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OBITUARY

John M. Hayes (1940–2017)

John Michael Hayes died peacefully on February 3, 2017, at the age of 76, of idiopathic pulmonary fibrosis at his home in Berkeley, California. John was born on September 6, 1940 in Seattle, Washington, but grew up in Montana and Iowa, attending 13 schools before graduating from high school in Perry, Iowa, as his family moved regularly for his father's job with the Chicago, Milwaukee, St. Paul and Pacific Railroad. John earned his B.S. in Chemistry at Iowa State University in 1962 and then entered the Ph.D. program in Chemistry at Massachusetts Institute of Technology (MIT), where he worked in the laboratory of Professor Klaus Biemann. John completed his Ph.D. thesis entitled *Techniques for High Resolution Mass Spectrometric Analysis of Organic Constituents of Terrestrial and Extraterrestrial Samples* with Professor Biemann in 1966.

After graduating from MIT, John worked as a postdoctoral fellow with Dr. Edward Anders at the Enrico Fermi Institute at the University of Chicago before entering the U.S. Army in 1967. As a Captain in the Medical Service Core, he served his active duty as a Research Scientist at the Chemical Evolution Branch, NASA Ames Research Center, Moffett Field, California through 1968. In 1969 he was a NATO-NSF postdoctoral fellow in the Organic Geochemistry Unit, Department of Organic Chemistry, at the University of Bristol, UK.

In January 1970, John was appointed Assistant Professor of Chemistry at Indiana University (IU), and was promoted to Associate Professor in 1974 and Professor of Chemistry in 1977. From 1970 to 1984, John also held an adjunct appointment in the Department of Geology, then a joint appointment as a Professor of Geological Sciences from 1984. He was named a Distinguished Professor of Biogeochemistry in 1990 and was the Chair of the Department of Geological Sciences from July 1994 to July 1996. In August 1996, John left IU to become a Senior Scientist in the Department of Geology and Geophysics and Director of the National Ocean Sciences Accelerator Mass Spectrometry (AMS) Facility at the Woods Hole Oceanographic Institution (WHOI). John was also appointed Professor of the Practice of Biogeochemistry in the Department of Earth and Planetary Sciences at Harvard University (1997–2000). In 2007, John retired from WHOI and settled in Berkeley, CA, where he maintained a relationship with the University of California, Berkeley.

John met his future wife, Janice Maria Boeke of Hubbard, Iowa, as a fellow undergraduate student at Iowa State University. John and Janice were married after their graduation in 1962, and Janice traveled with John through his many positions and locations. John and Janice Hayes celebrated their 51st wedding anniversary before Janice's passing in 2013. They are survived by their children, James T. Hayes of Honolulu, Hawaii, Anne Hayes Hartman of Oakland, California, and Rachel M. Hayes of Nashville, Tennessee, and their grandchildren, Diego Enriquez, Johanna Hartman, Sarah Hartman, and Rylan Hayes.

2016 photograph by Roger E Summons

John's thesis work in Klaus Biemann's laboratory centered around data collected from a high-resolution double-focusing CEC 21-110 mass spectrometer, identifying organic compounds in meteorites [1]. During his military service at NASA Ames, John had extensive access to a CEC 21-110B, expanding his high-resolution work of organic compound identification [2]. At the University of Bristol, John became involved in the analysis of returned lunar samples for organic compounds. Using a Varian CH-7 mass spectrometer, John conducted pyrolysis experiments, identifying resulting hydrocarbons in the lunar materials [3]. Thus, it was not surprising that when John was offered a position at IU, he would request funds for a Varian CH-7. It was also not a surprise that John had chosen/accepted an assistant professorship position at IU. When he was a graduate student, he had met and received samples from Warren G. Meinschein, an organic geochemist working at Esso Research. Meinschein left Esso to become a

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Professor of Geology at IU in 1966 and was undoubtedly instrumental in recruiting the young Hayes and providing him laboratory space and initial funding. It did not hurt that Meinschein also had a CEC 21-110B that John could use. Meinschein and John shared laboratories and developed joint projects, including analyses of lunar materials, and they published 14 papers together through 1980. During this time, NASA had an annual lunar science conference in Houston for researchers receiving lunar samples to present results. John and graduate student David J. Des Marais presented novel observations on the processing of carbon, nitrogen, and hydrogen in the lunar regolith.

At IU, John also pursued his interest to understand stable isotope discrimination of organic molecules and to develop capabilities to measure both the $^{13}C/^{12}C$ ratios of individual molecules in mixtures and the $^{13}C/^{12}C$ patterns within molecules. He and Meinschein sought to understand the diverse biogeochemical processes that create naturally occurring organic matter. This work required an isotope ratio mass spectrometer (IRMS), and John and Des Marais modified a conventional dual gas inlet system and a basic Varian GD150 IRMS to measure micromole quantities of CO_2. Using the single-sector Varian CH-7 with a computer-controllable accelerating power supply, graduate student Dale A. Schoeller developed instrument control software and an ion counting method to measure nanomole quantities of CO_2 that was delivered to the Varian CH-7 from a dual inlet system, achieving precise $^{13}C/^{12}C$ ratio measurements of CO_2 [4]. I followed as a graduate student with John, developing a continuous flow system with a GC in tandem with combustion/reduction tubes for precise measurement of ^{13}C and ^{15}N from combustion products of CO_2 and N_2 from GC peaks [5]. This new technique, to be later called GC-combustion-IRMS (GC-C-IRMS), made it possible to measure natural abundance variations in ^{13}C and ^{15}N in organic compounds in a complex mixture that could be separated on a GC. When fused silica GC columns with lower flow rates were developed, John worked with Finnigan MAT to develop the Delta line of GC-C-IRMS instruments. John and students then worked to produce GC-pyrolysis-IRMS instruments for the measurement of ^{2}H at natural abundances from H_2. These IRMS instruments have been expanded significantly in their capabilities and find natural homes in environmental, biogeochemical, biomedical, and forensic science laboratories. John published 29 papers in *Analytical Chemistry* on these various developments in mass spectrometry.

In the beginning, John published in *Analytical Chemistry* using his initials, "J. M. Hayes," a tradition many of his students adopted too, until somewhere around 1996. At that point John changed to using his full name ("John M. Hayes"). This demarcation can be seen between his first 17 papers in *Analytical Chemistry* through 1995 versus his next 12 from 1997 through 2005.

Shortly after John Hayes arrived at IU, a tenured professor, Dennis G. Peters, approached two untenured assistant professors, John and Gary M. Hieftje, with the proposition to join him in writing a textbook on analytical chemistry. Such an effort is not considered a good idea because it distracts from publishing the research needed to gain tenure, but John and Gary did agree, and together the three wrote and published in 1974 their analytical chemistry text [6], known as the "purple book" because of its cover color. Most of us just referred to this text that was adopted at a number of institutions as "Peters, Hayes & Hieftje." Joseph A. Loo, *JASMS* Editor, notes that the purple book was his "favorite reference" as a student and is still near his desk today. In 1976, an introductory version of the text was prepared and published, but the purple edition remains a classic in analytical chemistry.

Although John Hayes is well known for his fundamental contributions to mass spectrometry and analytical chemistry, he is most well-known and respected for his contributions to the field of geochemistry. His thesis work on organic compounds in meteorites was a springboard to his work on organic content of lunar rock samples. Next, John developed methods to interpret isotopic discrimination by microorganisms in sedimentary deposits that could be used to define the biogeochemistry of early organic matter and the Earth's earliest ecosystems. In a series of papers in Nature and other highly ranked journals, John and his colleagues interpreted isotopic evidence for the transition from an anoxic to an oxygen dominated world and the evolution of our biosphere during the Precambrian and Phanerozoic periods. He expanded his work into the use of hydrogen isotopic discrimination and its measurement in biogeochemistry. His work is recognized by microbiologists as well as geochemists. At WHOI, John wrote a series of reviews on biosynthetic pathways and their induced isotopic fractionation, and created databases for others to use.

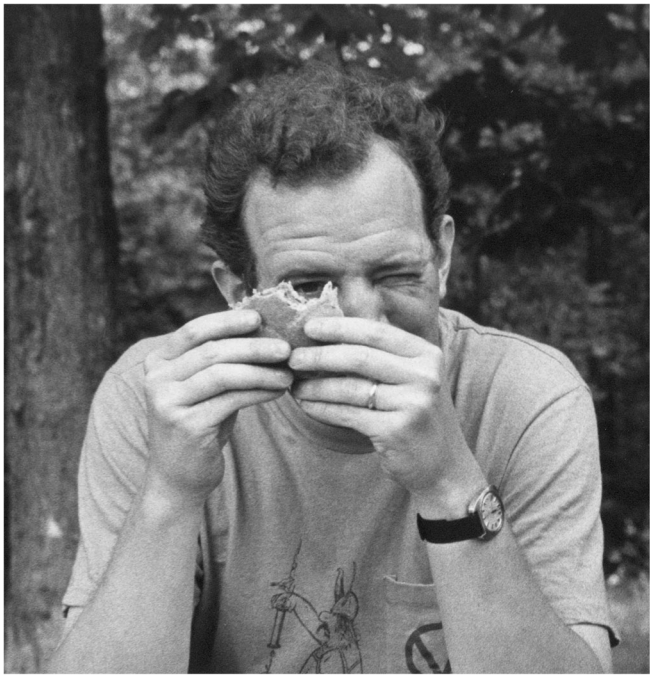
As director of the AMS Facility at WHOI, John began using ^{14}C measurements and compound-specific changes of ^{14}C, as well as radiocarbon age-dating for interpretation of biogeochemical events. Sample preparation for AMS was tedious and time-consuming. Thus, John initiated development of the first continuous-flow ion source for AMS radiocarbon dating. This development was more than just an application of existing techniques, requiring significant modification of the ion source itself. Professor Alex Sessions of Calltech, who was a graduate student and then postdoctoral fellow with John and who had worked on this project, called this development "revolutionary" for AMS.

John Hayes published more than 200 research papers, two textbooks, and four book chapters. He has served as editor, associate editor, editorial board member, organizer and chair of conferences, and scientific reviewer. His scientific contributions have been recognized by a

number of awards and honors: Fellow of the Geochemical Society and European Association for Geochemistry (1996), the European Association for Geochemistry Urey Medal (joint with Geoffrey Eglinton, 1997), the Geochemical Society Alfred Treibs Medal (1998), and Goldschmidt Medal (2002), Member of the National Academy of Sciences (Geology, 1998), Fellow of the American Geophysical Union (2001), the American Chemical Society Geochemistry Division Medal (2003), Fellow of the American Academy of Microbiology (2009), and Foreign Member of the Royal Society (2016).

John is well remembered by everyone with whom he associated, and he touched many people in major ways. But there are several specific facets of John that are remembered by many and summarized briefly here. Ron A. Hites, who arrived as a graduate student in the Biemann laboratory at MIT in 1965 and later became a faculty member in Chemistry at IU at John's insistence, writes that "I was immediately impressed by John's native intelligence and, frankly, his booming voice. He could make almost any comment seem profound when he said it." Cathy E. Costello, another Biemann lab member also remembers John from meetings and gatherings, noting that "he had that amazing voice; I always said that he could read the phone book aloud and anyone listening would be enchanted."

Professor Hites also comments that "John was my go-to guy for literary clarity. He was the most erudite, intelligent guy I knew." John certainly helped many students "clarify" their writing, but Gary Hieftje notes that John also clarified the writing of many of his colleagues. Everyone who worked with John knew how deeply he cared about his students. Even after you received your manuscript back, heavily annotated with a red pencil, you appreciated what he was trying to do for you and your science. Katherine H. Freeman, who finished her Ph.D. in Geological Sciences with John in 1991, and now a distinguished professor at Penn State University, writes, "John was generous to students, young scientists, and anyone with a question for him. Young or old, a conversation with John could evoke feelings of apprehension because you knew he would listen with his full attention, just as he read our manuscripts with sharp-eyed intensity. He was always eager to learn something new, just as he was to help clarify and strengthen the best of our ideas." Thus, I include a photograph of a young John from 1976 at a group party. John was ever inquisitive, here pondering the origin of the carbon isotopes in his hamburger.



1976 photograph by Dwight E. Matthews

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