The Early Earth

Origin of the Earth. HORTON E. NEWSOM, JOHN H. JONES, *et al.*, Eds. Oxford University Press, New York, and Lunar and Planetary Institute, Houston, TX, 1990. vi, 378 pp., illus. $50. From a conference, Berkeley, CA, Dec. 1988.

Lord Kelvin calculated that Earth began to solidify 40 million years ago, thus starting a long-time confrontation between geologists and "natural philosophers." Following the discovery of radioactivity, Earth was viewed as having a cold, tranquil beginning. The Schmidt-Safranov accretional theory gave long accretion times, 10^8 years, for Earth. Gravitational energy radiated away, and planets formed in an unmelted condition. In standard geological models, the planet heated up gradually as a result of the decay of radioactive elements. Much later the "core formation event" heated and differentiated Earth. However, it has long been clear to some earth scientists that early Earth was hot and that an origin involving extensive melting was unavoidable. The Hanks-Anderson rapid-accretion hypothesis implied a hot origin, with differentiation and core formation simultaneous with accretion. This book continues the debate.

The arguments for a hot origin include the absent early geological record, an ancient magnetic field, remarkable concentration of certain elements into shallow regions, occurrences of old ultrahigh-temperature rocks, depletion of volatiles, isotopic fractionations, calculated cooling rates, and the fact that the upper mantle is close to the melting point everywhere. Rapid accretion is one way to explain the evidence for an early hot Earth. Modern accretion theories invoke large impacts, which are essentially very rapid accretion events. These heat and melt the early Earth even while spreading out the accretional history. There is now little doubt that the physics of accretion, combined with the evidence for large impacts, angular momentum, and the presence of the moon, demands a molten early Earth, perhaps with repeated melting episodes. An Earth covered by a magma ocean must exist throughout accretion if the planet is collecting energy faster than it can radiate it away. As this magma ocean crystallizes, it becomes a slush and is eventually responsible for chemical stratification and outward segregation of large-ion and crustal elements by a "radial zone-refining" process. The zone-purified refractory crystals, at depth, eventually transform to high-pressure phases as Earth grows, without ever having been in high-pressure equilibrium with the near-surface ocean. There are still earth scientists, however, who argue for a homogeneous, well-stirred mantle and for "primordial" rocks and an "undegassed" mantle and that most of Earth never experienced wholesale melting and differentiation. These authors and their views are well represented here.

The 20 independent chapters by 31 authors address aspects of the solar nebula, accretion, giant impacts, the moon, the magma ocean, core formation, the continental crust, the hydrosphere, and the origin of life. The main themes are accretion, the magma ocean, siderophiles, and core formation, but no consistent treatment is attempted. Although there are important contributions dealing with the physics of accretion and the details of core formation, this book falls far short of being a book on the "Origin of the Earth." The gaps in it are enormous, and balance is missing. There can be no understanding of the origin of our planet without input from petrology, geophysics, and geochemistry. There is also a great deal of circular reasoning. Rocks from the shallow mantle are chosen as representative if they appear "primitive" and "unfractionated." They are then used as evidence that Earth has not been fractionated. These rocks are assumed to be typical of the whole mantle, and therefore it is assumed that the mantle is homogeneous and different from other bodies. The paradoxes and problems pointed out by the editors in their summary sections have more to do with outmoded paradigms than with Earth. The "primordial mantle" and "genesis rock" concepts have been abandoned by their originators, but their ghosts are hard to exorcise. Mantle rocks have complex origins that involve melting, depletion, and re-enrichment. Even if all mantle rocks can be proved never to have equilibrated with the core and the present lower mantle, this would rule out only the more naive schemes of differentiation and magma ocean evolution on a fully formed planet.

A large fraction of the book is devoted to siderophiles and topics such as core formation and inhomogeneous accretion. The majority of the index entries refer to siderophiles, core, metals, sun, solar nebula, meteorites, asteroids, and other planets. There are no entries for peridotite, olivine, eclogite, basalts, isotopes, komatüte, geophysics, recycling, heat flow, magnetic field, or phase changes. Thus this is a book about a hypothetical planet, not one that necessarily evolves to Earth or that satisfies many terrestrial data.

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Some Other Books of Interest

Optics, Physiology and Vision. A Festschrift Honoring Professor Gerald Westheimer on His 65th Birthday. SUZANNE P. MCKEE and KEN NAKAYAMA, Eds. Pergamon, New York, 1990. vi pp. + pp. 1529–1921, illus. $45. Also published as *Vision Research*, vol. 10, no. 11 (1990).

In August 1989 a symposium was held to honor Gerald Westheimer on his 65th birthday, and this volume is composed of revised versions of papers presented on that occasion. The volume opens with an introduction by Suzanne McKee, who traces the course by which Westheimer traveled from Nazi Germany to the position he has occupied at the University of California since 1960, stops along the way having included Australia, where as an adolescent he was apprenticed to an optometrist, and Cambridge, England, where he worked with Horace Barlow and others who constituted what was "surely one of the most illustrious groups ever assembled in vision research." McKee also gives a brief account of Westheimer's research, beginning with his dissertation work on saccadic and smooth-pursuit eye movements using a "novel approach . . . we would now identify as linear systems analysis" and noting his influential work on aspects of human spatial vision. There follow 26 technical papers, arranged alphabetically by first author. One of the more general papers is Barlow's "Conditions for versatile learning, Helmholtz's unconscious inference, and the task of perception," in which he presents an argument that "to understand perception one must view it as prologue to learning." Another is Steinman *et al.*'s "New directions for oculomotor research," which reviews Westheimer's contributions to the subject and discusses the implications of the capability, due to new instrumentation, of observing oculomotor performance under more naturalistic conditions. The remaining papers, mostly reports on their authors' own research, include among their topics aspects of spatial discrimination, hyperacuity, and stereopsis. The volume also includes a list of Westheimer's publications, 1945–1990.—**K.L.**

Evolutionary Innovations. MATTHEW H. NITECKI, Ed. University of Chicago Press, Chicago, IL, 1991. x, 304 pp., illus. $44.95; paper, $17.95. From a symposium, Chicago, IL, May 1988.

The 1988 Field Museum spring systematics symposium was devoted to the theme of innovation in evolution, and the book that has resulted is presented as a "cross section of present-day ideas" on the subject. In an