BIOGRAPHICAL MEMOIRS

Samuel A. Bowring

September 27, 1953–July 17, 2019
Elected to the NAS, 2015

A Biographical Memoir by Lindy Elkins-Tanton, Jahandar Ramezani, Randy Van Schmus, and Wallace Bothner

Samuel A. Bowring was the Robert R. Schrock Professor Emeritus of Geology in the Department of Earth, Atmospheric, and Planetary Sciences at the Massachusetts Institute of Technology (MIT). Over the course of his career, Sam defined the leading edge of the field of U-Pb geochronology. His lab's ability to measure both accurate and precise dates of rocks over the age of the Earth and his determination to make data transparent and reproducible across labs and techniques pressed an entire community forward and helped redefine our understanding of Earth processes and history. Sam discovered and dated the oldest intact crustal rocks on the Earth, defined the age and rates of evolutionary radiation at the dawn of multicellular life, and demonstrated the timing and suddenness of the most severe extinction of life in Earth history, among many significant studies and discoveries. Sam was known for his fierce determination, his outstanding mentoring and constant inspiration to his students, his dedication to teaching and overall to science, but also for his humor and his cooking skills, both in the field and at his collegial parties at his house.

Early Life and Career

Sam was born September 27, 1953, in Portsmouth, New Hampshire, and grew up in Durham, New Hampshire. He lived with his father, James Reginald Bowring, and his mother, Ursula, his two brothers, Jim and Joe, and his sister, Margaret Ann. Sam's father, who went by Reginald, had been born in Sheffield, England, in 1911 and emigrated to Winnipeg, Manitoba, in 1930**,** where he enrolled in the University of Manitoba. He earned a bachelor's degree there in 1936 and then enrolled at the University of Alberta, earning a master's degree in 1941. He then earned a Ph.D. at Iowa State College in 1944. After graduating, he worked with the United Nations Relief and Rehabilitation Administration and then the U.S. Office of Price Administration in Washington, D.C. Sam's mother was born Ursula Barbara de Antonio on March 8, 1923, and raised in Scranton, Pennsylvania. She graduated from Barnard College in 1944 with a degree in economics and sociology and moved to Washington, D.C., where she also worked for the U.S. Office of Price Administration. There she met Reginald Bowring, and they married in Scranton in September 1947. Reginald then took a position as a professor of resource economics at the University of New Hampshire

(UNH) in 1948, and the couple began raising their family in Portsmouth. Ursula later became active in town meetings and the local Democratic Party as well as in several social and feminist organizations.

According to some faculty and student friends at UNH, Sam enjoyed an active childhood in Durham. He was first exposed to the earth sciences in his last year as a day student at Phillips Exeter Academy, graduating in 1971. The next year he started the more prescribed program in geology at UNH, with a minor in hydrology. For the next four years, he was a bit of an insatiable rebel. He fell in with an active, supportive faculty and a like-minded, welcoming crew of fine students. Quoting one of his geology student comrades, they "worked hard and played harder." He just fit in, and his 1956 International Harvester pickup truck didn't hurt! He was fully engaged in and out of class and had an uncanny ability to draw critical connections among a variety of disciplines and observations, including Boston and UNH sports, as well as social, political, and environmental issues. Following evening dining hall work or the night shift at Cabletron winding transoceanic cable in the bowels of a seagoing ship, he'd sometimes doze off in early morning classes, only to wake and ask key questions. There was never a dull moment.

Sam was always eager for field labs and adventurous projects. He and his advisor, Wallace Bothner Jr., once spent a wet night on the back side of Mount Tripyramid, sampling the plutonic rocks of New Hampshire's White Mountains. They and the rocks survived, and his new Limmer boots got a proper soaked break-in for his upcoming Appalachian Trail trek from Katahdin to Pennsylvania; this was in addition to week-long field exercises in the folded Appalachians of Virginia as a student and later as an undergraduate teaching assistant. He participated in weekend-long New England Intercollegiate Geological Conference excursions in the fall, rain or shine. He was an exceptional summer field assistant in a U.S. Geological Survey-supported uranium and groundwater radon investigation in Acadian and White Mountain Magma Series granites, and he managed to scoop some nice trout out of a small tributary for supper.

Sam took on special projects in geophysics with Francis S. Birch and in geochemistry with Henri E. Gaudette. Sam's four years at UNH were a remarkable, unusually productive two-way street for the UNH faculty and for Sam and his fellow students. It was a time of challenge, learning, and testing. At least three of Sam's professors at UNH (Gaudette in geochemistry, Birch in geophysics, and Bothner in field petrology and structure) would have been delighted had he stayed there for graduate work, but the Southwest called him, and he wisely answered.

Sam graduated cum laude from UNH in 1976. He left Durham for Socorro, New Mexico, where he attended the New Mexico Institute of Mining and Technology from 1977 to 1979, studying under Charles Chapin and doing a thesis on the Oligocene-to-Miocene ash-flow tuffs of the near-by Magdalena Mountains, completing his master's degree in 1980. This study involved extensive field work, further honing Sam's skills.

While at New Mexico Tech, Sam became aware that the extensive Precambrian basement rocks throughout New Mexico and Arizona needed more field work and isotopic dating. To further these interests, Sam contacted William R. "Randy" Van Schmus to pursue doctoral study in the Isotope Geochemistry Lab at the University of Kansas (KU) Department of Geology. When Sam came to KU for doctoral studies in 1979, his previous education had solidified the work ethic, insight, and intellect needed to continue advanced research. But to advance his interests, he needed analytical facilities, support, and opportunity. The Isotope Geochemistry Lab and the university had good analytical facilities and a support team in Van Schmus and Marion E. Bickford. Then a major opportunity developed in the form of Van Schmus's new National Science Foundation project with Paul Hoffman in the Northwest Territories of Canada. Sam accompanied Van Schmus for this project, and they subsequently joined Hoffman's field party in the summer of 1979 for initial field indoctrination and sample collecting.

Sam and Paul immediately bonded as colleagues, leading to Sam's succeeding four years (1980–83) in organizing and running his own field parties in the Northwest Territories with Hoffman and support from the Northwest Territories territorial geologist office. He also met several other students in Paul's field party, notably John Grotzinger, who would play a major role in his future. Opportunity had knocked, Sam had opened the door, and he charged through, culminating in his pioneering studies in the Wopmay Orogen (where he also happened to collect a sample of the soon-to-be-famous Acasta Gneiss). Sam credited the faculty at KU with allowing him the intellectual freedom to pursue whatever research he wanted, but in fact, it would have been very difficult to hold him back! Not only did he do all the field work and extensive laboratory work for his Ph.D. studies in the Northwest Territories, but he also published papers on several other independent projects in New Mexico and Oklahoma.

Graduate school is a learning experience, and at KU Sam showed signs of becoming a great teacher, not hesitating to educate fellow students and faculty in the Isotope Geochemistry Lab or about any exciting research he encountered during endless hours in the library pre-Internet. Sam's personal demeanor continued basically unchanged from his high-school days, with the additional note that he was an avid fan of jazz, especially artists like Art Pepper and Charlie Parker. The KU public radio station had a jazz program from

1:00 to 3:00 p.m. every weekday, and if Sam was in the lab, his radio was playing and students and faculty were treated to abundant doses of his favorite music. At least one faculty member (Van Schmus) came away with a continuing appreciation of that art form.

Sam left KU for a faculty position at Washington University in St. Louis (WashU) in 1984, where he showed his ability to develop U-Pb geochronology in the isotope facilities. This "going solo" was the proof that Sam would become a successful research scientist. He continued to explore research on many fronts at WashU, including teaming up with Karl Karlstrom for studies in the American Southwest, resulting in several notable publications.

It was at WashU that Sam met and married his wife, Kristine, gaining two stepdaughters, Kelley Kintner and Sara Henrick, all of whom survive him.

Oldest Rocks on Earth

While working on an unrelated project at WashU, Sam began re-analyzing the oldest sample from his Ph.D. studies in the Northwest Territories, using improved techniques that allowed measurement of ages on select single grains of zircon. As a result, he showed that the initial age of ~3.4 billion years measured on that sample was the result of mixing of old and young components in a multigrain population. As indications of very old ages emerged, he turned to Ian Williams in Australia, submitting samples for analysis by ion microprobe. Their landmark paper in *Geology* in 1989 defined the 3.96 billion-year-old Acasta Gneiss as the oldest known rock in the world at that time. Suddenly Sam had a new focus for his research, and he continued to refine this work over years.

As his colleague and friend Timothy Grove expressed the work in the citation for Sam's Walter H. Bucher Medal, "Through his rigorous field efforts in the Northwest Territories of Canada and his geochronological studies, Sam established that the Acasta gneisses were Priscoan in age (>4 billion years old). His geochemical studies of these early crustal remnants showed that these rocks were similar to today's arc-derived continental crustal rocks, supporting the notion that crustal recycling started early on in Earth history and has continued to the present."

As Sam pursued this and other avenues of research during 1991, opportunity knocked in the form of a job offer from MIT. After consultation with family, friends, and former teachers, he decided to accept the offer, and his career blossomed fully.

"No Dates, No Rates": Major Evolutionary Events in Earth History

Although the evolution of continental crust was the hallmark of his early scientific career, Sam was among the first to recognize the significance of high-precision geochronology in deciphering the tempo of biologic and paleoenvironmental change in deep time. This has been done by analyzing layers of volcanic ash interbedded with sedimentary strata that preserved key fossil and geochemical records throughout the globe.

Arguably the most important evolutionary event in the last 3 billion years of Earth history is the explosion of multicellular life at the onset of the Cambrian almost 540 million years before the present. The work of Sam and his group on classic successions in Namibia, Oman, and elsewhere greatly advanced the understanding of this pivotal evolutionary stage and constrained its duration to not more than 6 million years: unimaginably fast by geologic measures.

Sam's focus on ancient life events was soon extended to the end-Permian mass extinction, a cataclysmic event that nearly extinguished life on this planet almost 252 million years ago and the most severe of its kind known from the geologic record. The intensive efforts of Sam, his long-time colleague Shuzhong Shen, and their teams of students and researchers spanned nearly three decades and focused on world-class successions in China. They were able to pin the end-Permian extinction event to 251.941 ± 0.037 Ma with an incredibly short duration of less than 60 (30 ± 30) thousand years. Joining an NSF Continental Dynamics project led by Linda Elkins-Tanton, they explored in detail the enormous but short-lived volcanic eruptions in Siberia and demonstrated their viability as the primary driver of the end-Permian extinction. The abruptness and severity of environmental degradation and associated extinction of species serve as an example of what is likely the future of our planet now.

Sam was always headed into the field or just back from the field. From his earliest work in geology, he spent time looking at the actual rocks to understand their relationships and complexities and to search out the best samples for dating, and he subsequently taught all his students to do the same. In the field in Siberia, he searched for datable rocks from the Siberian flood basalts and chilled everyone's spines with stories of huge Soviet mining transport trucks sinking into freezing rivers, along with his and his field team's escape through the roof emergency door. This experience was added to that of being harassed and stalked by bears in the Canadian sub-Arctic and by a mountain lion in the Rockies. In every story, his sardonic voice would also describe the rocks, their field relations, and what happened to them. And then if a really great anecdote came up, he would heave into a soundless bout of laughter.

Armed with his infamous slogan, "No dates, no rates," Sam and his multinational teams of students, researchers, and collaborators aimed to pin down major events in the evolution of life on the planet up and down the geologic

time scale, from the appearance of the earliest metazoans to the rise of mammals. Their discoveries related to the rates of extinction, recovery, and radiation were a big step in recognizing the complex interconnections among tectonics, climate change, and biologic evolution, while emphasizing the overall interconnectedness of the Earth system. This research endeavor has continued in Sam's Isotope Lab at MIT ever since. Sam was in a constant quest for collecting and dating ash beds. Once Sam was asked by a colleague what he would do if he won the lottery. He looked into the distance for a moment, and then said, "I would buy a huge warehouse, and I would fill it with mass spectrometers, and I would date every geological event out there."

"Whose Date Is It?": Precision and Reproducibility in Radioisotope Geochronology

With advancements in laboratory techniques and instrumentation in the 1990s, the precision and resolution of radioisotopic dating improved and, in parallel, the complexities of isotopic data and ages came increasingly to light. Sam was among the first to recognize inter-laboratory and inter-technique replicability as a major stumbling block in achieving an accurately calibrated geologic history at the turn of the millennium—a problem that grew into a fixation for the rest of his career. He embarked on a decade-long mission to build an international community of geoscientists, including additional geochronology laboratories worldwide, and compel them to tackle head-on what he perceived as the biggest shortcoming of the discipline.

The relentless efforts of Sam, along with Doug Erwin and other colleagues, crystallized into EARTHTIME, a community initiative supported by the National Science Foundation and various foreign national agencies, with an elaborate program of interlaboratory calibration and protocol development. Under EARTHTIME, isotopic standards and tracers were produced and precisely calibrated so that all labs "use the same clock." The program included extensive community engagement and education efforts spearheaded by Sam and Kirk Johnson. Today, the vibrant and expanding international EARTHTIME community is a legacy of Sam Bowring and his vision for cooperation and transparency in geochronology.

Teaching and Mentoring

For those of us fortunate enough to take his classes, Sam created his own culture, in fact, almost his own weather system, in the classroom. Everything was rigorous, complete, rooted in scientific history, and brought into the current moment with hand samples to identify (also his famously terrifying habit during Ph.D. general exams) and visits to labs to see science in action. He taught undergraduates and graduates, everything from freshman seminars to graduate-level radiogenic isotope geochemistry and crustal evolution. He was not one of those famous senior scientists who "gracefully" declined to teach; he was always right there, bringing in students and inspiring them.

In 2000, his MIT colleague Kip Hodges created a freshman learning community course around problems with no obvious solutions. In 2006, Sam took over the course, now called Terrascope. It had solidified into a highly successful community of learning, where students guide their own research on a pressing issue of sustainability, take a spring break field trip related to that issue, and then present their findings at the end of the year. This effort helps MIT bring climate change and sustainability issues into the undergraduate curriculum from the beginning.

Some of Sam's biggest efforts were with field camps, which he continued to lead, perhaps longer than was ideal for his health. In addition to undergraduate and graduate field camps, he, along with colleagues Tim Grove and Oliver Jagoutz, took pre-freshmen to Yellowstone National Park each summer, showing them the fascination and glory of geology. Over his career, Sam trained and mentored more than twenty graduate students and influenced generations of undergraduates.

His door was always open, and he had a way with the single incisive piece of advice that often guided that person's next steps, be it student or colleague. One student wrote, "I took Sam's freshman class, Terrascope, at MIT and it is an understatement to say it changed my life. The first day of the term, Sam asked us 'how do you eliminate carbon dioxide emissions?' It's been over a decade now, and I'm still trying to find an answer. Sam's question has driven my whole career…." Similarly for myself, Elkins-Tanton, it was Sam's question to me that led me to propose continental dynamics for the grant that led to our end-Permian/Siberian flood basalts understanding.

Honors and Late Career

While I (Elkins-Tanton) was his colleague at MIT, I seldom knew when Sam received an award or accolade. He was not a self-aggrandizer. Nonetheless, he was a fellow of the American Geophysical Union and a recipient of its Walter H. Bucher Medal and Norman L. Bowen Award, and a Fellow of the Geochemical Society, the American Academy of Arts and Sciences, and the Geological Society of America. As a graduate student, I had watched with awe when Sam gave conference talks, delivered at speed, with rigor and utter self-assurance, seemingly taking the whole audience to school while explaining his work.

When Sam began to be affected by the brain tumor that would eventually cause his death, we, his colleagues, saw

some troubling symptoms of confusion, but Sam's drive to do geology seemed rooted in the deepest parts of his identity. Throughout the devastating challenges of treatment, Sam's mind was always on his work. Later, when he was no longer able to be in the lab, he would discuss his wishes for upcoming field expeditions with us when we sat with him. It was during this time, in 2015, that a special visit was paid to bring him, in person, the certificate for his election to the National Academy of Sciences.

Sam died on July 17, 2019, in Massachusetts, and will continue to be greatly missed by his friends and colleagues.

Selected Publications

1984 With P. F. Hoffman. Short-lived 1.9 Ga continental margin and its destruction, Wopmay orogeny, northwest Canada. *Geology* 12:68–72.

1989 With I. S. Williams, and W. Compston. 3.96 Ga gneisses from the Slave Province, Northwest Territories, Canada. *Geology* 17:971–975.

1993 With J. P. Grotzinger, et al. Calibrating rates of early Cambrian evolution. *Science* 261:1293–1298.

1995 With T. Housh. The Earth's early evolution. *Science* 269:1535–1540.

1998 With D. H. Erwin, et al. U/Pb zircon geochronology and tempo of the end-Permian mass extinction. *Science* 280:1039–1045.

2000 With M. W. Martin, et al. Age of Neoproterozoic bilatarian body and trace fossils, White Sea, Russia: Implications for metazoan evolution. *Science* 288:841–845.

2006 With D. J. Lehrmann, et al. Timing of recovery from the end-Permian extinction: Geochronologic and biostratigraphic constraints from south China. *Geology* 34:1053–1056.

2013 With T. J. Blackburn, et al. Zircon U-Pb geochronology links the end-Triassic extinction with the central Atlantic magmatic province. *Science* 340:941–945.

2014 With A. W. Epstein and C. F. Harvey. Engaging first-year students in team-oriented research: The Terrascope learning community. In: *Geoscience Research and Education: Teaching at Universities*, ed. V. C. H. Tong, pp. 223–236. Innovations in Science Education and Technology, Vol. 20. London: SpringerNature.

2015 With S. D. Burgess. High-precision geochronology confirms voluminous magmatism before, during, and after Earth's most severe extinction. *Sci. Adv.* 1(7):e1500470

2016 With W. C. Clyde, et al. Direct high-precision U-Pb geochronology of the end-Cretaceous extinction and calibration of Paleocene astronomical timescales. *Earth Planet. Sci. Lett.* 452:272–280.

With J. P. Pu, et al. Dodging snowballs: Geochronology of the Gaskiers glaciation and the first appearance of the Ediacaran biota. *Geology* 44:955–958.