and molecular scale features of 1:1 (kaolinite and lizardite) and 2:1 phyllosilicates (muscovite, illite, and smectite), as well as related minerals (albite, aastrophyllite, calcite, hematite, uranium phosphates, zeolites, and gypsum). A detailed comparison of the AFM images to the crystallographic data is presented. In the case of lizardite, images obtained from the basal oxygen surface are contrasted with the AFM images of the outer hydroxyl surface. The authors present several filtering routines along with some useful hands on suggestions for obtaining high quality images of clay surfaces at high resolution. This chapter concludes with a discussion of AFM applications in the study of mineral-water interface. In these intriguing studies, AFM was used to image Cs atoms located within the siloxane cavities of clinocllore.

Patricia Dove and J. Chermak review fluid cell applications of SFM to study dissolution, precipitation, and growth, and nucleation reactions of calcite, quartz, and hematite in Chapter 3. Through control of the solution phase in contact with mineral surfaces, in-situ SFM images can be obtained over time to study the influence of sorbed ions, pH, temperature, and the presence of organic molecules on growth patterns and formation surface precipitates. These applications permit in situ observation of the solid phase (e.g., changes in microtopography) to be examined under carefully controlled conditions in an aqueous environment.

The last two chapters by A. Blum and K. Nagy review the application of SPM methods to study illite/smectites and fibrous illite particles. In Chapter 4, A. Blum discusses the application of SFM to determine the thickness of illite/smectite handling, treatment, and mounting methods are discussed as are image artifacts and related limitations. The relationship of these SFM methods is presented. The final chapter by K. Nagy shows how SFM methods can be used to determine growth rates of fibrous illite particles. Sample preparation and presentation methods are discussed along with a discussion on how to use SFM data to quantify growth rates.

Overall, the book contains a valuable collection of information for scanning probe microscopists or geoscientists contemplating the use of scanning probe microscopy for a particular application. The scope of the book extends beyond clay minerals to many other significant mineral phases of geochemical importance. At a time in which book prices seem to rise much faster than inflation, the volumes in this series are a good bargain. The topics covered in this volume are of interest to researchers interested in the shape, size, composition, defect structure, microtopography, or reactivity of mineral surfaces.

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IGNEOUS PETROLOGY, 2nd Edition. By Anthony Hall. Longman Group Ltd., London, 1996. xiv & 551 p. \$35.06

Reading the second edition of Anthony Hall's textbook, *Igneous Petrology*, left me feeling unstuck in time. Like Billy Pilgrim in Kurt Vonnegut's *Slaughterhouse Five*, I seemed to be simultaneously in different eras of petrologic thought. This was not at all unpleasant and in fact it connects with strengths of the book that make it a valuable addition to the literature, but it leaves me uneasy about recommending it as a text for undergraduate students at whom it is implicitly aimed.

Hall's new text is the modestly revised successor to a first edition that appeared in 1987. The stated objective of the book is "to review what is known of the origin of igneous rocks and magmas." It is assumed that "...the student... will already have some knowledge of mineralogy and of the petrography and classification of igneous rocks." The text is organized logically into two long sections, each encompassing seven chapters. The first section deals with the occurrence, composition, and evolution of magmas, and the second section deals with major igneous rock groups. An interesting mix of information is tabulated. Coverage of elemental and isotopic data is not bad, though rather spotty, and there are many useful tables of data on the physical and chemical characteristics of melts, rocks, and elements and on the distributions of rock types and characteristics of their field settings. Figures are abundant and clear, but there is a total absence of photomicrographs and field photos. Although they are useful, the many maps, cross-sections, and field sketches are not a sufficient replacement for photos. The table of contents is very complete and the index, though not extensive, seems adequate. The book has been carefully proofread, as I found almost no typographical errors or errors in figures.

The first section, on occurrence, composition, and evolution of magmas, includes chapters titled "Igneous activity at the present day," "Volcanism," "Intrusion," "The chemical composition of igneous rocks," "Melting and crystallization," "Isotopic composition," and "Magmatic evolution." The initial chapter presents the environments where magmatic activity is evident at the surface today (i.e., modern volcanism), forming a very logical beginning to the subject of the text. The second chapter discusses physical controls, styles, and products of eruptions. Chapter 3, "Intrusion," is lengthy and contains many field examples, but it seems rooted in strong 1960s interest in and ideas about pluton emplacement. Present-day interpretations and controversies, for example concerning diapirism, dike transport, and syntectonic emplacement, are omitted. "The chemical composition of igneous

rocks" (Chapter 4) provides a great deal of useful information concerning elementary geochemistry as it relates to magmatic processes and chemical variation of igneous rocks. It neglects, however, to address quantitative ways of interpreting elemental data (e.g., modeling of trace element partitioning; graphical evaluation of mixing and unmixing). Chapter 5, "Melting and crystallization," presents a much more thorough evaluation of crystal-liquid phase equilibria than is available in most petrology texts. It is uneven in clarity—some of the treatment is clear and incisive, some rather murky. Schematic illustrations, used to good advantage elsewhere in the text and potentially valuable here to help students to visualize processes, are absent. Instead, there are an enormous number of classic phase diagrams. "Isotopic composition" (Chapter 6) covers a lot of ground but it is largely descriptive and rather outdated. It lacks any quantitative treatment of isotopic systematics and fails to explain the controls of isotope evolution: If a student didn't already understand the connection between parent/daughter ratio, time, and evolution of isotope ratio, he or she would not get it from this chapter. The concluding chapter of the first section (Chapter 7, Magmatic evolution) is again very thorough in covering all imaginable ways in which magma compositions can be modified (or at least all that I can imagine). The student receives a clear idea about what can happen to a magma, some nice insights into evaluating magmatic products, and plenty of examples. The coverage strikes me as sometimes quirky (e.g., "liquid fractionation" given more coverage than mingling and mixing of magmas; statements that contamination plays a major role in the evolution of granitic rocks, but only a minor one for basalts, and that there are no incompatible elements in granites).

The second section describes major groupings of magmas and igneous rocks, with chapters titled "Basalts," "Granites," "Andesites," "Alkaline igneous rocks," "Kimberlites and ultrapotassic igneous rocks," "Peridotites," and "Anorthosites." These are useful, information-filled chapters on petrogenesis, with most major hypotheses for origin of all major igneous rocks presented and discussed. However, the coverage of newer ideas is sparse and a few misstatements and misconceptions are present (e.g., that temperatures of 900 °C are expectable at the base of 30 km thick crust and that crystals do not separate from felsic melts).

The greatest strengths and weaknesses of Hall's text arise from its sense of our understanding of petrology through time: It admirably recognizes ideas of the past forty years or so upon which our present knowledge is built, but at the same time it is detached from the evolution of that knowledge in recent years. Scanning of the references gives an idea of this reliance on the past (12% are from the 1990s, 34% from the 1980s, 29% from the 1970s, 24% pre-1970s). Presenting older studies and interpretations is invaluable because they can illuminate the origins of present interpretations and the way in which scientific thinking evolves. It can also bring to our attention overlooked studies of the past that clarify problems that we face today. Many worthwhile older studies are dealt with here, especially field-oriented investigations that made valuable use of observations that are often neglected with today's emphasis on geochemistry. However, there is no real sense of history here. Ideas from 1960 are commonly treated together with those of the mid-1990s with no distinction and no indication of new building upon old. Hence, my sense of being "unstuck in time." The reader is left with the impression that *when* an idea is proposed is not relevant. In fact, many ideas of the 1990s have developed by taking into account and testing the knowledge and hypotheses that had accumulated in previous decades—or at least they should have. Clear examples of both the neglect and the use of older studies in modern work would strengthen the text and validate its historical emphasis.

Besides its window into past petrologic research, the text has other noteworthy strengths. It is thorough in its coverage, introducing the reader to an enormous range of topics. Though not always emphasize-

ing modern interpretations, the text touches upon almost all important controversies in igneous petrology and it provides more basic data and field examples than most competing texts. It is readable and well organized.

Igneous Petrology appears to aim for the undergraduate market. At least in the United States, I believe that it misses this mark. First, as noted above, I believe that it will be confusing for undergraduates who need both to recognize modern interpretations and understand their historical underpinnings. Although the material is here to reach this goal, it is not presented in an easy to understand context. Second, it assumes a background in petrography and petrologic terminology that very few of our undergraduates have before taking petrology. Third, it has no problem sets, and it generally does not provide a background that lends itself to development of the instructor's own problem sets. On the other hand, the text is also less than ideal as the sole text in an advanced igneous petrology class, for some of the same reasons. Any advanced class should provide a much more thorough, quantitative treatment of the interpretation of petrochemical data.

Does *Igneous Petrology* have a niche? Although it is not an appropriate text for an unsophisticated reader who expects a clear, up-to-date evaluation of the latest petrologic ideas, I would nonetheless emphatically say, yes, it is a book to be taken very seriously. It is a very good reference book for graduate students and faculty with an interest in igneous petrology. There is a large amount of information here that is extremely useful. It could be a valuable supplementary text in a graduate class, where quantitative geochemistry is provided by the instructor or another text and the implicit historical evolution of thought can be sorted out by the more sophisticated student. At \$35.06, the paperback text is a bargain. I can honestly say that I enjoyed reading the book and learned a lot in doing so. I urge libraries to purchase it and encourage interested students and faculty to buy it as well.

A final note: I should emphasize that my criticism of Hall's text is tempered by my respect for the magnitude of what he has accomplished. It is easy for me to spot what I consider its flaws, but compiling this quantity of information into a coherent form is an impressive achievement, one that I cannot imagine doing myself and that I very much appreciate his having done.

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MAGMAS, FLUIDS, AND ORE DEPOSITS. Edited by J.F.H. Thompson. Mineralogical Association of Canada, Nepean, Ontario, 1995. Short course Volume 23, vi+525 pages; \$48.00.

The role of magmatic processes in ore genesis has been intensely debated for over a century. The spatial association of igneous rocks to ore deposits of different types has been empirically applied in minerals exploration for a long time, but understanding and integrating the genetic interrelations of hydrothermal processes and magmatism into exploration models and programs has been slower to occur. Diverse research studies on magmatic processes during the past decade or two and the increasingly more challenging task of exploration have resulted in a renewed interest in magmatic-hydrothermal processes within the economic geology community. This volume is a collection of review papers presented at a short course on magmas, fluids, and ore deposits held in Victoria, British Columbia, that reviews magma genesis, magmatic-hydrothermal processes during emplacement and crystallization, tectonics, and implications for ore formation.

The first six chapters in the volume are well-documented reviews of theoretical and experimental studies of volatile production and evolution during assimilation (Chapter 1), fluid evolution in layered intrusive sequences (Chapter 2), degassing processes during magma-

chamber crystallization (Chapter 3), applications of silicate-melt inclusions to magmatic volatiles studies (Chapter 4), experimental and computational study of metal partitioning between melts and vapor and vapor and brine or both (Chapter 5), and gold partitioning among selected sulfides and magnetite in chloride solutions (Chapter 6). These chapters are reviews of already published work with only brief discussions and interpretations of new data. They serve as a laboratory backdrop to the field-based studies that follow.

Chapters 7 through 13 review the empirical evidence for the linkage between magmatic processes and some types of ore deposits. Fluid inclusions serve as the primary source of evidence on the role of magmas in porphyry copper (Chapter 7) and porphyry molybdenum deposits (Chapter 8). Rare alkalis (Li, Rb, Cs) and high field strength elements (Nb, Ta, W, Sn), which are incorporated into peraluminous melts during melting reactions involving aluminous minerals in the crust, are empirically observed to occur in and to be associated with Li-Cs-Ta bearing granites, pegmatites, and rhyolites (Chapter 9). Chemical reaction-path modeling quantitatively predicts the wallrock alteration and ore deposition observed in these lithophile metal deposits, supporting the empirical observation (Chapter 10). Along convergent plate boundaries, the isotopic compositions of discharging geothermal fluids show that magmatic waters may constitute up to several percent of the discharge, with volatiles being derived from various sources (Chapter 12). The discharge rate of material and fluids from volcanoes and metal fluxes are correlated, with volcanic eruptions containing higher metal concentrations than passive degassing of low-pressure vapors from volcanoes (Chapter 13). New data from the analysis of fluid-inclusion gases (Chapter 11) from ore deposits in close proximity to igneous rocks are more similar to emissions from active volcanic fumaroles in various tectonic settings than are inclusion gases from deposits more distant from intrusive rocks.

Case histories regarding the central theme of the book are presented in Chapters 14 and 15. Isotopic, thermochronometric, and bubble-like textural features in granite are evidence that rare earth element- and uranium-bearing veins are genetically linked to the emplacement of the Capitan pluton in New Mexico (Chapter 14). The possibility that saline formation waters may contribute to some porphyry copper ore fluids and the proportional contribution is considered at Yerington, Nevada, from the analysis of previously published and new data (Chapter 15).

Chapters 16 to 21 are overviews of the role of magmatic fluids in the genesis of a spectrum of ore-deposit types. These papers are on

alkalic-rock related porphyry copper deposits (Chapter 16), "alkalic type" epithermal deposits (Chapter 19, "low sulfidation" epithermal deposits (Chapter 20), and sea-floor hydrothermal systems that produce volcanogenic massive-sulfide deposits (Chapter 21). Although differing in emphasis, each paper presents the geochemical characteristics of the deposit type and a conceptual model of how the deposits are formed. The last chapter discusses how the magmatic hydrothermal models might influence exploration strategies in volcanic-arc environments (Chapter 22). Organized around different deposit types, this Chapter emphasizes the implications of location of deposits relative to intrusive centers and translates geochemical information into descriptive terms.

The volume succeeds admirably at its goal of reviewing the current thinking of advocates of magmatic contributions to many types of hydrothermal ore deposits. It is adequately illustrated and the reference listings provided in each paper are current and extensive. At a time when scientists interested in ore deposits must keep up with research results in a plethora of international journals, this review is a quite useful and affordable introduction for the advanced student and practicing geologist. The volume has a few main shortcomings. First, it requires considerable prior knowledge of geochemistry and ore deposits to understand the logic and arguments used in many of the papers. Second, the authors all appear to be cut from the same cloth, thereby depriving the reader of many alternative perspectives, (e.g., the very high empirical correlation between the occurrence of volcanic-rock related polymetallic lead-zinc veins and replacements and continental platform to slope sedimentary rocks in the basement or the possibility that lakes may contribute alkalis and chloride to hot-spring systems). Third, the symposium wholly disregarded the new insights on the physics of magma rise and ponding into pluton-sized bodies in the shallow crust and the implications this has for ore genesis. Fourth, the interrelations of shear stress and fluid-flow velocity and acceleration in the shallow crust are important topics that are not considered. Finally, the volume largely ignores ore-depositing systems with more enigmatic relations to magmas (e.g., syndeformation systems and shear zone-hosted hypo- to mesothermal veins). Consequently, the volume is most useful as a review and pathfinder to supportive literature for the more advanced student or experienced geologist, but does not stand alone as a balanced resource for introductory studies.

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