

redox equilibria. The physical meaning of volatile behaviour in metamorphism is considered, and fluid inclusion evidence for volatiles briefly described. The most important composition-assemblage diagrams used to evaluate metamorphic rocks are introduced and their limitations and properties critically appraised. Buffering concepts are described with reference to $T-X_{\text{CO}_2}$ sections, with the importance of graphite stressed. Following a consideration of reaction monitors of fluid activities, a lengthy section is devoted to the reaction progress approach to quantifying fluid/rock ratios. Whilst this approach is important and has been influential, it is only one of several methods for evaluation of fluid/rock interactions and it is unfortunate that stable isotopic studies of fluid infiltration and advances in advective/dispersive front modelling are not introduced here or described.

Part II, 'Metamorphic facies and metamorphic belts', reiterates the importance of Eskola's facies concept and deals with its problems as well as providing a historical account of its further development before arriving at a modified working definition of facies. The three-fold P/T ratio facies classification as recognised through field $P-T$ curves is then expanded upon following Miyashiro's original concept. At this point a slightly unnecessary diversion is introduced with a detailed account of 'diachronous progressiveness' — essentially one type of age/grade relationship. Whilst the field array may indeed be diachronous, this section rather over-elaborates on a general concept that should be implicit. The 'petrographic characteristics' of facies are described through distribution graphs of minerals against grade or metamorphic zone, but few of the textural features that may be observed in the rocks are discussed. The tectonothermal evolution of belts is linked into Miyashiro's original postulate of paired metamorphic belts. Although recent detailed observations on proposed paired belts have cast doubt on generalised models for their occurrence, these problems are not remarked upon in this book. Examples of various P/T belts are given, including 'classic' terrains (e.g. Barrovian, Franciscan, Japan). A clear, if simplified, history of the Alps as a collisional belt is also presented. This, however, does not focus upon key aspects and controversies such as the ultra-high pressure metamorphism as seen in the Dora Maira Massif, and the role of extensional tectonics in unroofing. On the positive side, extension is considered in relation to low P/T belts such as the Hercynian. Almost all the more detailed examples of metamorphic terrains given in this part of the book are Phanerozoic, and it is doubtful whether students reading this text alone would be able to appreciate the abundance and diversity of Precambrian metamorphic terrains.

In part III (Individual metamorphic facies), each facies is described, from their general background features and some typical examples, to information on critical reactions and assemblage fields. Although brief, each section gives the reader some appreciation of the important issues and questions relating to many of the facies. For example, the granulite facies is considered in greater depth and with more insight than presented in other recent general metamorphic texts. The high P/T facies are also described with some attention being given to ultra-high pressure cases, if only briefly. Contact metamorphism only warrants five pages of this book — a treatment which in no way reflects the recent intense interest in the dynamics of this important form of metamorphism.

Although very recommendable as a good general text this book is by no means comprehensive, and it is unfortunate that several themes which are important in modern work are not explored or explained. For example, petrographic aspects such as metamorphic textures, their relations to deformation and the use of reaction textures in interpretation of metamorphic histories receive very little attention. The implications of related fields such as stable isotopic studies and geochronology for modern metamorphic petrology are also not given adequate coverage. A chapter dedicated to thermal models and their continuing development would be a valuable addition, as would greater treatment of extensional settings and metamorphic core complexes. Ultra-high pressure metamorphism involving coesite- and diamond-bearing eclogite facies rocks, surely a major area of new investigation and discovery with fundamental implications for crust/mantle dynamics, is only noted briefly. Despite these shortcomings, Miyashiro's book is superior to most other metamorphic texts available and the £24.95 paperback edition undoubtedly should become standard reading in many metamorphic courses.

S. L. HARLEY

Stanton, R. L. *Ore Elements in Arc Lavas*, Oxford (Oxford University Press), 1994. x + 392 pp. Price £85.00. ISBN 0 19 8540507.

The purpose of this monograph is two-fold, as stated clearly by the author: (1) "to investigate the patterns of behaviour of 'ore' and associated elements during the crystallization of a volcanic island-arc lava series" and (2) "to contribute to a solution of the problem as to whether exhalative ore deposits of the volcanic regime are derived from the melt by magmatic processes or by much later sea-floor leaching". The author elegantly establishes in the introductory chapters the close relationship between polymetallic massive sulphide formation and felsic

volcanism in the island-arc environment, as exemplified by the Solomon Islands Younger Volcanic Suite (SIYVS). Thus, although the bulk of the book (Chapters 5–23) is concerned with describing ore element distributions and petrogenesis in the SIYVS, the context of this study is established (Chapters 1–4) within the framework of an important and outstanding problem in the genesis of massive sulphides.

After a brief introduction (Chapter 1) and a briefer outline of the general nature of exhalative ores and their volcanic associations (Chapter 2), the historical development of ideas of the origins of exhalative ores and theories for their origin are created in Chapters 3 and 4 respectively. Chapter 3, in particular, is an incisive piece of writing that gives a selective overview of the progress of ideas in this area — although it may not have been a specific aim of the book, this chapter alone provides a wonderfully clear picture of the scientific process and the (development of theories in a particular field. The author concludes in Chapter 4 that the currently predominantly held view, that sea-water leaching of preexisting volcanic rocks is the major process by which ore-forming elements are sourced, is not a satisfactory explanation and proceeds to focus on the major alternative hypothesis involving derivation from magmatic solutions.

In order to make some predictions as to the bulk chemical composition of exhalative ores from the ore element distributions in associated magmatic rocks, the author, using the SIYVS as an example, proceeds to provide a detailed description of their petrology (Chapter 5) and of the distribution of Cu, Zn, Pb, Ba, Sr, P, Ca, Ti, V, Cr, Ni, Fe, Co, Ni (Chapters 6–19) and sundry other elements (Chapter 20) within various rock units and the minerals comprising them. This represents a very substantial piece of work incorporating nearly 1000 XRF, ICP-MS and neutron activation analyses of whole rock and mineral separates as well as over 10 000 electron probe microanalyses. From the factual base provided, abundance patterns in crystallizing melts are treated in Chapter 21. For copper, in particular, it appears that fractional crystallization alone cannot explain the patterns observed, and elemental loss through magmatic solutions is invoked as a second important process. Chapter 22 considers evidence for the magnitude of ore element losses from magmas via volcanic exhalations. The implications for petrogenesis of the lavas and associated exhalative ores are discussed in Chapters 23 and 24 respectively, with the SIYVS exemplar being used as the basis for modelling ore element behaviour in other arc environments.

This is a well written and carefully crafted volume. It is easy (indeed, a pleasure) to read and the essence

of the work is clearly encapsulated in the succinct concluding statements at the end of each chapter. The minimum of treatment of hydrothermal fluid chemistry and the lack of detailed discussion on the possibility of ore element fractionation through non-magmatic processes is, however, in my opinion, a major and unfortunate drawback of the volume in as far as an attempt is being made to explain the metal sources for exhalative ore deposits. Nevertheless, the monograph makes an important contribution to an important problem, and the detailed chemical and mineralogical analysis of the Solomon Islands Younger Volcanic Suite stands on its own as a remarkably substantial piece of work. Although at £85.00, this book might not be purchased by individuals other than those with a deep interest in arc lavas or exhalative ore genesis, I would highly recommend it for purchase by institutional libraries.

D. A. POLYA

Trounson, J. H. (Burt, R. and Waite, P., Eds.). *Cornwall's future mines*. Exeter (University of Exeter Press), 1993. xvi + 164 pp. Price £14.95. ISBN 085 9894096.

J. H. Trounson's knowledge of Cornwall's mineral potential was extensive, arising from more than 50 years' association with the mining industry. It was thus not surprising when, during the 1960s, he was asked by the Department of Trade and Industry to produce a series of reports on areas of Cornwall considered worthy of future mineral exploration. Unfortunately, by the time these reports were finished he was told that they were no longer needed (and he didn't even receive any remuneration for his efforts!). The unique information he compiled was thus in danger of remaining unpublished and being lost forever. It is thus fortunate that The University of Exeter has been able to publish these manuscripts, not least as a tribute to an individual who did so much to assist the mining industry during his life.

This work contains descriptions of about 50 selected mining sites of promise in Cornwall; some are large and well-known, whilst others are small and obscure. It outlines their development history and the reasons why exploration or exploitation of promising deposits was either not successful or was terminated. It then summarizes the reasons why the author considers them to be worthy of further exploration. It is notable that the factors which curtailed mining operations were varied and often not geological. These include mine ownership problems, the intervention of war, lack of finance, flooding, depression of the tin price at the end of the last century, and the sudden deaths of key personnel.