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'. . . .

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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 dynamic phenomena. It covers the dynamics of fault motion with an emphasis on shear rock propagation, phenomenological characteristics of earthquakes (e.g. relationships between magnitudes, energy and frequency and scaling relations) and earthquake occurrence with several illustrative examples of natural earthquakes. The concepts of 'barriers' and 'asperities' are clearly explained both in terms of natural earthquakes and mechanical implications. A typographic error: "Ishimoto–Aida relation" on p. 187 (second line from the bottom) should read "Ishimoto–Iida relation".

Chapter 5, The Seismic Cycle, integrates results from various fields (seismology, geodesy, active fault research, paleoseismicity and simulation of fault motion) to shed light on the complete seismic cycles. Crustal deformation during the complete seismic cycle is shown clearly by the use of several examples. Detailed discussions are also given on the perfectly periodic model, the time-predictable model, and the size-predictable model (Fig. 5.13), and so far natural data suggest that the time-predictable model is correct. However, the author demonstrates that a variety of modes of a seismic cycle can be created from a simple, four-block coupled model of faults. This chapter ends with a quotation from G. K. Gilbert (1909), sometimes regarded as the 'father of seismogeology', expressing his notion on the seismic cycle. It is surprising that a geologist foresaw the basic features of the seismic cycle so long ago.

Chapter 6, Seismotectonics, summarizes seismicity under various tectonic settings such as subduction zones and extensional regimes. A brief account is also given on the relative role of seismic and aseismic faulting, the mechanism of deep earthquakes, and induced seismicity. The author proposes many interesting ideas to account for the characteristics of seismicity in each tectonic setting. However, some of his ideas are controversial, but there is no space here to comment on them. Perhaps, 'seismotectonics' is the area to which structural–tectonic geologists can contribute most in the future.

The last chapter, Earthquate Prediction and Hazard Analysis, gives an excellent summary of the current status of research on earthquake prediction. Typical examples of earthquake precursors are seismic quiescence prior to an earthquake, seismicity with a characteristic doughnut pattern, foreshocks, crustal deformation as revealed by geodetic survey, and hydrological, geochemical and electrical resistivity changes. Those interested in earthquake precursors should also be interested in Mogi's (1985) book, *Earthquake Prediction* (Academic Press), which provides a more comprehensive summary of earthquake precursors. The current mechanical interpretations of those precursors are clearly summarized in this chapter. However, no universal mechanism for the observed precursors has been identified as yet, and earthquake prediction is still at the empirical stage waiting for a major breakthrough (see p. 377). Nonetheless, I believe that the comprehensive approach taken in the present book is the most orthodox approach to earthquake prediction.

Additional comments will be given below on a few topics which structural geologists may find of interest. The author's classification of the lithosphere into schizosphere and plastosphere (Fig. 5.10) is unique and may be new to many readers. The presence of an aseismic plastosphere makes the author's model different from the traditional lithosphere–asthenosphere model, and viewing the lithosphere in this way has many implications on seismicity and crustal deformation as discussed in various parts of the book.

This classification is based primarily on the fault model of Scholz (1988) shown in Fig. 3.19. Although this model may appear very similar to a model which I proposed in 1989, the two models differ in the mechanical meaning of the depth extent of the seismogenic zone. The author idealizes that a change from velocity weakening (potentially unstable) to velocity strengthening (stable) in the frictional properties of faults coincides with the onset of plasticity in the transitional regime between the brittle and fully plastic regimes, based on the experimental data of Stesky (1978). However, experimental data on the shearing deformation of halite clearly indicates that velocity weakening behaviour extends well into the semiplastic regime where plastic deformation is predominant, forming mylonitic deformation textures.

The difference between the two models changes the rheological interpretation of the lower half or lower one-third of the seismogenic zone, and hence more work needs to be done in the future to establish a realistic fault and plate boundary models. Experimental data on high-temperature frictional properties of faults at a large displacement are desperately needed both for monomineralic and multimineralic shear zones. Moreover, structural geologists would immediately notice that those faults models have not yet incorporated deformation via solution–precipitation processes, possible superplastic flow of ultrafine-grained material constituting the central part of *deep* faults, and the effects of chemical reactions in fault zones. In particular, there is a great deal of geological evidence displaying the solution–precipitation processes, although no account is given in this book on its possible significance (e.g. p. 313). Evidently, the establishment of fault and plate boundary models is the area in which rock mechanists and structural geologists should co-operate more.

The present book is about the only book available now that fills the gap between earthquakes, as studied in seismology, and faulting, as mechanical and geological phenomena. I can strongly recommend this book to structural–tectonic geologists.

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Fractures in core

Kulander, B. R., Dean, S. L. and Ward, B. J., Jr (1990) *Fractured Core Analysis: Interpretation, Logging, and Use of Natural and Induced Fractures in Core.* American Association of Petroleum Geologists, Methods in Exploration Series, No. 8. American Association of Petroleum Geologists, Tulsa, Oklahoma, U.S.A. 88 pp. Price $43; AAPG members $29.

Increasing awareness of the existence and importance of fractures in aquifers and oil and gas reservoirs, and rapid advances in inclined-well drilling technology require a better knowledge of natural fractures in the subsurface. The most direct access to the information about subsurface fractures is, of course, drilling and coring. Unfortunately, however, drilling and coring processes themselves induce fractures in core samples. Thus, one of the crucial steps in utilizing the information provided by core samples is to distinguish between the drilling- and handling-induced fractures and natural fractures. This book provides a general framework and many specific examples for distinguishing natural fractures from induced fractures in oriented and unoriented core.

Although many books on natural fractures are available, as far as I know, only one (*Geologic Analysis of Naturally Fractured Reservoirs* by R. A. Nelson, 1985, Gulf Publishing Company) contains substantial information on drilling and coring induced fractures. So, the book by Kulander and others is unique in focusing entirely on recognition and classification of natural and induced fractures in core, and on procedures for recording the data and their interpretation. The book appears to be the extension of a previous book by B. R. Kulander, C. C. Burton and S. L. Dean entitled *Application of Fractography to Core and Outcrop Fracture Investigation* which has been out of print for several years. For those readers who have the previous book or are familiar with it, the present book is based primarily on Chapter 7 Laboratory Fracture Examination Procedures and on Chapter 8 Fractographic Characteristics and Formation Modes of Natural, Coring-induced, and Handling-induced Fractures of the previous book.

The book has several chapters, but only three of these form the skeleton of the book; Chapters 3 and 4, and Chapter 9 which is referred to as the "Appendix". Chapter 3 provides a number of distinctive characteristics of many natural fracture types encountered in cores. Chapter 4 deals with induced fractures in core such as disc, petal-centerline, torsion, scribe knife, and a few unconsolidated sediment fractures and a number of handling-related fractures. The illustrations of specific fractures, both photographic and diagrammatic, are excellent. Several color photographs are very helpful with the visual image of core samples and the associated fractures.

Other chapters of the book are rather short and appear to be more suitable as either sidebars or appendices. One of these (Chapter 5) includes an example of a logged natural fracture zone (Enclosures 1 and 2), which is the most impressive demonstration of the occurrence of natural fractures in core and the applications of fracture geometry and fractography to distinguish between natural and induced fractures. Another one (Chapter 6) provides a color diagram showing a summary log of what is referred to as "fracture-tectonic features", which may be useful for practitioners in the energy industry as well as engineering geology firms.

The strength of the book lies in the fact that it efficiently utilizes fracture geometry and fracture surface morphology to help us understand fracture kinematics and to infer possible mechanisms, natural or man-made, for their formation. I would recommend it to anyone who deals with subsurface fractures. The book may also prove to be useful