Memorial to Francis Birch
1903–1992

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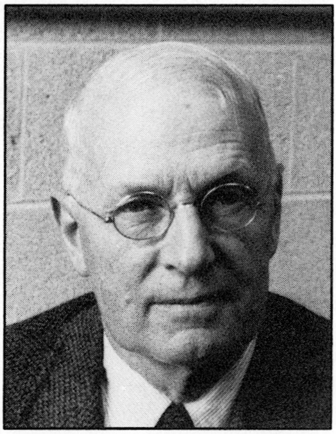

Francis Birch, the leading geophysicist of his day, died at home in Cambridge, Massachusetts, on January 30, 1992. Francis was a firm friend of geology, and was active in his support of the Geological Society of America. A member since the 1930s, he was elected Fellow in 1942, and was awarded both the Arthur L. Day Medal (1950) "...for outstanding distinction in the application of physics and chemistry to the solution of geological problems," and the Penrose Medal (1969). He was a member of the Council of the Society from 1956 to 1958 and from 1963 to 1965, and was president of the Society in 1964. His presidential address, "Speculations on the Earth's Thermal History," was published in the *Bulletin* in 1965. Although not a geologist by training, Francis was always careful to take all relevant geologic features into account, especially when making heat-flow calculations or gravity measurements. He also became interested in volcanoes and geysers through L. C. Graton, with whom he made an expedition to Iceland in 1947, and to Yellowstone Park a year later.

Geophysicists concerned with the nature of Earth's deep interior probably owe more to Francis Birch than to any other scientist of his day. By investigating the behavior of solid materials at high pressure, and by combining these results with seismic observations and with heat flow and gravity measurements, he was able to propose Earth models that were marked improvements over their predecessors and that survive as the basis of most of the models that have since appeared. The data he collected and the measurements he made were essential to the development of modern geophysics.

Francis was born in Washington, D.C., on August 22, 1903, the son of George Albert and Mary Clayton (Hemmick) Birch. His parents named him Albert Francis, but he preferred to be known simply as Francis later in life. He attended public schools in Washington and entered Harvard in 1920, graduating in 1924 with a degree magna cum laude in electrical engineering. After two years as an employee of the New York Telephone Company, he obtained an American Field Service fellowship that led to two years of study in France. After a brief stay at the University of Dijon, he went on to do research on magnetism at the University of Strasbourg in the laboratory of Pierre Weiss. In 1928 Francis returned to Harvard as a graduate student in physics, working primarily on high-pressure research in the laboratory of Percy Bridgman. He was an instructor and tutor in physics from 1930 to 1932, and received his doctorate in 1932.

During this period an interdepartmental program to study the physics of Earth and the physical properties of its materials was initiated at Harvard by physicist Percy Bridgman and his friend, geologist Reginald Daly. Upon receiving his doctorate, Francis Birch was promptly appointed Harvard's first research associate in geophysics, a position he held until he became an assistant professor in 1937. Francis then rose through the academic ranks, becoming Sturgis Hooper professor of geology in 1949, a chair he held until his retirement in 1974. When he became chairman of Harvard's Division of Geological Sciences in 1958, the geologists were housed in an ancient museum building, and Francis occupied Dunbar Laboratory, a converted garage off Hammond Street in Cambridge. He worked tirelessly, first with potential benefactors and later with the architect, to obtain the modern laboratory space that was so desperately needed. The Hoffman Laboratory of Experimental Geology and Geophysics was completed in 1963, the last year of his chairmanship.

Although he had no prior background in geology, Francis quickly established close and profitable working relationships with the geology faculty, a group of quite different people, each dealing with one aspect or another of our richly varied Earth. To maintain effective communication amid this diversity, there was an informal lunch table at the Harvard Faculty Club where one could learn of the discoveries, hopes, and enthusiasms of one's colleagues. Francis quickly became a central member of the group. Ideas were exchanged freely in an atmosphere of trust and mutual respect. All of us gained much from it. Ideas spawned there often found their way into print. Francis, always meticulous in acknowledging his sources, would sometimes surprise us by carefully citing, months or years later, something that had been scrawled casually on an overturned placemat.

During the second world war Francis took leave from Harvard in 1942 to enter four years of government service, for which he was awarded the Legion of Merit in 1945. He had done research at the radiation laboratory at M.I.T. as early as 1940, and was appointed a member of the staff there (1941–1942), but left soon to serve as a lieutenant commander, later commander, in the U.S. Navy (1942–1945), first in the Bureau of Ships in Washington, D.C. on proximity fuses, and finally with the Manhattan Project at Los Alamos where he headed the research on the Hiroshima bomb.

The studies first suggested by Daly and Bridgman were to conduct experiments bearing on the elastic properties of rocks and minerals at high pressures and temperatures, in order to better interpret seismic data. Francis's results, together with the work of his students and the earlier data of Bridgman, were successfully formulated and extrapolated in terms of Murnaghan's (1937) theory of finite strain. Francis was editor of the *Handbook of Physical Constants*, published in 1942. From about 1940, initially in collaboration with Harry Clark, Francis also became concerned with the thermal conductivity of rocks and with the nature of heat sources and the mechanisms of heat transfer. From about the mid-1940s he began investigations of phase transformations at high pressures. The above studies provided the basis for his classic paper, "Elasticity and Constitution of the Earth's Interior" (1952). This paper has been the prototype for virtually all of the more recent earth models. These models include a metallic core below 2900 km, solid at the center but liquid in its outer parts, a lower mantle between 900 and 2900 km composed of high-density silicate phases, and an upper mantle and crust of lower density silicate phases.

Thermal conductivity data made it possible in the late 1940s and 1950s to make heat-flow estimates on the basis of temperature measurements in tunnels, wells, and drill holes. Measurements by Francis, or by students and others under his guidance, were made in the Colorado Front Range, in the West Texas basin (with Harry Clark), in the Swiss Alps (S. P. Clark), and on Eniwetok Atoll. Later, thanks to National Science Foundation funding and technological advances, it became possible to have drill holes made across the United States purely for heat-flow measurements. This work was done in the 1960s (with R. F. Roy, E. R. Decker, and D. D. Blackwell) and published in 1968. Regional gravity measurements by several students (notably R. J. Bean, P. E. Byerly, P. J. Hart, W. B. Joyner, W. H. Diment, M. G. Simmons, and M. M. Fitzpatrick) were carried out in the northeastern states and adjacent Canada, and in California, more or less concurrently with the heat-flow measurements.

Francis's career was characterized throughout by a clear understanding of what needed to be done and how to go about doing it. Both his experiments and his observations of the natural world have stood the test of time. His data on elastic properties and thermal conductivities, and the extensive heat-flow and gravity measurements he and his students made contributed immeasurably to geophysics as we know it today. His recorded publications were many, but there are also many contributions on which his name does not appear. His name appeared only rarely as coauthor on the published results of his students' theses, and then only for strong reasons. He was always helpful to younger colleagues by providing both encouragement and material assistance. A reserved and rather private personality hid an underlying warmth and an intense loyalty to his colleagues and students. His students held him in awe and deep respect. When he shared a major award with the British geophysicist Sir Edward Bullard, his students were disturbed by the asymmetry, and they referred to him for some years thereafter as "Sir Francis."

Francis was elected to the National Academy of Sciences in 1950. He chose affiliation with the geology section of the Academy, remaining there until 1989, when, after a period on inactive status, he returned to active membership as an affiliate of the geophysics section. He was awarded the William Bowie Medal of the American Geophysical Union (1960), the National Medal of Science (1968), and the Vetlesen Prize of Columbia University (1969, shared with Sir Edward Bullard), and he received honorary doctorates from the University of Chicago (1970) and Harvard (1982), the latter as Harvard's "...great explorer of the Earth's interior." Francis also received the Bridgman Medal (1983) of the International Association for the Advancement of High-Pressure Science and Technology, and he was a Fellow of the American Physical Society, an honorary member of the Geological Society of London, and a member of the Royal Astronomical Society of Great Britain, receiving its Gold Medal in 1973. Other memberships included the American Academy of Arts and Sciences, the American Philosophical Society, and the Seismological Society of America.

More than 600 of the world's leading geophysicists attended a symposium in Cambridge, Massachusetts, on "The Nature of the Solid Earth" (April 16–18, 1970), honoring Francis's first 40 years of teaching at Harvard. A festchrift volume of the same title and edited by a former student, E. C. Robertson, was published two years later.

Francis is survived by his wife, Barbara (Channing) of Cambridge, Massachusetts, whom he married in 1933, and by their three children: Anne C. Hughes of Cambridge, Francis S. Birch of Durham, New Hampshire, and Mary N. Birch of Cambridge. Many happy summers were spent at their farm in Kensington, New Hampshire, and later at Wareham, Massachusetts, on Buzzards Bay. Also surviving are three brothers: David S. Birch of Garden City, New York, John A. Birch of Chevy Chase, Maryland, and Robert F. Birch of New York City; as well as five grandchildren and six great-grandchildren.

A story told several times by Francis reveals something of his approach to geophysics: It concerned a dream reported to him by R. A. Daly in which Daly lowered a clock on a wire into a well. Why? "...in order to find out what time it was *down there.*"

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Note: A more complete bibliography, and further biographical details, are on file at the Harvard University archives.

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