BOOK REVIEWS

MANTLE CONVECTION IN THE EARTH AND PLANETS. G. Schubert, D. L. Turcotte, and P. Olson. Cambridge University Press, 2001, 940 p. $200.00 hardback ($74.95 paperback).

Earth's mantle overturns itself about once every 200 Million years (Myrs). *Prima facie* evidence of this overturn is the motion of Earth's tectonic plates, about thirteen major ones today. This number waxes and wanes as we go back in time. In fact, plate motion reconstructions based upon the magnetic isochron record of the ocean floor reveal that even during the relatively recent 100 Myrs of Earth history some plates have been lost almost entirely to subduction while new plates have appeared in their place.

Supporting evidence also comes from seismic tomograms of Earth's interior, i.e. from "cat scans" of our planet. Over the past five years these cat scans have dramatically improved in quality, yielding high-resolution images of Earth's interior that would have seemed impossible two decades ago. The tomographic images reveal subducted oceanic plates plunging to the bottom of the mantle, effectively marking cold, downwelling currents and providing us with a snapshot of highly time-dependent convection inside the planet.

The fluid behavior of the mantle over geologic time, of course, places mantle convection firmly into the realm of fluid dynamics, and that is where the new book "Mantle Convection in the Earth and Planets" by Gerald Schubert, Donald L. Turcotte and Peter Olson comes in. Over the past three decades geodynamics, the field that describes the dynamic evolution of our planet from quantitative principles of continuum mechanics, has made remarkable progress. The authors stood at many of the most important crossroads along that way. Without their contribution, geodynamics as we know it today would be unthinkable. Their great ambition in this new book is to trace nearly every aspect of that arduous journey, and to put on record what is known about convection in the Earth and in other planetary mantles. That one might even attempt such ambitious undertaking marks a coming of age for the field, noteworthy in itself.

But let us start at the beginning. Twenty years ago Donald L. Turcotte and Gerald Schubert published "Geodynamics: Applications of Continuum Physics to Geological Problems" (Wiley, New York, 1982). That book became immensely important by teaching generations of Earth scientists the physical principles at work in mantle convection. In doing so it provided an essential step beyond the simplistic cartoons of Earth's interior that unfortunately are drawn to this day in many geologic textbooks. The new book, at 940 pages, is more than twice the length of Turcotte and Schubert's classic work. Organized into 15 chapters, the book starts out with historical remarks on continental drift, a description of plate tectonics, and three chapters on composition, thermodynamic properties, and viscosity of the mantle. It then lays out the dynamic framework of mantle convection with three detailed chapters on the basic (Navier Stokes) equations, linear stability, and approximate solutions. These technical chapters will be liked by specialists and are bound to hold their ground for years. They also demonstrate how much we can learn about convection in the mantle without resorting to numerical solutions. Of course, the equations of mantle convection are nonlinear, and a deeper understanding of how convection may take place inside the Earth has emerged only in line with our growing ability to study sophisticated computer simulations of the process, essentially an outcome of the dramatic increase in computational power over recent years. Consequently, in chapters nine and ten the authors present numerical convection simulations in two and three dimensions. At this point the book is ready to take a turn. It does so with a delightful chapter on hot spots and mantle plumes, followed by a chapter on chemical geodynamics that will see revisions, and a chapter on the thermal history of the Earth. Two synthesis chapters, one on convection in the moons and planets, the other on the nature of convection in the Earth's mantle, conclude the book.

The great strength of "Mantle Convection in the Earth and Planets" lies in its exhaustive coverage of all aspects of mantle convection, often accomplished with detailed references to original literature. Undoubtedly this makes the book an important tool for specialists. However, the approach comes at a price. Non-specialists will find it hard to distinguish what has been done from what has been learned, particularly when some of the heated debates have run their course of time. I also find that many chapters could be more focused, and sometimes discussion is duplicated across chapters. This makes the book valuable as a supplementary reference for other courses, but the current structure may not lend itself easily to coursework.

The book will leave many readers searching for the direction of geodynamic research over the next years. To a point, this is less essential. Great surveys by their nature tend to take stock and "Mantle Convection in the Earth and Planets" is no exception. However, geodynamic research today is in a state of rapid change, driven by bold observational initiatives, for example in seismology, unprecedented computational power, and the availability of new sophisticated mathematical tools, such as adjoint modeling techniques. Together these developments are opening the road to integrate a wide array of observations into geodynamic model calculations. They will thus tend to intensify collaborative efforts among geodynamicists and their colleagues from other fields, an opportunity that should be communicated more clearly.

But these are minor comments on a book that represents a remarkable achievement. Let me conclude by saying that readers interested in a concise and accessible account of mantle convection should certainly consult the recent book by Geoffrey Davies "Dynamic Earth" (Cambridge University Press, Cambridge, 1999). That text is proving highly effective throughout my teaching of the subject and draws praise from many of my students. Like Gerald Schubert, Donald L. Turcotte and Peter Olson's work has the makings of a classic. Together these two new books convey a remarkable sense of progress in our understanding of deep Earth processes, and I am convinced they will fill an important gap in the literature.

HANS-PETER BUNGE
Department of Geosciences
Guyot Hall, Princeton University
Princeton, New Jersey 08544