Journal of Structural Geology, Vol. 15, No. 6, pp. 809 to 815, 1993
Pergamon Press Ltd. Printed in Great Britain

BOOK REVIEWS

Textbook of structural geology

Twiss, R. J. and Moores, E. M. 1992. *Structural Geology*. W. H. Freeman & Co., New York. Price $59.95 (hardback; ISBN 0-7167-2252-6).

In an ideal world, the recommended textbook for a given course would be one written by the course teacher. However, given the real situation where the vast majority of courses have to make do with texts written by third parties, this new textbook by Robert Twiss and Eldridge Moores is probably the next best thing. Described in the Preface as an introductory text, this hefty 530-page work could be used to support several structural geology courses spanning the range from undergraduate to post-graduate levels. This is made possible because of the unique layout of the text which separates the observational, descriptive aspects of geological structures (which are more accessible for the beginner) from sections dealing with their mechanical interpretation (and requiring some background in physics and mathematics).

This book has most of the essential ingredients of a good structural geology course text. Structural geology is concerned to a large extent with the variety and beauty of natural forms and the authors have done service to their subject by collecting together a large number of visually attractive images to catch the eye of the student. Through more than 500 figures, the student is treated not only to the usual line drawings and outcrop snapshots but also to a fair number of air photos and seismic sections. These figures are not only abundant but are of excellent quality. The third dimension, so vital yet so often ignored, receives full attention. The coverage of topics is encyclopedic. Attempts by the reviewer to discover new areas of the subject which have been omitted failed totally.

The book's 22 chapters are grouped into five parts: Introduction; Brittle Deformation; Ductile Deformation; Rheology; and Tectonics. The first of these includes a chapter entitled Overview which defines the subject areas of structural geology and tectonics in terms of rock deformation on different scales. This is followed by a rather mixed chapter called Techniques of Structural Geology and Tectonics which, in spite of its name, devotes little space to practical methods but instead gives brief mention of the popular formats for representing geological structures (maps, sections, etc.). For example, stereographic projection is described here in concept but plotting procedures are not gone into.

Part 2 begins with a systematic survey of the principal classes of brittle structures dealt with from a largely geometrical standpoint. This is achieved in chapters entitled Fractures and Joints; Introduction to Faults; Normal Faults; Thrust Faults; and Strike-slip Faults. Coverage is exhaustive with the inclusion of up-to-the-minute topics such as metamorphic core complexes, shear criteria and models for hanging-wall deformation in normal faults. In common with some other texts, the basis of the klippe-window method of estimating minimum thrust displacement is poorly explained. Surely the sinuosity of the outcrop trace is irrelevant. Thankfully though we are spared the alternative, so-called *bow-and-arrow rule* for finding thrust movement; a rule no-one has successfully convinced me is valid. There are errors (e.g. Fig 4.2) where the throw of a fault is defined as the equivalent to vertical component of the net slip instead of the vertical component of the dip separation, but these are few and far between. In keeping with the overall layout of the book, we are kept waiting for the theoretical aspects of brittle deformation. We thus encounter stress for the first time in Chapter 8 though the wait is worth it. The treatment is serious and at the same time reader-friendly. For example the average reader will appreciate the pages headed "What is a vector?" and "What is a tensor?" Although the stress tensor is defined, the Mohr construction is the route chosen for stress calculations, including those in three dimensions. I would like to have seen mention of the pole of the Mohr circle because it simplifies understanding of how orientations are expressed in Mohr space. This chapter benefits from the worked out examples included at the end. Chapter 9, Mechanics of Fracturing and Faulting, deals with theoretical fracture criteria and experimental brittle deformation. The geological applications of these subjects, including those in the field of palaeostress analysis, are developed in Chapter 10, Mechanics of Natural Fractures and Faults.

The first chapter of the book devoted to ductile deformation is called The Description of Folds. The terms that a geologist uses to describe the finer points of a fold's anatomy are all there together with alternative schemes used for geometrical fold classification. Kinematic folding models receive attention in Chapter 12 but I cannot help but think that the discussion here and in the two chapters which follow is hindered by the fact that strain theory has not been dealt with at this stage in the book. For example, flexural-slip folding is explained in terms of flexed card decks but the resulting strain patterns are not discussed. In this chapter the geometrical features of superposed folds are well illustrated but the 2-page discussion is probably insufficient for the student intending a practical analysis of real field data. Chapters 13 and 14 are concerned with foliations and lineations; their morphology and genesis, respectively. Geometry of Homogeneous Strain receives rigorous treatment pitched at an advanced undergraduate/post-graduate level. Again quantitative aspects are not side-stepped but this time the Mohr construction is not used. I was somewhat disappointed by the fact that although it is explained that tensors can be used to describe strain, the example used is not applicable to the large magnitude strains found in rocks. Besides this, the authors are to be commended on the way they lead the reader through the terminological minefield of rotational strain, coaxial strain and vorticity. The succeeding chapter looks at structures such as folds and foliations from the point of view of strain distributions. This is followed by a chapter, Observations of Strain in Rocks, dealing with the principal techniques of finite strain analysis.

Part 4 consists of three chapters on rock rheology. The first deals with the flow behaviour of rocks during laboratory deformation conditions. Here and throughout the book results are presented in text and diagram form without reference to their source. To have to do detective work to match the items with the reference lists at the end of each chapter could irritate slightly. The chapter that follows contains a useful summary of the deformation mechanisms operating on a microscopic scale in rocks undergoing ductile deformation. Discussion of mechanisms involving the movement of dislocations leads on in a natural way to the subject of crystallographic fabric development. The section is concluded by Chapter 20 which is concerned with the mathematical and analogue modelling of ductile deformation.

The final part of the book is devoted to tectonics. A general survey of the principal tectonic features of the Earth is followed up by looking at greater detail at the make-up of orogenic belts. This chapter provides the opportunity for pointing out the value of several sub-disciplines of our subject, such as kinematic analysis (using folds and foliations) together with fabric and strain analysis.

In summary, this attractive well-produced book, with its comprehensive coverage of topics, is the one to refer to for finding out what terms like crenulation cleavage, Nabarro–Herring creep and strike-slip duplexes mean; there are better books around for finding out how to implement practical techniques for structural analysis. *Structural Geology* is therefore an ideal book to complement other existing texts which place greater emphasis on problem solving, worked examples and exercises for the student.

Richard Lisle
Cardiff, U.K.

Shear sense, and more

Hanmer, S. and Passchier, C. 1991. *Shear-sense Indicators: A Review*. Geological Survey of Canada, Paper 90-17. Geological Survey of Canada, Ottawa, Canada. Price Can $9.10 (Canada); $10.20 elsewhere. Twelve 35 mm colour slides of Figures: Can $21.40 (Canada); $24.00 (elsewhere).

It is the nature of rapidly advancing scientific endeavour that publication lags behind the development of ideas and concepts. This perhaps is exemplified by structural geology. Over the past 20 years our appreciation of large-scale deformation patterns in orogenic belts has acquired a new rigour. First came the attempts to quantify finite strains from measurements of deformed objects and the integration of these data to establish finite displacement fields across large tracts of orogenic belts. Two limitations led to this treatment of orogens as broad simple shear zones becoming marginalized. It was realized that much of the displacement is accommodated on discontinuities or within zones where the strain is too high to quantify accurately. And finite strain integration obscures the history of an orogen as a structure that evolves incrementally, with complex patterns of displacement localization. Through the 1980s many orogenic studies have focused on the discontinuities, by restoring the displacements recognized on cross-sections and by establishing the displacement directions using small-scale structures. These two complementary paths branch and represent a natural progression from the original strain integration concepts. Yet during this period the graphical restoration of structural profiles through section balancing and the use of small-scale structures to determine shear sense have been controversial, misunderstood and misrepresented by the sceptical. We all need to step back to see the applications, the assumptions, uses and abuses of these methods. Review texts can provide these essential perspectives. We still await such a work for section balancing. But Simon Hanmer and Cees Passchier through their slim volume for the Geological Survey of Canada go most of the way with shear criteria.

Shear-sense Indicators: A Review is an excellent little book, clearly designed, nicely presented with many superb illustrations. Indeed for a small additional cost it comes with 12 colour slides of small-scale structures. In a way that is rare for many structural texts, the authors go beyond merely demonstrating that they know their business but actually attempt to communicate it to the reader. It is not merely a catalogue of photographs— 'here it is and this is what it means'. There is a valuable theoretical discussion on the theory of strain combinations, anisotropy, the behaviour of rigid bodies, coaxial and non-coaxial deformation. There is a users' guide to where to look, all in 25 pages. Sure, it's brief but the 5 pages of closely packed references allow access into the specialist literature. Then comes the structures, grouped into 'shape fabrics (foliations)', 'inclusions and appendages' and 'veins and folds'. There are over 80 illustrations of theory, example and experiment. The value is excellent, being rather cheaper than the cost of a copyright-breaching photocopy.

Brevity is a bold path to follow; this is a lot to cover in 72 pages. There are bound to be critics—their favourite small-scale structure or paper unmentioned. Surely there will be few harsh words raised by those of us who have been hassled by undergraduate students who demand directed reading and are not impressed by the legion of papers on, say, extensional crenulation cleavage. Yet Hanmer and Passchier do not offer too many easy answers where natural ambiguities exist. There is plenty of good advice, particularly concerning rotated porphyroblasts and so-called 'tiling structures'. The onus is on sound observation linked to robust theory.

Yet I do have some quibbles. Folds, historically the most important shear criteria (through the vergence concept) and yet most abused, only scrape a couple of pages. Antivergence doesn't feature. Perhaps this reflects the book's parentage. The authors have involved plenty of examples from basement gneiss terrains but very little from deformed well-layered sequences. Minor structures prolific in high level fault zones (e.g. shear fibres, Riedel shears) are missing entirely. This is a pity. Second, naturally most field photographs have been annotated with the authors' estimate of shear sense. Yet these come from disparate locations with no corroborative evidence for the inferred shear senses. Ideally all these examples should have been grouped from a few, well-constrained and therefore neotectonic, settings. But generally, there have been few studies that catalogue all the small-scale structures in a single, unikinematic shear zone. My final quibble relates to the requotation of one of my colleagues concerning the mental state of deforming materials. Next we'll attempt to establish the energy balance of orogens by estimating the pain threshold of rocks.

So Simon Hanmer and Cees Passchier should be congratulated on producing a user-friendly yet thought provoking booklet. In their preface they hope that their "contribution will stimulate others to critically re-examine . . . the structures and interpretations . . . and to reassess the kinematic significance . . . placed upon them". I share their hope, because these concepts are important to all geologists, and the promotion of these ideas to a general audience is more important than the occasional petty squabble over a single interpretation. Mind you, those 'winged inclusions'. . . .

Rob Butler

Leeds, U.K.

Earthquake mechanics

Scholz, C. H. 1990. *The Mechanics of Earthquakes and Faulting*. Cambridge University Press, Cambridge, U. K. Price £25.00 or $34.50 (paperback, ISBN 0-521-40760-5).

The earth sciences have become multidisciplinary in nature particularly since the emergence of plate tectonics nearly three decades ago. Hence ambitious structural geologists should focus on major unsolved problems in earth sciences that attract a diverse community of earth scientists, while making full use of the knowledge and techniques that have been cultivated in the fields of structural geology and tectonics. The mechanisms of earthquakes and earthquake prediction are undoubtedly this type of crucial problem, not only from a scientific point of view, but also in view of the social implications. In fact, earthquake hazards exceed other natural disasters in producing the highest death toll. Therefore, successful earthquake prediction has long been a serious wish of a great number of people living in earthquake-prone countries.

This new book by Chris Scholz leads us toward a better understanding of the mechanism of earthquakes and the eventual realization of earthquake prediction, by providing an excellent synthesis of a wide variety of topics such as rock mechanics (rock rheology), seismology, geodesy, structural geology, seismotectonics, seismoengineering and earthquake prediction. The author employs a mechanistic approach to this goal, in the hope that once the mechanisms of earthquakes are known, the physical basis of earthquake precursors will become clear. Moreover, the full understanding of the mechanisms of earthquake generation may lead to innovations in the method of earthquake prediction. The comprehensive and thorough approach taken by the author to this problem is indeed remarkable. The author is perhaps the only one at present who can integrate the large and diverse literature relevant to the present subject in a unified framework. Although the topics covered in this book are too diverse for a full account to be given on each subject, the book will be a useful textbook for advanced undergraduate students, graduate students and scientists to grasp the entire framework of the science of the 'mechanics of earthquakes and faulting', as well as a useful reference book for researchers in this subject.

The first two chapters, Brittle Fracture of Rock, and Rock Friction, concisely review all important aspects of brittle fracture and friction of rocks. These two chapters provide the basis of the author's mechanistic approach to earthquake phenomena, as elaborated in later chapters. The main topics treated in Chapter 1 are the basic concept of fracture mechanics for three modes of cracking, macroscopic failure criteria, experimental data on the brittle fracture of rocks (fracture strength, dilatancy prior to brittle fracturing, fracture energy, the effect of scale on rock strength, pore-pressure effect on strength, dilatancy hardening and subcritical crack growth due to stress corrosion) and the brittle–plastic transition. Chapter 2 deals with the adhesion theory of friction, topography and frictional interactions of rock surfaces, experimental data on rock friction (including the effects of temperature, pressure and pore fluids), the transition from frictional slip to plastic shearing flow, wear processes, fault constitutive properties and types of fault motion. The book by M. S. Paterson (1978), *Experimental Rock Deformation—The Brittle Field* (Springer), is also excellent supplementary reading for students on these subjects.

Chapter, 3, Mechanics of Faulting, deals with the Hubbert–Rubey theory of overthrust faulting, formation and growth of faults, fault rocks and fault models, the debate on the strength of fault zones (state-of-stress problem), and fault morphology and its mechanical effects. I find this chapter very interesting and think that structural geologists can contribute greatly to the subjects covered here. Readers must be cautious about Fig. 3.14, a schematic diagram of Riedel shears, which I think is erroneous. The R_2 Riedel shear *must* be symmetrical to R_1 with respect to T. The 'R_2' in this figure is normally denoted as X by other workers, and the 'P' Riedel shear is missing in this figure.

Chapter 4, Mechanics of Earthquakes, treats earthquakes as dy-