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Memorial of Charles Wilson Burnham, 1933–2021

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Charles Wilson Burnham was born in Detroit, Michigan, on April 6, 1933, to parents Charles Hubbard Burnham and Anne Wilson Burnham. His early years were spent in Winchester, Massachusetts. In the fall of 1950, he enrolled at MIT, following in the footsteps of his father and grandfather before him. Although his major was engineering and business, he developed an interest in geology and took many courses in that subject. After graduation in June 1954, he started a Masters program in geology, spending an additional year at MIT. However, his studies were interrupted by military service: the years 1955–1957 were spent on active duty in the U.S. Air Force, where his duties were mainly in meteorology and ice physics. Returning to MIT, Charlie entered a Ph.D. program in the field of mineralogy and crystallography, studying under the pioneering crystallographer Martin Buerger. He received his Ph.D. in 1961, with a dissertation entitled *The structures and crystal chemistry of the aluminum-silicate minerals.* The choice of this topic was an early indication of Charlie's interest in the structures of important rock-forming minerals.

After receiving his diploma, Charlie assumed a post-doctoral fellowship at the Geophysical Laboratory of the Carnegie Institute of Washington from 1961–1963. Later he was appointed staff scientist, a position he retained until 1966. The period 1961–1966 was a watershed in the history of mineralogy and crystallography because this was when the development of a new generation of automated X-ray diffractometers was accompanied by the availability of powerful mainframe computers such as the IBM 7094. One of Charlie's first accomplishments at Carnegie was to install a modern single-crystal X-ray diffractometer to carry out state-of-the-art crystal structure analyses. Charlie was an early adopter and leader in developing computer software to handle data streams from automated diffractometers. As noted in the introduction to the Carnegie Institution yearbook of 1963, "Modern scintillation and proportional counting techniques, and high-speed digital computers, are now the crystal structure analyst's most powerful tools."

Building on his doctoral research on the structures of aluminum silicate minerals, he pursued structural studies of *mullite*, another aluminum silicate generally used in its synthetic form in the ceramics industry. Mullite has a unique structure on account of its nonstoichiometric composition involving oxygen vacancies that are charge balanced by aluminum substitution for silicon. Later, in collaboration with Donald H. Lindsley, Charlie investigated the structure of the *ferrosilite* ($FeSiO_3$) polymorphs that Lindsley had synthesized. This proved to be a new pyroxenoid-type structure having a single silicate tetrahedral chain containing a nine-tetrahedra repeat group. At the time, only pyroxenoids with 3, 5, and 7 repeat chains were known. Subsequent work with Lindsley in the binary *ferrosilite-wollastonite* ($FeSiO_3$-$CaSiO_3$) system led to synthesis, and structural analysis of a 7-repeat pyroxenoid equivalent to the mineral *pyroxferroite*, which subsequently was found in lunar samples returned from Apollo 11.

Charlie Burnham. Photo by John Brady.

Although the environment for pure research at the Geophysical Lab remained unparalleled, the opportunity to interact with students, both undergraduate and graduate, led Charlie in 1966 to accept an appointment as Associate Professor of Mineralogy in the Department of Geological Sciences at Harvard. As with his arrival at the Geophysical Lab in 1961, Charlie found that equipment for crystallographic research was limited and old. Supported by funding from both Harvard and the National Science Foundation, he acquired and installed a computer-controlled electronic counter-equipped automated single-crystal X-ray diffractometer. This upgraded lab equipment was used extensively by a large number of graduate students and post-docs in the ensuing years. Charlie was promoted to Professor of Mineralogy in 1969, remaining in that position until his retirement in 1996.

Working with a number of students and post-docs during the 1970s and 1980s, Charlie's group pioneered structural studies at high temperatures and high pressures using a miniature diamond cell. These studies led to successful predictions of silicate structures at high temperatures and pressures typical of regional metamorphism and igneous rock formation at conditions deep within the Earth. A collaboration with Prof. James B. Thompson, Jr., and graduate student David Veblen led to the discovery and description of an entirely new class of triple-chain silicate minerals, including *chesterite* and *jimthompsonite*.

In the 1980s, Charlie recognized that it was possible to build on the wealth of structural studies reported in the two previous decades that had established accurate interatomic distances for atoms in a variety of structures. These known interatomic distances could, in turn, be used to develop ionic pair potentials. Mathematical techniques such as distance-least-squares (DLS)

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could then be used to simulate complex mineral structures. In addition, the development by W.R. Busing at the Oak Ridge National Laboratory of a general structure energy minimization program allowed even more extensive simulations. At the same time, Prof. Roy G. Gordon and coworkers at Harvard developed the modified electron gas (MEG) theory for ionic structures, providing another way in which ionic pair potentials could be established. All these developments led to a golden age of simulations of ionic crystal structures.

A gifted and renowned teacher, Charlie worked with a number of graduate students and post-docs who went on to successful careers of their own. Charlie was especially proud that some of these young scientists earned recognition, such as the prestigious MSA Award or the Roebling Medal of the Mineralogical Society of America. Charlie himself served as President of MSA from 1989–1990. Seven of his students and post-docs themselves became MSA Presidents. Beyond his research interests, Charlie was dedicated to the development of the next generation of geologists and spent much time in undergraduate instruction and mentoring. In addition to his teaching of mineralogy, he also offered a popular Freshman Seminar on glaciology and glacial geology. He was instrumental in the management of the Harvard field camp in Wyoming, which was run in conjunction with other Ivy League institutions. Charlie served the Department of Geological Sciences as Head Tutor for more than ten years.

Outside of his professional activities, Charlie was also active in the local environmental community, working on major issues in backcountry management. He served as President of the Appalachian Mountain Club in 1979–1980 and participated in negotiations for land acquisition and the routing of the Interstate 93 highway through the narrow pass of Franconia Notch in New Hampshire. Charlie was also involved with the Mount Washington Observatory, where he served as Trustee for many years, including a stint as Vice President. An avid skier, Charlie also promoted youth ski racing nationally and served as a course official in two separate Olympic competitions.

Charlie passed away on December 13, 2021. He is survived by his wife, Mary Sue, as well sons Jeffrey and David, and six grandchildren.