Theories and Origins in Planetary Physics

[Review of the books *Nebulous Earth: The Origin of the Solar System and the Core of the Earth from Laplace to Jeffreys; Transmuted Past: The Age of the Earth and the Evolution of the Elements from Lyell to Patterson; Fruitful Encounters: The Origins of the Solar System and of the Moon from Chamberlin to Apollo*]

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Doel, Ronald E.
Department of History (and Department of Geosciences), Oregon State University
*Reviewing Author

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*By Ronald E. Doel**

Stephen G. Brush. *Nebulous Earth: The Origin of the Solar System and the Core of the Earth from Laplace to Jeffreys.* (History of Modern Planetary Physics, 1.) xii + 312 pp., illus., tables, bibl., index. Cambridge/New York: Cambridge University Press, 1996. $54.95.

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Interest in the history of the earth sciences in the nineteenth and twentieth centuries has expanded rapidly in recent years. As a marker of intellectual boundaries, the designation "earth sciences" is admittedly ill fitting: no institutional structure or body of knowledge corresponded to that term until after the turn of the twentieth century, and professional relations between astronomy and geophysics differed greatly across national boundaries. Yet scientists moved freely between these neighboring fields to pursue problems in terrestrial and planetary physics, and scholars have begun to trace their paths across this vast and interesting terrain. New works address such topics as the contributions of Pierre-Simon Laplace and his contemporaries to refining the theory of celestial mechanics, efforts to map and to interpret the earth's magnetic field, the rise of meteorological theory and practice, science in Antarctica, and twentieth-century investigations of the nature of the solar system.[1] Scholars have also focused on oceanographic expeditions, the work of major

* Department of History (and Department of Geosciences), 306 Milam Hall, Oregon State University, Corvallis, Oregon 97331.

[1] For recent books see, e.g., Charles C. Gillispie, *Pierre-Simon Laplace, 1749–1827: A Life in Exact Science* (Princeton, N.J.: Princeton Univ. Press, 1997); René Taton and Curtis Wilson, eds., *Planetary Astronomy from the Renaissance to the Rise of Astrophysics* (New York: Cambridge Univ. Press, 1989); Robert P. Multhauf and Gregory A. Good, *A Brief History of Geomagnetism and a Catalog of the Collections of the National Museum of American History* (Washington, D.C.: Smithsonian Institution Press, 1987); William Glen, *The Road to Jaramillo: Critical Years of the Revolution in Earth Science* (Stanford, Calif.: Stanford Univ. Press, 1982); C. Stewart Gillmor and John R. Spreiter, eds., *Discovery of the Magnetosphere* (History of Geophysics, 7) (Washington, D.C.: American Geophysical Union, 1997); James Rodger Fleming, *Meteorology in America, 1800–*

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research centers such as the U.S. Geodetic Survey and the Carnegie Institution of Washington, the introduction of physical and chemical methods in the earth sciences (including the biogeochemical ideas of Vladimir I. Vernadsky, which helped define the concept of the earth's biosphere), and the influence of military patronage on space science and oceanography after 1945.[2] The rejection of continental drift and the eventual acceptance of plate tectonics in the late 1960s has lately become a small industry, while other high-profile controversies, such as the mass extinction debate and human recognition of global climate change, are vibrant new fields of scrutiny.[3] Even reprints of classical treatises have begun to appear: an English translation of Alexander von Humboldt's *Kosmos* (1848), which helped give shape to the disciplines of climatology, ecology, and geography, is once again in bookstores.[4]

A defining characteristic of this scholarship is its inclusive definition of the earth sciences as an interdisciplinary subject, its insistence that nineteenth- and twentieth-century studies of the earth and the solar family be treated as parts of a broader conceptual whole. Several factors have been responsible for this approach. One is the greater attention field sciences, as opposed to laboratory sciences, have been receiving as a focus of historical inquiry. For instance, the recent *Osiris* volume dedicated to *Science in the Field* testifies to a growing body of scholarship on research requiring synoptic observations of diverse phenomena over large spatial distances and raises important questions about such wide-ranging topics as instrument design and calibration, disciplinary organization, scientific practice, regional and international cooperation, and standards of evaluation. Another factor is the increased willingness of historians to move away from such canonical topics as Darwinian evolution and the development of modern physics, many of which have a disciplinary cast. A final factor has surely been growing popular and cultural interest in the earth as a threatened province. As Peter J. Bowler has recently declared, the conceptual unity of the "environmental sciences" is not intrinsic but instead "imposed by the public's growing awareness of the threat posed to the environment by our own activities."[5]

1870 (Baltimore: Johns Hopkins Univ. Press, 1990); Frederik Nebeker, *Calculating the Weather: Meteorology in the Twentieth Century* (San Diego: Academic Press, 1995); Robert Marc Friedman, *Appropriating the Weather: Vilhelm Bjerknes and the Construction of a Modern Meteorology* (Ithaca, N.Y.: Cornell Univ. Press, 1989); and G. E. Fogg, *A History of Antarctic Science* (New York: Cambridge Univ. Press, 1992). On planetary astronomy and related fields see John G. Burke, *Cosmic Debris: Meteorites in History* (Berkeley/Los Angeles: Univ. California Press, 1986); Steven J. Dick, *The Biological Universe: The Twentieth-Century Extraterrestrial Life Debate and the Limits of Science* (New York: Cambridge Univ. Press, 1996); Ronald E. Doel, *Solar System Astronomy in America: Communities, Patronage, and Interdisciplinary Research, 1920–1960* (New York: Cambridge Univ. Press, 1996); Clayton R. Koppes, *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven, Conn.: Yale Univ. Press, 1982); and Joseph N. Tatarewicz, *Space Technology and Planetary Astronomy* (Bloomington: Indiana Univ. Press, 1990).

[2] See Robert Marc Friedman, *The Expeditions of Harald Ulrik Sverdrup: Contexts for Shaping an Ocean Science* (La Jolla, Calif.: Scripps Institution of Oceanography, 1994); Hugh R. Slotten, *Patronage, Practice, and the Culture of American Science: Alexander Dallas Bache and the U.S. Coast Survey* (New York: Cambridge Univ. Press, 1994); Gregory Good, ed., *The Earth, The Heavens, and the Carnegie Institution of Washington* (Washington, D.C.: American Geophysical Union, 1994); Kendall Bailes, *Science and Russian Culture in an Age of Revolution: Vernadsky and His Scientific School, 1863–1945* (Bloomington: Indiana Univ. Press, 1989); David Oldroyd, *Thinking about the Earth: A History of Ideas in Geology* (Cambridge, Mass.: Harvard Univ. Press, 1996); David H. DeVorkin, *Science with a Vengeance: The Military Origins of the Space Sciences* (New York: Springer, 1992): and Chandra Mukerji, *A Fragile Power: Scientists and the State* (Princeton, N.J.: Princeton Univ. Press, 1989).

[3] See especially Homer LeGrand, *Shifting Continents and Drifting Theories* (New York: Cambridge Univ. Press, 1988); Naomi Oreskes, *The Rejection of Continental Drift* (New York: Oxford Univ. Press, 1999); William Glen, ed., *The Mass Extinction Debate: How Science Works in a Crisis* (Stanford, Calif.: Stanford Univ. Press, 1994); and Spencer R. Weart, "The Discovery of the Risk of Global Warming," *Physics Today,* 1997, *50*:34–40.

[4] Alexander von Humboldt, *Cosmos: A Sketch of a Physical Description of the Universe,* trans. E. C. Otté (Baltimore: Johns Hopkins Univ. Press, 1997).

[5] Peter J. Bowler, *The Norton History of the Environmental Sciences* (New York: Norton, 1992), p. 2; and Henrika Kuklick and Robert E. Kohler, eds., *Science in the Field, Osiris,* 2nd Ser., 1996, *11.*

Two significant questions about the earth that scientists have sought to address since the nineteenth century are its physical history (including its age, composition, and chemical evolution) and its ultimate origins as a member of the solar family. In this important and thoroughly researched three-volume work, the culmination of a nearly two-decades-long effort, Stephen G. Brush takes on scientific interest in these topics since the late 1700s. Brush's works unfold chronologically: his first volume deals with a broad expanse of nineteenth- and early twentieth-century research, encompassing celestial mechanics, the nebular hypothesis, the discovery of the earth's core, and theories about its geochemical history. In the second volume Brush turns to the topic of the earth's antiquity, providing a sweeping technical overview of the well-known late nineteenth-century controversy between Lord Kelvin and geologists over the age of the earth, as well as debates over uniformitarianism, mid-twentieth-century efforts to date the earth's origin, and the cosmic evolution of matter (including the efforts of astrophysicists to interpret nucleosynthesis in stars and its application to the formation of planets). His third volume focuses primarily on twentieth-century theories of the origin of the solar system and concludes with a review of lunar research from the eighteenth century through the post-*Apollo* era. Two chapter sections in the first volume, on Saturn's rings and geomagnetic secular variation, are cowritten with collaborators. Each volume is designed to be read independently of the others. Yet even taken as a whole, the three display remarkably little overlap, save for a few aspects of Brush's treatment of cosmogony and the interpretations of the chemical evolution of the earth. Indeed, they could well have been published as a single volume, with the benefit (lacking here) of a comprehensive concluding chapter, one that might have called larger issues into question.

A real strength of Brush's work is his careful analysis of episodes of discovery and his familiarity with the broad conceptual realm of the planetary sciences. Readers will have no doubt of Brush's mastery over the technical details of the myriad subjects he treats. Brush provides comprehensive accounts of efforts to unravel puzzling variations in the orbital motions of the planets, particularly the long inequality of Jupiter, the solution of which ultimately convinced Laplace's contemporaries that the solar system was a clockwork-like, deterministic system; he is equally at home in describing the theoretical seismology pursued by the German geophysicist Emil Wiechert, the geochemical arguments by Werner Kuhn, Arnold Rittmann, and William H. Ramsey concerning the earth's core, and the accretionary cosmogony proposed by the Soviet astrophysicist Viktor S. Safronov. One reward of Brush's exhaustive research is his ability to illuminate lesser-known figures and research traditions: he devotes considerable space to the controversial yet widely discussed plasma-based cosmogony developed by the Swedish Nobel laureate Hannes Alfvén as well as to the early twentieth-century discovery of the earth's solid inner core by the Danish seismologist Inge Lehmann. Brush also succeeds in demonstrating that even the most apparently straightforward scientific accounts of discovery often omit the complicated twists that underlie actual scientific work: Kelvin's claims about the earth's solid structure inspired geophysicists to intensify their study of the earth's physical and chemical properties and thus had a more lasting influence than his better-remembered efforts to convince geologists, prior to the discovery of radioactivity, that the earth was at best several millions of years old, too young for biological evolution to have occurred. Only occasionally does Brush give short shrift to key episodes. Continental drift and plate tectonics are cited only in passing, and the contributions geologists made to interpreting the moon's history, which were considerable, are left out in favor of extensive discussions of geochemical and geophysical results.

One of Brush's pursuits over the years has been to employ the history of nineteenth- and twentieth-century physical science to assess the adequacy of Kuhnian, Popperian, and Lakatosian theories of science to evaluate the production of scientific knowledge, and Brush turns to these issues again here. He is particularly effective in pointing to historical examples that refute Imre Lakatos's claim that scientists never falsify a theory before the emergence of a better theoretical alternative. He notes, for instance, that by the mid 1930s astrophysicists abandoned the encounter theory of cosmogony—which held that another star sideswiping the sun had drawn out filaments of matter that condensed into the planetary system—after calculations by Lyman Spitzer, then a graduate student of the eminent astrophysicist Henry Norris Russell, demonstrated its weakness; not until a decade later did an alternative hypothesis (a modified form of the nebular hypothesis) again win favor, despite persistent interest in the problem (Vol. 3, pp. 85–87). Although philosophical issues are not his central concern, Brush demonstrates that cosmogony in the twentieth century does not end in a dramatic climax; instead, like many branches of planetary science, it has a history filled with numerous dead ends, unproductive detours, and quarrels over competing methodological approaches. As Brush does not not employ historical periodizations in framing his often-encyclopedic narrative—he prefers to focus on long-term conceptual developments—these themes help give structure to his books.

It is clear that Brush also has a broader aim for this three-volume work: to widen the debate over standards for writing the history of science. Brush has long played a leading role in this debate. In his 1995 *Osiris* essay "Scientists as Historians," which summarized his views, Brush criticized the excessively "contextualist" approaches of historians who lack advanced training in science (Brush holds a Ph.D. in physics) and diminish the achievements of scientific thought. Rejecting Paul Forman's demand that historians of science achieve independence from their subjects, Brush called for greater familiarity with the tacit knowledge shared by scientific communities and attention to the "intense desire of research scientists to produce new discoveries."[6] The design of the History of Modern Planetary Physics series illuminates Brush's preferences for narrating the development of scientific ideas, for (in metaphorical terms) he focuses primarily on military tactics while setting aside the causes of the war. Like Alexandre Koyré, whose work he clearly admires, Brush has based his account primarily on his careful reading of original scientific papers. Biographical information about scientists, when provided, is typically relegated to footnotes and is often limited to his subject's educational background and scientific contributions. Moreover, Brush's conceptual landscape is largely devoid of social, cultural, political, professional, or institutional forces. Historians of science who have labored in recent years to identify the role of biography, national styles of science, disciplinary practices, research schools, and patronage in shaping the pursuit of scientific practice will find few of their interpretations and insights reflected here.

Brush seems convinced that this largely internal narrative provides a richer, more enduring history than contextual approaches, and his conviction will not be lost on his readers. In the provocative first chapter of his second volume, Brush contrasts the emergence and growth of history and geology after 1800 as intellectual fields. By the turn of the twentieth century, Brush argues, geology showed progressive tendencies—including a theory of volcanic energy and the concept of uniformitarianism—whereas historians had made little progress toward creating historical paradigms. Even in the late twentieth century, he claims, scientists talk shop at lunch, but historians do not; scientists distribute preprints and collaborate on papers, while historians avoid such practices and generally work in isolation. In particular, Brush laments what he terms the impulse of professional historians to shirk controversy, encouraging them "to engage in vigorous debate with each other on specific questions of fact and interpretation and, more importantly, to change their conclusions as a result of such debate" (p. 32). Although he does not define what he means by historical "facts" (and regrettably does not discuss Peter Novick's *That Noble Dream*

[6] Stephen G. Brush, "Scientists as Historians," *Osiris*, 2nd Ser., 1995, *10*:215–231, on p. 228; and Paul Forman, "Independence, Not Transcendence, for the Historian of Science," *Isis*, 1991, *82*:71–86.

in this context), Brush finds the historical community deficient. To advance, historians need to become more like social scientists.

Many historians of science will resist Brush's call for a more theory-based history and challenge his assertion that historians are less professionally rigorous or cooperative than their colleagues in the sciences. Indeed, as Eric Hobsbawm has argued, we ought not expect history to "progress" as the natural sciences do.[7] But Brush has worked in both the history and physics departments for two decades (at the University of Maryland), and his claims merit careful consideration. In particular, how important are professional and disciplinary factors in analyses of the evolution of scientific ideas? Do they matter in narratives of the intellectual foundations of any field, including the planetary sciences? Do they affect the conceptual developments so central to Brush's historical account?

Several examples suggest that they do. Brush is certainly well aware that what defines the planetary sciences is their interdisciplinary character: many critical problems, from the age of the earth to the structure of the moon, placed geophysicists elbow-to-elbow with geochemists, astrophysicists, geologists, and experts in celestial mechanics. In the absence of disciplinary structures, publication outlets, and reward systems, individual alliances matter greatly, and sparks sometimes fly. But Brush's reluctance to engage recent work on disciplinary practice and research schools, and his unwillingness to stray far from textual exegesis, limits his ability to reach what might have been deep insights into the production of knowledge. Noting that interdisciplinary research in cosmogony at Chicago did not survive the death of the eminent geologist Thomas C. Chamberlin in 1928, Brush lightly declares that Chamberlin's colleagues "did not acquire the right amount of personal momentum to go into stable orbits or condense into a family of cooperative followers of a research programme" (Vol. 3, p. 88), although careful consideration of the burgeoning literature on research schools might well have suggested why this was so.[8] Similarly, Brush declares that Harold C. Urey rejected the influential cosmogonical model proposed by the American astronomer Gerard P. Kuiper in the mid 1950s because it failed to explain the silicate concentrations in the terrestrial planets. This reason was indeed one factor. But Urey's rejection of Kuiper's model marked the bitter breakup of a five-year-long interdisciplinary collaboration between this Nobel chemist and the United States's most eminent planetary astronomer, an estrangement that enraged and depressed both men, disturbed a General Assembly of the International Astronomical Union, and hindered personal relations between members of these disciplines (and their graduate students) for more than a decade. Intellectual disagreements provide only a partial explanation for Urey's dismissal of Kuiper's ideas, and perhaps not the most important part. Such examples can be multiplied. As Loren R. Graham and others have convincingly argued, leading Soviet astrophysicists who adhered to dialectical materialism reacted negatively along philosophical lines to religious inferences in Western cosmogonical ideas well into the 1970s; although Brush is quite willing to allow for the influence of Christian thought on the reception of the nebular hypothesis in the nineteenth century, he declares that religion no longer influenced this field in the twentieth.[9] Only in Brush's extended discussion of Chamberlin's planetesimal cosmogony is there a vivid depiction of social, professional, and institutional

[7] Eric Hobsbawm, "Has History Made Progress?" in *On History* (New York: New Press, 1997), pp. 56–70.

[8] For a discussion of this literature see Gerald L. Geison and Frederic L. Holmes, eds., *Research Schools: Historical Reappraisals, Osiris,* 2nd Ser., 1993, *8.*

[9] Loren R. Graham, *Science in Russia and the Soviet Union: A Short History* (New York: Cambridge Univ. Press, 1992), pp. 380–427; Ronald E. Doel and Robert McCutcheon, "Historical Introduction" to the special volume *Astronomy and the State in the U.S.S.R. and Russia, Journal for History of Astronomy,* 1995, *26*:3–20; and Alexsey E. Levin, "The Otto Schmidt School and the Development of Planetary Cosmogony in the USSR," in *The Origin of the Solar System: Soviet Research, 1925–1991,* ed. Levin and Stephen G. Brush (New York: American Institute of Physics), pp. 3–18.

factors that shaped this eminent geologist's research. Not surprisingly, this passage is one of very few instances in these volumes in which Brush relied on archival evidence as well as scientific publications.

Nor does Brush, despite his prevailing concern for intellectual history, disregard all social questions, and this fact raises a second set of concerns. In his second volume Brush asserts that planetary science suffered a decline in prestige during the twentieth century, primarily because physicists viewed it as "not worthy of the best minds" (Vol. 3, p. 144). He backs up this assertion by pointing to such factors as the geophysicist William Menard's views on the stagnation of American geology after the 1930s, remembered comments from physics colleagues as the space age began in the 1960s, and his own recollections as a young practicing physicist. Brush's personal insights ought not be discounted, and planetary studies certainly expanded far less rapidly than nuclear or solid state physics. But his reliance on intellectual considerations alone ignores a world in which international competition and funding and available instruments and social prestige *also* mattered. Geophysics was not a field the Rockefeller Foundation supported until the late 1920s, when the Great Depression deeply eroded its research grants, and the rise of physics was tied to the great technical advances of the second industrial revolution. As Spencer R. Weart has poignantly argued in his recent study of human recognition of global change, a world transfixed with the transforming powers of nuclear physics gave little support to seemingly esoteric studies of glacier retreats or links between eccentricities in the earth's orbit and climate.[10] Intellectual "worth" is not an ahistorical concept, and the problem demands a more thorough investigation than Brush provides here.

Some of these concerns might have been addressed had Brush engaged the emerging body of historical writings about the earth sciences with the same formidable vigor that he uses in analyzing scientific texts, but there are unfortunate omissions in his coverage. In reviewing the rejection of continental drift, for instance, Brush relies on the classic late 1970s writings of Henry Frankel without addressing the important 1988 work of Naomi Oreskes, which demonstrated that national styles of geological theorizing, rather than the absence of a suitably defined physical mechanism, was a key factor behind American resistance to drift.[11] Nor do these volumes address David DeVorkin's recent work on the military's role in conceptually defining the space sciences after World War II or Bowler's pioneering 1992 survey of the environmental sciences; one review that Brush cites as evidence of historians' inattention to the development of geophysical programs by physicists is twenty years old. Although the epistemological and methodological issues considered by these authors may not have seemed central to the story that Brush wishes to tell, their scholarship is arguably of more than tangential significance to intellectual accounts of recent science.

Brush's volumes are an important contribution to the history of this richly interdisciplinary field: they are the most comprehensive accounts of modern attempts to understand the age of the earth and its physical evolution, and they reflect Brush's unparalleled familiarity with these topics. But they do not offer a definitive history of the planetary sciences. The need to integrate the intellectual development of planetary science into broad social, cultural, professional, disciplinary, and ideological frameworks should propel further scholarship on this vital subject for years to come.

[10] See Gregory Good, "The Rockefeller Foundation, the Leipzig Geophysical Institute, and National Socialism in the 1930s," *Historical Studies in the Physical and Biological Sciences,* 1991, *21*:299–316; Robert E. Kohler, *Partners in Science: Foundations and Natural Scientists, 1900–1945* (Chicago: Univ. Chicago Press, 1990), pp. 250, 276–277; and Spencer R. Weart, "Global Warming, Cold War, and the Evolution of Research Plans," *Hist. Stud. Phys. Biol. Sci.*, 1997, *27*:319–356.

[11] Naomi Oreskes, "The Rejection of Continental Drift," *Hist. Stud. Phys. Biol. Sci.*, 1988, *18*:311–348.