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Introduction to the Physics of the Earth's Interior

Larry Lines

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Aller au sommaire du numéro

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Introduction to the Physics of the Earth's Interior

By Jean-Paul Pourier
Cambridge University Press
Cambridge, UK CB2 2RU
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2000, 312p., US$34.95 paperback
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Reviewed by Larry Lines
Department of Geology and Geophysics
University of Calgary
Calgary, Alberta T2N 1N4

This book analyses the Earth's interior by applying physics to describe measurements made outside the inaccessible regions of the Earth such as the lower crust, mantle, outer core, and inner core. This comprehensive publication should appeal to students of global geophysics. Except for the discussions on elasticity and seismology, it will have limited appeal to exploration geophysicists involved with exploration of the upper crust. The physics of the Earth's interior is examined through the use of thermodynamics, seismology, solid state physics, equations of state, melting and transport properties, gravitational fields, and electrical conductivity. The integration of these studies is used to produce complete Earth models.

The book initiates the global Earth discussions by reviewing the thermodynamics of solids using relationships between entropy, enthalpy, Gibbs free energy, and Helmholtz free energy functions. It lists Maxwell's relations describing the connection between "intensive quantities" (generalized forces) and "extensive quantities" (generalized displacements). The first chapter summarizes an introductory course in thermodynamics while giving crucial relations between thermal and mechanical constants used throughout the book. The second chapter discusses elastic moduli, an area where most crustal seismologists will feel more comfortable. There are some very good discussions of elastic constants, with clear connections between stress, strain, entropy, and pressure. It is interesting to see how the book relates the effects of pressure and temperature to elastic moduli. In order to more completely understand the nature of the Earth's interior, the next chapters of the book involve solid state physics. Lattice vibrations are probed through discussions of density of lattice states, Debye's approximation, specific heat, and vibrational energy. This leads to discussions of the equations of state, which in turn then lead to Birch's Law, describing the relationships between velocity and density for various rock types. The theories of Fermi and Feynman are used to describe the equations of state within the framework of quantum mechanics. The book spends a considerable amount of time on the physics of melting. In the author's words, "melting (or fusion) is an extremely important phenomenon for solids since it causes them to cease being solids and to transform to the liquid state of matter, thereby losing crystalline long-range order and resistance to shear." Melting is explained as a complicated phenomenon which, when applied to mantle and core minerals, is used to provide constraints on the temperature profile of the Earth. The melting and phase diagrams of iron are emphasized, in view of the importance for models of the Earth's core.

In dealing with the dynamic properties of the Earth, Pourier makes a nice connection between transport properties, electrical and thermal conduction. This is all nicely tied together with equations describing fluid flow and electrical conductivity. In using an integrated approach to describe the Primary Reference Earth Model (PREM), the author gives a comprehensive diagram relating seismological, compositional, and thermal Earth models. There is a very lucid discussion of the Adams–Williamson relationship, which provides a density distribution within the Earth. Given constraints of gravitational observations and the Earth's moment of inertia, Pourier explains why it is believed that the core consists mainly of iron. This is just one example of the many excellent insights provided by the author. However, excellence does not imply perfection. There is one final step that appears missing and this is the relationship between Earth dynamo models and magnetic field observations. There is little discussion of the Earth's magnetism in this book.

Despite this one imperfection, this book does a very good job of describing the physics of the Earth's interior and integrating most of the data and models in a comprehensive manner. It is an excellent introduction to global geophysics. Given the reasonable price of the paperback edition and its information, I would highly recommend this book to Earth scientists.