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Book Reviews

Continental extension

Coward, M. P., Dewey, J. F. & Hancock, P. L. (editors) 1987. *Continental Extensional Tectonics*. Geological Society of London Special Publications No. 28. Blackwell, London. Price £40, $115.

There has always been great interest among geologists in the continental rifts of East Africa, the Rhine, the Rio Grande and others. In the past dozen years or so the topic of extensional tectonics has broadened considerably from a study of such rifts and interest in it has grown to a very high level. This volume reflects very well the developments in the field and current thinking on crustal extension. It contains 39 of the 88 papers presented at the conference of the same title held in Durham in April 1985 under the auspices of the Geological Society of London. There are in aggregate 91 authors of the papers in the volume, and it is interesting to note that not one paper covers either of the classic areas of the Rhine Graben or East African Rift. These rifts, which have received so much attention in the past, represent incipient stages of continental extension. The papers in this volume largely deal with the effects of much greater extension, which leads ultimately to continental fragmentation.

The surge of interest in extensional tectonics is, I believe, due to several factors. First, in the mid-1970s the significance of the low-angle normal faults in the metamorphic core complexes of the Basin and Range province began to become clear. Second, deep seismic reflection studies of COCORP in the western U.S.A., BIRPS in the continental shelf around Britain and similar programs elsewhere have provided compelling evidence for the widespread existence of large low-angle faults in the middle crust, and these faults have been related to the type of structure seen at the surface in the Great Basin of the western U.S.A. Third, the increased understanding of fabric development in shear zones has provided the evidence for the existence of many low angle extensional ductile faults now exposed at the Earth's surface.

The volume is divided into five sections; the first deals with fault geometry and mechanics (10 papers), the second covers the very important Basin and Range province and East Pacific margin (16 papers), the third the NW European continental shelf (eight papers), the fourth the Middle East (three papers) and the last extension in thrust belts (two papers). The categories of course are not so clear-cut as this division may seem to imply, so that, for example, mechanical considerations are treated in papers in each of the five sections. Much of the material, as is often the case in conference proceedings, is not new, but there is also much that is.

In several papers on mechanics, in the first section, it is shown that lithospheric extensional strength is inversely proportional to crustal thickness and to heat flow, and that continental lithosphere is generally weaker than oceanic lithosphere. A specific analysis of Basin and Range structure suggests that Tertiary extension occurred because the crust had been previously thickened during Mesozoic orogeny.

The papers in the second section on Basin and Range extension give good expression to the wide range of views that have been proposed, and most of the key researchers who have worked in the region have papers here. The ideas on core complexes are well represented and the remarkable Tertiary mid-crustal detachment faults, separating brittle cover from ductile basement are nicely described. The various papers cover microstructures, large-scale structures and structures evident from seismic reflection data. Three papers examine active faulting and kinematics of crustal movement in the Great Basin and Rocky Mountain region.

The tilted block geometry of extensional faults and presence of detachment horizons so clear in the southwest U.S.A. are inferred in the NW European Continental Shelf around Britain; there are three papers on this and a fourth paper deals with gravity modelling. Seismic reflection data play a prominent role in establishing these structures, which are related to late Paleozoic and Mesozoic continental break-up. Other papers in this section consider the geometry of faults, sedimentation and basin development associated with rifting events of various ages in Britain and Norway.

Two papers in the short section on the Middle East deal with the kinematics of extension in the Suez rift and the Sinai triple junction and a third paper documents the complex pattern of faulting in western Turkey.

The final section on Extension in Thrust-belts contains just two papers, one dealing with evidence for extension in the Honshu fore-arc off Japan, based on DSDP results, and the second with extension in the Himalayan orogen. Both papers show that normal faulting can occur at high crustal levels, decoupled from thrusting presumed to occur at greater depths.

A few general themes can be drawn from these papers. A first of course is that detachment faults, separating upper 'brittle' crust from lower 'ductile' crust, may be very common. A second is that crustal extension frequently follows crustal compression and old compressional structures may become reactivated as extensional structures. It is also true that compression may follow extension and that old low-angle normal faults may become reactivated as thrust faults. A third is that the three-dimensional geometry of extensional fault systems, like thrust fault systems, can be very complex, making palinspastic reconstruction and balancing sections decidedly not a trivial exercise.

There is a wealth of material in this book. I would strongly recommend it to anyone interested in finding out about current ideas on the mechanics of rifting and continental extension or wanting good descriptions of extensional structures in several important areas.

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Methods of structural analysis

Marshak, S. & Mitra, G. (editors) 1988. *Basic Methods of Structural Analysis*. Prentice-Hall, Englewood Cliffs, New Jersey. 446 pp. Price £36.40, $46.90 (soft back).

This is another addition to the growing number of texts designed to act as structural geology course manuals (e.g. Ragan 1973, 1985, Ramsay & Huber 1983, 1987, Rowland 1986). It differs from these by its divisions into two main parts, the first written by Marshak & Mitra, and the second comprising eight chapters authored by eight contributors plus the editors, in varied combinations.

The book is divided into three parts. Part I, *Elementary Techniques*, contains eight chapters whose titles are: (1) Measurement of attitude and location, (2) Interpretation and construction of contour maps, (3) Geometric methods [1], (4) Geometric methods [2], (5) Introduction to stereographic projection, (6) Stereographic poles and rotations, (7) Calculation of layer attitude in drill holes and (8) Equal-area projection and structural analysis.

Part II entitled *Special Topics*, is made up predominantly of chapters by contributing authors. The chapter titles are (9) Interpretation of geological maps (L. B. Platt), (10) Analysis of data from rock deformation experiments (T. Engelder & S. Marshak), (11) Description of mesoscopic structures (G. Mitra & S. Marshak), (12) Analysis of fracture array geometry (A. Goldstein & S. Marshak), (13) Objective methods for constructing profiles and block diagrams of folds (S. Wojtal), (14) Introduction to cross-section balancing (S. Marshak & N. Woodward), (15) Analysis of two-dimensional finite strain (C. Simpson) and (16) Interpretation of poly-deformed terranes (S. Mosher & M. Helper).

Part III consists of four appendices; (1) Review of the key concepts of maps, cross-sections, diagrams and photos, (2) Basic trigonometry, (3) Suggestions for mapping geological structures and (4) Templates for plotting geological data.

My immediate impression on examining the book was that the list of chapter headings seemed strangely organized. For example, it would seem more logical for the chapter on the description of mesoscopic structures (11) immediately to precede the chapter dealing with the structural analysis of these structures (8), rather than be placed three chapters later. It is also clear from the chapter headings that most of the chapters deal with the basic methods of geometric analysis. Consequently Chapter 10, which is essentially an essay on experimental rock deformation, comes as something of a surprise. Although it is clearly written and is one of the chapters I enjoyed reading most, it does not fit comfortably or logically with the other chapters. Perhaps this is to be expected in multiply authored texts.

As well as the standard chapters that can be found in all structural manuals there is an excellent chapter (12) on fracture analysis which provides a lucid and helpful guide to data collection and processing. I was however rather disappointed with the casual (and misleading) definitions given for the conditions necessary for the formation of shear and hybrid (shear/extension) fractures, definitions of crucial importance to this chapter. The authors state that shear fracture occurs when all the principal stresses are compressive and that hybrid fractures form when one of the principal stresses is tensile and when the Mohr circle touches the failure envelope at two points. They omit to mention that the essential condition that determines whether shear or hybrid fracture occurs is the state of normal stress across the potential fracture plane. If this is compressive (and this condition can be achieved under conditions where all the principal stresses are compressive or when one of them is tensile) then shear failure results. If it is tensile, hybrid fracture occurs. This criticism does not, however, significantly detract from the contribution this chapter makes to an area which few books have had the courage to tackle.

Topics such as stereographic projection, structural analysis in both single- and poly-deformed terrains and the description of mesoscopic structures are adequately covered and compare favourably with other comparable texts. The chapter on the analysis of two-dimensional strain (15) provides a brief introduction to strain and illustrates the main techniques of strain determination. It was however disturbing to read in the introduction to this chapter that we would be primarily concerned ". . . with permanent strains that develop as a consequence of plastic deformation". Using the term plastic, with its specific rheological implications, as a synonym for the more general term ductile (which is used elsewhere in the chapter) seems rather casual, especially in this context. In defining the parameters of strain it could have been made clearer that the parameters relate to strain "in a particular direction". I would also have liked to see a distinction made between lines of no longitudinal strain and lines of no finite longitudinal strain. It was refreshing to see the chapter rounded off with a brief discussion of the use geologists make of strain data once it has been acquired.

The explosion of interest in cross-section balancing and section restoration in the last 10 years requires that the subject be covered in any teaching manual. Chapter 14 provides a good introduction to this subject. I was particularly impressed by the second half of the chapter which successfully introduces the various problems associated with cross-section balancing by considering a series of progressively more complex examples. The chapter deals only with thrust systems and ignores extensional structures and the balancing of sections from extensional terranes. Consequently techniques such as the chevron construction are not covered.

It is difficult to produce a book of this size devoid of minor errors and this book has its share of typographical errors and errors of omission (e.g. labelling missing from diagrams). Sometimes the errors are particularly unfortunate, as for example in Chapter 1 where, after carefully distinguishing between the rake (pitch) and plunge of a lineation, the text refers to the plunge of some slickensides in figure 1 but quotes the pitch. Nevertheless, on the whole the book compares favourably with other manuals and I would recommend that it be given serious consideration by anyone involved in giving an introductory course in structural geology. However its price is high for a paperback (particularly in £ sterling), which could limit its sales as a student course book.

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Map interpretation

Lisle, R. J. 1988. *Geological Structures and Maps.* Pergamon Press, Oxford. 150 pp. Price £9.95 (flexicover), £19.50 (hardcover).

There has long been a need for a book which tackled the interpretation of geological structures from maps with the logical approach that this book adopts. It breaks away, largely, from the dependency on unrealistic 'problem' maps used by past texts and yet is not as esoteric in its approach as two other recently published books in the same broad field (Moseley 1979, Butler & Bell 1988). In spite of the reservations I express below this excellent little book should be a suitable text for many first-year courses in British Universities as well as for some A-level syllabuses. I doubt, however, the publisher's 'blurb' that it will match G.C.S.E. syllabuses.

The book, subtitled *A Practical Guide*, is concerned with the interpretation of simple structures from geological maps. It deals in turn with uniformly dipping beds, folding, faulting, unconformity, igneous rocks and folding with cleavage, the first three chapters being the more substantial. The geometry of the relevant structures is well described, definitions and classification are meticulous and the principles of map interpretation carefully explained. This is aided by excellent diagrams and sketch maps often using two colours and good use is made of some 40 black and white photographs. Most chapters contain some worked examples and each concludes with problems using small maps, often based on real situations, as well as photographs. No answers to the problems are given and there is no indication of what the publisher's response would be to a request to photocopy maps for class use. Few text errors were discovered, although on problem 3.6 there is one small area wrongly ornamented and one dip value seems incorrect.

My most serious criticism is of the approach to the recognition of folds. The author, quite properly, encourages the student to distinguish outcrop (boundary) patterns that are a consequence of folding from those due to topographic interference. However, throughout this chapter there is little emphasis placed on the simple analysis of dip information in the recognition of fold geometry. All the example and problems maps which are meant to distinguish fold and topographic effects on boundary patterns depend on the identification of hinge points and axial surface traces from the drawing or envisaging of structure contours. In each case, because of the absence of any dip information, there are at least two possible ways of drawing quite regular structure contour patterns, giving contradictory interpretations. This reveals the limitations of the 'problem' map, which generally the author eschews; real maps of single-phase folding of this simple geometry would (or should) contain sufficient dip information to distinguish between these interpretations.

I would also have liked to have seen more emphasis on the use of the known stratigraphic order in the interpretation of structure and vice versa. Although proper emphasis is given to the use of structure contours, their use in the construction of both profiles and normal cross-sections is not explained. Some consideration should also have been given to the construction of hinge shape where there is neither plunge nor structure contour information. A modified Busk construction would have been useful and I would have expected at least a mention of the problems of balancing and restoration.

In the chapter on faulting, the emphasis is on classification and the distinction of slip and separation. I would have liked to have seen more attention given to faults, especially to their mutual attitudes, their relation to shortening and extension of the crust and in general to their geometry on real maps. Unconformities are quite fully treated (though not the analysis of non-planar surfaces) and igneous rocks receive a short but not unreasonable treatment in the context of the book. However, I would like to have seen more than two problem maps bringing the various aspects of interpretation together.