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Principles of Rock Mechanics

Weijermars, Ruud, 1997. Alboran Science Publishing, PO Box 76321, 1070EH Amsterdam, The Netherlands. Tel: 31 20 3640331, Fax: 31 20 3640 145, HYPERLINK mail to: Alboran@xs4ALL.NL, 359 pp. ISBN 90-5674-002-4. Price: softcover US$36.95.

Principles of Rock Mechanics is one in a new series of textbooks published by equally new Alboran Science Publishing. "Lectures in Geoscience" texts are intended to be readable, extensively illustrated, and inexpensive. *Principles of Rock Mechanics* is meant to be used as a first introduction to rock mechanics and "suitable for teaching advanced undergraduate and post-graduate students". It is tailored for a one-semester course.

The author is presently on the faculty at King Fahd University of Petroleum and Minerals in Saudi Arabia. In the book's preface, Weijermars outlines the growth of this new text based, in part, on "an increasing need to incorporate the basic concepts of continuum mechanics into the realm of structural geology". To avoid producing another encyclopedic text on structural geology, the author sought to separate more descriptive aspects of structure from the processes of deformation, and to restrict the present text largely to mechanical principles.

It is not entirely clear whether the text is designed for a rock mechanics course or to be an ancillary resource for a structural geology course. The preface refers to two titles, Modelling of Rock Deformation and Principles of Rock Deformation, in addition to the publication title *Principles of Rock Mechanics*. Although short sections of the book cover failure-related topics, continuum mechanics is the primary focus.

The book is softbound with a two-column format; it contains numerous line drawings and black and white photographs. For the most part, the drawings avoid busy patterns and gradients, so they are clear to view. Most, though not all, photographs have enough contrast that details are visible. Abundant exercises are placed throughout the text. An appendix contains the solutions to these exercises.

Principles of Rock Mechanics has sixteen chapters and one appendix. The chapters are evenly collected into two sections: Part 1, Mechanics and Rheology, and Part 2, Tensors and Deformation Analysis.

Part 1 contains the following chapters: (1) Introduction to rock mechanics, (2) Physical quantities and continua, (3) Force, pressure, and stress, (4) Stress, (5) Elasticity, (6) Brittle failure, (7) Ductile creep, and (8) Viscosity and flow laws. The introduction relates the importance of quantitative investigations in rock mechanics to issues of geotechnical significance, such as mine collapses. The author soon supports his emphasis on continuum mechanics, however, by describing flow in rocks and fluids.

Chapter 2 is a brief discussion on units of measurement for time, space, and matter. Chapter 3 follows with a focus on derived quantities relevant to rock mechanics. This section has some exercises involving useful applications of these quantities, such as slope stability, tunnel construction, and drilling procedures. Chapter 4 is devoted to stress. In addition to explaining the directional (and areal) properties of stress, the concept of normal and shear stress, and the Mohr circle for stress, this chapter also has a convoluted comparison of total stress and deviatoric stress.

Chapter 5 begins with rheological models for elasticity, frictional sliding, and a new analogy, the plug-pull model, that evidently is meant to represent something akin to stick-slip behavior on faults. Elastic moduli and a few aspects of strain relevant to the nonrecoverable deformation of rocks are introduced here.

Crack initiation and propagation, joints, faults, and Mohr envelopes for failure are in Chapter 6. In contrast, Chapter 7, Ductile creep, introduces concepts of shear zones, steady-state foliations, mechanisms of creep, and deformation maps. Part 1 of the textbook is completed with Chapter 8 on viscosity and flow laws and a discussion of some of the mechanisms that may accommodate non-Hookean behavior. Part 1 spans 142 of the 306 pre-appendix pages of *Principles*.

In parallel with the beginning sections of Part 1, Part 2 starts with a review of mathematics. Chapter 9 is an overview of ordinary and partial differentials, integrals, tensors, and complex functions presented in eight pages. This overview will be difficult to assimilate by students who have not completed (or attempted to complete) one or two courses in calculus.

Chapter 10, on stress tensors, is perhaps the best-written review of topics in Part 2. Here the text logically follows a progression from the introduction of the stress ellipsoid and how the construction relates to the tensor representation of a state of stress to techniques for resolving normal and shear stress on a plane. Weijermars includes a few book references at the end of Chapter 10; it is surprising that the popular books by Nye (1985, Physical Properties of Crystals—Their representation by tensors and matrices, Oxford Science Publications) and Means (1976, Stress and Strain—Basic concepts of continuum mechanics for geologists, Springer-Verlag) are not listed.

A similar treatment of strain and the strain tensor are in Chapter 11. It concludes with a very brief note on the mathematical associations of stress and strain for elastic and viscous behavior in rocks. Chapter 12 is a comparatively lengthy discourse on deformation tensors. The content of this chapter is mainly what you would find in the 'kinematics' chapters of an introductory structural geology textbook. Deformation history, progressive deformation, determination and comparison of finite strain, and the components of deformation (rigid-body motions, strain, and dilation) lead to a summary discussion of the deformation tensor. Undoubtedly, the instructor will have to supplement this presentation with additional materials for most students.

Chapter 13 introduces such concepts as streamlines, flow nets, and stream tubes, all pertaining to particle motions in the continuum. Ultimately, these quantities support an understanding of velocity gradients and progressive deformation, but the subject is a bit advanced for a text at this level.

Chapter 14 is essentially an exposition on folds and folding in single layers. The presentation, in great length, focuses on folds in viscous regimes. No mention is made of bending and buckling, which may be of great importance in geotechnical applications of layer distortions.

Chapter 15, practical strain analysis, is a comprehensive summary of techniques for measuring total strain from finite rock structures, such as sheared fossils. (I think I shall be retired before I ever see a sheared trilobite in any of my field areas!) This coverage is obligatory in any geologically oriented text on rock mechanics, but it does not address the application of strain analysis to 'practical' problems in, for example, construction on or within earth materials. Part 2 and the textbook conclude with a short chapter on the role of laboratory models, misappropriations of some concepts, and what new technologies might assist in applied rock mechanics.

Principles of Rock Mechanics is truth in advertising. It is an abbreviated introduction to the field, albeit mainly for continuum mechanics. Many high level concepts are introduced but not extended. Applications, that is the use of rock mechanics principles to solve problems in engineering and other geotechnical fields, are mostly restricted to in-text exercises.

In what context might this book be used? I do not know of many undergraduate geology programs in the U.S. that have a complete, one-semester course in rock mechanics. Courses in structural geology, engineering geology, environmental geology, and geology for engineers certainly include many of the topics in *Principles*. Numerous established texts supply these courses, however. Engineering curricula typically require soil and rock mechanics as well as other geotechnical courses, but *Principles* is really written for specializations in geology.

Principles of Rock Mechanics could be used as a text for the rock mechanics component of engineering geology if student prerequisites include structural geology and math through calculus. For a structural geology course, Earth Structure (van der Pluijm and Marshak, 1997, McGraw-Hill) is a better choice, for it also aims at a readable, accessible level for undergraduate geology students.

Principles would suffice as a text in a seminar course for upper level undergraduates and graduate students, provided additional resources were available to examine some topics in greater depth. This book might also find an audience with in-service professionals who wish to get a review or overview on rock mechanics. For geotechnical applications, however, a good engineering geology text would nicely complement *Principles*. Of course, dedicated students may get out their hand lenses and read Elasticity, Fracture, and Flow by Jaeger (1969, Chapman Hall), or C. Jaeger's Rock Mechanics and Engineering (1979, Cambridge University Press).

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The Manson Impact Structure, Iowa: Anatomy of an Impact Crater

Koeberl, Christian and Anderson, Raymond R. (eds) The Geological Society of America Special Paper 302, 476 pp., $99.50. ISBN 0-8137-2302-7.

A 2 km diameter meteorite travelling at 20 km/s, northwest across northern USA, hit the Earth at a low angle of perhaps 30 in Iowa, near the town of Manson. The impact caused a crater 38 km in diameter, yet the oblique angle of the impact meant that it was only 325 m deep and threw debris in a mainly northwesterly direction, as far as 500 km away into Nebraska and South Dakota. Early reports tell of a tsunami covering Sioux City in several metres of sediment and causing major disruption to the Missouri River.

Now ask yourself why you haven't heard about this disaster.

Well, OK, it happened 74 million years ago so you didn't miss it in the TV news... but the real reason is that it didn't kill many dinosaurs or cause any mass extinctions as far as we know. Meteorite impact craters are not rare, they are actually fairly common: with over 20 in the U.S.A. alone and over 150 on Earth, the historical problem has been the 'humour' factor. Until the Alvarez *et al.* paper in *Science* in 1980 made people take notice of the subject, very few were brave enough to risk their research careers on something which might cause amusement and derision among their colleagues. In fact although you may not have heard of the Manson crater, it is now one of the best understood and intensively studied craters on Earth and as such has a great deal to teach us about the mechanisms of crater formation. Before the discovery of the Chicxulub crater on the Yucatan peninsula, Manson was one of several suspects for the K/T mass extinction.

The Manson Impact Structure, Iowa, Anatomy of an Impact Crater is a collection of articles which arose from work on core samples after the Iowa Geological Survey Bureau and the US Geological Survey drilled the Manson Crater in 1991–1992. Just about every conceivable microscopical, chemical, isotopic, and geophysical technique was thrown at these core samples. The result is a unique and fairly exhaustive series of studies into all aspects of terrestrial crater formation showing what can be uncovered concerning crater formation processes from geology. In fact the work covers everything from simple petrography and documentation of the lithologies, to detailed trace element geochemistry of the impact rocks and their products, isotopic dating, microstructural studies, and even tracing the ejecta caused by the impact into possible tsunami deposits in neighbouring geological formations. In such a collection some of the work is bound to be slightly obscure and the various detailed geochemical studies seem now fairly redundant, not adding anything to our knowledge of the impact. However, in all fairness, they must be seen in the light of the original motivation for the work. Why did they drill this particular crater? The reason is that it was known from stratigraphical constraints to have formed around the time of the K/T boundary. Couple this with the fact that it's in America where most of the best preserved K/T boundary samples have been found and the fact that two years earlier a paper published in *Science* indicated an age of 65 Ma, coinciding exactly with the boundary. When the studies were initiated, the workers thought they were dealing with a crater which may have thrown debris around the world. Understandably, workers were attempting to document the geochemistry precisely in order to compare them with ejecta found across the continent. When, a few years later, the age was revised to 74 Ma, the detailed geochemical studies became much less meaningful but they have been included because this is the only place where such studies could be published.

From a structural geology point of view, the book has one big plus and one big minus; it lacks a good study of the macroscopic deformation features, yet it contains several papers describing and illustrating microstructures, particularly the famous PDFs (planar deformation features). Although detailed seismics were shot, there seems to have been no attempt to look for listric faults of a collapsing crater wall as seen in the Sudbury Impact and there appears to be no analysis of shear indicators in deformed samples within the country rocks. On the other hand, the analysis and descriptions of PDFs (regarded by many as the most reliable indicator of a meteorite impact) are excellent. In fact this is the best series of papers detailing these critically important features I have seen collected together and treated in context with their source.

There are also good papers on the Ar–Ar analysis of shocked, mixed feldspar (K-feldspar and plagioclase), analysis of the hydrothermal alteration which seems to be a characteristic of all impacts and both theoretical and experimental consideration of the asymmetry of the Manson Impact. Finally there is a wonderful pair of papers, worth reading even without the rest of the book; the first by Maureen Steiner and Gene Shoemaker putting forward the case for an extensive deposit northwest of the Manson impact crater as a tsunami deposit and the second by Brian Witzke, Richard Hammond and Raymond Anderson describing the same deposits and coming to completely different conclusions. It is of course impossible to know who is correct without further work but the two papers are a great example of two groups looking at the same rocks, through different eyes.

Whether you buy this book or not, I heartily recommend it as a source book for meteorite impact studies.

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