maximum dimensions are quoted, but when cropped pictures include only part of a specimen, there may be some ambiguity: a visual scale would have served better.

Finally, a Selected Bibliography is provided as a resource for browsing. It is remarkably extensive, yet few of these references appear in the text. This is one of several aspects of linking in the book that could have been implemented better. Another would be better connection between the text and the colour plates: easily possible by reference to plate numbers. An omission is the absence of any significant reference to mineral compositions and chemistry. While the inclusion of mineral formulae in the text or in captions can be repetitive, and possibly distracting, a glossary of mineral species with formulae would enable readers to appreciate better chemical associations and relationships.

Nevertheless, the strengths of this excellent book far outweigh its shortcomings. I thoroughly recommend it as a source of reference and I am sure it would be a welcome asset for any mineral enthusiast.

PETER WEBB

Bethke, C.M. *Geochemical and Biogeochemical Reaction Modeling* Second Edition, 2007, Cambridge University Press, Cambridge, UK. 564pp., Price £45, ISBN 978 0 521 87554 7

The geochemical modelling package 'Geochemist's Workbench' is well known as a powerful tool for the interpretation and understanding of water–rock reactions. Craig Bethke, who developed the software, has a deep understanding of aqueous geochemistry combined with mathematical and computational skills. This book has to be an essential companion to *The Geochemist's Workbench*, as it explains so much concerning what the software does, why it does it, and how the operator can develop the skills of modelling by interacting with it.

Teaching 'thermodynamics' or theoretical geochemistry is a challenge. Bethke appears to have overcome that challenge, because the book is structured and written in ways that genuinely encourage the reader to progress. Typically, chapters are introduced with fairly simple concepts, often illustrated with interesting, quirky, and familiar examples drawn from everyday life that illustrate theoretical principles. Individual chapters are short, easily digestible, and readily adopted as teaching packages.

After an introduction to modelling that sets out basic conceptual principles in a very accessible way, the book is divided into three parts. First, equilibrium in natural waters is considered, introducing the reader to understanding the modelling of equilibrium (including technical issues relating to the mathematical description of equilibrium) before discussing complications: redox equilibria, the need to consider activity coefficients and how to model brines, sorption, ion exchange and surface complexation. This section takes up almost half of the book, and culminates in discussion of the modelling technicalities of automatic reaction balancing and uniqueness. The text occupies 12 chapters up to this point, and in each case very clear links are made to Geochemist's Workbench to the extent that it is impossible, practically, to use the book without having the software running alongside.

Once the reader has mastered the art of equilibrium modelling, he (or she) is led into the domain of reaction process modelling. This second major section of the book considers mass transfer and reaction path modelling (with varying temperature, activity and fugacity paths), buffers, and then kinetic modelling of mineral dissolution/precipitation and redox. There are substantial chapters on the modelling of microbially-mediated kinetics, and stable isotope fractionation. The section culminates with chapters describing the modelling of flowing groundwater systems, in which dispersion and advection are considered as well as water–rock reaction, and reactive transport.

Having established the theoretical framework for the discipline of geochemical modelling, Bethke devotes the third section of the book to examples of the application to specific scientific and engineering problems. Using familiar starting points, he illustrates the use of modelling to understand hydrothermal fluids, then geothermometry and the evaporation of seawater. He then moves into sediment diagenesis and the kinetics of water–rock interaction in an aquifer. Weathering however, defeats the modeller, and identifies a challenge for the future (3rd edition perhaps?). Becoming increasingly applied to problems of commercial interest, there are chapters on oxidation and reduction (uranium and organic aquifer contaminants), waste injection wells (how modelling could have prevented industrial disasters), petroleum reservoirs and acid mine drainage. The final two chapters address groundwater contamination and modelling of

microbially-mediated systems. So there really is something for everyone.

As with many books of this type, the appendices are particularly useful. Very brief details are given of 17 geochemical modelling software packages that have been used over the last 30 years or so, including key publications describing each package and web sources of the software. A second appendix paces the reader through the Harvie Møller and Weare activity model, and a third appendix lists the mineral species in the Lawrence Livermore National Laboratory database. A final appendix briefly discusses non-linear rate laws. Finally, there is an extensive list of references (~350), containing a portrait of the 'great and the good' of experimental and aqueous geochemistry from the last four decades.

As stated earlier in this review, the book is best used alongside an operational version of *The Geochemist's Workbench*. It is designed well as an instructional book, well suited to geochemistry courses at Masters level or to support PhD students in their work. Individuals who lack a strong mathematical foundation will struggle with large parts of the text. They will however be able to use *The Geochemist's Workbench* mechanically without necessarily understanding the mathematical basis that underpins the software, and will be able to work through the book, skipping the difficult bits. In contrast, students who have taken appropriate mathematics courses at university level (undergraduate and postgraduate) will find their use of geochemical modelling enriched, becoming competent in the use of software by virtue of understanding its mathematical limitations as well as limitations imposed by analytical chemistry.

Assuming that the reader is able to grapple with the theory, this book is an extremely valuable resource. It provides an essential basis for understanding the chemical behaviour of waters in natural systems. It is very easily accessible to a mathematically literate reader, and demonstrates the breadth of application of modelling to a range of geological and engineering problems. Those lacking a strong maths background will find this book challenging but rewarding given its diversity of application and clarity of explanation.

DAVID MANNING