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BOOK REVIEWS

Oman's wealth of geology

Robertson, A. H. F., Searle, M. P. and Ries, A. C. (editors) 1990. *The Geology and Tectonics of the Oman Region.* Geological Society Special Publication No. 49. The Geological Society, London, U.K. 845 pp. Price £99.

As noted in the Preface of this Special Publication, there has been an extraordinary surge of international interest in the geology and tectonics of the Oman region. A major driving force for this awakening interest has been the need of the Government of Oman to undertake a geological survey of the country and evaluate its economic potential; this in turn has involved two major oil companies, Shell in the 1960s, and Amoco in the 1980s, together with major scientific teams, particularly from the United Kingdom and the United States in the mid-1970s to the mid-1980s, and France from 1982 to 1984.

Oman is without doubt a scientific gold mine. All geologists ought to visit Oman because of the first-rate exposure, relatively easy accessibility to the most important features and their variety. Geographically, the Oman Mountains lie on the NE edge of Arabia. Geologically, they are the remnants of one or more huge slabs of ophiolitic rocks—the largest and best exposed in the world—lying tectonically on a series of other thrust sheets made up of different facies that ultimately pass structurally down into the thick Phanerozoic cover of the NE edge of the Arabian platform. Unscramble the thrusts and one finds an orderly lateral change from a seemingly passive continental margin to a piece of ocean-floor. Thus Oman allows one to view the evolution of a passive margin from its inception some time in latest Paleozoic to earlier Mesozoic interval to its destruction in latest Mesozoic time without the need to drill it or seismically profile it. One can see the details of how ocean-floor is formed, and one can observe the results of its emplacement. So the story goes.

This reviewer's involvement in Oman has ranged from armchair poring over maps and reports to a hectic 'Geotour' organized in 1976 by the Open University and further secondhand experience at the conference organized in Edinburgh in 1988 whose outcome is this publication. The Edinburgh conference is a consolidation of much that had been started two or more decades ago. The publication contains 48 papers—too many to cite individually. They are subdivided into a large section of 33 papers on the evolution of the Oman Tethyan Continental Margin; 12 papers on the geology and tectonics of South Oman and three on the regional tectonic setting.

There is an excellent 18-page introductory commentary by the editors, which mentions all the contributions individually, sets them in context and draws the reader's attention to significant advances or differences in approach or conclusion. An index map (Figure 1 on p. xii) keys the contributions to their geographic position.

The publication contains a wealth of information in a concise, readily accessible form. In particular, there is a great deal of detailed new structural, stratigraphic, paleontological and sedimentological data whose availability must in part be due to the far-sighted and generous attitude of several of the commercial enterprises who supported its initial collection. There is not much on the Oman ophiolite itself, which is understandable given the publication of the Geological Society Memoir 11 on the Northern Oman ophiolite 2 years before the conference.

While it may be perhaps invidious to select particular papers for mention, this reviewer recollects being surprised by the unexpected account of the geology of the South Oman Salt Basin by Heward. Unlike most of Oman, the Salt Basin contains economically significant oil fields, with possibly as much as 12 billion barrels of oil in total. Their evolution is a fascinating story for a structural geologist and sedimentologist. It is an excellent example of how the movement of salt has influenced and been influenced by its cover. For example, the inversion of former peripheral synclines has given rise to large turtle-back anticlines. Smaller anticlines have also formed over remnant masses of dolomite and shale. Working out the details of this evolution must have required considerable patience and insight.

To this reviewer there are two curious general aspects of this publication: firstly, there are no new fundamental tectonic questions that are being asked in this publication in the sense that the same questions were being asked 10 or more years ago. The reason for this may be simply the second curious aspect: the answers to these fundamental questions are still almost as uncertain now as they were a decade ago.

In other words, while the details have been filled in for many parts of the Oman story, how these details bear on these larger questions is either not known or is still disputed. For example, the age of the formation of the Oman continental margin is still not agreed upon. Blendinger and others suggest ocean-floor spreading was already taking place by early Late Permian time, in contrast to the more prevalent view that the continent broke up in Middle to Late Triassic time (leading to the formation of a Middle to Late Triassic ocean?). The only preserved ocean-floor (the Oman ophiolite) is, of course, of a different age again, having crystallized in Late Cretaceous time. Were there really three margins, or three phases of margin formation? How can we tell? Or, on an entirely different matter, why are the Oman Mountains there in the first place? After all, they were at sea level in Late Cretaceous time. What Cenozoic process has raised them up? And so on. These comments are not meant to imply that these questions are unanswerable, but rather that new methods may need to be developed to tackle them.

The editors and the Geological Society of London are to be congratulated on the rapid publication of the volume—just over 2 years from Conference to bookshelf—in comparison with at least one major international conference held 3 years ago—in no way connected to the Geological Society—whose papers have only just been reviewed! Though the price of £99 may seem high, its 845 pages are excellent value, less than one-quarter of the price per page of another regional synthesis this reviewer came across recently.

The volume is highly recommended as providing an insight into the evolution of a continental margin from its inception to its destruction by the emplacement of a slab of ocean-floor onto it, a process of fundamental geological importance, though one that is still not well understood.

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A colourful three-dimensional view of subsurface structures

Brown, A. R. 1988. *Interpretation of Three-dimensional Seismic Data.* American Association of Petroleum Geologists, Tulsa, OK, U.S.A. 253 pp. Price $72 ($48 to AAPG members), hardcover.

This book is one of the American Association of Petroleum Geologists' memoir series and is based on short courses in three-dimensional seismic methods given by the author. It is the second edition of a book originally published in 1986, and the need for revision in such a short time is testament to the speed of developments in this field. The advantages of three-dimensional seismics in the mapping of subsurface geology are very dramatically illustrated throughout the book. Within the oil industry the increased resolution of sub-surface structure is already proving valuable in both exploration, reservoir evaluation and production. Although clearly aimed at the practising oil geologist, there is much in this book for the structural geologist and I will direct my comments mostly to these aspects.

In the last few decades, seismic profiles have played an increasingly important role within structural geology, providing much needed data from the sub-surface. The structure contour map, for long the tool of

the oil geologist and source of undergraduate practical exercises, is now being applied to more complex structural situations with a view to three-dimensional balancing and restoration of deformation. Just how accurate are structure contour maps and two-dimensional sections? Are the data good enough for the fairly sophisticated interpretations and restorations now being postulated? This book on three-dimensional seismic data goes a long way to answering such questions and illustrates the general strengths and weaknesses of such data.

The basic idea of three-dimensional seismic experiments is to gather data using a closely spaced grid of receivers, in such a way that processing can be applied in three-dimensions rather than assuming all reflections come from a single line of section. It is the resulting three-dimensional migration which distinguishes these data from so-called three-dimensional reconstructions based on two-dimensional sections.

A very vivid illustration of the power of the method is given by some data from the Gulf of Thailand—data which is used to illustrate many aspects of both structural and stratigraphic interpretation throughout the book. On p. 51, two contour maps (Figs. 3-8 and 3-9) are presented which compare interpretations based on two- and three-dimensional seismic surveys, both with 10 wells to control interpretation. The two-dimensional interpretation shows an irregular pattern of faults, obviously drawn by uncertain correlation of faults from different sections; the structure contours strike into the fault traces at high angles. The three-dimensional interpretation, on the other hand, not only shows more faults, but these are arranged in a sub-parallel array, with clearly defined offsets, relay ramps, etc. The structure contours intersect the fault traces at low angles defining rollover in the hangingwalls and footwall uplift. To anyone familiar with the detailed geometry of faults in outcrop (or where sub-surface data are plentiful) the difference is striking. To put it bluntly, the interpretation from three-dimensional data is believable whereas that from the two-dimensional data is not. This is a very sobering thought and I would strongly recommend every structural geologist to examine these maps before interpretation of any subsurface data on faulting, particularly two-dimensional seismic sections! There are many more equally illuminating examples in the book, including some involving deformation around salt domes.

Whilst the book presents examples of state-of-the-art three-dimensional seismic data, most of it in glorious colour, the author also succeeds in leading the reader through the various techniques used in the display and interpretation of such data. The basic ideas behind three-dimensional seismics are outlined in the introductory chapter, which includes a very instructive example of the value of three-dimensional migration based on synthetic seismograms. There are also some beautiful images of salt domes—many of which are explained in more detail elsewhere in the book. The manipulation of three-dimensional seismic data is clearly a job for the computer graphics workstation. Chapter 2 presents an interesting discussion of some of the graphical techniques used, again with a major emphasis on the colour display of the amplitude and phase of the reflected waves.

Chapter 3 deals with *Structural interpretation*—basically how to map horizons (reflectors) and faults in three-dimensions. The structural concepts are simple and should be familiar to any geology graduate; the real insight is in how the data, particularly the horizontal sections, provide high resolution images of the structure in three-dimensions. I particularly appreciated the inclusion of a set of 24 horizontal sections, 8 m apart, from which readers can construct their own structure contour map (in two-way travel time of course!). This is a good example of the straightforward presentation of practical examples which characterizes the book. Another excellent example, which would provide a very nice exercise for students, is given in the Appendix. The use of computer graphics to display both horizontal and vertical sections as block diagrams provides some excellent three-dimensional visualization of structure.

Chapter 4 deals with stratigraphical aspects and includes some beautiful images of channel sands. Chapter 5 considers reservoir identification, particularly the recognition of 'bright spots' and 'flat reflections' from oil–gas–water contacts. In both these chapters there is some excellent imagery, which includes many interesting fault structures.

Chapters 6 and 7 deal with the more technical aspects of tuning phenomena and reservoir evaluation. Tuning is an effect produced by the interaction of reflected waves from the top and bottom of a bed; as they converge there is constructive interference to produce an amplitude maximum at the 'tuning thickness', below which the reflected energy decreases, making the bed invisible. Reservoir evaluation involves the extraction of quantitative information from seismic amplitudes to provide information on such features as the lithology, porosity, pay thickness, pressure, nature of fluid and hydrocarbon saturation of the reservoir.

The final chapter (Chapter 8) consists of seven case histories, written up by the original investigators. These mainly illustrate the value of three-dimensional seismics to the oil industry, but many are of structural interest. The East Painter field in the Overthrust Belt of Wyoming, shows a small triangle zone and there is a beautiful image of inversion in an Upper Permian gas field in NW Germany. Most of the examples are from extensional terrains, several of growth faulting in the Gulf of Mexico and some excellent images from Trinidad and the Ivory coast. In many cases comparisons are made between interpretations based on two-dimensional and three-dimensional surveys and these emphasize the point that the latter give much clearer insights into the geometry of fault systems. In one example from the Cougar prospect in the Gulf of Mexico, where the three-dimensional survey was carried out with a 15 m point spacing, a 4 × 4 km block revealed over 20 faults where only two were known from the original two-dimensional survey.

In summary this is a beautifully presented book, with clear text and excellent colour illustrations. It provides a very informative and visually stimulating introduction to three-dimensional seismic reflection surveys. The influence of such data on the development of structural geology will undoubtedly grow as more data become available outside the oil companies. My only negative comment is that the figures have very short and uninformative captions with most of the discussion in the text; due to the abundance of the illustrations the text in many places gets well ahead of the relevant figure making it difficult to study both simultaneously. Aside from this minor point, I found the book gave a very clear insight into the methods and application of what is surely one of the most significant technological developments in subsurface methods. The book is a must for any library and, given the high quality and lavish use of colour illustration, good value at $72 ($48 to AAPG members).

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