and underground), geochemistry, geobotany, geophysics, sampling, prospect evaluation, drilling and mining methods, project planning, and management, means that none can be discussed at length. Some criticism can be levelled for example at the presentation of the geological section (Part 1), which is perhaps too generalized and would have been improved by more individual 'case history' examples. The reader will find this an interesting book but unfortunately, not a particularly good reference source for factual data and literature relating to specific prospecting problems, as this reviewer found when seeking information on duricrust (caliche) geochemistry.

Despite these criticisms, Professor Peters's book provides a much needed introduction to the wide variety of subjects that comprise practical mineral exploration and mining geology. It is recommended to lecturers, students, and recent graduates working as geologists in the minerals industry.

J. McM. MOORE

Habashi (F.). *Chalcopyrite: its Chemistry and Metallurgy*. New York (McGraw Hill) 1978. xi + 165 pp., 89 figs., 24 tables. Price £12·90.

As the title of this book indicates, the objectives of the author have been to review the chemical properties and metallurgical treatment of chalcopyrite, the most abundant copper-bearing mineral. Apart from an extremely brief discussion of the compositions and stabilities of bornite, cubanite, and idaite, no other ternary or binary compounds of the Cu-Fe-S system are dealt with in this text. The book is divided into twelve short chapters, most of which deal exclusively with the metallurgical treatment of chalcopyrite. These include discussions of the concentration of chalcopyrite by flotation methods and of metal extraction by thermal oxidation, reduction, aqueous oxidation, chlorination, and electrolytic treatment. One chapter reviews the structure and physical properties of chalcopyrite, and one deals with minor and trace elements in chalcopyrite and their effect on metallurgical processing. Only scant mention is made of the natural occurrence of this mineral. The concluding chapter is a statement of the author's view that the future of chalcopyrite metallurgy is in acid (probably HCl) pressure leaching of flotation concentrates at *c.* 110 °C in the presence of oxygen.

The book is written in a clear and concise style and the quality of presentation of text and figures is excellent. Each chapter is followed by an extensive reference list subdivided in terms of chapter subheadings. In reading the sections dealing with chalcopyrite metallurgy, one is struck by how many of the processes described seem only to be characterized empirically. Rarely have reaction rates and reaction mechanisms been properly investigated. Mineralogical studies in recent years have shown the complexities of the central portion of the Cu-Fe-S system, with such phases as talnakhite, mooihoekite, and haycockite being the result of different ordering processes during the breakdown of the high temperature 'intermediate solid solution'. It is a pity that the implications of this work have not yet been considered in relation to metallurgical processing; perhaps these aspects could be treated in a future edition of the book.

This book will be bought chiefly by metallurgists, but mineralogists and economic geologists working with copper sulphides will find it a useful review of the theory and practice of chalcopyrite metallurgy.

D. J. VAUGHAN

Navin (T. R.). *Copper Mining and Management*. Tucson (University of Arizona Press), 1978. 426 pp., 26 figs. Price $9.75 paper, $16.50 cloth.

Although this book by the Harvard Business School-trained Professor of Management at the University of Arizona adds little to knowledge of mineralogy, it is of interest to mineralogists in that it provides a conspectus of one of the greatest of mineral industries, evidently written with much inside knowledge. The year 1775 is chosen as the start of the modern era, dating from James Watt's agreement with Matthew Boulton to produce the former's patented steam engine. The dominant part played by the mines of Cornwall and Devon in the early Industrial Revolution is mentioned; about 100 were active, employing 60 000 men up to 1830, but with capacity for only about 15 000 tons of copper production per year. Of greater importance was the fact that Cornubia supplied talent, chiefly at foreman level, to every copper camp in the world up to World War I. Large-scale copper mining began, following Douglas Houghton's report, in Michigan about 1844, but for the USA the modern period began in 1881 with the discovery of Butte (Montana), Copper Queen and Morenci (Arizona), and the first look at Bingham Canyon, Utah, the last-named destined to become the prototype 'porphyry copper' deposit. Although British interests had developed mines in Chile and acquired Rio Tinto in Spain in the 1870s, by 1900 seven out of ten of the world's leading copper mines were in the USA. Today, Chuquicamata (Chile) leads the field, but it is believed that at Udokan (Siberia) Russia has the potential to develop the

world's largest copper mine. Nchanga (Zambia) holds third place and Bingham Canyon, for long supreme, fourth; Panguna (Bougainville) developed by RTZ is fifth.

The book is divided into three parts: I. Management of Copper Technology; II. Strategy in the Industry; III. Company Histories. The first section covers exploration, mining, smelting, refining, fabricating, sales, and politics while the second gives an illuminating historical review, by periods, somewhat weighted towards the United States, but interestingly written. Among the companies reviewed are, of course, Anaconda, Kennecott, AMAX, ASARCO, and Phelps Dodge, with nine other American concerns, and six foreign companies. Here one can only regret that it has been possible to say so little about the Soviet Union in view of its increasing importance in so many fields of mineral production. As is well known, the copper industry is more sensitive than most to fluctuations in world economy that have a marked effect upon price and therefore upon exploration, development, and associated technologies. The industry has survived reasonably well the onslaught of nationalization, but seems as far as ever from finding an answer to the vagaries of price.

KINGSLEY DUNHAM

Gribble (C. D.), Durrance (E. M.), and Walsh (J. N.). *Ardnamurchan: a guide to geological excursions.* Edinburgh (Edin. Geol. Soc.), 1976. x + 120 pp., 2 figs., 14 geol. sketch-maps, 1 coloured geol. map (in pocket). Price £2·00.

Although based on the earlier guide by Richey, this field guide includes recent ideas on the form and structure of such Tertiary igneous centres and outlines some of the remaining problems, which include the spatial and temporal association of acid and basic magmas that gave rise to most of the plutonic intrusions of Centre 2. A 68-page text is followed by a comprehensive bibliography covering the recent work on the igneous rocks of Ardnamurchan, and by details of seven excursions (45 pp.). There is a glossary of Ardnamurchan place names (but no derivation of the name *Ardnamurchan*) and an important new geological map (1:40 000). Extra copies of the latter are available (both folded and flat), price 60p each.

In Centre 3 one of the problems still unresolved is whether the intrusions comprising the complex dip inwards or outwards: although none of the recent studies has disproved the original concept that the intrusions are a series of outward-dipping ring dykes, the fluxion structure of three of the gabbros suggest a funnel or saucer shape (if it is assumed that the fluxion structure is a flow phenomenon and lies parallel to the wall of the intrusion). All the basic rocks of Centre 3, the eucrites, gabbros, and the dolerite, are closely related and form three separate and distinct groups of rocks, which are part of a differentiation sequence (MM 40-335). The tonalite and quartz monzonite in the very centre of the complex cannot have formed, however, by continued fractionation of the magma and are interpreted as hybrids formed by partial remelting and assimilation of country rocks into basic magma.

Despite the general title, the main text pays scant heed to the Moine country rocks, which have a story to themselves (MM **32**-866), and although more detail is accorded to the Mesozoic sediments, little mention is made of their metamorphism. Glebe Hill sapphire locality in the hypersthene gabbro is documented, however, whether this plagioclase–spinel–corundum assemblage represents xenoliths of an aluminous bole produced by weathering of adjacent Tertiary lava or thermally metamorphosed basic igneous rock.

But in the main it is for the excellent documentation of the Ben Hiant vent associated with Centre 1, the layered hypersthene gabbro and the granophyric quartz dolerites of Centre 2, the ring intrusion of Centre 3 and the Great Eucrite, and the spectacular cone-sheets on the coast near Kilchoan that this guide will be welcome. Its true pocket-size will ensure its use in the field and its price should ensure its presence on the shelves of most petrologists (or in their pockets).

R. A. HOWIE

Walton (Anne). *Molecular and Crystal Structure Models.* Chichester (Ellis Harwood, Ltd.) and New York (John Wiley: Halsted Press), 1978. 201 pp., 58 figs. Price £9·00.

Although Dr Walton's book is about molecular and crystal structure models of all kinds, quite a large proportion of it is of relevance to readers concerned with the structures of minerals and related inorganic compounds. The three kinds of model most used in this context are: spheres in contact, balls and spokes, and polyhedra. Their relative merits are discussed, and for each many examples are mentioned, made from a wide variety of materials including metal, glass, plastics, wood, and paper. Information is given about ready-made complete models, model-making kits for assembly, and even more basic do-it-yourself versions; for the latter, suitable jigs, adhesives, and other accessories