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.

Hugh Rollinson

Harare, Zimbabwe

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

contrast, Carr (Chapter 13) proposes that normal faults are rather planar and need not to be underlain by a regional detachment. Scott's interpretation results in a classical picture of extensional systems as described in many areas of the Basin and Range. Carr's proposition invokes a more complex tectonic history. Planar normal faults formed within a pull-apart volcanic rift, that was the breakaway zone for detachment faulting to the west. Finally the two authors disagree on too many points to be reconciled. Chapter 7 is a kinematic analysis, using an original computer method, of more than 1000 strike-slip and dip-slip faults; it comes to the conclusion that two extensional events, first SE- and second WSW-directed, indicate a progressive clockwise rotation of the extension direction as it is commonly substantiated is the Basin and Range. The authors note the difficulties of presenting their numerous data graphically. Although this does not alter the scientific ground, most diagrams are rather non-aesthetic and illegible.

Chapters by Snow and White (Chapter 21), Stewart and Diamond (Chapter 22) and Marzolf (23) form the second most interesting part of the volume. Chapters 21 and 22 emphasize the relationships between sedimentation and extensional tectonics. Chapter 23 attempts to restore early Mesozoic basins, dismembered by Cenozoic extension. Chapter 21 is a well-exposed field example of sedimentation associated with normal listric faulting and rollover flexure, which can help to understand analogous structures generally observed on seismic profiles. Chapter 22 is a remarkable study of the evolution of a basin pattern and related faulting. Steward and Diamond argue a two-stage evolution: the first stage involves a major, low-angle detachment responsible for the basin location. The second stage corresponds to high-angle, normal faulting which results in dismemberment of the basin. The authors finally suggest that this changing pattern of extensional tectonics may be related to variations from high to low strain rates through time. Chapter 23 proposes a reconstruction of regional sedimentation patterns (covering all areas concerned with the other chapters of the volume) during the early Mesozoic. This may greatly improve our understanding of basin development during both the Mesozoic and the Cenozoic.

As the volume is a special issue of the Cordilleran section meeting, articles concern mainly regional aspects. But some of them have more general implications. Geographical ordering of chapters is somewhat disappointing for the reader who is not aware of western North American geology and in particular of Nevada and California. Areas covered by most articles are rather small and their general setting is usually insufficiently informative. The reader needs a detailed road map to find his way around. An introductory map presenting the whole area with locations of each case study would have been welcome. As a consequence, the volume seems intended for American geologists and not outsiders involved with extensional tectonics. The Basin and Range province is known to be one of the most appropriate areas for studies of extension. Although the general lack of correlation between adjacent domains does not provide a comprehensive picture of the whole province, this volume provides an excellent insight of geological problems related to extensional tectonics. The average length of articles is more than 20 pages, including numerous illustrations. Out-of-text detailed geological maps and seismic profiles also highlight the considerable work done. The quality of printing is irreproachable (only the one line drawing—Fig. 5 of Chapter 7—is inverted with regards to the corresponding photograph). If compilation of such detailed regional studies may appear, at first view, somewhat forbidding, it is a necessary step in progressing with investigations on extensional tectonics. The impressive number of geological data compared with the relatively low price ($115) makes this volume a very suitable contribution for structural geologists interested in extension.

Jean Van Den Driessche

Montpellier, France

The golden age of remote sensing

Beaumont, E. A. and Foster, N. H. (compilers). 1992. *Remote Sensing.* American Association of Petroleum Geologists Treatise of Petroleum Geology Reprint Series, No. 19. The American Association of Petroleum Geologists, Tulsa, Oklahoma, U.S.A. 607 pp. Price $40 (hardcover); $32 (softcover).

The relationship between remote sensing and petroleum geology has always been tenuous, lacking the obvious synergy that has led to a much wider acceptance and appreciation of remote sensing in the minerals industry. Nonetheless, oil companies have been major users of satellite data (if not major publishers of applications or case histories) and it was with great interest that I read the latest volume *Remote Sensing* in the AAPG Petroleum Geology Reprint Series.

To some extent this volume marks a turning point in remote sensing. It looks back at the 'golden age' of remote sensing, describing the early attempts to make sense of a completely new set of data. We are now in the dawn of the next age of remote sensing. New satellites (LANDSAT 6, SPOT 4, ERS-1 and Fuyo-1) all provide us with an abundance of data: in particular satellite-borne radar will image parts of the world that may never have been imaged before. But the real revolution is coming with the ability to carry out desk-top processing and analysis of satellite imagery, moving imagery out of the specialist lab and onto the explorers' desks.

The next remote sensing compilation should be unrecognizable, containing computer applications, visualizations, etc., but moreover much more usage by the exploration geologists and less by the remote sensing expert.

Oil Company management are generally unconvinced about the applicability of remote sensing to oil exploration, often swayed by persuasive technologists. While nobody will question the vital role high quality, ground-registered satellite data plays in field work or surface mapping of any type—especially when used in conjunction with portable satellite navigation equipment—many data are under-interpreted, and used as shiny wallpaper or gifts to important officials!

The remote sensing literature is plagued by esoteric and arcane papers—my favourite is about measuring sheep density—and one arrives at the few excellent and relevant geological papers with a feeling of relief. This volume is a rich collection of such nuggets and contains many of my personal favourites. It is an unenviable task to compile a selection of papers; the editors have done a credible job, though straying on the side of conventionality.

The volume begins with a section on general methods. This includes several chapters from the essential textbooks by Floyd Sabin and James Campbell. These provide much of the necessary background and enable this volume to be used without much prior knowledge of remote sensing.

Sabin's chapter Resource Exploration, reprinted from his textbook, was a genuine landmark in remote sensing; the first clear exposition of the value of remote sensing. It contains all the elements of a good remote sensing study: superb imagery giving regional coverage, detailed understanding of the terrain and surface features, and the combination of application of physics with common sense and a little inspiration.

James Campbell provides some of the necessary nuts and bolts with discussions of image interpretation and details of the orbiting satellites. The latter, published in 1987, is an invaluable reference for those elusive facts about the satellite systems but could have done with an addendum to include the status of the latest satellites.

One paper that was new to me was Jim Taranik and Trautwein's 1977 discussion of integration of techniques. This is a timely reminder to those who are obsessed by technology of the need to make sure that the essentials are well understood. It is salutary to realize, despite the advances in technology, how little we have progressed in 15 years. This paper was one of those relatively unknown gems that this AAPG series tends to unearth from the more obscure publications.

Zeev Berger's analysis of low relief basins is a masterful analysis of subtle surface features as clues to sub-surface features. Rock's paper on geobotanical anomalies associated with petroleum seepage was a careful study that inspired many, though the promise was never really fulfilled, or used predictively.

The thermal imagery section I found the least satisfactory in the book, with only two papers on the subject, and strangely an excellent summary of general remote sensing by Goetz and Rock that seemed out of place in this section. The thermal band is a capability of LANDSAT that has been under-utilized, and geological applications of AVHRR have also not been fully exploited. The two excellent papers on thermal imagery include a typically clear exposition by Sabin dating from 1969, the oldest paper in the book. This is a fascinating topic that has never realized its potential.

The section on radar was particularly interesting with several operational examples. The papers included a variety of studies, mainly from oil companies, largely in tropical regions, that show the value of radar, and the great potential of the new generation of radar satellites to image both areas that are rarely seen through cloud, and sea surface effects. There were some tempting examples of SEASAT data from Koopmans and also Elachi. Wing and Macdonald have two papers showing the use of airborne radar in detecting subtle structures in dense central American jungle.