

Book Reviews

***Modern Approaches to Ore and Environmental Mineralogy*, edited by Louis J. Cabri and David J. Vaughan. Short Courses Volume 27. Mineralogical Association of Canada, Ottawa, Ontario, 1998. 421 pp. ISBN 092129400X. US\$48.**

My expectation on reading the title of this volume was that it would contain a series of case studies on how mineralogy could be useful in understanding ore and environmental issues. Instead, the book is almost entirely composed of descriptions of modern techniques used in mineralogy. It contains a collection of papers that formed the basis of a short course held under the auspices of the International Mineralogical Association's Commission on Ore Mineralogy (COM). The content ranges from sample preparation, the use of a simple optical microscope and crystal chemistry of ore minerals to a description of the advantages and disadvantages of sophisticated pieces of equipment for particular types of mineralogical analysis. Thus there are chapters on the electron microprobe (EPMA) especially its use in trace element analysis, low-vacuum scanning electron microscopy (SEM) where coating is not necessary as in ordinary SEM, proton microprobe particle induced X-ray emission (PIXE) for heavy elements, secondary ion mass spectrometry (SIMS) for all elements and isotopic discrimination, high-resolution SIMS or SHRIMP, cathodoluminescence for distinguishing minerals formed under different conditions, and image analysis with applications in mineral processing. For completeness I would like to have seen a chapter on the use of laser inductively coupled plasma mass spectrometry (ICPMS). Throughout, there is an emphasis on how these techniques can be used to analyse ore minerals, and the last two chapters deal with the mineralogy of sulphide-bearing mine wastes, acid mine drainage and the use of minerals to neutralize weathering products. The techniques chapters concentrate on the types of elements suitable for analysis in minerals and their detection limits. How the equipment works, 'the nuts and bolts', is described in detail for both standard and advanced pieces of equipment, and the effect of the analysis on the sample is also considered, examining the process as destructive or non-destructive on the sample. Limitations of analysis and problems of calibration with the use of standards and the possibility of standardless analysis are also highlighted. Although individual chapters are by different authors the equipment being discussed is often compared within that chapter with other

equipment more fully described in other chapters and so there is a chance for the reader to decide which is the best technique to choose for a particular problem. Each chapter is written by an acknowledged international leader in their analytical field and it is an impressive lineup of experts. This volume is not the type of book that one should read from cover to cover but it provides a very useful starting point for someone needing to know about a particular mineralogical technique because chapters start from basics and progress to cutting edge new developments in the uses of the techniques and there are abundant references for further information. The book is full of useful tables of properties of minerals and has some spectacular colour plates. The preface states that ore mineralogy is an important subject but is currently too little valued. I agree entirely with this statement, as mineralogy is such a fundamental part of all materials in geology and the environment, and an understanding of the mineralogy is vital to understanding processes that formed all Earth's materials. This book is full of information on how to study the structure and chemistry of minerals, and it is up to the reader to extract ideas from this text to help them solve their mineralogically based problems.

Hazel Prichard
University of Wales, Cardiff

***What Drives Metamorphic Reactions?* edited by P. J. Treloar and P. J. O'Brien. Geological Society of London, Special Publication 138. 287 pp., indexed. ISBN 1-86239-009-6. US\$115/£69 for non-members and US\$57/£34 for members.**

The 14 papers in this volume were presented at the Metamorphic Studies Group meeting at Kingston University in September 1996. As can be expected, the contributions cover nearly as many different approaches to address the question in the title.

Jamieson *et al.* deals with thermo-mechanical modelling of Barrovian metamorphism in convergent orogens, emphasizing the subtle interplay between changes in convergence and erosion rates, radioactive heating through wedge accretion and cooling by subduction. For Proterozoic terranes in Australia, Sandiford & Hand's thermal

modelling suggest a link between anomalously high heat-flow, the depth of heat-producing element concentrations and regional HT–LP metamorphism.

Whitney & Dilek and Reche *et al.* use petrography to deduce P – T – t paths and reconstruct the tectono-thermal history of respectively, a Miocene metamorphic core complex in Turkey and two juxtaposed units of a Variscan terrane in NW Spain. The Vredefort Dome area in South Africa is interpreted by Gibson & Stevens as an example of Palaeoproterozoic, intracratonic metamorphism caused by impingement of a hot juvenile mantle plume onto the lithosphere of the Kaapvaal Craton.

Another case of mantle-driven metamorphism is made by Brown, this time through subduction of oceanic spreading ridges and enhanced heat flow through slab windows. As he points out, ridge subduction must have occurred numerous times in Earth's history but has not received much attention. Using the Cretaceous evolution of Japan as an example, ridge subduction may explain a combination of features such as the HT–LP metamorphism, near-trench magmatism, the presence of both MORB and slab-derived igneous rocks and migrating magmatic centres.

Harley provides a concise overview on the occurrence, phase relations, P – T limits and interpretation of P – T – t paths of ultra-high temperature (UHT) metamorphism of crustal rocks ($>900^{\circ}\text{C}$ at medium to high pressures). Apart from mineral assemblages such as sapphirine–quartz, orthopyroxene–sillimanite–quartz and garnet–ossumilite in metapelites, the presence of orthopyroxene with high Al_2O_3 contents (>7 wt %) is a strong indicator for UHT metamorphism. Thermobarometry more often than not results in anomalously low P – T estimates as a result of post-peak mineral reactions and Fe/Mg diffusion. Using an independent pressure estimate, the original Fe/Mg composition of the minerals can be 'back-calculated' and used to retrieve the true peak-metamorphic P – T conditions. The question of the tectonic setting necessary for UHT metamorphism is left open until more detailed and reliable geochronology is able to distinguish between UHT peak metamorphism and later, unrelated overprints.

Rapid heating or uplift-related decompression melting often leads to disequilibrium in Sr isotope compositions between partial melts and their sources. As shown by Harris & Ayres for the Miocene Himalayan granites these disequilibrium compositions can be used to estimate rates of melting and melt extraction. For the Himalayan case, this results in a surprisingly short time span of 200 000 years between the start of metamorphism and extraction of the melt from its source. In a companion paper, Whittington *et al.* argue that rapid uplift at peak metamorphic temperatures ($>650^{\circ}\text{C}$) can lead to decompression melting of metapelites through subsequent

muscovite and biotite dehydration melting reactions, thus explaining the formation of leucogranites in Nanga Parbat.

Rubie's contribution takes us down from orogen to grain scale, showing how sluggish nucleation of product phases may affect metamorphic reactions. Even in the presence of fluid and during ductile deformation, significant overstepping of equilibrium conditions may be necessary for reactions to occur. Reaction may then often take place rapidly, as illustrated by plagioclase breakdown in the Alpine Allalin metagabbro. Expected reactions may not take place at all, as a result of complete overstepping. Neither need product phases form at the same time; they may form sequentially and with disequilibrium compositions. This may have important implications for the interpretation of thermobarometry results for such assemblages (and also for isotopic dating of metamorphic mineral assemblages, I think). Barker & Zhang present the results of two-dimensional computer modelling that link the opening up of grain boundaries, microcracking and orientation of the external stresses with fluid migration, fluid pressure and preferred sites of retrograde reactions.

Worley & Powell introduce both DOS and Macintosh-based software for calculating AFM compatibility diagrams and pseudosections. By systematically varying pressure, temperature, time or compositional parameters the resulting succession of diagrams can be displayed as a movie. These animated diagrams can be used to illustrate the evolution of mineral assemblages and mineral compositions, adding an extra dimension to such diagrams.

Vernon presents a review of structural and chemical evidence for and against mass loss/volume reduction during cleavage formation. Unequivocal solutions to this problem should not be expected, because of interference of many factors such as small-scale protolith inhomogeneity, different degrees of open system behaviour, possible mobility of perceived immobile elements, effective changes in composition of microdomains as a result of porphyroblast growth, and the feasibility of extrapolating local volume losses to a regional scale. One question not addressed is why the fairly regular partitioning into P and Q domains, which is basically a form of pattern formation, should develop during deformation.

This brings us to this reviewer's favourite contribution, which is the first paper in this volume by Hodges. He offers an interesting and original model on how a narrow orogen like the Himalayas may lower its gravitational potential energy, by regarding it as an open system that was driven far from equilibrium by a thermo-mechanical feedback mechanism. In this case, coeval southwards thrusting on the Main Central Thrust and northwards extension on the South Tibetan detachment was coupled through (decompression) melting in the intervening

Greater Himalayan Zone. In this way the orogen managed to dissipate its excess energy by rapid sideways expulsion of hot middle crust.

Text, photographs and diagrams (some in colour) are of very good quality, as we are used to in Geological Society publications. As part of a series this volume

will find its way to many libraries, but aficionados of metamorphic geology might want to own their own copy.

Martin Timmerman
University of Leeds