

BOOKS

Bringing the Earth Down to Earth: The Geology and Geologists of the Lower 48

Annals of the Former World

▶ John McPhee
Farrar, Straus, and Giroux,
New York, 1998. 696 pp.
\$35.00 hc ISBN 0-374-10520-0

Reviewed by W. Gary Ernst

James A. Michener opened many of his epic novels, such as *Centennial*, *Alaska*, *Hawaii*, and *Chesapeake*, with short but illuminating accounts of the regional geology; in some, he even described scenes of the area's prehistoric life. The hook in Michener's books, of course, is the riveting drama of human history unfolding through the context of the inextricably interlinked lives of individual people—good, bad, and indifferent, but all memorable.

John McPhee has turned this technique around in his literary works dealing with the geologic development of the lower 48 United States. In these books, in the company of one or another noted American geologist: Ken Deffeyes, Anita Harris, Karen Kleinspehn, Dave Love, Eldridge Moores, and Randy van Schmus, he travels across the land—generally not far from Interstate 80—and describes the geology of the regions he is crossing. We are treated to aspects of his companions' personal histories, and, in a real sense, the account is as much about what makes geologists tick as it is about their terrestrial subjects. We also learn historical facts associated with the regions being described (the California gold rush, environmental conservation versus land development, the vineyards of Napa Valley, and the like). McPhee's latest effort, *Annals of the Former World*, is actually a splicing together of four earlier books (all from Farrar, Straus, and Giroux) dealing with specific regions of the country, plus a minor amount of add-on connective material: *Basin and Range* (1981); *In Suspect Terrain* (1983); *Rising from the Plains* (1986); and *Assembling California* (1993).

The plate-tectonic revolution in the Earth sciences began in the 1960s, and McPhee uses it as a framework for the geologic development of the continent.

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Otherwise, just about all the science he touches on has been well known for more than a century, but the paradigm of plate tectonics made it possible to fit together seemingly unrelated geologic observations and data as parts of an integrated whole. Earth scientists around the world exulted over this satisfying new quantitative understanding of the planet, and many laypersons "got the picture" from articles published in newspapers, magazines, and popular books. In *Annals of the Former World*, McPhee has chronicled this intellectual advance, still on a popular level, but in far greater detail and comprehensiveness.

Annals is divided naturally and sequentially into five parts—one for each of the four previously published books, with their titles retained, and a new fifth part, a connector, called "Crossing the Craton." "Basin and Range" deals with the Great Basin of the western US, a region in which Earth's crust is gradually, imperceptibly being stretched and thinned because of inferred extensional flow in the hot, ductile mantle beneath this segment of the continent. This beginning part also includes primers on plate-tectonic principles and on the enormity of geologic time. "In Suspect Terrain" documents the growth of continents and the mountain-building process, as well as the intensely debated controversies surrounding these topics, with examples from the Appalachians to the Pacific Rim. "Rising from the Plains" uses the spectacular geology of Wyoming as the springboard for treatises concerning the evolution of the crust and mantle plumes (hot spots) as well as care of the land. "Assembling California" describes the amalgamation of the present collage of juxtaposed terranes (that's right, McPhee now recognizes "terranes" as blocks of Earth's crust, "terrains" as topographic features). The assembly was produced by geologically recent plate-tectonic motions, and it is still going on, as emphatically indicated by seismic activity along some of the many anastomosing faults that transect California.

The newly conceived section, "Crossing the Craton" mentions the ho-hum geology of the High Plains, but of much more interest, describes in some detail the geologic history locked

up in the ancient Precambrian basement beneath the surface cover strata. Most of the evolution of North America took place during the great sweep of Precambrian time, so this is a fitting conclusion to the peek-a-boo look at the better-preserved younger geologic terrains presented in the first four parts of *Annals of the Former World*. For easy reference, the book contains 22 simple but elegant relief maps and a rather complete subject index.

This book represents a very readable compendium of McPhee's earlier works, with modest updating. He has done the Earth sciences as well as the general public a truly remarkable service in popularizing the concepts of geology and the doings of Earth scientists. I recommend it to anyone who wishes to better understand our planet—not a bad idea, inasmuch as it is the only one we are likely to inhabit for the foreseeable future.

String Theory

▶ Joseph Polchinski
Vol. 1. An Introduction to the Bosonic String. 402 pp. \$49.95 hc
ISBN 0-521-63303-6

Vol. 2. Superstring Theory and Beyond. 531 pp. \$49.95 hc
ISBN 0-521-63304-4
Cambridge U. P., New York, 1998.

String theory is a theory of remarkable depth and intricacy and is a strong candidate for a unified description of all the forces of nature. On the way to this exalted status, it has done service in a variety of other roles.

It started out in the late 1960s as a theory of hadrons, and then it provided the foundations for supersymmetry, as a by-product of the inclusion of fermions into the theory. When it became clear in the early 1970s that quantum chromodynamics was the theory of the strong interactions, string theory found employment as a theory of quantum gravity, albeit in ten spacetime dimensions. When theorists realized in 1984 that string theory could also incorporate the gauge interactions and chiral fermions of the standard model in four dimensions, it found its current position as a "theory of everything." During the last few years, progress in string theory has occurred at a frantic pace, leading to

new insights into the structure of black holes and the dynamics of gauge theories.

Given its scope, it is not surprising that string theory is exceedingly difficult to learn. This situation has been greatly improved by the publication of Joe Polchinski's two-volume *String Theory*.

Before Polchinski's book, aspiring students of string theory have relied on the textbook by Michael Green, John Schwarz and Edward Witten. The GSW book (*String Theory*, Cambridge U. P., 1985) did an admirable job of bringing together the main points of string theory as it was then understood. However, the central role played by two-dimensional conformal invariance was not fully understood at the time, and the revolutionary ideas of the past four years, involving strong-weak coupling duality, extended objects, and the applications to black hole physics and the dynamics of supersymmetric gauge theory, had not been dreamt of. Thus there has been a clear need for a more modern textbook.

The first volume of Polchinski's book—a necessary prelude to the second—develops the theory of the bosonic string. This theory is not thought to be physically realistic, but its development introduces many of the tools required for an understanding of the physically more interesting superstring. Following a brief overview, the bosonic string is quantized and its spectrum determined. Emphasis is placed on a geometrical point of view and the use of path integral techniques. This quickly leads to conformal field theory (CFT), which is used as an organizing principle throughout the text.

After developing the tools of string perturbation theory through the computation of tree-level and one-loop string scattering amplitudes, the first volume treats toroidal compactification of string theory. This is not meant to be realistic, but it can be treated exactly and introduces some of the modern ideas of string theory. In particular, the notion of T-duality, which relates large and small radius, is encountered, along with D-branes, which are extended objects whose central role in string theory duality was first appreciated by Polchinski. Volume 1 ends with brief summaries of some topics that presaged the development of nonperturbative techniques in string theory, such as the divergence of string perturbation theory, the high-energy behavior of string scattering amplitudes, and the structure of noncritical string theories.

Compared to the smooth, logical development of the first volume, the second volume, or superstring theory, begins rather abruptly by generalizing conformal field theory to superconformal field theory and then, only later,

discusses the geometry behind this approach. Type I and II superstrings, the heterotic string, and superstring perturbation theory are all developed in the first hundred or so pages. This terse treatment makes some sense: The geometry of superstrings is much less intuitive than that of bosonic strings, and a detailed treatment of higher-order superstring perturbation theory would be overwhelming for all but the most sophisticated readers. Nonetheless, I felt a bit rushed. I could have used more reminders of how this material relates to the first volume.

The book then discusses two of the recent successful contributions of string theory: the ability to understand nonperturbative effects and the resulting control of strongly coupled string theory, and the insight into the structure of black holes that has resulted from the study of the extended objects responsible for these nonperturbative effects. The reader who has persevered this far is now richly rewarded by a discussion of D-branes and string duality, which explains the basis for these developments and summarizes the main results.

The remainder of volume 2 is devoted to attempts to make contact between the ten dimensions of string theory and the four-dimensional world of particle physics. This includes presentations of more advanced CFT techniques and compactification of string theory on orbifolds and Calabi-Yau spaces. This leads to four-dimensional theories, which resemble supersymmetric extensions of the standard model and are the basis for much of the current work on low-energy supersymmetry. As mentioned in the preface, the treatment of Calabi-Yau compactification is necessarily incomplete. The book by GSW is a useful supplement to the material presented here.

The use of CFT as a central theme brings a great deal of coherence to this book, although at a price. Primarily the language of string perturbation theory, CFT can rather miraculously be extended to deal with weakly coupled nonperturbative phenomena such as D-branes. Topics that require a spacetime point of view and don't easily fit into the CFT framework are treated rather briefly, if at all. The Green-Schwartz formalism is one example; another is the rather sketchy treatment of the low-energy supergravity Lagrangians in eleven and ten dimensions. Solitons in string theory, which cannot be described in terms of D-branes, are also discussed rather briefly.

Overall, this is an impressive book. It is notable for its consistent line of development and the clarity and insight with which topics are treated.

While it was written with novices in mind, experts will find many new points of view and interesting results. It is hard to think of a better text in an advanced-graduate area, and it is rare to have one written by a master of the subject.

It is worth pointing out that the book also contains a collection of useful problems, a glossary, and an unusually complete index. Typographical errors seem to be few, and they are corrected and updates are provided at a dedicated Web site. In a fitting catch-22 of the computer age, the URL of the Web site is given incorrectly; it can be found at <http://www.itp.ucsb.edu/~joep/bigbook.html>.

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Accretion Processes in Star Formation

▶ Lee Hartmann
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How do stars form? Such a seemingly simple question has a surprisingly complex answer—so complex, in fact, that many of the details of the process of star formation are still poorly understood. What is certain is that it involves the gravitational contraction and fragmentation of massive, diffuse clouds of gas and dust in interstellar space. Thus, at its most fundamental level, star formation involves accretion: the inward flow of matter onto a growing protostellar core.

In *Accretion Processes in Star Formation*, Lee Hartmann has written a much-needed book that focuses on this all-important process. It offers a wonderful overview of the subject for graduate students in astronomy and physics and for star-formation researchers. Since the same physics that governs accretion flows in star-forming regions is important in other astrophysical systems (such as mass transfer in close binary stars), specialists in other fields should find this book of interest as well.

Hartmann takes a very broad view of accretion. In the introductory chapter, he outlines a plausible scenario for the evolution of the mass accretion rate in the idealized problem of single-star formation, beginning with the earliest contraction phase of an interstellar cloud and concluding with the initiation of hydrogen-fusion reactions in the newly formed star. This scenario is the organizational theme around which the rest of the book is built. In successive