

BOOK REVIEWS

Physics and Chemistry of Partially Molten Rocks. Edited by Nick Bagdassarov, Didier Laporte, and Alan Bruce Thompson. Petrology and Structural Geology Series 11. Kluwer Academic Publishers, 101 Philip Drive, Norwell, Massachusetts 02061, U.S.A., 2000, 271 p., US\$136, ISBN 0-412-84720-5.

Partially molten rocks cover a wide span; in the book here under review, melt ranges from 0.0X to 60 per cent by volume! In nature, therefore, partially molten rocks encompass a lot: ultramafic diapirs at depths of hundreds of kilometers, igneous intrusions of all stripes, regional migmatites developed in continental crust mostly between 60 and 10 km beneath the surface and at shallower depths in some contact aureoles, "wet" salt domes, and even glacial ice.

Study of partially molten rocks in geological systems is one of the fastest growing fields of research in petrology today. Recognition that only small proportions of melt can vastly alter the rheological properties of rocks as well as reduce their densities and thus substantially change their behavior, particularly where they occur in large bodies, has major implications for mineralogy, petrology, and tectonics. In the opening lines of the fourth chapter (p. 94), Didier Laporte and Ariel Provost state this succinctly: "The grain-scale distribution of partial melts is a factor of primary importance in determining the physical properties of partially molten rocks such as the permeability, the viscosity, which is very sensitive to the presence and the distribution of a melt phase, and the effective diffusivity, which may be increased by orders of magnitude due to the presence of an interconnected melt network. Permeability is specially important because it is, along with the viscosities of the melt and the host rock, one of the main parameters controlling the dynamics of melt segregation."

Physics and Chemistry of Partially Molten Rocks is the outgrowth of a symposium held at Strasbourg, France, at the end of March, 1997. The book is made up of eight chapters by 11 authors; three are single-author chapters, the others have from two to four authors each. That no author contributed to more than one chapter reflects the current compartmentalization of the field.

The opening pair of chapters treat the rheology of partially molten rocks. The first, by David Kohlstedt and three colleagues, points out that distinct flow laws govern anhydrous and hydrous systems. In a mixed basalt-olivine system, partially molten aggregates in the dislocation creep regime have creep rates five times

larger than those in melt-free olivine systems. This difference is not large, but as the authors note (p. 25): "... the viscosity of the mantle in and below the source region for MORB will be a factor >100 times smaller than the viscosity of the water depleted rocks above."

The second chapter (by N. Bagdassarov) in part bridges the gap with geophysics and the problem of the attenuation and dispersion of seismic waves. The author deals with the frequency dependence [from 20 to 2×10^{-3} (not 2.10^{-3} as on p. 29) Hz] of the seismic quality factor (Q^{-1}) in four rocks: gabbro (with salite!), spinel lherzolite, basalt, and dacite. Discussed are the case of <10% melt (grain-boundary sliding dominates), 15–50% melt (viscoelasticity), and >60% melt (particle rotation and the role of grain shape). A rheological threshold is reached at ~40% solids.

The succeeding brace of chapters analyze the topology of the melt phase. The first of the two, by Ulrich Faul, deals with theoretical aspects of liquid–solid distribution, presents experimental observations from the basalt–olivine system, and discusses the implications for partial melting in the upper mantle. Up to a few per cent of melt can be retained there with or without lattice orientation and is detectable seismically.

In the fourth (and longest) chapter of the book, Didier Laporte and Ariel Provost explore, through rigorous mathematical treatment, the concepts of interfacial energy, textural equilibrium and the role of anisotropy, as well as the all-important interconnection threshold. The range of wetting properties of partial melts in mantle rocks, crustal rocks, and sulfides leads to a panoply of segregation behaviors.

Melting processes and crustal assimilation are modeled in the ensuing pair of chapters. In the first, Harro Schmeling cites ample evidence that much of the mantle is at or slightly above melting temperatures. A Compaction Boussinesq Approximation is used to show that melt migration (intrusion and extrusion) is most likely at sites of thermal instabilities: mantle plumes and hot spots.

Luzius Matile, A.B. Thompson, and Peter Ulmer next present a fractionation model for calc-alkaline intrusions using a range of compositions. Primitive magmas (*i.e.*, picrite) are able to assimilate ~80% of fertile host-rocks (tonalite and pelite), whereas basalt can assimilate less than half as much. Only intrusions of batholithic proportions can assimilate effectively.

The two closing chapters deal with natural examples. In the first, Alice Hobson, François Bussy, and Jean Hernández treat migmatitic gabbro in a shallow contact aureole on Fuerteventura in the Canary Islands. This reviewer is unconvinced that important melting took place; instead, he suggests that the "partial melts" may have been fractionates from the adjacent PX1 gabbroic intrusion. The concluding chapter by Richard Wirth and Leander Franz, documents early partial melting in mantle xenoliths from San Carlos (Arizona, USA), Rhön (Germany), Victoria (Australia), and Saudi Arabia. The authors draw four geological implications, including "that width, structure and chemical composition of the melt film are the critical parameters for grain-boundary diffusion" (p. 263).

References are given at the end of each chapter. A condensed three-page index concludes the volume. The usefulness of this book for the non-specialist (such as this reviewer) is compromised by the absence of a table of abbreviations. Far too many letter symbols are introduced without definition. Those in the know will not be inconvenienced, but those on the outside who wish to peer in are at a disadvantage. More assiduous proofreading would have reduced the inordinate number of typos. Most are not serious, though the third address on page 3 will make francophones chuckle, and the last line of the second paragraph on page 21 will leave all readers scratching their heads. The non-justification of decimals makes some tables unnecessarily difficult to read. Finally, in this age of computerized composition, the leaving of partial blank pages, especially in the last half of the book (see pages 211, 213, and 248) is inexcusable and breaks continuity.

This book is not for the pragmatic physical mineralogist, nor is it for the gnarled field geologist. It isn't for the faint-hearted, either. *Physics and Chemistry of Partially Molten Rocks* is for the mathematically inclined whole-Earth theorist. In a sense, it deals with the big picture from a microscopic viewpoint.

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Minerals of Broken Hill. By William D. Birch (ed.). Broken Hill City Council and Museum of Victoria. Available through Albert Kersten Geocentre, P.O. Box 448, Broken Hill, New South Wales 2880, Australia. Ph/Fax 61 (08) 8087 6538; e-mail: geocentr@pcpro.net.au. 1999. 289 p. AUS \$120 (plus postage and handling). ISBN 0-9599486-9-4.

First published in 1982, this updated version of *Minerals of Broken Hill* commemorates the centenary of

mining operations in Australia's most renowned mineral deposit. Through attractive descriptions and splendid color photographs, the minerals of this mother of all Pb-Zn-Ag deposits are here promoted as perfect examples of the merging of nature, science and art. Small wonder, for Broken Hill places among the top five sources of mineral species in the world, and its mineral specimens are prized among collectors everywhere.

Several introductory chapters set the stage for the main thrust of the book. Beginning with "A History of Broken Hill", contributor G. Blainey makes abundantly clear the tremendous influence that this mining field has had on Australian life. To quote: "Like a meteorite falling in the darkness it lit up a vast terrain; and the glow remained for a long time." It seems, however, that timing is everything. Discovery tomorrow of another Broken Hill would likely raise no more than a ripple of national interest, so much have things changed.

In "The Life and Times of Charles Rasp", M. Sainisch-Plimer paints a masterly picture of the boundary rider ex-Saxon military officer (on the run for desertion) who, on September 3, 1888, pegged the darkest rock on the "broken hill". One wonders to what extent the element of pure chance favored this extraordinary character's fierce determination to undo the "Curse of Távora" on his family. This chapter recounts a tale of intrigue stranger than pure fiction.

In "The Identities and Their Minerals", contributors G. McNamara, O. Chalmers, W. Birch and T. Plimer record, in orderly fashion, facts and fascinating insights concerning the activities of researchers and collectors, both pioneering and modern, who have studied the Broken Hill orebodies. B. Stevens goes on to explain in "The Geology of Broken Hill" that although controversial, the origin of the orebody is currently viewed by most experts as a metamorphosed stratiform exhalative deposit. At the start of mining operations, Broken Hill contained a phenomenal 280 million tonnes of ore, much of it high grade, with Pb + Zn of 15 to 25%.

In "The Making of the Minerals", I. Plimer elaborates on genesis, and the reader discovers (if she/he has not already realized it!) the reason for the wealth of minerals at Broken Hill. It is not enough that each of the stacked pile of sulfide masses has a characteristic chemistry and mineralogy, and is chemically zoned from bottom to top along 8 km of strike! These same masses have been complexly deformed, highly metamorphosed, run through by shear zones, subjected to water-table fluctuations, and at various times throughout nearly 2 Ga of geological history, have been subjected to sub-aerial weathering! I wonder that Plimer seems almost apologetic (p. 83) for failing "... to present a simple paragenetic model or mineralogical zoning scheme for

the oxidized zone.” And so the stage is set for the main body of the book by Bill Birch on “The Minerals of Broken Hill”.

Systematic mineral collecting has rarely been the practice for most of Broken Hill’s history, a situation true not only of many major Australian mines but of a great many other classic localities. It boggles the mind to consider the marvelous museums of mineral species that were blasted to oblivion and shoveled out of the oxidized zone at Broken Hill. Consider, for example, this (p. 231) on-the-spot report in 1926 by George Smith (Inspector of Mines, New South Wales Mines Department): “One vug as large as a room contained so many (stalactites) that it was difficult to move about in it. The stalactites were of psilomelane thickly encrusted with white crystalline calamine [*i.e.*, smithsonite] resembling a covering of snow. Some were at least seven or eight feet long and a foot in diameter... The floor consisted of nothing but calamine. No other minerals were present and every portion of the vug was unsoiled and undamaged. It was the Writer’s privilege to spend some hours in the vug as soon as it was opened sufficiently to admit of entrance, and so far as he knows (not many) specimens were taken from it, though great numbers were available... With stoping in progress all around, this most interesting deposit was quickly destroyed. Though the finer crystals of calamine were lacking, it was, having regard to its size and unblemished condition, the most beautiful and impressive mineral occurrence ever seen by the Writer.”

Similar accounts exist of other pockets at Broken Hill of far more exotic secondary minerals than smithsonite and psilomelane. Most mineralogists can only dream about such experiences as those enjoyed by George Smith.

According to Birch, the large collections that now survive in museums and private hands represent only a

“grab sample” of that initially available. Even so, with closure imminent, there are listed and described here 280 species “confirmed or considered” to have occurred in the Broken Hill orebody. Eleven of these – marshite, miersite, raspite, willyamite, costibite, paradocrasite, mawbyite, segnitite, bernalite, kintoreite and brokenhillite – are new minerals, and most occur only as small crystals. Not surprisingly, several recognized “unknowns” await description (p. 256). Front and center in this alphabetical presentation, however, are photographs of: awesome crystals of azurite (to 15 cm!), some partially replaced by malachite, superb crystals of rhodonite, synonymous with the locality name, reticulated and complex crystal groups and arrow-head twins of cerussite, and astonishing mesoscopic eutectic intergrowths of galena and tetrahedrite. Pyromorphite (in all shapes and colors!) here ranks with anglesite, cerussite and stolzite among Broken Hill’s most beautiful minerals. Despite its unappealing chemistry, my favorite is raspite (like its namesake, it has character!), the monoclinic polymorph of stolzite (PbWO_4).

There are only pleasant surprises here. The photography is consistently excellent, thanks to Francesco Coffa, a natural history photographer and a specialist in minerals. Accompanying captions are succinct and indicate true size of the object. Meticulously prepared and edited, the book concludes with a “Table of Minerals”, a “Bibliography” and a short “Glossary”. Use of larger and more attractive (upper case!) lettering would doubtless help raise its merit as a coffee table showpiece. Far better is the likelihood that it will endure as a wonderful historical record and mineralogical directory of one of the world’s greatest mineral deposits.

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