Reviews

Coordinated by Amit Padhi

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Handbook of Borehole Acoustics and Rock Physics for Reservoir Characterization, by Vimal Saxena, Michel Krief, and Ludmila Adam, ISBN 978-0-128-12204-4, 2018, Elsevier, 484 p., US$120 (print), US$120 (eBook).

Acoustic logging provides the highest resolution information on the elastic properties of rocks penetrated by boreholes. The interpretation of acoustic measurements requires the link between the acoustic properties of the rock and its composition, porosity, fluid saturation, pore pressure, and state of stress to be established, and this falls within the domain of rock physics. The *Handbook of Borehole Acoustics and Rock Physics for Reservoir Characterization* brings these fields together.

The book presents the fundamentals of borehole acoustic logging and waveform processing and describes the rock-physics relations needed to relate acoustic measurements to the properties of rock formations with a focus on reservoir characterization. Reservoir properties considered include rock composition, porosity, fluid pressure, in-situ stress, laminations, and fractures.

Following a review of the concepts of homogeneity, heterogeneity, isotropy, and anisotropy, the book introduces elasticity and elastic wave propagation followed by an introduction to borehole acoustic logging and sonic waveform processing. A description follows about the depth of investigation characteristic of sonic tools and the influence of the altered zone in the vicinity of the borehole.

The book describes various rock-physics methods such as the use of bounds, the effective field approach of Kuster and Töksoz, and effective medium methods and presents models for treating granular media including the Hertz-Mindlin, Digby, and Walton models and the effect of cement between grains based on the contact-cement model. This model has many parameters, however, and a simpler approach is worth investigating. Various empirical methods resulting from fits to experimental data sets on specific rock types capture the variation of elastic wave velocities with porosity and composition for specific rock types. Such relations may not transfer to other rock types, however.

Following the discussion of theoretical and empirical relations, the book presents applications of borehole acoustics including the estimation of permeability using Stoneley waves, fluid saturation based on poroelasticity theory, anisotropy, estimation of static moduli from dynamic measurements, rock strength, pore pressure, and in-situ stress.

A chapter on core measurements explains how laboratory measurements on cores can be integrated with borehole acoustics and seismic measurements using rock-physics theory to obtain an improved description of reservoir properties and to assess the validity of the various rock-physics concepts and relationships. This chapter provides a useful overview of various experimental systems for the measurement of rock elasticity including the use of ultrasonic transducers, resonance techniques, stress-strain measurements at seismic frequencies, and scanning acoustic and atomic force microscopy.

The final two chapters present the use of cased-hole acoustics to perform cement evaluation and formation evaluation through the casing, various workflows and worked examples including prediction of elastic moduli from empirical and theoretical relations, and applications of fluid substitution modeling. Appendices present tables of the elastic properties of common rock minerals and pore fluids as well as conversion factors between different measurement units.

Although the authors give a list of references at the end of each chapter, these references are often not cited in the text, making it difficult for the reader to access the relevant literature since the original source of the material often is not clear.

A good balance between mathematics and applications makes this book an accessible reference for students, researchers, and industry professionals interested in the characterization of reservoirs using borehole acoustic waves.

— Colin M. Sayers
Houston, Texas

Waves and Rays in Seismology: Answers to Unasked Questions, by Michael A. Slawinski, ISBN 978-9-813-23987-6, 2018, World Scientific, 576 p., US$158 (print), US$126 (eBook).

As the subtitle implies, this refuses to be another textbook for seismology as we know it. Instead, the author wants to examine the foundations of seismology as a scientific discipline. That the book amply achieves this goal while also covering, especially in Chapters 2–3 and 5–6, a selection of the "usual" topics (continuum mechanics and linear elasticity, body and surface waves) is to its credit. Free from the need to dwell on how good of a textbook it may or may not be in the traditional sense, I will focus on the scientific self-examination that is its aim. To begin, I must agree with the viewpoint espoused in Chapter 1 — that a careful definition of the subject itself is timely and necessary.

What kind of a science is seismology? Surely it is a collection of theory, methods, and observations that pertain to the physical properties of the earth. In the author's most reductive presentation, he defines it as a branch of continuum mechanics. In one sentence: momentum balance and Hooke's Law are hypotheses from which the seismic equation and its solution are derived by mathematical deduction. With the subject matter thusly defined, the premise of the book becomes clear. What are the axioms on which our knowledge is based? What can we really know when we proceed with this "hypotheticodeductive" formalism? Where do the limitations of a "semiphenomenological" theory lie?

These are some very long words, but Chapter 2 is the shortest treatment that I know of (I mean it as a compliment) of the general theory of seismological continuum mechanics. Indeed, it is just about "a body, a motion, and a system of forces acting within it." A notion of spacetime, a system of coordinates and ways to transform them, and field equations follow from balance and conservation principles.

Chapter 3 deals with the specific theory of elasticity. Again, Slawinski swiftly hits upon the essential points of Hookean constitutive behavior, accentuating essential notions pertaining to finite and infinitesimal deformation, and prestress. He formulates original viewpoints on crystal properties, symmetry classes, and their interdependencies. In these pages, I started learning some new things and reappreciating some old truths ("Mohr's circle offers to symmetric second-rank tensors in R^2 an image analogous to an arrow for vectors"). Despite their brevity, these two chapters are a textbook in miniature, with considerable space devoted to solved problems and liberally sprinkled with historical references.

Chapter 4 is a monograph in itself — a much more voluminous technical treatise on effective symmetry and equivalent media. It includes averages of symmetry groups at a point (reductions of anisotropy), or averages of elasticity parameters over a spatial region (reductions of inhomogeneity), and how those relate in detail. This body of theory is of great practical importance for numerical forward models and to understand the limitations of inversions with inadequate data. This chapter asks and answers a great number of questions that many will appreciate finding coherently explained.

Chapters 5 and 6 resume the textbook-like treatment of body and surface waves. Section 5.2., on the various solution approaches to seismic wave equations, contains nuggets of knowledge that nicely tie together the disparate approaches, which I will integrate into my own teaching. Chapter 6 is an up-to-date treatment of surface waves in layered media that reminded me of earlier generation textbooks (specifically by Ewing, Jardetzky, and Press) that are now out of print.

Chapter 8 ties up some loose ends on the effects of gravity and heat conduction on wave propagation. More excitingly, it reopens an intriguing window into the seismic effects of weak gravitational waves.

Where, one might ask, are the answers to the unasked questions of the subtitle? Chapter 7, which deals with variational principles in general, uses Fermat's principle to delve into a philosophical discussion of its teleology. These pages are for anyone who has ever wondered how the ray knows what stationary path it should take. To arrive at an answer requires delving into the historical and philosophical foundations of our discipline, building bridges, taking a holistic view, and not eschewing ramifications for which others might lack patience. A unique feature of this book is that it considers such questions and answers as intellectually rewarding as the nitty gritty of the mathematical properties of, say, transversely isotropic materials. For this alone, Slawinski's book is to be considered a "buy" — a bargain, considering that those who balk at reading an entire book on just the philosophical underpinnings of our discipline (see Brown and Slawinski, *On Foundations of Seismology: Bringing Idealizations Down to Earth*) will find Chapter 9 lucidly coming to the point.

This book is a unique addition to a library that, large or small, is unlikely to have any other book like it. Illuminating the foundations of seismology, without shaking them, it doubles, at times, as a textbook (with problems, solutions, a large bibliography, and detailed appendices), covering what could be considered reasonable for an upper-class introductory course. At times, it offers an in-depth treatment of some of the more esoteric aspects of our field, and is thereby likely to appeal to those of us who teach students with some prior exposure to seismology and who are able to handle seismology as a branch of physics. And of course it is perfect for those who are eager to explore the epistemological questions arising from the sort of thinking that begins when the pages of almost all other textbooks end.

— Frederik J. Simons
Princeton, New Jersey