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BOOK REVIEWS

Planetary Materials. J.J. Papike, editor. Reviews in Mineralogy, Volume 36, Series Editor P.H. Ribbe. Mineralogical Society of America, Washington, D.C., U.S.A. 1059 pages, US$40 for nonmembers, US$30 for members. ISBN 0-939950-46-4.

This is the lengthiest volume to date in the *Reviews of Mineralogy* series. The text consists of seven chapters written by knowledgeable investigators largely, but not exclusively, from the Institute of Meteoritics, University of New Mexico. The volume is an attempt to synthesize the known mineralogical information on planetary materials, with planetary materials somewhat loosely defined to cover everything from cosmic dust to planetary (lunar, martian) samples. The chapters are arranged in a logical fashion from primitive to more evolved materials. The volume begins with an overarching Introduction to planetary materials and proceeds through Cosmic Dust, Chondritic (Primitive) Meteorites, Non Chondritic Meteorites (from more evolved Asteroidal Bodies), Lunar and Martian (Meteorite) samples, culminating in a summarizing chapter on the Comparative Planetary Mineralogy of the principal rock-forming minerals: pyroxene, feldspar and olivine in "differing planetary environments".

This volume contains a treasure load of data, information and interpretation. It runs to 1039 pages, and some of the chapters are books in themselves. For example, the chapter on Chrondritic Meteorites by A.J. Brearley and R.H. Jones is almost 400 pages long. The volume contains approximately 420 figures and 240 tables of data, and ends with a subject index, meteorite index and lunar sample index. The provision of indices is an anomaly in *Reviews in Mineralogy*, and is a real plus for this complex volume. I would buy this book just for the lists of references at the end of each chapter. This is an impressive compilation of information that will save others countless hours of searching through the literature. It belongs on the shelf or perhaps even the desk of every educator and researcher concerned with the mineralogy and petrology of extraterrestrial rock-forming materials.

With different authors for each chapter, there are stylistic and format changes with each change in topic. This breaks the volume up and added to its readability. I found the font size for the text (10 point) on the small side for easy reading. What really detracts from the volume are the figures. The jacket of the volume beautifully illustrates in color some examples of planetary materials and their features. The continuous-tone photographs in the text, however, generally lack contrast and, in some cases, fail to display fully the textures and relations they are intended to illustrate. This is not the fault of the materials themselves or probably the original photographs. It is the fault of the printing process. I found some of the line diagrams difficult to read. The use of different fonts, styles, abbreviations and symbols within a single chapter, due to the reproduction of previously published line-diagrams from different sources, is distracting. Another nitpick is in the chapter on Lunar Samples and, to a lesser extent, with Meteorites. This has to do with sample-numbering scheme, which is not explained; at least, I did not find it explained. It will be difficult for the uninitiated to make much sense, for example, out of what is meant by 15007, 292/293 or 14304c95("a"), without doing some research. There are also a few cases like this with abbreviations and terminology. The authors have, for the most part, aimed the work at colleagues and others relatively well-informed in planetary mineralogy and petrology.

Despite these negatives, if you have real interest in planetary mineralogy and petrology, you need this volume. As I have noted already, it is worth buying a copy just for the references. Rest assured, however, you are getting much more than just references for your money. This is a reference book, which benchmarks our knowledge of the mineralogy of extraterrestrial (planetary) materials.

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What Drives Metamorphism and Metamorphic Reactions? P.J. Treloar and P.J. O'Brien, editors. London, Geological Society Special Publication 138, 1998, 287 pages. £69 or US$115 (hardcover). (ISBN 1-86239-009-6)

What Drives Metamorphism and Metamorphic Reactions? is another attractive, compact, and expensive (about CDN $175) volume in the Geological Society of London's series of Special Publications. The volume opens with a short introduction by the editors that begins with a succinct historical overview, and goes on to weave into a smooth fabric our current understanding

of the heat sources of regional metamorphism by using the contributions that make up the volume (not in their order of presentation!). A tour de force. The editors conclude that owing to advances in quantitative phase petrology and the plate-tectonic paradigm, we know far more about this complex – not chaotic – subject than did our predecessors. The text that follows is made up of 14 chapters that average about 20 pages, each with their abstracts and references. A seven-page general index concludes the volume.

The opening chapter, "The Thermodynamics of Himalayan Orogenesis", by K.V. Hodges, exposes the reader to the labyrinthine complexities of Himalayan metamorphic rocks, particularly those in the Greater Himalayan Zone, and the possible role of leucogranites as magmatic lubricants that may have favored southward-directed tectonic extrusion. Metamorphic heat? This came from radiogenesis in deeply buried rocks, and frictional heating by faulting. The orogen, and by suggestion perhaps all orogens, should be viewed as a system pushed so far from equilibrium as to initiate a new set of boundary conditions which, in turn, may lead to an unexpected series of events and oscillations. To this reviewer, we are here straddling the gap between complexity and chaos.

R.A. Jamieson and her Nova Scotian colleagues next take a more conventional approach and use numerical analyses of coupled thermal-mechanical models of convergent orogens. Parameters are defined, and the results of a series of runs are depicted on colored cross-sections. By appropriate "tweaking" of rates of convergence, distribution and contribution of radioactive elements, rates of erosion, and so on, the authors come up with P–T–t paths appropriate for Barrovian and blueschist fields. With so many variables, these results cannot be considered unique, but they point in useful directions.

In the shortest chapter of the volume (8 pages), Donna Whitney and Y. Dilek propose that thermal spikes falling on the heels of Barrovian trajectories in core complexes are caused by intrusion of granitic magma, possibly generated by partial melting during the earlier regional metamorphism. The heat source for the Barrovian event is not discussed.

The tie between subvertical folding and magmatic intrusion is called upon by J. Reche, F. Martinez, and L. Arboleya in the fourth chapter to account for the complex interrelationship of low- and medium-pressure Variscan metamorphism in northwestern Spain. A series of photomicrographs, KFMASH P–T pseudosections, and tectonic cross-sections seek to render digestible an impressive array of local petrographic and structural detail.

Next, Simon Harley treats ultrahigh-temperature (UHT; 900–1100°C), moderate-pressure (7–13 kbars) granulites, a hot topic over the past decade. He lists and characterizes the principal occurrences of these rocks, pointing out that Fe–Mg exchange geothermometers are hopelessly inadequate to measure T. More promising are retrieval calculations. Recognition of UHT rocks rests chiefly on the interpretation of reaction textures by, for example, using FMAS petrogenetic grids to qualitatively evaluate changes of T and P. High-Al (>7% Al_2O_3 by weight) in orthopyroxene is another indicator. This chapter is petrological and casts little light on the topic of the volume. In fact, Harley concludes: "The precise tectonic settings necessary for the development of UHT metamorphism remain problematic."

M. Sandiford and M. Hand, treating Proterozoic terranes in Australia, suggest that a buried anomalous heat-producing layer alone may account for the Abukuma facies-series rocks observed. The authors' calculations show that T is highly dependent on the depth of the anomalous layer, that only limited burial may be enough to induce metamorphism, and that only a few km of erosion may terminate it. A refractory lower crust (perhaps a residue from partial melting and high-level emplacement of granite that predated regional metamorphism by as much as 150 Ma) would resist melting at the Moho.

Quite a different picture is painted by Roger Gibson and Gary Stevens for low-P rocks exposed in the Vredefort Dome. They propose that intraplating by mantle-derived magmas (when the Kaapvaal Craton was atop a Proterozoic hot spot) was the heat source for metamorphism. The same magmatic event is held responsible for the nearby Bushveld. The interpretation is upheld by radiometric dating.

In the volume's longest chapter (33 pages, including nine pages of references), Michael Brown discusses the role of plate tectonics, specifically triple-junction interactions at convergent plate margins, and ridge–trench interactions and slab-window formation. He relates these to the development of high-T, low-P metamorphism in Japan, citing magmatic and thermal manifestations. Brown points out that most evidence of plate interactions in pre-Mesozoic rocks have been erased. Undaunted, he tackles two Precambrian examples: one from Australia, the other from Canada's north.

Nigel Harris and Michael Ayers, in the succeeding chapter, bring us back to the Himalayan granites discussed by K.V. Hodges in the opening chapter. Based on Sr-isotopic equilibration in migmatites requiring appreciable time (> 200 ka), and the relative rapidity of melt extraction, the authors conclude that metamorphic heat resulted radiogenically in a thickened crust.

Alan Whittington and coauthors describe in detail the petrogenesis of high-grade Himalayan pelites from Nanga Parbat, Pakistan. No heat source is postulated for metamorphism, but P–T–t paths indicate nearly isothermal decompression for the final metamorphic episode, assumed to have been spurred by exceptionally rapid exhumation.

The sad state of knowledge of nucleation kinetics in metamorphic petrology is handled by David Rubie. The field is cluttered with a mix of assumptions and igno-

rance. Even such basics as the magnitudes of overstepping in metamorphic reactions is a source of discord. A few specific solid-state, dehydration, and melting reactions are discussed by Rubie and shown in part to be extraordinarily sluggish. Misinterpretation of metastable phases can cause errors in P–T estimates. This chapter is an interesting contribution, but it is unclear how it ties to the theme of the volume.

The same comment applies to the following chapter by Ron Vernon, which is a review and discussion of the question: "What is the structural and chemical evidence for loss of mass or volume (or both) during metamorphism?" Following a thorough (and well-illustrated) exposition, the author reaches seven conclusions. Particularly interesting are that so-called immobile elements (Ti, Al, and Zr) may be relatively mobile in some circumstances, that prograde metamorphism may be regarded as effectively isochemical, and that leaching of some igneous rocks may lead to pelitic compositions.

Andrew Barker and X. Zhang treat the role of microcracking and grain-boundary dilation during retrograde metamorphism. They examples they use, respectively, are a medium-grade pelite from Norway and a scapolite gneiss from Scotland. The two mechanisms are shown to be effective in promoting fluid access to seemingly unfractured rocks. The chapter addresses one aspect of the question: What drives *retrograde* metamorphic reactions.

The volume ends at the movies; a chapter by B. Worley and Roger Powell entitled: "Making movies: phase diagrams changing in pressure, temperature, composition and time." Using available software, the authors show how to animate phase diagrams (AFM) through T and P space. Animation emphasizes the dynamic nature of dynamothermal metamorphism. I'll leave it to the computer buffs to wrestle with this one.

In summary, *What Drives Metamorphism and Metamorphic Reactions?* is a reference work that deals only partly with its stated purpose. The fifth and the last 5 chapters are at best peripheral. Nevertheless, the volume is a fine source of ideas for graduate students and professionals, and shows the thrust of current thinking. It also offers guideposts for future work.

To approach this book, read first the editors' excellent Introduction. Go then to the abstracts to choose. The general index (p. 281–287) also will be helpful. This is not a book to read indiscriminately from cover to cover. Keep in mind that the area covered is vast: from field to laboratory, from pencil to animated computer graphics.

Printed on high-quality glossy paper and bound solidly, the volume should resist years of thumbing in libraries. The elevated price and narrow scope, however, may hinder individual purchase. There are a few typos. The only one worthy of mention is the incorrect formula for garnet on p. 270. Finally, it is unfortunate that the wonderful tourmaline–spinel symplectite on the cover could not be related directly to one of the contributions.

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