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 plutons (advection) or increased heat flow (conduction)? A related question concerns the generation of the contemporary mantle melts. Is it by decompression melting of upwelling mantle, typical of constructive plate margins or by flux melting, characteristic of subduction zones? Processes which are controlled predominantly by tectonics such as thermal blanketing or decompression melting through rapid unroofing are not extensively discussed.

One approach to the heat problem is to invert it and deduce from the chemistry of the granite the nature of the source and its thermal state. In a similar way the presence of mafic enclaves in a granite may offer clues to the nature of the heat source. For example, the Velay granite in the Massif Central contains mafic lower crustal xenoliths which are shown to be indicative of mafic, mantle-derived melts which underplated the lower crust providing both a source for the granite and a heat source for the partial melting. A study of the Nd-isotopic composition of Cainozoic rhyolites from the western United States shows that the crustal component in the melts varies from <10% to >80%. A knowledge of the tectonic setting shows that the controls on crustal melting are the crustal geothermal gradient and the rate of influx of mantle-derived magma into the base of the crust. An elegant study of the Archaean granites of the Yilgarn block shows how high precision zircon ages can be used to decipher a magmatic chronology for the region. The time intervals between separate magmatic episodes are used to argue for a mantle plume as the thermal energy responsible for late Archaean granite plutonism.

A topic which is not dealt with at length, and yet of great interest to the readers of this journal, is the mechanism of emplacement of granitic intrusions. It seems that the diapir model is 'out' and that the favoured means of magma transport is through dykes and fissures. An important observation is that we must draw a distinction between processes of emplacement and those of ascent, for what is seen at the emplacement level may have little to do with the ascent mechanism. A thermal modelling study shows that granite generation and emplacement is a causative factor in localizing deformation. A study of the zoned Criffell Pluton in Scotland emphasized the role of rheological segregation in controlling the geometry of the zoned pluton.

Of continued interest is the relationship between the tectonic setting of a granite and its magma chemistry. The particular emphasis in this volume is on extensional tectonics. Chemical changes in granitic–rhyolitic magmatism associated with the change from a convergent to extensional setting are documented from the western United States. An extensional environment is also the preferred tectonic setting for Proterozoic Rapakivi Granites from Finland and from S. Greenland. There are a few surprises however, for a Cretaceous calc-alkaline suite from Queensland is also thought to have been produced in a divergent, rift-related setting, rather than a convergent tectonic setting. These rocks are thought to have inherited their 'arc-like' signature from a Mesozoic arc source. A new distinctive magma type is also proposed—C-type granites, igneous charnockites, although not assigned to a particular tectonic environment. C-type granites are granites which are emplaced directly into the lower continental crust and are distinguished on the basis of their chemistry from metamorphic charnockites—granitic rocks which have been subjected to granulite facies metamorphism.

I enjoyed this volume. My intention to read all the abstracts to gain an initial overview was continually frustrated as I kept finding myself drawn into the details of papers. The publishers state that it "represents the most authoritative and comprehensive review of granite geology available". I agree, for it competes well with recent and more specialized, regional volumes on granites and on partial melting. It is well produced. The double column style is compact but readable, the diagrams are clear and there are few typographic errors. My only reservation is that a book of this bulk would have been better in hard back. For £55.00 it is expensive for the individual, but essential for a library.

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Basin and Range

Wernicke, B. (editor). 1991. *Basin and Range Extensional Tectonics Near the Latitude of Las Vegas, Nevada.* Geological Society of America Memoir 176. Geological Society of America, Boulder, Colorado, U.S.A. 510 pp. + nine plates in a slipcase. Price $115.00 (hardbound; ISBN 0-8137-1176-2).

The book *Basin and Range Extensional Tectonics near the Latitude of Las Vegas, Nevada* contains 23 articles collected at the 1988 Cordillera Section meeting of the Geological Society of America in Las Vegas. Chapters correspond to articles, geographically ordered from cratonic to miogeosynclinal areas, i.e. from the east to the west. Although they deal with several problems, articles may be grouped into three main topics.

The first chapter by Severinghaus and Atwater is an introduction to the plate tectonic context of the Cenozoic extension. The authors investigate the geometric and thermal evolution of a subducting slab beneath western North America. They show that a rapid transition from a long, cool slab to a short, warm one occurred during Paleogene times and resulted in a slab gap beneath North America. By slab gap, the authors mean a region where no slab was formed and bordered by coherent slabs. This concept is at variance from the slab window previously proposed for the same area. They note that only the northern edge of the slab-free region is well defined because of large thermal contrast. They finally suggest that the passage of this edge below the North American plate may be related to geological events such as the onset of extension in the southern Basin and Range. Although Severinghaus and Atwater do not address the problem of the driving mechanisms of extension, their hypothesis supports a recent interpretation of gravity collapse-induced extension that requires a dramatic change in boundary conditions of orogenic belts.

Chapters by Turner and Allen (Chapter 2), Taylor (Chapter 8), Carr (Chapter 13), and Coleman and Walker (Chapter 20) are concerned with relationships between magmatism and tectonics. These regional studies are well documented, including geochemical and geochronological data, but significance of the ages are not systematically discussed in the light of the methods used. Regional investigations result in various conclusions. Chapters 2, 13 and 20 argue for contemporaneous volcanism and normal faulting. Chapter 8 is more provocative and concludes that there is no genetic relationships between crustal magmatism and extension. Taylor considers that both processes are independent because normal faulting occurred earlier, during and later than volcanism in the studied area. Indeed, he notes that the tectonic association of lithospheric extension with volcanism has been established for a long time, and that both processes may be related to the same large-scale deep-seated process in the mantle. But his conclusion is hasty. Correlation between extension and crustal magmatism would have required more careful a discussion, in particular with regards to the thermal structure of an extending, previously thickened crust.

Chapters by Axen *et al.* (Chapter 6), Bartley and Gleason (Chapter 9), Guth (Chapter 11), and Cemen and Wright (Chapter 14) constitute one of the most interesting parts of the volume. They address relationships between Mesozoic thrusting and Cenozoic extension. Chapter 6 is an outstanding, detailed study on the identification of thrusts and low-angle normal faults when stratigraphic, abnormal superposition of terranes does not allow an unambiguous determination of the contact nature. This is especially the case in orogens that have undergone simultaneous extension and compression. Chapter 9 is also of interest. Bartley and Gleason show that the "hinterland", a term that usually applies to a Mesozoic tectonic framework in the Great Basin, is a part of the "Sevier thrust belt" disrupted by intense Cenozoic extension. They convincingly conclude that this term is misleading because it does not correspond to a specific structural zonation during Mesozoic compression. This draws attention to the marked consequences of extensional tectonics on the finite structure of orogenic belts.

Chapters by Faults *et al.* (Chapter 3), Duebendorfer *et al.* (Chapter 4), Rowland *et al.* (Chapter 5), Michel-Noël *et al.* (Chapter 7), Jayko (Chapter 10), Scott (Chapter 12), Spencer (Chapter 15), Serpa (Chapter 16), Labotka and Albee (Chapter 17), McKenna and Hodges (Chapter 18) and Hodges *et al.* (Chapter 19) address various problems of kinematics and mechanisms of normal faulting. Chapter 3 presents a precise analysis of the strain pattern within an accommodation zone between adjacent tilted blocks areas with opposite vergence. Despite a high angle between the extension direction and the accommodation zone, no major strike-slip or transfer fault developed, which is contrary to similar tectonic settings in other areas (e.g. Chapter 10). The kinematic model is not convincing and requires mechanical justification. However, it points out accommodation zones which are major features in extended regions. Along with regional aspects, Chapters 4, 5, 19 and Chapters 12, 17, 18 provide useful estimates (i) of displacement and uplift magnitude and (ii) of strain, extension and uplift rates, respectively. The structural analysis of Chapter 12 results in a conceptual cross-section which differs distinctly from the model set up in Chapter 13 for the same area, namely the Yucca Mountain in southwestern Nevada. Scott (Chapter 12) suggests that listric normal faults sole into one shallow, westward-dipping regional detachment. In