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# BOOK REVIEWS

## Stress

Engelder, T. 1993. *Stress Regimes in the Lithosphere.* Princeton University Press, Princeton, New Jersey, U.S.A. 475 pp. (ISBN 0-691-08555-2.) Price $75.00, £50.00.

There are books about earthquakes, about plate tectonics, fracture mechanics, drilling and core logging, plastic flow of rocks, and so on. A common thread that runs through all these subject areas is stress. Thus by taking stress as the central theme of his book *Stress Regimes in the Lithosphere*, Terry Engelder has been able to write an excellent overview of many of the above topics. Anyone who thinks of stress as a dry subject will change their views through reading this book, for Terry has used the underlying concept of stress to link many topics together in a very readable way.

Final year undergraduates will be able to follow all of the book without difficulty, but its scope is so wide that it will be an invaluble reference source for graduate students and professional geoscientists working in the fields of structural geology, geophysics, tectonics, and both 'pure' and engineering rock mechanics. The volume is well illustrated with line drawings throughout, and almost 900 literature references are collected at the end.

The volume begins with a 'basics' chapter in the form of a short introduction to elasticity. Then immediately the discussion is centred on states of stress in the context of the lithosphere. There is no traditional development of stress theory in the usual abstract way. Thus the author manages to avoid the concept of shear stress and Mohr circles until the third chapter, which deals with stress in the shear-rupture and frictional-slip regimes. The second chapter is concerned with the propagation of extensional cracks within a fracture mechanics framework, and it is of course possible to do this without explicitly introducing the concept of shear stress. It is always emphasized that the stresses that can be attained in any part of the lithosphere are primarily limited by rock strength and mode of failure. It is a novel way to discuss stress, but one which works very well.

The fourth chapter deals with stress in the ductile flow regime, and a useful overview of plastic flow of rocks is provided. In each chapter special attention is given to the various mesoscopic and microscopic features of naturally deformed rocks that can be used to infer palaeo-stress states. For example, the inference of regional stress patterns from fault slip data, and the utility of subgrain and recrystallized grain sizes in the plastic flow regime are outlined.

Five subsequent chapters deal with *in situ* and residual stress states and their measurement. The descriptions of techniques are illustrated with a large number of short case-history accounts. Chapter 5 gives a thorough description of hydraulic fracturing methods. Chapter 6 deals with borehole and core logging, the examination of fracture traces on borehole walls and cores, the use of borehole breakouts and techniques related to acoustic wave propagation. Chapters 7 and 8 describe stress relaxation and stress meter measurement techniques for *in situ* and residual stresses, and Chapter 9 deals with inelastic effects related to microcracking. Chapter 10 describes the storage and detection of residual and remnant stresses in rocks.

The final three chapters are concerned with large-scale phenomena. Chapter 11 describes stress states associated with earthquakes and the stress changes that accompany them. Chapter 12 examines the compilation of stress data from all sources, culminating in the compilation of the world stress map. The closing chapter examines sources of stress in the lithosphere in terms of the forces that drive plate tectonics and consequent smaller scale phenomena, lithospheric flexure, lateral changes in crustal thickness and density variations, etc.

A book like this can never be perfect; one can quibble over the handling of small points of detail and there are occasional drafting errors to keep readers on their toes (e.g. flow stresses shown a factor of 10 too small in fig. 4-9), but these in no way detract from what is undoubtedly an extremely useful volume.

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## Viscous flow model

Keith, M. L. (1993) *Geodynamics and Mantle Flow: An Alternative Earth Model.* Elsevier, Amsterdam. Price $105.75; Dfl 185.00.

This book, in the words of the author, is a "re-examination of geodynamics", proposing an alternative to the currently accepted plate tectonics hypothesis. It therefore consists of two conceptually distinct parts (which, however, are not systematically separated in the text): a criticism of the internal contradictions of plate tectonics and its failure, in the author's opinion, to account for the evidence; and a proposal of a different hypothesis (termed the Viscous Flow Model) to explain the Earth's dynamics.

I should state at the outset that I am probably as unsympathetic as the author towards the excesses of orthodoxy, and that I would also subscribe to the idea, to which he refers approvingly, that University Science Departments post a notice reading "*We are not here to worship what is known but to question it*". However, Keith presents a very biased reading of current plate tectonics models; and his alternative model certainly has more problems with the evidence than plate tectonics does.

No one would question that the plate tectonics model is occasionally at odds with isolated items of evidence, but surely the most important point in its favour is that, *on the whole*, it gives a viable explanation of geodynamic processes, and a "paradigm" to interpret the tectonic history of the Earth. This is not, however, Professor Keith's opinion. Among the facts which he thinks do not fit the plate tectonic hypothesis he cites: the evidence of long-term coexistence of continental crust and underlying keel; the approximate equality of average continental and oceanic heat flow; the shallow depth ($\leq$10 km) of the brittle–ductile transition in oceanic regions; the perpendicularity of maximum horizontal compression and strike of the mid-oceanic ridge as measured *in situ* in Iceland; the lateral variations in lithosphere thickness; and the distribution of geoidal heights. (This is not a complete list.)

Most Earth Scientists have no trouble in accepting these facts *within* the plate tectonics model. The idea that sub-continental mantle forms a 150–200 km thick chemical boundary layer that translates as a unit with the overlying crust is of current use; global analyses of heat flow have shown the different origin of continental and oceanic fluxes; lateral variations in lithosphere thickness, as measured for instance by surface wave dispersion, agree well with plate tectonics predictions, especially in the relatively simple oceanic areas; and the state of stress in a plate is a function of the sum of forces acting on it—with horizontal compression normal to divergent boundaries not so strange after all.

The author's objections arise, I submit, from an excessively literal interpretation of plate tectonics arguments. For instance, he states on several occasions (see e.g. pp. 156 and 295) that the "uniform 100 km thickness of lithospheric plates" is contradicted by observation. But the plate model does not propose that the thickness is uniform—on the contrary, it varies with age, clearly in oceanic areas, more messily in continental areas, where subsequent tectonothermal events may have reset the tectonic clock. Similarly, no one would quarrel with the statement that the depth of the brittle–ductile transition is approximately one order of magnitude less than plate thickness. It is the author's identification of the thickness of the brittle layer with elastic plate thickness (see pp. 179 and 294) which is not supported by observation: as flexural studies have shown, the thickness of the lithosphere as load-bearing layer is larger than the thickness of the topmost brittle layer. Sometimes the misinterpretation seems to arise from unfamiliarity with the problem, despite the very large number of references. For instance, what Keith terms the "gravitational paradox" (the fact that geoid highs are associated *both* with subduction zones and with mid-oceanic ridges), which he considers "inexplicable within the framework of the plate tectonics model" (p. 296), can be explained by the combined effect of internal mass anomalies *and* displacements of the free boundary. As a matter of fact, as is well known in the geophysical literature, a very large part of geoidal