related to the Hercynian collision, but the rock masses which collided are dominantly of Upper Proterozoic to Lower Palaeozoic protolith ages.

The last chapter contains a plate tectonics-oriented synopsis of the Palaeozoic by the editors, mostly for the Hercynian stages of the central European crust. The results of many authors, including the editors, are summarized in a mobilistic model for the region which will be a valid source for many years to come. The authors and the editors did a good piece of work. Let us hope that the following period in deciphering crustal features in Europe will be free of the divisions which have burdened earth scientists in the region, in this century.

P. Bankwitz

Potsdam, Germany

Australian times

Young, G.C. and Laurie, J.R. (editors) 1996. *An Australian Phanerozoic Timescale.* Oxford University Press, Melbourne. 279 pp., plus separate folio of 12 stratigraphic charts. ISBN 0-19-553951-6. Price: £110.

This volume compiled by the Australian Geological Survey Organisation (AGSO) presents a new global perspective on the Phanerozoic timescale, correlating extensive Australian and overseas research on biostratigraphy, geochronology and magnetostratigraphy. The book is thus an exceptional contribution to the development and refinement of the Phanerozoic time-scale. As the title suggests, the primary focus of the book is on Australian data. Despite this, rescaling of the geological timescale is presented in a global context, thus ensuring that it will be an essential framework for stratigraphers worldwide.

The book is divided into two sections, with the first providing an overview of each of the Phanerozoic geologic periods, together with summaries of the methods of biochronology, isotope geochronology and magnetostratigraphy. A chapter is also devoted to numerical calibration of the major Phanerozoic boundaries. A set of detailed explanatory notes for the set of biostratigraphic charts of each Phanerozoic period comprises section 2. The separately boxed folio of charts, integrates data on magnetic reversals, sea-level curves, and isotopic data used for age control, and the relationship of Australian biochronological zonation schemes to standard global time-scales presented wherever possible. Formation details are also presented for Australian sedimentary basins for some periods (e.g. for the Permian).

As a petrologist, much of the detail presented in the second part of the text is well beyond the bounds of my field, but nevertheless provides the up to the moment information on the timescale required by most geologists. If your field of interest is stratigraphy, palaeontology or palaeogeography, these explanatory notes provide the necessary detail for your field. From the point of view of an Australian stratigraphic context, this volume is a mandatory requirement.

The first section of the text is of more appeal to the non-stratigrapher/palaeontologist, and will be a valuable teaching aid for both undergraduate and postgraduate courses, with its overview of each of the Phanerozoic geological periods, and discussion of the methods of biochronology, isotope geochronology and magnetostratigraphy and numerical calibration of the major Phanerozoic boundaries. However, some shortcomings are apparent in this section of the book (which, given the scope, is hardly surprising). For example, it is disappointing that while there are 30 pages on magnetostratigraphy, there are only six pages on biochronology, and only four pages on isotopic geochronology. This seems a shame, given the recent advances in geochronological methods, particularly at the research School of Earth Sciences at the Australian National University and AGSO—especially in U-Pb zircon dating. The chapter on numerical calibration is also surprisingly succinct, but does cover the necessary aspects, with relevance of the geochronological data explained in section 2.

Despite this criticism, the collation of such a massive amount of data as presented in this volume represents an enormous amount of work—a project unlikely to be undertaken by anyone other than an organisation such as AGSO. The data are comprehensive and are presented in a standardized, easily followed format. The 79-page bibliography is a testament to the extensive literature review undertaken, and also provides the researcher with further data sources. Overall presentation quality is high, definitions are well explained, indexing is thorough, and the book is presented in an easily followed, logical format. The quality of printing, binding and editing is splendid, and the folio charts are presented in a high quality format. Perhaps one criticism here would be the complete lack of colour diagrams in either the book or the charts; however this is probably a warranted cost-saving measure in an otherwise high quality product.

In summary, this book makes accessible a vast amount of information which is presented in a high quality book and chart format. The editors, their many contributors, the publishers, and the Australian Geological Survey Organisation, should be congratulated on an excellent publication.

Bill Landenberger

Newcastle, Australia

Granites a third time

Brown, M., Candela, P.A., Peck, D.L., Stephens, W.E., Walker, R.J. and Zen, E-an. (editors) 1996. *Third Hutton Symposium. The Origin of Granites and Related Rocks. Transactions of the Royal Society of Edinburgh: Earth Sciences*, **87**. Parts 1 and 2. Royal Society of Edinburgh, U.K. 359 pp. Price £47.00.

This volume of 33 papers represents the proceedings of a symposium held at the University of Maryland at College Park, Baltimore in August 1995. The Hutton Symposium Series has grown out of a meeting organised jointly by the Royal Societies of Edinburgh and London in 1987 to mark the bicentenary of the work of James Hutton. This, the third in the series of Hutton Symposia, published by the Royal Society of Edinburgh is the latest statement from the 'granite community' on the health of their discipline.

It was the final chapter of this volume that caught my attention first, for it seemed that *Clarke's* survey of the 'Status of Granite Science' was a good place to begin this specialist volume. I was hoping for some answers to rather general questions about the achievements and future directions of 'Granite Science'. In response to my enquiry about the current status of granite research I found a carefully honed summary of the 'granite paradigm', although I felt that the discussion on the future of granite research lacked focus. My disappointment was short-lived, however, for this volume contains a number of major review papers which point the way forward for granite geology with great insight.

If a dominant theme can be identified in this collection of papers it is the physics and chemistry of granite melts, with a particular focus on the processes operating in the source regions of granitoid magmas. Three other themes are also significant. These are the mechanisms of granite segregation and ascent, the association between granites and mineral deposits and the relationship between granites and crustal evolution.

Constraining the Source of Granite Magmas

The extent to which granites 'image' their source regions has been the subject of continuing debate amongst granite petrologists over the past two decades. The debate centres on the granite 'source rock model' in which it is argued that granite magmas are probes of the deep crust. Critical to this viewpoint is the extent to which granites are modified during their extraction from the source and ascent to the surface. This subject is debated by *Chappell* and *Collins* for granites from the famous Lachlan Fold Belt in south-eastern Australia. These granites are thought to be divisible into two major groups (the well known S and I-type granites) on the basis of their chemistry. Chappell argues that the observed trace element variations are not modified by fractional crystallisation and that the observed rock chemistry can be related to the unseen source region. In contrast Collins argues that whilst an apparent division between types of source region is evident in the major element chemistry, isotopic studies suggest a continuum of compositions. He presents new Nd and Sr isotopic evidence to show that the Lachlan Fold belt granites derived from three source regions. Similarly, *Krogstad and Walker* show that the Proterozoic Harney Peak Granite in South Dakota, was derived from multiple sources, comprising mixtures of early Proterozoic and Archaean sediments. *Pichavant et al.* sound a further word of caution over the 'source rock model' and show from experimental studies of Himalayan leucogranites that oxygen activities measured in granites cannot unequivocally be attributed to their source region.

A forward modelling approach towards granite source regions is taken by a number of authors who show from experimental studies the products that can be expected from the partial melting of lower crustal rocks. In an important review *Thompson* explores the question of the fertility of crustal rocks during anatexis. Extrapolating current data to provide a predictive model for dehydration melting in realistic crustal lithologies he shows how pelite assemblages will melt under conditions of varying water activities at pressures between 0–20 kb. Experimental studies by *Patino Douce* and *Nekvasil and Carroll* show that the composition of granitic melts is not only constrained by the composition of the source region, but also by intensive variables such as pressure, temperature and water activity. Quantifying these intensive variables is the subject of a review by *Anderson*, who summarises the range of thermometers and barometers applicable to granitic systems. An alternative approach is illustrated by *Hogan* who shows how the reaction space method of J.B. Thompson can be used to interpret the crystallisation history of a granite. *Baker and Rutherford* in a study more directed to hazard mitigation emphasise the importance of identifying oxidising, sulphur-bearing magmas in order to identify magmas of the type found at Mt Pinatubo.

The extent to which crustal melting can be approximated by equilibrium processes is becoming a major topic of investigation amongst granite geologists. *Pichavant et al.* show that the kinetics of the melting reactions may lead to Sr-isotope disequilibrium between source and melt, such that the Sr-isotope ratio of a granite may not reflect that of its source. This view is also supported by evidence from trace elements. *Bea* shows that for minor phases such as apatite and zircon the size of grains and their location within the rock determines the extent to which they contribute to the composition of the melt. In a very important paper for the future of zircon U–Pb geochronology *Watson* calculates the parameters which control the fate of zircon during crustal fusion. Using finite difference numerical simulations to characterise the rates of diffusion-controlled zircon dissolution he outlines the circumstances in which zircons will survive a crustal melting event.

The close association of mafic and felsic magmatism is of great relevance to contemporary granite studies for it is recognised that mafic magmas may provide the thermal energy necessary to produce felsic magmatism. However, in two parallel studies *Poli et al.* and *Wiebe* conclude that contemporaneous mafic and felsic magmatism produces confused geochemical signatures which are difficult to interpret in terms of the source of the felsic magmas. Similarly, *Flinders and Clemens* explore the origins of mafic enclaves using insights derived from chaos theory. They conclude that

> 'many enclave suites .... are .... unlikely to provide data that will adequately constrain (the granite's) origin' and 'it seems possible that, for many granite intrusions, enclave studies will prove to be an interesting, but time consuming petrological cul de sac'.

A damning commentary on the number of petrologist-years invested in enclave studies.

Melt Segregation and Ascent Mechanisms

Papers on the subject of the melt segregation and ascent are likely to be of most interest to the readers of this journal. Here a combination of field, laboratory and numerical modelling studies are presented in order to constrain the processes of granite melt segregation. *Barboza and Bergantz* in a study of pelite melting show that melt segregation requires a very high input of heat, over a long time interval and that the melt only escapes when aided by fracturing. The high level of thermal energy required for melt segregation is also emphasised by *Sawyer* who argues from migmatite studies that melt segregation capable of producing granite intrusions takes place only in the highest grade part of migmatite terrains. Experimental studies by *Holz et al.* and *Dingwell et al.* emphasise the importance of melt viscosity upon the process of segregation and outline the variables which influence viscosity. *Rushmer* shows, in a review of recent experimental data, that melt interconnectivity and segregation are possible at lower melt fractions than those considered possible by the critical melt fraction model. However, she shows that whilst melt interconnectivity can be established, melt migration may not always take place.

The current controversy over the ascent mechanism of felsic magmas—dykes or diapirs—is discussed in papers by *Weinberg* and *Petford.* Weinberg argues that because there are problems in the initiation of dykes the ascent mechanism will vary from diapiric at the site of magma generation, to dykes in colder, stiffer crust. Petford, on the other hand, argues for dykes as the principal means of magma ascent, showing that dykes with widths appropriate to their magma-viscosity are found in the field, and that magma-flow rates within dykes are capable of filling plutons. He concludes that shallow crustal laccoliths, fed by dykes, fit most of the requirements for a unified ascent and emplacement model for granite plutons. Batholiths are therefore created from the coalescing of a large number of flat bottomed, dome-roofed laccoliths fed by dykes. *Paterson et al.* mapped the wall and roof zones of plutons emplaced in subduction related arcs. They show that at mid crustal levels magma emplacement is matched by the downward transfer of country rock within the pluton to the region from which the magma was derived and suggest that magma emplacement in arcs is the driving mechanism for a crustal-scale exchange process.

Mineral Deposits Associated with Granite Magmas

The relationship between granitoids and metallogeny in southwest North America is reviewed by *Barton.* He identifies the importance of mineral–aqueous fluid equilibria in granitoids as the primary control on the composition of mineralising fluids. A view which is at variance with that of *Blevin et al.* who emphasise the importance of granite source compositions and fractional crystallisation as the primary control on metal concentration. Using numerical modelling, *Hanson* shows how the emplacement of a granite can stimulate fluid flow in the shallow crust and how, over time, there is a changing balance between magmatic and meteoric fluid flow. Direct evidence for such high temperature silica-rich hydrothermal fluids is given by *Lowenstern and Sinclair* in a study of a W–Mo bearing quartz–feldspar porphyry.

A further aspect of granite associated mineralisation is discussed in *London's* comprehensive review of granite pegmatites. This paper demonstrates that there has been a major paradigm shift in the understanding of the origin of granitic pegmatites—away from the Jahns–Burnham vapour saturation model of the 1960's, towards a model in which pegmatite mineral compositions and textures are explained in terms of the undercooling of melts.

Granites and Crustal Evolution

For me this volume raises some interesting questions about the nature of 'granite science'. These questions arise inevitably from my own interaction with the granite community as an occasional contributor but more frequently as a 'user' of their data and ideas. My concern arises over my perception of what are first and second order questions in granite geology. In my view, the first order question for granite petrology is the origin of the earth's 'granitic' continental crust. Second order questions, and currently the preoccupation of much of 'granite science', are about the internal reordering of the continental crust. The argument is well stated by *Drummond et al.* who point out that

> 'The focus of granite rock petrology has leaned towards the study of high-K granites.... ' and yet 'To understand the birth of the continental crust and its subsequent growth, we should refocus our studies towards the sodic end of the 'granite' family.'

My concern is over the lack of emphasis within the granite community on the major questions of crustal evolution. Questions which, in many cases, they are uniquely qualified to answer. In this volume I found only four contributions which were directly concerned with the evolution of the whole crust. *Nakajima* argues that the growth of the south-eastern Eurasian continental margin in SW Japan was episodic by demonstrating that Cretaceous granitoids in the middle crust were emplaced 15 Ma earlier than granitoids in the upper crust. *Rapela and Pankhurst* show that crustal growth in the Patagonian Cordillera was active 750 km east of the present oceanic trench. Geochemical arguments suggest that the crust-forming granitoids were produced by the partial melting of a basaltic underplate. *Drummond et al.* draw attention to magmas of the tonalite–trondhjemite–dacite (TTD) suite which dominate the preserved Archaean crust. Since over 70% of the present-day crust was produced by the end of the Archaean the genesis of TTD magmas is crucial to understanding the origin of the continental crust. TTD magmas are thought to have formed by the dehydration melting of basalt during the subduction of young warm oceanic lithosphere—a view supported by the study of adakites, contemporary analogues of Archaean TTDs.

The application of isotope studies to granitic rocks has historically provided major insights into the process of crustal evolution. Here *Johnson et al.* review the application of two previously untried isotopic systems to the origin of granites and the problems of crustal evolution. They show that the Lu–Hf system offers the potential to track the role of garnet in crustal processes and that the Re–Os system may afford the opportunity to monitor the role of a basaltic contribution to the processes of crustal genesis.

In short however, despite my personal reservations about the future direction of granite research, this is an excellent volume. The diversity of topics is wide, the quality of the papers is high and the inclusion of some timely reviews makes this a volume well worth having. I believe it is essential as a library purchase, but at £47.00, perhaps less likely to appear on the book shelves of individual scientists.

Hugh Rollinson

Cheltenham, U.K.

Elastic materials

Davis, R. O. and Selvadurai, A. P. S. 1996. *Elasticity and Geomechanics*. Cambridge University Press. 201 pp. ISBN 0-521-49506-7, Price: £55.00 (hardback); ISBN 0-521-49827-9, Price: £18.95 (paperback).

This book describes the fundamental principles of the elasticity of isotropic materials and illustrates how these principles may be used to solve a range of problems in soil mechanics connected with foundation engineering. It is a textbook written primarily for upper level undergraduate students in engineering geology or civil engineering, with the expressed aim of being sufficiently comprehensive to provide a sound introductory overview of its subject matter to students of that level.

The main body of the book is divided into four chapters. The first develops the basic concepts underpinning linear elasticity theory. This begins with the notion of a continuum and proceeds to show, from the description of the deformation of a continuum, how strain is defined. The discussion of strain is concluded with an account of the strain compatibility equations. This is followed by an account of stress (including a surprisingly brief discussion of the Mohr circle representation), of principal stresses, of stress invariants and of the stress equilibrium equations. The chapter concludes with an introduction of how the notions of stress and strain may be combined to formulate and solve problems in elasticity.

Chapter 2 is concerned with the elastic constants of an elastically isotropic material. Each of the five elastic constants are described in turn, and illustrated with reference to physical examples. Hookes law is then presented in its general form linking the stress and strain matrices, and the notion of the stress and strain deviator matrices is introduced. The theoretical part of the chapter is concluded with a discussion of the relationships between the elastic constants and the bounds that these relationships place on their magnitudes. The second part of the chapter describes how the elastic constants of soils may be evaluated using various laboratory and field techniques. This description is set within the context of the relative advantages and disadvantages each technique has in terms of accuracy and cost.

In chapter 3 the solutions of a number of special problems in elasticity, fundamental to a range of more general geotechnical problems, are described. These include the point load problems of Boussinesq, Kelvin, Cerrutti, and Mindlin, as well as the line load problem of Flamant. The strategy is not to discuss mathematical techniques for finding solutions to these problems but rather, in each case, to formulate the problem and then to show that the solutions derived elsewhere (in standard elasticity texts) do indeed solve it. The chapter concludes with a description of the usefulness of stress functions, as illustrated with Airy's stress function.

The final chapter applies the solutions developed in chapter 3 to some of the basic problems encountered in foundation engineering. The problems considered pass from that of a simply loaded region (e.g. by a liquid storage tank) on the surface of a homogeneous elastic half-space, to more difficult problems involving non-uniform loads, rigid foundations and layered half-spaces. The chapter concludes with a short discussion of the consolidation of soils under structures, with an analysis of some of the previously described field techniques used to determine elastic constants, and with an analysis of the problems associated with constructing earth structures such as embankments.

A highly important part of the book is a suite of seven appendices which are used to remove much of the mathematical discussion from the main body of the text. These include a derivation of the strain compatibility equations, the derivation of essential concepts in Cauchy's formulation of the stress tensor, a proof of the uniqueness of solutions in classical elasticity theory, and accounts of Saint-Venant's principle, of the principles of virtual work, and of Betti's reciprocal theorem.

This is an excellent book. Its real strength lies in its style. This is a subject matter which is liable to appear unnecessarily intimidating to those new to the field, and so to counter this problem the authors have deliberately written the text in an almost conversational tone, but one which at the same time, carries the hallmarks of having been tried and tested on large numbers of students to ensure great clarity of expression. The strategy of removing the more detailed mathematics to the appendices works well, for it allows the reader to follow the main strands of the argument in physical terms, and yet to have the important mathematics to refer to as desired. The text is well illustrated and the problem exercises at the end of each chapter seem to be well chosen. This reviewer also liked the brief historical comments (which are not too long to get in the way), and the references to landmark papers in the development of the subject, all of which serve to heighten the sense that the book conveys a comprehensive overview at introductory level.

The book satisfies its intended function as an undergraduate textbook for courses in engineering geology or civil engineering admirably, although naturally its usefulness will depend upon the desired course content. There is no doubt that substantial parts of it (and in particular, the first two chapters) would also be of value for structural geology undergraduates concerned with the mechanical analysis of geological structures. In addition, although it would be viewed as introductory, it is so well argued that it could serve as a useful, easy to read, companion to the standard elasticity texts used by undergraduate students during first courses in solid mechanics in which a more mathematical treatment of the subject is developed. Given its potential as a background reference for a wide range of undergraduates, it is therefore a little disappointing to see that the book is rather overpriced for its size. One suspects that at £18.95 it will be too expensive to purchase merely as a background text, although for those undergraduates among the targeted readership (i.e. for whom the whole book is directly relevant) it will perhaps be a price well worth paying.

S. J. Covey-Crump

London, U.K.