NATIONAL ACADEMY OF SCIENCES

ROBERT M. WALKER
1929–2004

A Biographical Memoir by

P. BUFORD PRICE AND ERNST ZINNER

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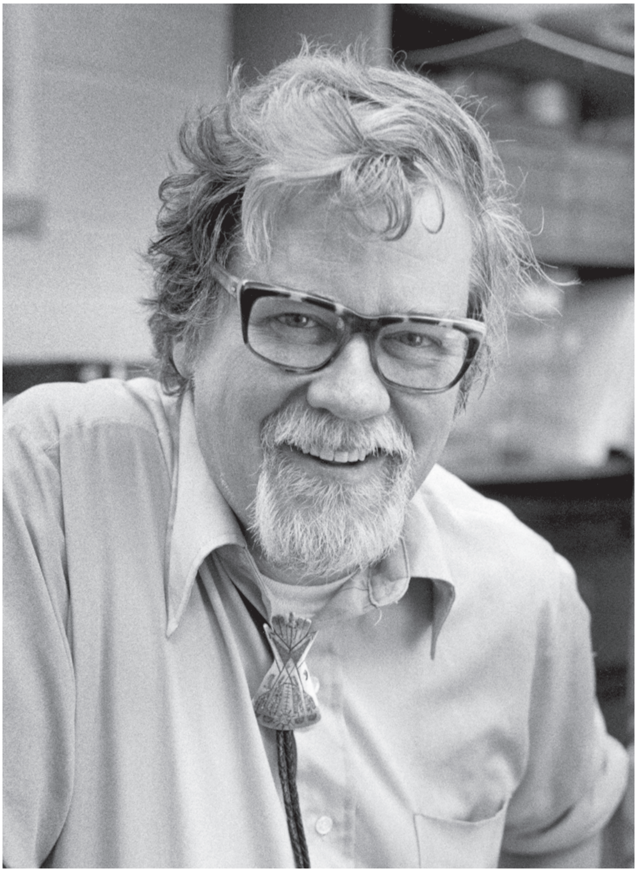

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Robert M. Walker

ROBERT M. WALKER

February 6, 1929–February 12, 2004

BY P. BUFORD PRICE AND ERNST ZINNER

ROBERT WALKER DIED ON February 12, 2004, in Brussels, Belgium, after an extended battle with stomach cancer. He was a visionary with two great dreams, both of which paid off handsomely. He conjectured that meteorites and lunar rocks contain a record of the ancient radiation history of the solar system in the form of fossil tracks of radiation damage. With his colleagues at General Electric Research Laboratory, he made that dream come true. He conjectured that grains that originated in stars could be found in meteorites and analyzed individually to provide new insights into basic astrophysical processes. With his colleagues at Washington University in St. Louis, he made that dream come true, too. As he liked to put it, "In high school, I promised my sweetheart the sun, the moon, and the stars. We now have samples of the moon, we have samples of stars, and we have samples of the sun."

Bob was born on February 6, 1929, in Philadelphia. His father left him and his mother when Bob was only four. While working in New York City, his mother met and married Roger Potter, a construction worker, whom Bob regarded for the rest of his life as his real father. During the Great Depression, when there were few jobs, the three of them moved to a farm near Cobleskill, New York, where his mother's parents lived. The winters were long and cold, and surviving on the farm during the Depression was challenging. He had to walk a mile, sometimes in blizzard conditions, to catch the bus to elementary school. When Bob was 12 they moved to the Bronx, where he went to Thomas Knowlton Junior High School, which he described as "a perfectly awful ghetto school" and a dangerous place where many students carried weapons. He worked throughout this time as a paperboy, then as delivery boy and helper in a tuxedo and wedding dress store. Bob supported himself through college. Inspired by a couple of good teachers, and despite the fact that no one from Knowlton had ever been admitted to the Bronx High School of Science, he took the entrance test and was admitted, largely on the strength of his essay on the wonders of astronomy. In those days it was all male and mostly Jewish. Now it is mostly Asian and 50 percent girls. Bob learned that he could excel at science in a dog-eat-dog environment. From the age of three, initially influenced by his maternal grandfather, who owned a butterfly collection, he had wanted to become a scientist. On Saturdays he haunted the Museum of Natural History and the Hayden Planetarium, where he marveled at their meteorite collection.

As a result of his family's move back to upstate New York, he transferred to Cobleskill High School for his junior and senior years. His science teacher there allowed him unlimited use of the lab. As senior class president he gave a speech on "living with the atom." It was 1946, just after the war, and a recruiter for Union College in Schenectady persuaded him to enroll in their physics program. During the summers of his college years, in a cement factory where his stepfather was then working, Bob carried heavy loads and helped to repair kilns in almost unbearable heat. He graduated from Union College in 1950, fourth in a class of 400.

As a graduate student at Yale under the nominal direction of Earl Fowler, Bob was the first student to do a thesis using his own experimental apparatus at the Brookhaven Cosmotron, the first accelerator capable of producing strange particles. Fermi was setting up a nuclear emulsion experiment across from where Bob was working, and Bob crossed paths with a number of other future Nobel Prize winners who were doing experiments there. In his thesis he was among the first to show that strange particles had to be produced in pairs. During his time at Yale, other graduate students told him about their research on cosmic rays, which were then poorly understood. This early contact may have influenced his thinking about cosmic ray tracks in meteorites a few years later.

After he finished his Ph.D. in 1954, he met with his draft board in Schenectady, New York. They told him that if he were to take a university position in high-energy physics, he would be drafted, whereas if he were to take a position at General Electric (located in Schenectady), he would be deferred because of the essential defense work being done at the main GE plant. Traditionally, industrial research laboratories send recruiters to cultivate promising graduate students, and so it was quite a surprise when Bob showed up at the employment office of the GE plant and said he wanted a job. He joined the GE Research Laboratory and started research in solid-state physics, an area about which he then knew nothing. He thrived in the free atmosphere that characterized some sections of the lab in those days. He first collaborated with George Watkins, with whom he set up an electron paramagnetic resonance (EPR) spectrometer to study defects in solids. Together with Jim Corbett, he used electron irradiation to produce intrinsic defects in silicon for EPR studies. Their experiment with electron-beam-induced defects was the first to demonstrate the unexpectedly high mobility of lattice vacancies in silicon, and it provided the key approach that eventually led Watkins to a detailed understanding of defects in silicon.

Bob then collaborated with Corbett in studies of intrinsic defects in metals by irradiating them in an electron beam at cryogenic temperatures and then monitoring the change in resistivity during annealing. Their technique became a classic: using an electron beam instead of a proton beam they were able to produce vacancies and interstitials by displacing single atoms. Among their findings was that interstitial atoms in copper move easily at ultralow temperatures. During their experiments, both Bob and Jim received severe radiation burns to their arms due to failure of an interlock to shut off the beam. Bob was given skin grafts a number of times by a specialist at Washington University, where Bob ended up spending his career from 1966 onward.

It is interesting to try to trace the origin of great ideas in science. Bob was a constant source of scientific ideas, two of which memorialized him in the history of science: fossil tracks of nuclear particles in natural solids and stardust in meteorites. One of us (P.B.P.) was intimately involved in the first great idea, and the other (E.Z.) was involved in the second one. At a meeting in France in September 1960, R. S. Barnes showed Bob electron micrographs of tracks left by fission fragments in mica. E. C. H. Silk and Barnes had mounted sheets of mica against a thin layer of uranium, exposed the sandwich to thermal neutrons in a reactor, stripped thin layers from the mica, and examined them in an electron microscope. To Barnes the discovery was not worth pursuing, because the tracks faded in a few seconds in the electron exposure, because only tiny amounts of mica could be observed, and because the method seemed applicable only to mica exposed to fission fragments. But Bob had long been thinking about the possibility that cosmic radiation might produce permanent records of the irradiation history of the early solar system in meteorites or lunar rocks. The tracks in mica, together with his childhood interest in meteorites, his thesis work on tracks in a cloud chamber, his recollection of the work of students at Yale on cosmic rays, and his research at GE on radiation effects in metals stimulated him to do calculations of ways that cosmic rays might produce permanent damage in the form of tracks in crystals in meteorites. In July 1961 he persuaded one of us (P.B.P.), who was an expert in the study of defects with transmission electron microscopy, to join him. Thus began a long and fruitful collaboration. He showed Price that cosmic rays passing through mica in meteorites might lead to tracks of spallation recoil nuclei that could be seen in the electron microscope, provided the threshold for track production was somewhat lower than for fission fragment tracks.

Within a few months they solved the problem of track fading with the discovery that immersing the mica in hydrofluoric acid "fixed" the tracks by removing the cylindrical regions of radiation damage, leaving fine holes a few nanometers in diameter. They took passing note of the possibility of creating molecular sieves made of irradiated and etched mica, but concentrated on the question of whether mica was sensitive enough to record etchable tracks of spallation recoils. Using the 3-GeV proton beam at the Cosmotron, they found spallation recoil tracks, which showed that cosmic rays should produce detectable tracks in at least one mineral (mica).

In early 1962, looking in the vicinity of a pleochroic halo in thin etched mica, they, in collaboration with W. G. Johnston, discovered the first example of "fossil" tracks radiating from the region around the halo. The etched tracks originated in spontaneous fission of ^{238}U, and the dark-colored spherical region was the result of radiation-induced color centers produced by alpha particles from uranium alpha decay. The uranium was concentrated in a micron-size zircon grain at the center of the pleochroism. This discovery established that tracks in mica survive more than 100 million years and led them to the invention of the now-famous fission track dating method of geochronology. To Bob the most important consequence of the fission track dating method was the proof that cosmic ray tracks would be stable over geologic time periods.

Bob had learned that, of the naturally occurring radionuclides, only ^{238}U spontaneously fissions at a rate high enough to be of interest: $\sim 10^{-16}$ per year, more than a million times lower than the total decay rate, which is mainly *via* alpha decay. He proposed a clever way of measuring the uranium concentration precisely in the region of sample where one is observing fission tracks. The idea was first to etch the mica and count spontaneous fission tracks and then expose the mica to a known dose of thermal neutrons in a reactor and count the new tracks due to neutron-induced fission of the rarer ^{235}U isotope. Knowing the ratio of ^{238}U to ^{235}U in nature, one could solve two equations for the two unknowns—track retention age and ^{238}U concentration—as a function of counts of spontaneous and induced fission tracks.

At about this time Bob had a devastating conversation with Harold Urey, who told him that there was no hope of finding mica in the moon or meteorites! Countering this setback was their discovery that prolonged etching of mica enlarged the track diameters enough that they could easily be seen in an optical microscope, with the implication that minerals that could not be cleaved into thin flakes might serve to record etchable tracks as well as mica. It is interesting in hindsight to recall that Walker and one of us (P.B.P.) had convinced themselves that tracks could not be etched up to optical dimensions; it was not until an engineer asked whether they could produce a single micron-size hole in mica as a device for fabricating microcircuits that they were led to discover how to make tracks visible by optical microscopy. With the ability to control track diameter, they abandoned electron microscopy in favor of the much simpler optical microscope, which permitted one to study minerals present in meteorites and to scan very large areas for rare events.

Beginning in late 1962, in collaboration with Robert Fleischer, another expert on defects in solids, they carried out experiments on a rich variety of topics, both fundamental and applied. In order to encourage free investigation of speculative ideas, the three of them agreed on an effective rule, that each of the three would be a coauthor of every paper and that they would always list their names alphabetically. This paid off handsomely. For example, Fleischer decided not to be inhibited by his colleagues' view of a track as a disordered, chemically reactive region. He discovered that two kinds of noncrystalline solids—glasses and polymers—could record etchable tracks, which forced a revision of their model of track structure and ultimately led him to invent the "ion explosion spike" model of track formation. Walker was on a sabbatical in Paris at the time and would not believe that Fleischer's claim about tracks in noncrystalline solids was correct until he irradiated and etched glass himself and confirmed the discovery.

Throughout the collaboration the wisdom of their rule was demonstrated. Walker returned from a trip, excited about the possibility of searching for magnetic monopoles in minerals, and he devoted time to calculations of the radiation damage rate of a monopole while one of us (P.B.P.) and Fleischer were busy doing experiments. Fleischer became interested in using the new fission track dating method in some tedious experiments that ultimately paid off: confirmation of the concept of spreading of the sea floor on either side of the mid-Atlantic ridge; confirmation of the then-disputed approximately 2-million-year age of hominids from the Olduvai Gorge; and studies of fission track ages and upper limits on cosmic ray exposure ages of tektites. A year or so later one of us (P.B.P.) measured fission tracks in several different minerals in an iron meteorite, which established the presence of the now extinct nuclide ^{244}Pu in the early solar system and allowed the cooling rate of the parent body to be estimated. Sometimes the three of them pursued both productive and unproductive ideas at the same time.

During the heady period after the discovery of ancient tracks, the number of ideas for applications of the nuclear track technique mushroomed. Among the early scientific applications were the discovery of ternary fission of heavy elements induced by heavy ions and the realization that one might be able to find rare cosmic ray events in meteoritic crystals. Among the early technological applications were production of molecular sieves; deposition of quasi-one-dimensional solids inside etched tracks; neutron dosimetry; radon dosimetry; neutron radiography; mapping of spatial distributions of uranium, thorium, boron, and lithium; alpha autoradiography; and uranium exploration via radon fluxes.

During Bob's 1962-1963 sabbatical, he was joined by Michel Maurette, then a graduate student at University of Paris (Orsay), and by Paul Pellas, a mineralogist at the Paris Museum. Under Bob's supervision Maurette was the first to fulfill Bob's dream of seeing cosmic ray tracks in a meteoritic mineral (olivine). After Walker's return to GE, he, Fleischer, one of us (P.B.P.), and Maurette reported their observations of cosmic ray tracks in 23 meteorites, showed that most were due to slowing nuclei of iron and neighboring elements, and announced the discovery of elements much heavier than iron in the cosmic radiation. The determination of atomic numbers of ultraheavy cosmic ray tracks in meteorites was crude but sound; it depended on calibrations with heavy ion beams at the Berkeley Heavy Ion Accelerator, from which the atomic number of the slowing ion could be related to the length of the etchable track. Characteristic of Bob's computational ability was his work reported in their 1967 theoretical paper that discussed six potential kinds of fossil particle tracks in meteorites. For decades after their discovery of trans-iron cosmic rays, Fleischer, Price, Walker, and Russian researchers at Dubna searched in vain for superheavy elements ($Z \sim 110$) and magnetic monopoles in meteorite crystals, using heavy ion calibrations together with improved etching techniques and various procedures such as partial annealing to get rid of the background of abundant tracks of iron cosmic rays. The attractive feature of meteorites as track recorders—a collecting time measured in tens of millions of years—was thwarted by the complexity of the partial relaxation of the radiation damage during such a long time and by the dependence of track-recording sensitivity on chemical composition of the mineral under study.

While the early research on etched nuclear tracks was proceeding from one triumph to another, Walker was also building an organization called Volunteers for International Technical Assistance. Known as VITA, the organization was born in 1959, when he and a small group of colleagues in Schenectady decided to contribute their know-how to solve technical problems in developing nations. One of its earliest successes was an inexpensive, effective solar cooker consisting of an umbrella coated with reflective foil. He was its first president and served on its board of directors for several decades. One of the secrets of VITA's success is the policy of putting the client in direct contact with the VITA member who handles his problem. It now boasts more than 7,000 engineers and scientists who volunteer their time to projects ranging from a *Village Technology Handbook* to a digital communications satellite system that relays information from VITA headquarters to ground stations in such places as Somalia and Indonesia.

Two technological spin-offs of the nuclear track technique led to the creation in the 1960s of industries owned in part by General Electric. The first and still the best-known is the Nuclepore filter, available in hole size from 0.015 to 10 µm, made by irradiating a long sheet of thin polycarbonate film with collimated fission fragments in a nuclear reactor and then etching it in hot sodium hydroxide to the desired hole size on an assembly line. This is one of the most valuable items in the stockrooms of microbiology laboratories, and yet biologists don't know who invented it or why it is called "Nuclepore." As with Kleenex, it is now a generic word rarely shown with its trademark symbol. The second is the radon dosimeter originally sold by Terradex Corporation and now marketed as RadTrak, by Landauer Corporation. Its high signal to noise and compact size make it the detector of choice with which to record alpha-particle tracks from decay of radon gas seeping into homes—a serious radiation hazard in some parts of the United States and other countries. The device is simplicity itself; a small piece of an alpha-track-recording polymer suspended in a porous box that is collected and the tracks measured after a month or so of exposure in a home. No doubt the environment at the GE Research Lab stimulated the three collaborators to think of practical applications of their research.

By 1966 Bob realized that despite the wonderful years he had spent at GE, the atmosphere for basic research there was deteriorating and life for him would be better at a university. He moved to Washington University as the first

McDonnell Professor of Physics. Three years later, one of us (P.B.P.) moved to Berkeley as a professor of physics, and the long-standing collaboration ended not long afterward, except for a few interludes in which the three of them coauthored review papers and wrote their famous monograph on *Nuclear Tracks in Solids*.

At General Electric Bob's intellectual efforts had been focused on his own research in collaboration with a couple of other scientists. After the move to Washington University, Bob's mode of operation changed in a fundamental way. As a professor of physics he greatly expanded the scope of his activities. He created the Laboratory of Space Sciences on the fourth floor of Compton Laboratory, where he not only gathered a number of gifted graduate students, postdocs, and collaborators but he also created a place with a unique atmosphere of camaraderie and open interaction. While he was not necessarily involved in all the scientific activities of the group, he was a constant source of new ideas, and with his boundless enthusiasm he was an inspirational leader. In the 1970s he led in the revitalization of the Geology Department, transforming it into the Department for Earth and Planetary Sciences. New faculty members appointed with Bob's leadership included Ray Arvidson, Ghislaine Crozaz, Larry Haskin, and Frank Podosek in Earth and Planetary Sciences, and Charles Hohenberg in Physics.

Bob's efforts to create a permanent structure that would ensure the pursuit of space science at Washington University culminated in the establishment of the McDonnell Center for the Space Sciences in 1974 through an initial large gift by the McDonnell Aerospace Foundation. Bob served as the director of the center from its inception until 1999. When he made his pitch to the members of the foundation (among them James S. McDonnell, the founder of the

McDonnell Company), he chose two graduate students to make the presentations.

The center provided funds for endowed faculty positions in the Physics and Earth and Planetary Science departments, graduate fellowships and support for visiting scientists, and seed money for innovative scientific projects by center members. It became an international scientific meeting place through which passed dozens of visitors over the years. One was Ramanath Cowsik, who spent three months each year at the center before becoming a professor in the Physics Department in 2002. Today the 80 members of the McDonnell Center include professors, research scientists, and students at Washington University doing research in meteoritics, lunar science, planetary imaging and geophysics, theoretical and observational astrophysics, high-energy astrophysics, general relativity, extraterrestrial materials, and cosmic ray studies.

Bob had a knack for inspiring and motivating others for science. An example is his recruitment of one of us (E.Z.). In 1971, when he was completing a Ph.D. in high-energy physics, Zinner had a chance encounter with Bob in the elevator. During the ensuing discussion, which lasted several hours, Bob charmed him to the extent that Zinner decided to give up high-energy physics and join Bob as a postdoc the next year. During more than three decades, he saw Bob convert the laboratory from a place that concentrated on nuclear track studies into a place with sophisticated micro-analytical instruments, such as the ion microprobe, NanoSIMS, scanning electron microscope, transmission electron microscope, and Fourier transform infrared spectrometer. This equipment, and Bob's vision, led ultimately to the discovery of stardust in meteorites and interplanetary dust particles and to their detailed isotopic and mineralogical characterization.

The exciting research environment of Bob's fourth-floor laboratory was celebrated at a symposium in his honor at

Washington University in March 2003. Many previous students, postdocs, and collaborators gathered to honor Bob's scientific achievements and leadership. While the symposium presented scientific talks on a wide range of disciplines, it became clear in one testimony after another how universally loved and respected Bob was. Another important role Bob played as a leader of the fourth-floor group was that he took upon himself the administrative burden to secure financial support for the whole group. This enabled the other researchers largely to concentrate on their respective research.

In parallel with readying his laboratory for the arrival of lunar samples in 1969, Bob, together with Jim Arnold, Paul Gast, and Jerry Wasserburg ("The Four Horsemen"), played a major role in the establishment of the Lunar Receiving Laboratory.

Fleischer, Price, and Walker found themselves in a healthy competition in the quantitative use of nuclear tracks to study the radiation history of lunar samples. At least four kinds of energetic particles strike the moon: solar wind particles, suprathermal solar particles, solar flare particles, and galactic cosmic rays. In addition to these external sources of tracks in lunar rocks, internal sources include the spontaneous fission of ^{238}U and (in the early history of the solar system) of ^{244}Pu. Among the topics they studied were dating of lunar rocks and glassy impact spherules, analysis of gardening and erosion rates of lunar soil using solar flare track densities as a function of depth in soil particles, comparison of the average present-day and ancient spectra of heavy ions emitted in solar flares, suprathermal ions from the sun, ^{244}Pu fission tracks in ancient lunar rocks, cosmic ray exposure history of lunar rocks, and tracks of solar wind ions heavier than iron. The *Apollo 12* mission returned a sample of glass from the *Surveyor III* spacecraft, which had landed on the moon two and a half years earlier. The glass recorded tracks produced by suprathermal solar particles and by heavy ions emitted in solar flares. Bob was the principal investigator of an experiment in which various track detectors (glasses, plastic, mica) as well as metal foils for the capture of implanted noble gas solar wind ions that were taken to the moon with the *Apollo 16* and *Apollo 17* flights were exposed to solar radiation. It turned out that mica records heavy ions (iron and heavier) in the solar wind (having an energy of only ~1 keV/nucleon) and the heavy solar wind flux could be studied in this way.

Bob served on the scientific team that advised NASA on the handling and distribution of moon rocks and soil samples from the first Apollo missions. At the end of the Apollo program, he and James Arnold were invited to dinner at the White House along with the Apollo astronauts, Werner von Braun, and others.

Bob's wide-ranging interests sometimes led to activities beyond the confines of his space-related scientific work. For example, the use of thermoluminescence by Bob and two of his students led to the authentification of an ancient Greek bronze horse, which in turn led to Bob's founding of the Center for Archaeometry, whose focus was the application of modern scientific methods to art conservation and to the dating of art and archaeological objects. This center brought together scholars from widely diverse disciplines—art historians, conservators, chemists, and physicists. For several years researchers on the fourth floor worked on the restoration of sculptures in the midst of research on meteorites and lunar samples.

Bob's acquisition of an ion microprobe was inspired by the group's comparative studies of both cosmic ray tracks and micrometeorites in lunar samples. He thought that the ion probe might make it possible to identify ions implanted in lunar samples. Unfortunately instruments then available did not have high enough mass resolution to eliminate molecular interferences. That did not diminish Bob's hope that with an improved instrument wonderful things could be found if one could measure the elemental and isotopic composition of extraterrestrial samples on a small spatial scale.

This hope was nurtured by two other developments. One was Robert Clayton's discovery in 1973 of isotopic anomalies of oxygen in refractory inclusions from primitive meteorites. The existence of these anomalies demonstrated that not all material from which the solar system was formed had been completely homogenized, so that some pre-solar grains might have survived. A second development was Don Brownlee's successful recovery of interplanetary dust particles (IDPs) in the stratosphere. Bob immediately realized the scientific potential of this type of extraterrestrial material, and he started a vigorous program of their study, using as many microanalytical techniques as were then available. These originally included analytical transmission electron microscopy and Fourier transform infrared spectroscopy but were later extended to the ion probe and to two-step laser-desorption laser-ionization mass spectrometry. His successes contributed to a large extent to the establishment of IDP studies as an important branch of meteoritics.

In the late 1970s the French company Cameca developed a new ion probe with sufficiently high mass resolution to separate molecular interferences from atomic ions for most elements of interest. In 1980 Bob raised the money for purchase of a Cameca ion probe from the McDonnell Aerospace Foundation. During the academic year 1980-1981 he and his wife, Ghislaine Crozaz, spent a sabbatical, first in India and then in Paris, and in the spring of 1981 Bob and one of us (E.Z.), who was spending a year in Vienna, negotiated with Cameca the detailed specifications of the instrument. The fact that such negotiations usually followed a lunch with a fine French meal and ample wine posed a challenge, but Bob lived up to this challenge splendidly. The instrument arrived at Washington University in the spring of 1982. This was a hectic time for the fourth-floor researchers because, while some were breaking in the ion probe, others were constructing a capture cell experiment for NASA's Long Duration Experimental Facility (LDEF), a bus-size satellite that could carry large-area passive experiments and was supposed to spend one year in Earth orbit. The Washington University experiment was designed to capture material from IDP impacts. Unfortunately, as a consequence of the *Challenger* disaster, LDEF remained in orbit for five years, and that long exposure led to the destruction of most of the thin plastic covers over the capture cells. That and problems of contamination on the spacecraft impaired the quality of the results. On the other hand, the Cameca ion probe led to exciting developments. Its first application was the measurement of hydrogen isotopic ratios in IDPs, revealing large deuterium excesses. This led to a whole series of isotopic measurements on these particles over many years.

A few years later, in 1987, when Ed Anders and his colleagues at the University of Chicago had obtained a residue that was extremely enriched in neon-22 and a component of xenon synthesized by slow neutron capture (the s-process), the Washington University ion probe was able to identify the carriers of these noble gases as pre-solar silicon carbide, condensed in the expanding atmospheres of red giant stars. Thus, Bob's old dream of holding stardust in his hands was finally realized. This was just the beginning of the stardust story. The study of pre-solar grains expanded rapidly and today is an important new branch of astrophysics. The fourth-floor group leads in studies of pre-solar grains with discoveries of new types of stardust, detailed isotopic characterization of countless grains in the ion probe, and mineralogical studies in the transmission electron microscope. Bob was involved in many aspects of this work. Examples are the *in situ* detection of pre-solar silicon carbide grains, the discovery of pre-solar oxide grains, and the identification of complex aromatic molecules in pre-solar graphite grains.

However, this is not the end of the story. In his quest to extend instrumental capabilities to the analysis of ever-smaller amounts of material, Bob devoted the last years of his life to the implementation of a new type of ion microprobe, the NanoSIMS. This instrument has several important advantages over the previous generation of ion probes: the primary beam can be focused into a much smaller spot than was previously possible; the transmission at high mass resolution, necessary for most isotopic measurements, is higher by a factor of 20 to 30; and the instrument has several secondary ion detectors that make it possible to measure several isotopes or elements simultaneously. As a result of these features, isotopic compositions of smaller grains can be analyzed than was previously possible. In one of his last actions as director of the McDonnell Center, Bob provided some of the funds for the acquisition of a NanoSIMS and was instrumental in securing additional funds from NASA and the National Science Foundation. The instrument was delivered at the end of 2000. Bob was again correct in his hunch that wonderful things would happen if one could only analyze very small samples. The NanoSIMS has led to several important discoveries. One was the identification of pre-solar silicate grains in IDPs and primitive meteorites. Although it turned out that pre-solar silicates are more abundant than most other species of pre-solar grains, the reasons that previous searches had been unsuccessful were that these grains are smaller than 1 micron in size and that minerals in primitive meteorites are dominated by silicates originating in the solar system. The identification of pre-solar silicates requires the isotopic analysis of tens of thousands of submicron grains, and it is this capability of the NanoSIMS that led to their discovery.

In his last scientific effort Bob returned to the application of nuclear tracks. His idea was to measure both the ^{238}U and ^{235}U content of pre-solar silicon carbide grains—the ^{238}U by spontaneous fission tracks and the ^{235}U by irradiating the grains with both thermal and fast neutrons. Such a measurement might give information on the formation time of the parent stars of the grains and to their neutron exposure in the stars. Sadly, his disease and death prevented his fulfilling this dream that united nuclear tracks with stardust.

As part of his continuing interest in the study of meteorites, Bob participated in the 1984-1985 and 1990-1991 expeditions sponsored by the National Science Foundation to collect meteorites in Antarctica. For this work he received the Antarctic Service Medal. Despite the numerous recognitions that came his way, Bob was always concerned, first and foremost, with the pursuit of science for its own sake, rather than for his own glory. He was a tireless spokesperson and lobbyist for science.

Walker and his wife, Ghislaine Crozaz, a professor in the Department of Earth and Planetary Sciences at Washington University, maintained a residence in St. Louis, but they had been spending much of their time in Brussels since his retirement. Walker is survived by his wife; his two sons, Eric Walker (with wife, Terry, and children, Marie and Andrew, of Cottage Grove, Minnesota) and Mark Walker (with wife, Trisha, and son, Alden, of San Antonio, Texas); and his spiritual daughter, Meenakshi Wadhwa (of Chicago).

We are indebted to Ghislaine Crozaz for her help with this memoir and to Roland Schmitt for sharing with us his unpublished article "A Discovery and Its Uses: The Story of Particle Tracks in Solids."

HONORS

1964 Co-winner, American Nuclear Society Award for Distinguished Service
1966 Yale Engineering Association Annual Award for Contributions to Basic and Applied Science
1967 Doctor, honoris causa, Union College
1970 NASA Exceptional Scientific Achievement Award
1971 E. O. Lawrence Memorial Award of the U.S. Atomic Energy Commission
1973 Elected to the National Academy of Sciences
1975 Docteur, honoris causa, University of Clermont-Ferrand, France
1991 J. Lawrence Smith Medal, National Academy of Sciences
1992 Officier de l'Ordre des Palmes Academiques
1993 Leonard Medal of the Meteoritical Society
1997 Peter Raven Lifetime Achievement Award, St. Louis Academy of Science
1999 Asteroid 6372 named Walker by International Astronomical Union
2004 Doctor, honoris causa (posthumous), Washington University

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