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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 palaeostress 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 features can by explained by dynamic models of mantle convection compatible with seismic tomography.

The Viscous Flow Model proposed by Keith can briefly be summarized as follow. The continents and their thick keels act as thermal blankets on the underlying mantle, which therefore forms ascending currents under them; these currents originate horizontal flow moving radially away from continental cores; convective downwelling takes place below volcanic arcs, compressional mountain ranges, mid-oceanic ridges (the "Oceanic Range") and oceanic islands. Therefore, island arc lavas, mid-oceanic ridge basalts, oceanic island basalts and continental flood basalts are *all* assumed to have a common source in the partial melting of *downwelling* material, hypothesized to consist of thin sheets of recycled oceanic crust metabasalt mixed with variable amounts of sedimentary and mantle (peridotitic) components. Pressure-release melting of *upwelling* peridotitic material is assumed to be an important factor only in sub-continental areas—of which the Mesozoic volcanism in the Kaapvaal–Kalahari craton is offered as an example. Superimposed to this "near-steady state model" of convection, the author hypothesized the existence of episodic "surges", the triggering of which is tentatively ascribed to asteroid impact.

The author's attitude to the evidence changes when discussing data which are assumed to support his hypothesis. Expressions such as "... it seems more than coincidental that..." (twice on p. 175) and other similarly vague assertions abound. References are sometimes quoted selectively, sometimes misleadingly. An example of selective choice: statements to the effect that "... experimental studies (show) viscosity reductions associated with the onset of partial melting..." (see e.g. pp. 170, 171 and 180) give as main supporting reference an abstract, and the voluminous literature discussing the problem (how much partial melting does one need to reduce viscosity? What is the effect of non-equilibrium textures? What is the role of the partition coefficient of water?) is totally neglected. An example of misquotation: on p. 189 one finds a statement that "... A Coriolis effect (on mantle flow) cannot be ruled out... in view of the uncertainties regarding flow rate and the effects of variable viscosity and of mantle traction on the crust", followed by a reference. The reader who assumed that the reference supports the statement would, however, be mistaken: as a matter of fact, it does not deal with the Coriolis force at all, but it only makes the point that the strain rate and viscosity structure of mantle convection is likely to be highly heterogeneous.

The Viscous Flow Model, naturally, runs into problems when dealing with marine magnetic anomalies. The author analyzes at length this topic, and ascribes the anomalies to "... (1) buckling of the crust and repeated structure-controlled volcanism and (2) a superimposed sequence of ages related to crestward migration of the outer limit of volcanism on a subsiding Oceanic Range" (pp. 215–216). The idea is exceeding vague, and is nowhere submitted to critical evaluation. Similarly, the hypothesis that oceanic regions consist of a thin "elastic or visco-elastic" layer moving *towards* ridges contradicts most of what is known on the *worldwide* distribution (and not isolated values, which the author mentions as disproving the plate tectonics hypothesis) of heat flow, depth to the ocean floor and thickness of oceanic lithosphere.

A major problem with the Viscous Flow Model is that it is difficult to reconcile with the principle of conservation of mass under oceanic plates. Take for instance the Pacific and the Nazca plates: along a profile approximately from NW to SE, one encounters first the western Pacific subduction zones, then oceanic islands (Hawaii), then the East Pacific Rise and finally the Peru–Chile trench. According to the Viscous Flow Model, mantle flow below *each and every one* of these features is converging downwards from both directions. The author seems to be unaware of the problems created by this peculiar geometry.

The book also contains some strange loose ends for a work that admittedly has been many years in the making. Heat flow is usually given in mW/m^2, but $\mu cal/cm^2$ are used on p. 171 (which is, of course, wrong, but the omission of "seconds" in the denominator is probably a misprint), and HFU are mentioned on p. 181. The references are each given a number that does not correspond to their order of appearance in the text: actually, the long list consists of three or four sequences of alphabetically arranged entries, followed by additions in no particular order.

Finally, a word on the production of this book. It is a reprint of a long paper which appeared in *Earth Science Reviews*. The page numbers have not been changed: so, the book begins on p. 153 and ends on p. 337. The contents of the relevant volume of *Earth Science Reviews* and the instructions to the authors have, for some reason, been included. Strangest of all, the word "Earth" is missing from the title as given on the first printed page.

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Lesser Himalaya

Pande, I. C. and Saklani, P. S. (editor) 1991. *Tectonic and Metamorphic Investigations in the Kumaon–Garhwal-Himachal Lesser Himalaya* (*Current Trends in Geology Vol. XIII*). Today and Tomorrow's Printers and Publishers, New Delhi, India. Price Rs 495, $65.00.

This monograph from the Indian series *Current Trends in Geology* deals with the geology of the Kumaon, Garhwal and Himachal sectors of the Indian part of ther Lesser Himalaya. Much work has been done by a large number of Indian geologists in the Lesser Himalaya and a volume summarizing this confusing array of literature is welcome to students of Himalayan geology.

The most useful part of the book lies in the chapters dealing with the stratigraphy of these three areas of the Himalaya, particularly the historical aspect. However, the final chapters on the structure and metamorphic history have an out-dated flavour and show little resemblance, either in methods or models, to many studies that have recently been undertaken, or are ongoing in the Himalaya. Pande argues that the Himalaya orogen "did not originate from a single Tethyan geosyncline, nor did it form due to collision, subduction or abduction (?) of the Indian and Asian plates". He believes instead that "the Himalayan orogen owes its origin to activation of Deep Seated Faults which demarcate the Tethyan, Central Crystalline Axial, Lesser Himalayan Foothills zone and Indo-Gangetic Fore-deep". Pande is apparently more at ease with the Beloussov school of deep-seated faults penetrating the whole crust and vertical tectonics, and ill at ease with plate tectonics and large-scale horizontal movements. This view could not be more inappropriate for Himalayan geology, and I sometimes wonder whether we are looking at the same mountain belt.

The volume's reference list is largely restricted to Indian publications, yet in the last 10 years or so there has been a huge increase in the number of papers reporting quality research in the Himalaya on all branches of the geological sciences, by both Indian and foreign workers, published in international journals. None of this is referred to at all in this book. As long as this introverted approach remains there will be little or no new science. It is difficult to find aspects of this volume which will be useful to an international audience, except perhaps for the historical perspective of the stratigraphy of the Lesser Himalaya.

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