namic 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 for structural geologists who often are faced with questions such as "Are there fractures at depth? Can fractures stay open in reservoirs and aquifers? How do you separate tectonic fractures from surfacial ones in outcrops and road cuts?" And so on.

The weakness of the book, in my opinion, is generally organizational. The first three sections in the Appendix including fracture definition; surface morphology of opening fractures and its kinematic implications are the backbone of the book and should have been incorporated into Chapter 2. The last section in the Appendix on stress fields associated with drilling and coring operations belongs to Chapter 3. However, this section is ineffective because it neglects the stress concentration associated with drilling and coring. Fractures around the well bore, for example well bore breakouts, provide crucial information about the stress field that can be used in the interpretation of both natural and induced fractures in oriented and unoriented core samples. Finally, the field of natural fractures in rock and their flow properties is a complex broad topic, an adequate coverage of which is outside the scope of this book. The reader may want to supplement the book with several recent research articles on these topics.

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Fluids in the crust

National Research Council (1990) *The Role of Fluids in Crustal Processes.* National Academy Press, Washington, DC, U.S.A. Price $24.50 (cloth; ISBN 0-309-04037).

This book is a collection of papers dealing with the effects of fluids on endogenic geological processes, and aims to give an assessment of the emerging topic of fluid research. In 11 chapters, diverse aspects of fluid involvement in endogenic processes are discussed, and illustrated by case studies. Most chapters represent independent overviews of a particular sub-discipline, and have been written by a different author or combination of authors. In an introductory note, an overview of the subject is presented in which the diverse topics are discussed, and a "Recommended Research" paragraph is given. In Chapter 1, Bredehoeft and Norton discuss the basic equations of the pertinent processes: flow, advection, heat, stress and strain as well as mineral–fluid reactions, and the significance of these processes is illustrated by examples. Chapter 2 is a more specialized derivation by Norton of the equations of fluid–rock interaction near magma chambers. From Chapter 3 onwards, the style of the book changes, and more conceptual models are presented, and various techniques and results are given: e.g. joint development near batholiths (Titley); fluid dynamics and metamorphism and magmatism (Walther, Wickam and Taylor); the use and principles of stable isotope studies (Taylor); the signature of fluids in deep seismics (Oliver) and the effects of fluid on tectonics (Engelder, Nur and Walder).

Due to the diversity of authors and subjects, it is hardly possible to give a review of the entire book, as all the chapters should be evaluated separately. Therefore, I will limit myself to those aspects of the book which deal with structural geologic or tectonic processes.

Oliver (Chapter 8) presents one of the most intriguing models, relating far reaching horizontal fluid migration (e.g. hydrocarbons) to plate tectonics. The geographic distribution of oil and gas fields is related to the large scale crustal tectonic history. Although his model is speculative and debatable, it is interesting because it is a new idea, worthy of evaluation. Other chapters of the book which have a structural geologic bearing discuss the effects of high pore pressures on fault and joint dynamics. In this respect, the book offers a good overview of the subject, but not many new points of view are presented.

A fundamental omission of the book is that it lacks one or more chapters on the role of fluids in ductile deformation and recrystallization. This is very strange, as it is one of the most fundamental effects of fluids in crustal deformation. Furthermore, a book like this should include a chapter of the results of deep drilling experiments, as this gives more than anything else an account of direct sampling of the fluid phase at a depth deeper than superficial. Nevertheless, the book offers insight in many different aspects of fluid studies, the techniques and their limitations, and is a worthwhile purchase.

I can recommend this book to anyone who is interested in the topic, especially considering the price is $29.50 (export), which is moderately cheap for a hard cover copy.

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Granites

Brown, P. E. and Chappell, B. W. (editors). 1992. *Second Hutton Symposium on The Origin of Granites and Related Rocks. Transactions of the Royal Society of Edinburgh, Earth Sciences* 83. *Parts* 1 and 2. Royal Society of Edinburgh, U.K. 508 pp. Price £55.00.

The Second Hutton Symposium on the Origin of Granites and Related Rocks was held in Canberra in September 1991 and it is a great tribute to the editors that the Proceedings have become available in such a short time. The volume contains 43 papers and 70 abstracts and is therefore an almost complete record of the papers presented. Of the published papers, about a third are major review articles, whilst the remainder are more detailed case studies. The volume has two biases, one towards Australian geology, which is understandable given the location of the conference. The other bias towards petrology perhaps reflects the concentration of current effort in this field of granite studies.

This volume presents an up-to-date snapshot of what we know about the origin of granites. Major themes include the source of granite magmas and the relative roles of crustal and mantle contributions; the mechanisms and physical conditions of melting; the nature of the heat sources responsible for granite generation; the mechanisms of granite emplacement and the extent to which granite chemistry can be related to tectonic setting.

One of the most important questions about the source of granite magmas concerns the extent to which granite compositions mirror that of their source. It has been argued that many granite magmas contain significant amounts of crystals which did not precipitate from the melt. These crystals are residual (restite) and inherited from the source during partial melting. They remain in the melt because of the viscosity of the magma and the difficulty of separating the melt from unmelted residue. Three lines of evidence, presented by a number of different authors, offer strong support for the restite model. First, there is the direct observation of restite material in felsic igneous rocks. Two very clear examples are given, both from Spain, of a granite and a dacite, both rich in enclaves of sedimentary material. Second, a thermodynamic study of selected Australian granites showed that observed compositional variations are the result of restite unmixing and that some samples contain up to 65% restite, a view corroborated by an independent experimental study of plagioclase compositions. The third argument comes from observations made using the SHRIMP ion microprobe in which old zircons are identified in the core of some magmatic zircons crystals. These are thought to be inherited from and characteristic of the source of the granitic magma. These studies also show that in a single granite, inherited zircons may have a wide range of ages and challenge previous interpretations of discordia plots for granites containing inherited zircons.

The restite model is the underlying assumption of the S- and I-type granite classification, first proposed for the granites of the Lachlan fold belt in eastern Australia. S(edimentary) and I(gneous) type granites are recently redefined as S(upracrustal) and I(nfracrustal) granites to distinguish between sources which have been exposed to supracrustal weathering processes and those which are in the deep crust and formed by underplating. It is apparent, however, that many workers regard the S- and I-concept as one which does not export well and interpret S- and I-type granites as crust and mantle end-members in what is more normally a continuum. This is the premise in a Nd-isotope study which calculates the relative crustal component in a given granite magma. Mafic enclaves can also indicate the involvement of mantle processes although their relative volume in granite melts (*ca* 2%) is in conflict with volumes estimated from isotope data which suggest up to 70% mantle component. Further evidence for a mantle contribution to granite magmas comes from a number of regional studies. One very detailed experimental study of a garnet-bearing dacite from New Zealand concluded that the magma can only have originated at mantle depths.

If the restite debate has been current for several years a newer area of investigation for granite petrologists is the question of heat sources. A consensus is emerging that granites are produced as water undersaturated melts at relatively high temperatures (850–950°C) by vapour-absent melting of lower continental crust. What is the heat source for such a process? Many authors consider the mantle as the primary heat source, reflecting the predominantly petrological approach to granite genesis in this volume. Questions addressed concern the mode of heat transport from mantle to crust. Is it by emplacement of mantle-derived