Journal of Structural Geology, Vol. 13, No. 8, pp. 975 to 976, 1991
Pergamon Press plc. Printed in Great Britain

BOOK REVIEWS

Rock deformation and failure transitions

Duba, A. G., Durham, W. B., Handin, J. W and Wang, H. F. (editors) 1990. *The Brittle–Ductile Transition in Rocks (The Heard Volume)*. American Geophysical Union Geophysical Monograph 56. Price $42 ($29.50 AGU Member price).

This volume is one of the latest in the excellent series of collections of papers on particular research themes in pure geophysics, the AGU Geophysical Monographs. It is dedicated to the memory of Hugh Heard, following his untimely death in 1987 from cancer. Hugh made seminal contributions over a period of 35 years to geologically-oriented rock mechanics. His published papers generally included exceptionally detailed descriptions of the design of experimental apparatus and procedures. He was a remarkable innovator in the field of experimental techniques. I myself was privileged to learn from him during his sabbatical visit to Imperial College whilst I was a final year graduate student. However, Hugh was no dry experimentalist, but was equally interested in addressing the problems of the extrapolation of experimental data to the conditions of natural rock deformation.

The present volume reflects the range of Hugh's own interests and contributions, insofar as it is organized into two major sections. The first, comprising 13 papers, deals with scientific topics more-or-less related to the titular theme of the volume. The second section, comprising 10 papers, is devoted to a range of experimental techniques in rock mechanics.

The 'brittle–ductile' transition is a 'buzzword' of present times, with many geologists and geophysicists regarding it as being characterized by a particular depth in the Earth's crust. Many readers may therefore be astonished to find that in a book of this title the simple concept of a 'brittle–ductile' interface is not mentioned, neither in the initial keynote review of brittle–ductile transitional phenomena by Evans, Fredrich and Wong, nor anywhere else in the book. The popular view of brittle–ductile transitional phenomena, taken from a lithospheric-scale viewpoint, looking inwards, represents a gross oversimplification. All the authors in this volume examine modes of rock failure from a rock mechanics perspective, looking outwards. From this point of view brittle–ductile transitional phenomena are complicated. Whilst rules-of-thumb, useful for some purposes, can be derived, they must be regarded with great caution.

The remaining scientific papers deal with specific topics, although many of them are only peripherally connected with failure mode *transitions*. Kronenburg *et al.* describe the localization of a plastic shear zone in granitic rocks, in which high shear strains apparently correlate with high intragranular water content of quartz. Carlson *et al.* present a numerical simulation of thermal cracking in granite, and Tullis *et al.* describe experiments in which plastic flow localization becomes concentrated along cataclastic fault 'precursors' in feldspathic rocks.

Chester and Logan demonstrate further developments in studies at the Texas A & M Laboratory of the frictional behaviour of halite in simulated fault zones. From the same laboratory two further halite studies are included. Horseman and Handin describe the development of a high precision apparatus for triaxial studies on rock salt (this paper might have alternatively been included in the techniques section). Russell *et al.* describe stages in the development of a state-variable description of the flow of halite. This is an approach to the description of the constitutive behaviour of rocks which does not presume steady-state flow, and hence is of more general applicability than the familar power-law creep description. However, it requires a more comprehensive range of testing techniques and the acquisition of higher quality mechanical data than has been usual in the past.

As if to emphasize the fact that not all of Hugh Heard's contributions to materials science were on rocks, one paper on the mechanical properties of a metal alloy is included. In this, Chockshi and Mukherjee describe the use of moderate hydrostatic pressures to suppress cavity formation in and to enhance the ductibility of a superplastic Al–Li alloy.

Bernabe and Brace describe experimental data encompassing the cataclastic faulting to flow transition for Berea sandstone. This study involves the measurement of volume strains concurrently with deformation. Although such techniques have sporadically been applied for almost 30 years it is clear that an adequate description of the mechanical properties of brittle rocks cannot be obtained without attention to volume strains.

Kirby *et al.* describe aspects of anomalous brittleness in the deformation of hydrous minerals at high pressure, and relate it to anomalies in their thermal behaviour. Hacker and Christie describe experiments on both natural amphibolites and finer-grained samples synthesized by hot pressing. They found brittle behaviour over a wide range of conditions, except that plastic flow developed from precursory brittle faulting (cf. Tullis *et al.* earlier). The final two papers in this section deal, respectively, with shock loading of sandstone (Brown *et al.*) and microstructures and preferred crystallographic orientations of plagioclase in naturally deformed basic rocks (Ague et al.).

The techniques section of the volume is largely a review of a wide range of experimental methods, some traditional and some more exotic. Paterson reviews the geological philosophy behind the design of triaxial test equipment and describes in some detail the features of his latest gas-medium deformation machine. Green and Borch describe their new developments of the solid-medium technique, in which they trap a volume of molten salt around the test specimen capsule, in order to allow more precise measurements of differential stress at confining pressures up to 3 GPa. Sotin and Poirier describe a sapphire anvil cell which can be used for ultrahigh creep tests at low temperatures.

Cooper *et al.* demonstrate the use of a four-point bending sample configuration, which admits controlled variation of mean stress across a sample. They use this at high temperature to study effects arising from partial melt migration along the mean stress gradient. In a related paper, Kohlstedt describes the use of high resolution analytical TEM to deduced the distribution of partial melt in a peridotite.

One of the last topics worked on by Hugh Heard was the flow of ice over a wide homologous temperature range: Heard *et al.* describe the apparatus used to deform ices between 77 and 273 K. Amongst the unusual sample geometries which can be used to examine the effects of stress-state variations within a single test, Meike and Heard describe the truncated cone test. Mackwell *et al.* describe a high-resolution uniaxial creep apparatus, designed for single crystal work at high temperatures. Duba *et al.* describe equipment for the measurement of the electrical conductivity of silicates at high temperatures and controlled oxygen fugacity and, finally, Getting *et al.* describe the measurement of seismic attenuation at very low (natural) amplitudes.

In conclusion, this volume will serve as an indispensable reference work for researchers in the field of rock mechanics and related areas. It is also especially useful as a collection of descriptions of a wide range of experimental techniques, and is a fitting testament to the memory of Hugh Heard.

E. H. Rutter

Manchester, U.K.

A manual for teaching structural geology

Hatcher, R. D. and Hooper, R. J. 1990. *Laboratory Manual for Structural Geology*. Macmillan Publishing Co., New York, U.S.A. 217 pp. Price $25 approx. (softback).

This book aims to provide the core material for the laboratory-based component of a one-semester course in elementary structural geology. One of its strongest attributes is that it contains a wealth of properly structured examples which work, providing ample material for anyone setting up such a course or wanting to revamp an existing one. However the authors intend the book to be used directly by students and not just as a source book for instructors. To adopt a book to this extent, one has to agree not just with the selection of material but also the order of presentation and the mix of exercise and support material which it offers. This is a tall order and the authors deserve support for their willingness to become, as they point out, the first to publish such a manual in the U.S. for several decades.

The book has been produced almost entirely through the use of desk top publishing and computer graphics packages. This non-traditional approach has been largely successful, but there are a higher number of literal errors than one might expect and this may be a result of the production methods. The computer-generated diagrams are generally of high quality. However, the digitized versions of the Buffalo Valley quadrangle map (Chapter 6) also show up the limitations. They are of poor resolution and the overlaid isopachytes and structure contours use inappropriately wide lines.

There are 12 chapters, the first two being concerned with strain measurement and analysis. Chapters 3–8 develop the theme of geological maps, starting with the collection and recording of field data, building up through outcrop patterns, simple map problems, structure contours and isopachytes to a map analysis project. Chapter 9 deals with the plotting and analysis of stereonets, Chapter 10 is *Mesoscopic structures—analysis of folds*, the subtitle being the more accurate summary of its content. The final two chapters deal with the construction of geological cross-sections and some aspects of the balancing of them. Chapters 3 and 9 contain the material which appeared in Appendices 1 and 2 of Hatcher's 1989 textbook, *Structural Geology, Principles, Concepts and Problems* (Merrill, Columbus, Ohio).

This material reflects the content of many elementary structural geology courses with its mix of field, map and laboratory aspects. However, there are some notable omissions. Not only is there no discussion of, or student exercise concerned with, stress, the actual term is not even mentioned, the word force being preferred when some reference is unavoidable. Strain analysis is treated in some detail and the topic of longitudinal and shear strain parameters is discussed at the start. No link is made, though, to the measurement of such quantities in real rocks. There are many parts of the book where foliations and lineations are discussed, but nowhere is there a simple and compact set of definitions. A photograph-based exercise focusing on the recognition and description of tectonic fabrics would be a worthwhile addition.

Three sections of chapters deal with the field recognition of structures and the collection and recording of field data, the type of material found in books on the mapping of geological structures. About 10% of the book is devoted to this material, a significant proportion, yet the detail is not sufficient to provide a student with all that is needed. In any case a book of this size and format would not be taken into the field, the place where such material is really useful.

The Preface makes it clear that the authors, whilst providing some background material, expect the book to be used in conjunction with a more wide ranging text. It may be laudable that Hatcher does not use this as an opportunity to promote his own textbook, but such modesty causes problems. Students who have read the Preface may well remember that they must look to other sources from time to time, but will they realize at which points in the book this is necessary? If specific references were made to chapters and pages in Hatcher's textbook, then a student could be alerted to those times when further background reading is required.

There are clear variations in the level of explanation offered in different parts of the book. My first thought was that this was good educational practice, but I fear that generally that is not the case. On the one hand, in Chapter 4 the construction of structure contours is first explained in a step by step manner but the following two exercises are identical in form to the worked example, showing no progression. On the other hand, quite complex techniques are mentioned almost as an aside and the students left to make what they can of them; e.g. it is suggested that part of exercise 8.3 will require the creation of a 'form-surface map' with little explanation of what such a map is, or how the student should construct one.

The order of the material can be a matter of personal choice; however, some aspects of ordering are of deeper significance. I cannot agree with the way in which map analysis is developed and 'completed' (Chapter 8 takes the form of a small concluding project), before the introduction of stereonet analysis or the construction of cross sections.

The introduction to strain analysis in Chapter 1 would benefit from the inclusion of some more illustrative diagrams, e.g. to distinguish pure and simple shear. The shear zone exercise which concludes this chapter provides the first, but regrettably not the last, example in the book of explanatory material which becomes more cryptic as the concepts it is explaining become tougher. The conversion of the area under an x/y curve to a displacement is one with which numerous students have difficulty. To explain this with: "Note that the 'squares' may not be square, depending on the scales used for the x and y axis of the graph" is not going to help. Chapter 2, on the other hand treats the practical measurement of strain with reasonable clarity.

Chapter 3 deals with a wide range of material: much of it provides sound advice but I must take issue on two points. The section on the conversion between true and apparent dips consists first of a graphical solution, developed step by step and then converted to a trigonometrical formula. There is need for a simple block diagram which shows the three-dimensional relationships between the angles involved. The solution is presented as a 'black box' with no attempt to encourage the student to visualize the problem in three dimensions. (If only stereonets had been introduced by this point.) The last part of the chapter deals with the recording of field data in notebooks and on maps, and I cannot accept some of the recommendations which are made regarding what constitutes good practice. Their example shows a field map which carries only location numbers, no outcrop extent or structural data, and a notebook page which contains all the data. I can only remind the authors of their own words from the introduction to Chapter 8, ". . . illustrate the most fundamental consideration for anyone attempting to construct a geological map: it is often easier to make a geological map in the field than to take the field data and construct the map in the laboratory".

Chapters 4–8 cover the techniques required to construct and analyse geological maps. I was pleased to see that concepts introduced using cartoon maps were developed on examples of published maps. Consequently there was no sense of a division between semi-quantitative methods as applied to artificial maps and more descriptive analysis of real world problems. Chapter 7 includes summaries of both map and field-based criteria for the recognition of structures. Unfortunately, it is not always clear which is which, and I fear that students may well be confused rather than assisted by the material. The descriptions themselves are not always clear; for example the discussion on fault drag, hampered from the outset by the lack of an illustrative diagram, finally lost me with the sentence, "Reverse drag is produced by motion along the fault as it flattens".

The final chapters on cross-section construction are very disappointing. The steps required to produce a simple section are very carefully developed in Chapter 11 but the move into the world of section balancing in Chapter 12 is accompanied by an almost complete absence of explanation of the mechanics of what is involved. There is no clear explanation that the process of balancing a section is an iterative one, nor any guidance as to what can be learned from a section which hasn't balanced in order to improve the end result. The introduction to Chapter 12 includes the sentence "An important relationship regarding cross-sections is this: *just because a section balances does not mean the interpretation is correct, but if a section will not balance, the structure cannot be interpreted correctly and the section is incorrect*" (their italics). They then go on in the next paragraph to allow that ". . . deformation out of the plane of the section, or polyphase deformation may result in a perfectly valid section that will not balance". One wonders what a student is to make of these apparently contradictory statements, but I suspect that the italics will do their job and the view that an unbalanced section is always a wrong section will gain further supporters.

Inevitably I have highlighted problems, but the majority of the exercises work as planned and they provide a suitable grounding for students of a wide range of abilities. There are serious deficiencies, though, which would have to be corrected before I could envisage basing a complete course on this book. I hope that the authors will be encouraged to make use of their easily revisable format and produce a second edition soon.

John S. Whalley

Portsmouth U.K.