

taken into account. The problem is how can heterogeneity be incorporated realistically into computer models? This is not just a problem of turning the processing power on your massively parallel Cray supercomputer up a notch or two – there are serious conceptual challenges here. The problem of how to deal with heterogeneity, on all scales, is fundamental to this kind of work if reactive transport models are ever to be truly predictive, simply pretending the system is homogeneous and assigning average properties is not good enough.

Chapters 7 and 8 deal with bugs and their role in catalysing and buffering chemical reactions during solute transport in the subsurface (Rittmann and VanBriesen) and the role of organic matter in aquatic sediments (Van Cappellen and Gaillard). In particular, a full understanding of the microbial role in modulating pH, speciation and biodegradation is necessary in modelling fluid movement during sediment burial and diagenesis. The final chapter deals with both inverse and forward geochemical models applied to a real life case study of acidic heavy metal contaminated groundwaters in the Pinal Creek basin, Arizona using computer simulations such as NETPATH and PHREEQC. A USGS internet site and web page address with the latest downloadable hydrogeological modelling codes looks like a useful place to visit for those working in this field, or the simply curious.

In summary, this book will be of interest to anyone working in the general area of groundwater flow in crustal rocks, and for those still modelling flow in nonreactive systems, it highlights nicely the complexities and challenges of incorporating mineral–fluid chemical interactions.

N. PETFORD

Ammen, C. W. *Recovery and Refining of Precious Metals*, London and New York (Chapman & Hall), 1997, xii + 441 pp. Price £37.00. ISBN 0-412-72060-4.

This book records 50 years of experience by the author in extraction of precious metals from natural ores and industrial scrap. It is a wonderful journey through basic chemical phenomena such as oxidation, combustion, ionisation, electrolysis, solution and chromatography and their relevance to recovery of precious metals. Chapters include blow pipe tests, electrochemical principles, fire assay and summary master plans for wet chemical

methods to extract platinum-group elements, gold and silver. The writing style is unusual, being determined, convincing, enthusiastic and lively. The text is very readable, oozing wisdom and experience and is never boring. The author sets up and describes problems often over several pages and then produces the answer making for compulsive reading as the need to find and understand the answer to the problem becomes essential and exciting. This book is a must for people interested in precious metals, but who lack a chemical background and for those involved in hands-on processing of the precious metals. There is an emphasis on lengthy but memorable explanations of how and why chemical reactions occur, illustrated with everyday examples familiar to everyone. The author paints vivid images of processes and quite often lapses into anecdotes and hobby horses in between factual data. This makes the book very interesting, with unexpected new pieces of information suddenly appearing and either explaining something that had always puzzled you or introducing a refreshing break in the text. There is much information on all sorts of properties of the precious metals and how these properties can be utilised to recover them. The book is pragmatic and provides many recipes for precious metal recovery with cautions on dangers of the use of different chemicals. It includes much reference material surprisingly difficult to find elsewhere, and references to other useful texts are placed firmly in their entirety in the text at suitable points. The book is extremely well illustrated with clear, simple diagrams. Although the book is well written, topics are sometimes covered in unexpected chapters. For example, oxidation and rust occurs in the chapter entitled 'the platinum sisters' and chapter headings such as 'chemistry', 'various systems' and 'odds and ends and author's do's and don'ts' are not helpful, but there is a good index. In the first chapter the author plunges into gold extraction under the heading of ores. Many terms are explained carefully whereas others are introduced with no explanation. Often a term is used in earlier chapters and explained in later ones, almost as if the author is whetting the appetite of the reader and getting them used to the term before he produces the definition. The book is a little repetitive in places with subjects covered briefly in one part of the book covered in more detail elsewhere. The subject of recovery is viewed almost exclusively from a chemical point of view. Physical processes of recovery are briefly

mentioned and mineralogy is often very simplified. However, this book appears to me, as a geologist, to be an invaluable guide to recovery of the precious metals, containing many tricks of the trade, based on practical chemistry, avoiding high tech methods and black boxes. The author makes precious metal recovery look easy.

H. M. PRITCHARD

Eckert, A. W. *The World of Opals*, New York and Chichester (John Wiley & Sons, Inc.), 1997, xiv + 448 pp. Price £60.00 (ISBN 0-471-13397-3).

This is the first comprehensive book on opals for over thirty years and claims to give a complete guide to the science and history of this gem material. After a definition of exactly what constitutes an opal, the author provides a new look at opal formation, and this is followed by chapters describing opalized fossils and pseudomorphs, the mythology of opals (the 'bad luck' popular image being blamed on the one of Sir Walter Scott's Waverly Novels *Anne of Geierstein*), famous and otherwise noteworthy opals, types of opals, the world's major opal occurrences, and a glossary of opal-related terms; there is also an extensive bibliography and an index.

The chapter on the mode of formation of opals is based largely on the thesis that most of what has been taught about opals has been based on theories now proven, in part at least, to be incorrect. The author's style is distinctly idiosyncratic, and it is difficult to unravel the use of such terms as atom migration [metasomatism ?] and the definition of an electrolyte as "a liquid carrying a chemical that generates an electrical pathway through anything". The work of Sanders and Darragh in 1965 using electron microscopy to demonstrate that precious opal consists of aligned lepispheres and voids giving rise to a three-dimensional diffraction grating is acknowledged, but we are told that the refutation of part, if not all, of the other theories on the basic formation of opal must take place because of experiments carried out by a man from Lightning Ridge, New South Wales, who has succeeded in growing opals from 'opal dirt' in a liquid in glass jars in an incredibly short time (a few days to six months, followed by the secret electrolyte being siphoned off through a small hole in the container's cover, allowing air contact to dry the stone). These opals are said to be indistinguishable by sight from

natural opal, but have not yet been scientifically analysed; a lot of work has been done, but the experimenter quite reasonably wants to publish the results himself. We are thus left with various statements, but a lot of the author's work reminds one of a current British advertising campaign on the lines of "... I don't know the answer but I know a man who does". Nevertheless, the evidence of fossil pseudomorphs leads one to the conclusion that opalization does not necessarily require a geological time-scale in which to operate.

Putting aside these reservations, this book does succeed in giving an overall account of the occurrence of opals, not only in Australia, the United States and Mexico, but also in British Columbia, Honduras, Austria, the Czech Republic, Slovakia and Hungary. The descriptions of opal deposits in Opal Butte, Oregon, and the Virgin Valley area of Humboldt County, Nevada, are described in detail, and in the section on noteworthy opals, details are given of the Roebing opal (2560 carats) and the Bonanza opal (25 586 carats) both from Virgin Valley. Opal being what it is, many of the black-and-white photographs in the text are uninspiring, but 22 colour plates demonstrate the amazing variability in play of colour to be, seen in opals even from the same mine. A book that manages to be both provoking and informative, while we await the promised definitive work on the geology and chemistry of opal by the 'man who does'.

R. A. HOWIE

Harlow, G. E. (ed). *The Nature of Diamonds*, Cambridge (Cambridge University Press), 1997, x + 278 pp. Price £55.00 (hardback, ISBN 0-521-62083X); £19.95 (paperback, ISBN 0-521-62935-7).

In this comprehensive, large-format book, published in association with the American Museum of Natural History, a dozen or more experts on the geology, mineralogy, gemmology and social-economic aspects of diamonds cover every facet of this mineral.

After an introductory chapter, the nature of colour in diamonds is discussed (E. Fritsch), and this is followed by a chapter on the origin of diamonds and the involvement of relatively cool harzburgite keels at the base of the thickest, oldest parts of the Earth's crust (M.B. Kirkley), later subduction of basaltic oceanic crust resulting in some portions of it adhering to the bases of the