JOURNAL OF PETROLOGY | VOLUME 41 | NUMBER 12 | PAGES 1821–1825 | 2000

Book Reviews

***Encyclopedia of Geochemistry*, edited by Clare P. Marshall and Rhodes W. Fairbridge. Kluwer Academic, Dordrecht, 1999. 712 pp. ISBN 0-421-75500-9. £280.**

Geochemistry has been in the vanguard of what many have described as the second major revolution in the Earth Sciences. The development of plate tectonic theory marked the profound shift in emphasis from description of what was preserved in the geological record, to investigations of the processes responsible. Understanding of processes in turn requires the best possible estimates of when and how fast they took place. In very many instances what we can know depends on how well we can tell time. Geochemistry has evolved from its initial aims of documenting the compositions of terrestrial materials and ore deposits, to leading the way in designing new experiments to determine the controls on natural processes. Much of its contribution has been through the fields of isotope geochemistry, which has arguably redefined the old boundaries between the more classical subject areas in geological sciences. The age of the Earth, and hence the vastness of geological time, was a landmark for both practical sciences, and philosophically. For a while those huge tracts of time encouraged notions that things change slowly, and yet in practice many of the major changes have taken place in intermittent, short-lived high-energy events. It is perhaps less widely appreciated that geochemistry has led the way in the development of many analytical techniques, and this drive continues with the increasing application of high-resolution *in situ* measurement techniques. As models become more sophisticated it is even more important to be sure of exactly what has been analysed, its internal structure and its textural relation to other phases.

There have been a number of scientific encyclopedias that have tended to offer longer articles in key subject areas, often with colour illustrations. The *Encyclopedia of Geochemistry* is very different, for here is a determined attempt to be genuinely comprehensive across a vast field, and the result is extremely impressive. There are almost 350 short articles on topics that range from Crystal Field Theory to Meteorites, from descriptions of individual elements to subject areas such as Surface Geochemistry, from Geoavailability to Oxygen Isotopes to Precambrian Geochemistry. The list is impressive in scope: Hydrocarbons follow Holmium, History of Geochemistry, Henry's Law, Helium Isotopes, and Helium, and many of the contributions benefit from having been written by individuals who are highly respected in their fields. The articles are lucid, and invaluably they often manage to combine basic information with a flavour of the different subjects. Organic geochemistry is represented, and there are contributions on Natural Resources, Equilibrium, and Environmental Geochemistry of Plutonium, and specific analytical techniques such as Isotope Dilution, Neutron Activation and Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry. The space devoted to different topics varies from perhaps a sixth of a page on Astatine (the heaviest of the halogens!) to 10 pages on Earth's Ocean Geochemistry by Joris Gieskes. Other notable essays include those by Scott McLennan and Ross Taylor on the Earth's Continental Crust, Magmatic Processes in six pages by Robert Cullers, Phase Equilibria by Robert Luth, and the Earth's Formation and Geochemical Evolution by Herbert Palme. There are clear black and white diagrams where needed, a few photographs, useful bibliographies for further reading, and cross references to other topics.

This *Encyclopedia of Geochemistry* has been painstakingly put together over a number of years, and the care and attention to detail has been very worth while. Here is a volume that exceptionally compiles basic information, and the details of commonly used techniques, with essays of introduction to different subject areas. It is expensive, but it has been a considerable undertaking and it would be hard to argue that it is not worth the price. Every Library should certainly have a copy, as it will be widely used by students, researchers and teachers alike, and I have used it repeatedly in the few months it has been on my shelves. Fittingly, Bill Fyfe wrote the sections on Geochemistry and on Soil, and as he is always quick to remind us 'geochemistry has a key role in the future wise management of the Earth', and as 'in terms of human times, soil is a non-renewable resource, ... Today we have a soil crisis on this planet'. For all sorts of reasons, more and more people need to understand how the Earth works, and this volume is a considerable resource for those working towards that goal.

Chris J. Hawkesworth
Department of Earth Sciences
University of Bristol

***Potassic Igneous Rocks and Associated Au–Cu Mineralization*, 3rd edn, by D. Müller and D. I. Groves. Springer Verlag, Berlin, 2000. xiii + 252 pp. ISBN 3540663711. £44·50, US$79·95**

Potassium-rich igneous rocks are one of the most intriguing study subjects in igneous petrology and geochemistry. They show a very wide range of composition, from mildly potassic shoshonitic suites associated with calcalkaline magmas in arc environments to ultrapotassic leucitites, kamafugites and lamproites. Major, trace element and isotopic compositions are very variable, although all show high to extreme enrichment in several trace elements, such as Th, U, Rb, Ba and LREE. Potassic and ultrapotassic rocks occur in various tectonic settings, from island arcs and convergent continental margins to cratonic areas. They also have an economic interest, as they may be associated with mineralization and may host precious minerals, such as the case of diamond-bearing lamproites. Because of all these factors, potassic rocks have attracted the attention of petrologists, geochemists and economic geologists. Yet, books on these rocks are virtually lacking.

The book by Müller and Groves fills this gap by giving a review of classification, genesis, tectonic settings and economic aspects of potassic rocks. The book basically consists of two parts; in the first half (Chapters 1–4), the authors elucidate the aspects related to nomenclature, tectonic setting and petrogenesis of potassic rocks, and provide a short description of the main type localities from various tectonic settings. In the second part of the book (Chapters 5–19), the economic aspects are reviewed, placing emphasis on the association of potassic rocks with Au–Cu mineralizations.

Chapter 1 is an overview of the main compositional characteristics of potassic and ultrapotassic rocks, their nomenclature and mode of occurrence. Chapter 2 focuses on the tectonic setting of potassic rocks. Here, the authors show how some of the classical trace element discriminant diagrams do not work for potassic magmas and a new hierarchical scheme is erected to discriminate among potassic rocks from various tectonic environments, including continental arcs, postcollisional arcs, initial and late oceanic arcs and within-plate settings. Chapter 4 is a short description of selected type localities of potassic rocks from the five tectonic settings. Here, the Central Africa Rift Valley occurrence is used as an example of intraplate potassic magmatism, even though these rocks were not considered in Chapter 3, when the database was built up.

Chapters 5–7 face the controversy regarding the relative contribution of magmatic vs metamorphic and crustal vs mantle origin of fluids responsible for transport of precious metals associated with potassic magmatism. Relevant case histories of direct and indirect association between potassic rocks and Au–Cu deposits are described. The considered occurrences cover a wide range of ages and tectonic settings, from the Archaean mesothermal gold mineralizations of the Superior province (Canada) and Western Australia, to the Eocene Bingham (Utah) porphyry copper deposit, Miocene epithermal gold mineralizations of El Indio (Chile) and Pliocene–Quaternary mineralizations of Papua New Guinea. For each occurrence, information on age and nature of mineralization, regional geology, and age, petrology and geochemistry of associated potassic rocks are given.

Chapter 8 contains a short but informative discussion on the behaviour of halogens (F, Cl) in magmatic systems during partial melting and fractional crystallization, and on the role of halogen-rich fluids for the transport of metals in ore deposits related to potassic rocks. Particular attention is devoted to the role of redox conditions of magmas and mantle sources in determining the behaviour of these elements and their capability to transport metals.

In Chapter 9, petrological, geochemical and tectonic aspects discussed in the previous chapters are combined and reconsidered critically to explore the implications for strategies of mineral exploration.

Finally, Chapter 10 consists of various tables that report the main characteristics of various Au–Cu deposits, with details on age, type and exact location of mineralization, production and estimated reserves, texture, mineralogy and geochemistry of associated potassic rocks.

Academic geoscientists are mainly interested in the petrogenesis of potassic magmas and in the implications for composition and evolution of mantle sources. After reading this book, one looks at potassic rocks with very different eyes and better appreciates how many close relations exist between magmatology and economic geology.

In general the book is well written and clearly illustrated with well-drawn figures, and has several simple and informative tables. This makes the book easy to read.

There are also, however, a number of items that most people will probably consider to be questionable or unfounded. For instance, it is not clear why data on rocks from Central Africa were not considered in the database erected in Chapter 3. Yet Central Africa is a typical intraplate occurrence, as stated in Chapter 4, where the Virunga volcanic province is described as a typical example of intraplate potassic volcanism. An additional problem relates to the tectonic setting of various potassic occurrences, given the debate existing in the literature for many of them; for instance, is the Roman province an example of a continental arc or is it a postcollisional magmatic province as suggested by several researchers? The same problems apply to other occurrences, and raise doubts on the general validity of the discriminant diagrams presented by the authors. These,

however, look interesting and appear as good tools to characterize several types of occurrences, independent of the tectonic significance they may have. I feel that these diagrams will be extensively used and will certainly stimulate further research on relations between geochemistry and tectonic setting of potassic magmas. Also, the statement that lamproites are typical intraplate rocks will not be shared by those scientists working on lamproites from the western Alps, northern Apennines, SE Spain and other orogenic areas.

Overall, the book is valuable, well written and clearly illustrated, and will be an important reference text to scholars and students interested in potassic magmatism, mineralization, igneous petrology and economic geology.

Angelo Peccerillo
Piazza Università, Perugia, Italy

***Geochronology and Thermochronology by the $^{40}Ar/^{39}Ar$ Method*, 2nd edn, by Ian McDougall and T. Mark Harrison. Oxford University Press, Oxford, 1999. 269 pp. ISBN 0195109201. £65**

When the first edition of McDougall and Harrison appeared in 1988, it summarized the state of knowledge in Ar–Ar geochronology, and provided every graduate student and academic with essential details and knowledge of the technique. It was not an easy read, but went far beyond the summary chapters on Ar–Ar geochronology in general isotope geology texts. It had some foibles, such as the infamous errors in the diffusion equations in Table 5·1 (included, it was rumoured, to catch the unwary Ph.D. student). It was, and remains the essential reference book found in every Ar–Ar laboratory throughout the world. My edition was very well thumbed and continued to be one of the books most often pulled from the bookcase behind my desk. *Geochronology and Thermochronology by the $^{40}Ar/^{39}Ar$ Method* is the only dedicated book expounding $^{40}Ar/^{39}Ar$ dating techniques, theory and interpretation, and as such has had a huge influence on the Ar–Ar community.

The book is now over 10 years old and has been in need of a second edition for several years. So the question is, if you have the first edition, should you use up those very limited funds for books, to buy the second edition? The short answer is yes. As the authors state in their preface, there have been several improvements in the techniques, automation and lasers, in particular, but there have also been several advances in interpretation. I would go further and say that the techniques you will be using now and the application papers you will want to find, are described and referenced in this edition and not in the first edition. Now does that mean it is perfect ... every Argonaut's dream? Not quite, there are many good things about the new edition and a few not so good.

The first three chapters retain their original titles and retain the flavour of the first edition, chiefly by retaining many of the diagrams. However, the early chapters have been fully updated and I found excellent new sections on the use of lasers, including discussions of single grain analysis, dating young volcanic rocks and high spatial resolution techniques, which I think have been the main technical advances of the last decade. These new techniques have been important in the increase in popularity of Ar–Ar geochronology and growth in number of Ar–Ar laboratories. The sections on materials suitable for dating have also received comprehensive updates, including the newer literature examples and newly introduced mineral systems such as the manganese oxides. There are also particularly important updates to error calculation, the nuclear reactors and international standards. The question of intercalibration of standards, a particular area of controversy for Ar–Ar dating in recent years, is handled in detail.

The later chapters depart more completely from the original book, starting with a clear exposition of data presentation and interpretation. My first complaint, however, is that the anion vacancy model for excess argon diffusion at different rates has made it into the second edition. I thought most workers now attributed the release of excess argon at high temperatures to melt inclusions as shown by Esser *et al.* (1997), which is referenced elsewhere in the book. The rest of the section on excess argon is dominated by use of duplicate steps to correct K-feldspar cycle heating experiments and misses the opportunity for a general discussion of excess Ar in solid and fluid inclusions. The chapter on Ar diffusion theory and measurements is still the only complete text on the subject, and as such it is worth a book by itself, but, oh dear, Table 5·1 seems to have made it through to the second edition unchanged! The chapter contains the most up-to-date work on K-feldspars derived from cycle heating experiments. For those of you who have been asleep for the last decade, K-feldspar thermochronology is a technique developed chiefly by the UCLA group led by Mark Harrison, which can reveal continuous thermal histories from plutonic K-feldspars. All aspects of the technique are explained and discussed in the thermochronology chapter, including some aspects so new they have not even appeared in print yet! The applications and case histories chapter covers stratigraphic dating of igneous events and thermochronology, both of which are new and give real insight into the techniques. The stratigraphic geochronology covers the K/T, for some reason denoted the K/P by the authors, and a section on dating young tuffs associated with hominid evolution,

one of Ian McDougall's special interests. The section on thermal histories of continental crust details the contribution of K-feldspar thermochronology to thermal history studies, Mark Harrison's area of special interest. In fact, K-feldspar thermochronology permeates many new areas of the book, and its successes are applauded, as you might expect. Its seems, however, that the authors ran out of steam at the end, and two application sections, paleomagnetism and lunar geochronology, from the original book are repeated. Neither is particularly current and I would rather have seen some applications in the areas of current attention such as perhaps the huge increase in the use of plagioclase for dating extremely young volcanic rocks, discriminating against contaminating older grains in tuffs, dating manganese minerals or direct Ar–Ar dating of deformation.

Finally, is the second edition of McDougall and Harrison value for money as an Ar–Ar source book (because it is not cheap)? Do the readers of *Journal of Petrology* need this second edition? The answer is yes; it is easy to grumble if some aspects of the subject are not covered in detail, but in fact it is a remarkably difficult task to write such a source book and keep it up to date. The authors have succeeded in updating their original work and making it relevant to modern Ar–Ar dating.

Simon P. Kelley
Department of Earth Sciences, Open University

Mantle Petrology: Field Observations and High Pressure Experimentation (a Tribute to Francis R. (Joe) Boyd) **edited by Y. Fei, C. M. Bertka and B. O. Mysen.** ***Geochemical Society Special Publication 6.*** **The Geochemical Society, Houston, TX, 1999. 322 pp. ISBN 0941809056. US$55 for members; $85 for non-members**

Joe Boyd, a stalwart of petrology, officially retired from the Geophysical Laboratory in 1996 after 43 years of service. In an effort to immortalize this event in the annals of petrology, Boyd's colleagues organized a symposium, which resulted in this edited volume. Joe Boyd's versatility is legendary: his contribution ranges from 'hard core' experimental petrology and to field and laboratory based studies. Boyd's pioneering work on the nature of the Earth's mantle has inspired many, including this writer, to fall in love with those tiny gifts from the mantle, packaged as 'xenoliths', brought to the surface by lavas. Understandably, the editors, all of whom are theoreticians and experimentalists, tried to organize this volume in such a way that it appropriately reflects Boyd's research interests, and divided the various contributions into 'Field Observations' and 'High-Pressure Experimentation' categories. In a sense, the title of the first group is misleading inasmuch as the papers in this category involve highly sophisticated laboratory based isotopic and trace element studies of xenoliths and thus they go far beyond being simple 'field observations'.

The volume begins with an excellent synopsis of Joe Boyd's outstanding academic career, written by none other than Hatten S. Yoder, Jr, another legend in petrology. Part 1 (Field Observations) of the book consists of eight papers. The lead article, by Rudnick & Nyblade adopts the classic Boydian approach of figuring out the thermal state of the sub-continental lithosphere from P–T equilibration conditions of mantle xenoliths brought up by kimberlites. An interesting and significant shift in the work by Rudnick & Nyblade from the earlier work by Boyd and colleagues is in its adaptation of a more modern (and presumably better) thermobarometer. Rudnick & Nyblade then proceed to obtain constraints on lithospheric heat flow and on the thickness of the continental lithosphere based on the xenolith P–T values. The second paper, by Griffin *et al.*, revisits the issue of the compositional aspects of the continental and oceanic lithospheres, which was Boyd's theme in his well-known 1989 paper. These authors use a much larger database than was available to Boyd over a decade ago. Griffin *et al.* make an attempt at addressing the issue of secular variation in various compositional characteristics of the sub-continental lithospheric mantle. The authors appear to have introduced some new acronyms that this reviewer was not aware of. Shimizu's paper follows, with a short but strong cautionary note about how young mantle metasomatic events can significantly modify 'primary signals', i.e. the modal and chemical characteristics of the lithosphere that would have originally derived from some very old events. Aptly, the author wonders in the end about how much of a sampling bias is introduced by the kimberlitic xenoliths and about the utility of understanding the lithosphere from xenoliths. The fourth paper, by Pearson, moves away from elemental geochemistry, which is the topic of the first three papers, to isotope geochemistry. The author provides a review of the Sr, Nd and Os isotopic composition of kimberlitic xenoliths, and visits the issue of craton formation and history of the continental lithosphere in various localities. The distinctive recording capability of the Os system (as opposed to Nd, Sr systems) of early stages of craton formation is well brought out. The next paper, by Silver *et al.* on petrofabric analyses of xenoliths and seismic anisotropy, is an abrupt departure from the geochemically oriented papers. These authors explore a very new area of research on continental deformation to mantle tectonic processes using somewhat classical methods of structural geology. Haggerty's contribution offers a classic exposé

on diamonds and craton formation beginning with the meaning of the term 'craton'. This author combines a variety of data, ranging from simple geographical–geological associations to sophisticated isotopic analyses, to review the origin of diamonds. Haggerty takes this opportunity to put forth his petrogenetic model that combines diamond petrogenesis with superplumes, superchrons and kimberlite formation. Harte *et al.* then guide the reader to a very interesting suite of ultra-deep inclusions in diamonds from a location in Brazil. These inclusions provide an exciting window into the top 100 km of the lower mantle. The next paper, by Grove *et al.*, represents a significant departure from the previous chapters in that it looks into the origin of komatiites from a largely experimental perspective. In fact, the editors' decision to include this paper in the 'Observations' section (and not in the 'Experimental' section) is somewhat surprising. The origin of komatiites and continental lithosphere evolution was a topic of some interest to Boyd, who gave it some thought in his 1989 paper. Using new and other experimental data, mainly collected in the MIT laboratory, Grove *et al.* present a case of generation of Archean komatiites in H_2O-bearing conditions over paleo-subduction zones.

Part 2 ('High-Pressure Experimentation') of this book consists of eight more papers, from classical haplo-peridotite–basalts in simple analog systems to volatiles in the mantle. The first paper, by Smith, takes a close look at thermometers and barometers for upper-mantle lherzolitic assemblages and makes specific recommendation about which combination of thermometer and barometer to use. He also examines how temperatures estimated on natural lherzolites correlate with their textural and compositional aspects of equilibrium or disequilibrium (i.e. mineral zoning, isotopic disequilibrium and closure). Fei & Bertka then review experimental data that are relevant to deep mantle mineralogy and phase transitions. They start out with simple system phase relations, such as Mg_2SiO_4, and extend their review to natural lherzolitic bulk composition. All along they stay focused on subsolidus relations. The next contribution, by Presnall, examines the intricacies of phase relationships that would control fractional crystallization of basalt magma within the lithosphere (0–3 GPa). This review is based largely on the experimental work on the analog systems performed in his laboratory. The author then proceeds to discuss the petrogenesis of basalts erupted at mid-oceanic ridges, Hawaii and arcs. The two chapters that follow examine the origin of the cratonic lithosphere from a largely experimental perspective. Walter and Herzberg both model the nature of partial melting residues of a 'fertile' peridotitic mantle as a function of pressure and substantiate Boyd's earlier observation that cratonic lithosphere is generally (with at least one possible exception—Tanzanian craton) enriched in orthopyroxene. They review the plausible mechanisms that produced this enrichment: whereas Walter supports the concept of melt–wall rock (lherzolite) reaction as the mechanism for orthopyroxene enrichment, Herzberg argues that the enrichment is due to thorough mechanical mixing of orthopyroxenite cumulates and depleted olivine-rich residues of melting. Herzberg takes this a little further and argues for a connection between plume magmatism, komatiite formation and orthopyroxene enrichment of the cratonic lithosphere. The last three chapters review the phase relationships in the hydrous and carbonated mantle. Ulmer & Trommsdorff examine the stability of various hydrous phases and their breakdown reactions up to 10 GPa, whereas in the following chapter, Frost does the same at pressures in excess of 10 GPa. In the final chapter, Luth provides a review of how carbon is hosted in the mantle as a function of pressure. In the process, he examines many related issues, starting from mantle oxidation states to phase equilibrium of carbonated peridotites.

This book is 322 pages long, nicely hard bound, and is devoid of color illustrations and typographic errors. Black and white (and some grayscale relief) illustrations work well in most cases; only in one or two chapters are some illustrations a little cluttered. The publisher has made a real attempt at keeping the cost down. I like almost everything about this book and feel that every graduate student, post-doctoral fellow and professor of petrology should own a personal copy. Thanks to this journal I will cherish my own free copy!

Gautam Sen
Department of Geology, Florida International University