

The first chapter concerns itself with early ideas about the Earth's internal constitution and the discoveries of the early pioneers of earthquake seismology, such as Oldham, Milne, Gutenberg, Mohorovicic and Lehman. The last section of this chapter is a somewhat opaque explanation of how waves can be represented in the frequency domain.

Chapter 2 is a straightforward and clear account of the nature and properties of seismic waves, which anybody new to the subject should find to be very helpful.

In Chapter 3 the techniques and problems of observational seismology are outlined. Figure 3.4 provides an illustration of one of the main laws of observational seismology, i.e. that during or shortly before an important earthquake, the operator will switch off the recorder to change the paper or tape!

The main seismological divisions of the Earth into the crust, mantle, outer and inner core, are described in Chapter 4, together with short accounts of the internal structures of the Moon and Mars. The finer scale structure of the Earth is dealt with in Chapter 5, which makes very interesting reading especially in the accounts given of different investigations, and the action of their sometimes conflicting results upon current theories and subsequent studies.

Chapter 6 covers a topic of which, in my experience, many geologists are completely unaware. That is the study of free oscillations of the Earth generated by large earthquakes. Here, in relatively few pages, is a clear description of what they are, how they are studied, and what information they yield about the Earth's internal structure and anelasticity.

In Chapter 7 are summarised the various strands of evidence relating to the physical properties of the rocks forming the different parts of the Earth's interior and the temperature distribution.

Fifty exercises in Chapter 8 provide a gentle test of the reader's understanding of the book, and prompt questions about the material that otherwise might not come to mind.

If a succinct description of the Earth's internal structure and composition is required, then this book is worth reading, but that is not the book's main strength. The most absorbing aspect of the book is Bruce Bolt's account of *how* the Earth's interior has been explored, giving us the inside information on seismology and seismologists.

G. Westbrook

Metamorphic processes

Gillen, C. 1982. *Metamorphic Geology: An Introduction to Tectonic and Metamorphic Processes*. George Allen & Unwin, Winchester, Maryland. 144 pp. Price: hardback £12.00; paperback £4.95.

Whereas volcanic and sedimentary rocks may be seen forming on the Earth's surface at the present day, understanding the origin of metamorphic rocks, formed deep in the crust and exhumed only after millions of years of erosion, is conceptually much more difficult for beginning students of geology. Dr. Gillen's elementary textbook on Metamorphic Geology, designed to accompany G.C.E. 'A' level or first-year University (or Open University) courses in geology for students without previous geological background, will therefore be welcomed by both teachers and students. The author presumes that the student will at the same time be taking courses in other aspects of geology and will have access to a limited number of hand specimens, and possibly thin sections, of metamorphic rocks.

The book gives an overall view of the scope and significance of metamorphic rocks and metamorphic processes from first principles. Chapter 1 introduces the subject matter of the book, outlining the mineral composition, texture and field relationships of metamorphic rocks. Chapter 2 reviews the factors controlling metamorphism, including the environmental conditions within the Earth's crust; heat, pressure, pore fluids and the effect of differential stress; and describes how these conditions influence metamorphic processes such as crystal growth, diffusion and recrystallisation and suggests the possible relationships between environmental conditions and major movements of the Earth's lithospheric plates. In Chapters 3 and 4 the various types of metamorphic terrain are described in terms of the contact, dynamic and regional metamorphic associations; many of the examples being taken from the classic metamorphic terrains of the Scottish Highlands. In Chapter 5 the author describes how these types of metamorphic environments may be generated at plate margins or in regions of continental collision. He goes on to consider how these

processes may have varied through geological time and how these variations have influenced the development of the Earth's crust. The critical question here is the extent to which it is reasonable to extend present plate-tectonic interpretations back into the Precambrian. In his final chapter (6), the author explains how textural evidence can be used to recognise phases of recrystallisation, mineral growth and deformation which affected the rock since its origin as an igneous or sedimentary rock, reflecting the environmental conditions through which the rock had passed to reach its present metamorphic state.

The book is liberally illustrated with line drawings, maps, diagrammatic cross-sections and half-tones of rock outcrops, hand specimens and thin sections of metamorphic rocks. A series of short exercises are added to the end of each chapter, and the volume concludes with a useful glossary of terms used in the study of metamorphism and metamorphic rocks, suggestions for further reading and a list of excursion guides to areas of metamorphic interest in the British Isles. There is also a comprehensive index.

While the book is to be welcomed, it has some important deficiencies. The author has a staccato prose style and this, together with the printing of frequent keywords in bold type, detracts from the fluency of the text. The author frequently expresses his concern that the student should not be burdened with a plethora of new names and new concepts. This concern goes too far when important metamorphic minerals like glaucophane, prehnite, pumpellyite, lawsonite and jadeite are described, but not named, leading to the absurdity that rocks containing these minerals on Ernst's (1971) map of metamorphic zonation in California (taken from Miyashiro 1973) are all shown in the key as 'zeolite-bearing'. Although the book has pretensions to be an up-to-date exposition of current concepts in metamorphism and tectonics, the reader can detect a residue of older concepts such as orogenic cycles and the oversimplified view that orogenic belts develop from sedimentary basins.

Unfortunately, the book also provides many examples of careless editing: several figures lack scales; a detailed account of the Lewisian rocks of Northwest Scotland has no accompanying map; adjacent maps illustrating the extent of rocks affected by the Hercynian orogeny show different distributions in North America; Archaean rocks are described as 'all' metamorphic on one page and 'mostly' metamorphic on the next. There are also several obtrusive typographic errors.

Despite these shortcomings, the book is wholly admirable in its conception with proper emphasis given to the quantitative dominance of metamorphic rocks in the Earth's crust and to the importance of metamorphic processes in the evolution of the crust throughout geological time, drawing attention to the economic significance of metamorphic rocks where this is appropriate.

This short volume provides a valuable introduction to the study of the processes and products of metamorphism in their tectonic context and will provide an adequate basis for more advanced studies. It may be anticipated that demand for a second edition will enable the author to improve on the presentation of the first.

A. J. Barber

REFERENCES

- Ernst, W. G. 1971. Metamorphic zonation on presumably subducted lithospheric plates from Japan, California and the Alps. *Contr. Miner. Petrol.* **34**, 43–59.
Miyashiro, A. 1973. *Metamorphism and Metamorphic Belts*, Allen & Unwin, London.

Maps and structures

- Roberts, J. L. 1982. *Introduction to Geological Maps and Structures*. Pergamon Press, Oxford. 325 pp. Price: hardcover £20.00, US \$40.00; flexicover £7.50, US \$15.00.

A characteristic which is probably common to all structural geologists is the ability to perceive geometries in three dimensions. However, not all geology students are intuitive in this respect and thus textbooks of structural geology and map interpretation have to emphasize the topic. The stated purpose of this new book is to bridge the gap between the two groups of texts by describing structures in general and then explaining how they may be recognised on geological maps.

The book is divided into eight chapters: an introduction, a chapter on sedimentary rocks and outcrop patterns, five chapters on structures and their effects on outcrop patterns, and a final chapter on structural features of cratons and orogenic belts.

The introductory chapter covers a limited spectrum of material; briefly outlining maps in terms of relief, scale, map types (solid and drift), geological boundaries, cross-sections and symbols.

Chapter 2 is concerned with the basic principles and techniques employed to interpret maps, and covers them in two parts. The first part deals with stratigraphical nomenclature and the determination of stratigraphical sequence from a map. The second part of Chapter 2 includes the determination of dip and strike, the use of sedimentary structures, the significance of width of outcrop, the construction and use of structure contours, and the solution of three-point problems.

In Chapter 3 the discussion of individual groups of structures begins with folds. The reader is presented with a traditional description of fold geometries and attitudes which includes the analysis of morphology using dip isogons. Some discussion of boudinage is included in this chapter as well as the mechanics of folding.

The treatment of folds continues in Chapter 4, with particular attention being given to the effects of folds on outcrop patterns. There is also a full treatment of the influence of fold attitude on structural-contour patterns. Fold profiles are considered in terms of horizontal folds and rigorous methods for constructing profiles of cylindrical or parallel folds are given. Some of these methods have been superseded by stereographic techniques. Finally, contact strain in buckle folds and the importance of décollement surfaces are briefly discussed.

With Chapter 5 the organization of the book is changed; the description of structures and their representation on geological maps being combined into single chapters. Joints, veins and faults are discussed in Chapter 5, although the first two categories of structures are considered only briefly. Thus, the chapter rightly concentrates on faults, especially their morphology, attitude, senses of displacement and kinematic and dynamic classifications. Surprisingly, maps are little used to illustrate general points although the chapter is well illustrated.

Chapter 6 shifts to igneous rocks and their structure, with volcanics being considered first. Rock types are introduced, including some descriptions of textures in hand-specimens, a topic which is perhaps out of place in a book about structures and maps. Central volcanoes, lava plateaux and calderas are briefly described but other volcanic forms are not mentioned, and no maps of active or extinct volcanoes are included. The remainder of the chapter is concerned with intrusive rocks and begins with the effects of cross-cutting relationships, angles of inclination and concordancy. The next section about the occurrence of minor intrusions is well presented with excellent maps. Finally, major intrusions are considered, though no maps of lopoliths are included.

'Unconformities' are treated in a traditional manner in Chapter 7 with emphasis being given to types of unconformities, overstep, overlap, uplift and marginal unconformities, relative dating and reactivation. Illustrations in Chapter 7 include some simple subcrop maps.

In Chapter 8, 'Cratons and Orogenic Belts' Roberts describes some structures or processes not previously mentioned. For example, he deals with cleavage, refolding and migmatitic textures. There is, however, little attempt to demonstrate interrelationships between structures or to assess the general characteristics of the structural suites that are distinctive of cratons or orogens.

The book concludes with a bibliography of other texts in structural geology and allied disciplines, a list of British Geological Survey Maps and a comprehensive index. The execution of the line drawings used throughout Roberts' book is excellent, the use of graded ornament being particularly effective.

As a whole, the book suffers from attempting to integrate two topics (maps and structures) while nevertheless treating them separately. Somewhat surprisingly, examples from published maps of 'real areas' are not extensively used despite the hopeful comments in the preface. Although Roberts deliberately avoids too much discussion of the mechanical aspects of the genesis of structures, some of his accounts of deformation processes are dated. The book can, however, be recommended as a text with a traditional approach to structural geology and a strong emphasis on geological maps.

W. M. Dunne

The British Variscides

Hancock, P. L. (editor) 1983. *The Variscan Fold Belt in the British Isles*. Adam Hilger, 217 pp. Price: hardcover £34.00.

A paragraph on the dust cover of this nicely presented volume tells us that original contributions from leading specialists have been brought together to give the reader a comprehensive view of the Variscan fold

belt. This is not altogether true. In fact, the Variscan fold belt was carved up into divisions, mainly regional but also into aspects of the geology; each division was given to a specialist or small team to describe and the results put in order. The divisions are rational enough but the product is not comprehensive and the individual chapters are mainly reviews and not original contributions.

Before making an appraisal of this book I should like to say that, in my opinion, what is missing is a distinct head and tail. Whilst Rast's opening chapter goes some way to heading the volume it really contains material that should constitute a final chapter in which there is an integration or at least an attempt to find common threads to what had gone before. As it is, the volume ends in damp-squib fashion, fading into speculation and a couple of pages of useless tabulations.

The opening chapter deals with features of Variscan geology common to North America and Europe and the broad evolution of the belt. This is followed by chapters (2) on southern Ireland and then, in turn, South West Wales (3), the South Wales coalfield and its setting (4) and Bristol, the Forest of Dean and adjacent areas (5). Most of the rest deals with the South West Peninsula: on the deformation (6), the Lizard and pre-Orogenic volcanic activity (7), the granite batholith and post orogenic volcanism (8) and a separate chapter (though by the authors of Chapter 8) on the origin of the magmas and their relations to the evolving structure (9). Then follows a chapter reviewing recent (and not so recent) geophysical work in and around South West England (10) and the final chapter (11) is on sub-surface Variscan rocks through South East England into the Continent.

The space allocated to each of these must reflect the editor's view on the state of knowledge of the division or his assessment of its importance, and thus the equal weighting of southern Ireland and South West Wales may be justified. There is, however, an imbalance, so that constraining southern Ireland to twenty-seven pages might lead the reader to the view that it is a province with more stratigraphy than structure, no igneous rock component and not much to report in the way of geophysical studies. The chapter on South Wales, in contrast, becomes almost a field guide as well as a comprehensive account of stratigraphy and structure. Such imbalance is, I believe, inevitable and not a serious criticism.

Considering the space apportioned, the chapter on Ireland (2) is a good account and can be read with pleasure. In Chapter 3 the authors present a modern view of ground well known through the classic account by E. M. Anderson. There is emphasis on structural development and, apart from some curious phraseology and use of terms, it is a useful and readable review. Chapter 4 makes the geographical link between South West Wales and the Forest of Dean and Bristol districts. It is essentially a review with emphasis very strongly on the structure of the South Wales coalfield and its margins. Chapter 5 contains more stratigraphy but the structural geology is well described with a good account of the influence of early structures on Variscan deformation and the relations between structural evolution and stratigraphic development.

In Chapter 6 things go awry. Again the chapter is essentially a review and this must be expected in view of the diversity of the geology and the extent of the area. But, in reviewing literature, there is an obligation to present a balanced account of controversial problems and this the authors fail to do. Central to Hobson & Sanderson's chapter is detail of the 'problem of the fold confrontation' in mid South-West England, and the authors cite selected references from literature published between 1959 and 1973 to explain their point, completely neglecting more recent work. It is now established (e.g. Freshney *et al.* 1976, Isaac 1981, Stewart 1981, Turner 1981), that structures in this area are dominated by flat thrusts; allochthonous units with associated minor structures were stacked from south to north. In his introduction to the volume, the editor tenders what amounts to an apology; 'After the main text . . . had gone to press . . . relevant articles were published in the *Journal of the Geological Society* . . .' (i.e. Shackleton *et al.* 1982, Isaac *et al.* 1982) but this is only a poor excuse since descriptions of the thrusts were published some time ago. Much of the area in question is not well exposed and the detail only emerges after long days and weeks have been spent in painstaking mapping; it is not safe to project lines inland from cliff exposures. In a discussion of the paper read by Sanderson & Dearman (1973) John Sutton asked what efforts the authors had made to use the available palaeontological and stratigraphic information. The answer given then was somewhat evasive. Ten years on, much more data has slowly been accumulated and the question has more relevance than ever.

Old and experienced hands take on the igneous rocks of Devon and Cornwall for Chapters 7, 8, and 9. (It is not clear why Chapter 9 is separated from Chapter 8 which it follows logically and naturally.) All three chapters are well prepared and constitute a needed and hence