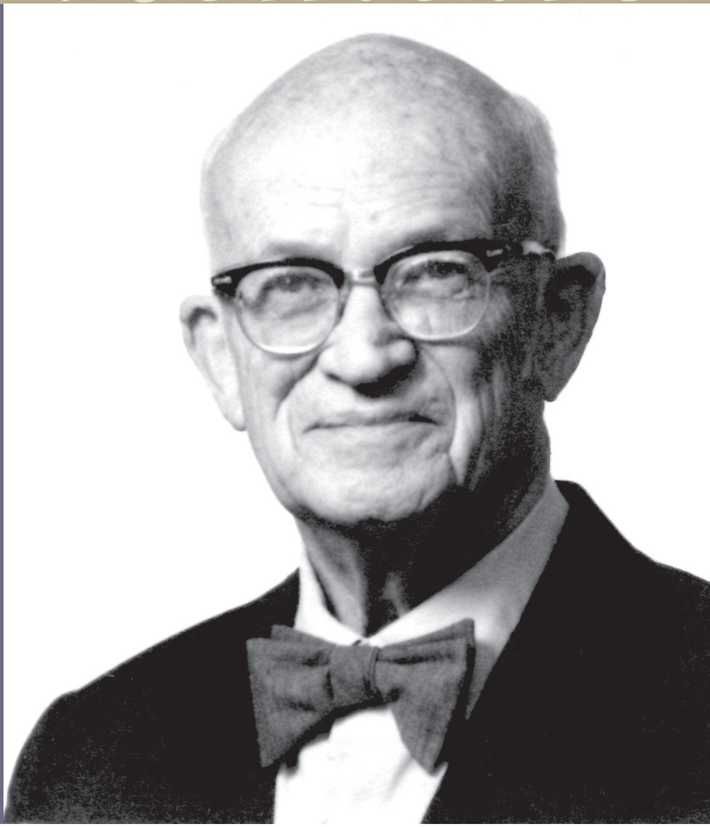
C. S. Barrett

1902–1994

BIOGRAPHICAL *Memoirs*



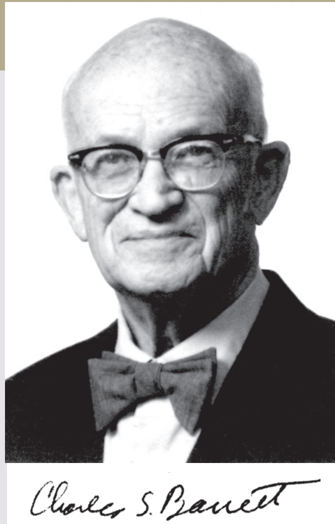
A Biographical Memoir by
Ted Massalski

NATIONAL ACADEMY OF SCIENCES

CHARLES SANBORN **BARRETT**

September 28, 1902–June 14, 1994

Elected to the NAS, 1967



By Ted Massalski

Charles Sanborn Barrett was widely recognized during his long career, from 1928 to 1994, as one of the key players in metallurgical physics. He not only made numerous contributions to our understanding of the structure of materials but also pioneered the development and use of sophisticated research techniques such as X-rays, radiography, electron microscopy, and electron scattering. Through this work Barrett helped bring about the transition from 19th-century metallurgy research, which focused on improving properties more or less through trial and error, to the rapidly growing field of materials science, which is concerned with first understanding a material's properties.

Barrett was especially noted for his persistent advocacy of relating materials' properties to their crystal structure and atomic-level interactions. He was also well known for his very effective ability to explain research results through clear writing and carefully detailed discussions.

Barrett, called "Chuck" by his numerous friends and acquaintances, was born in 1902 in Vermillion, South Dakota. During his early childhood years both at home and at school, and throughout his life, he displayed a striking interest in the natural world around him, how various things worked, how behaviors could be explained, and how they could be changed—that is, improved. Coupled with his natural ability to interact and communicate well with people, these characteristics were the basis for the progress and successes in his professional activities, which always fell somewhere between science and engineering.

Barrett attended college at the University of South Dakota, where he majored in engineering. While there, he worked as an operator at the university radio station, which he helped to build and extend, and he continued as a radio amateur for many years thereafter. After he received a B.S. degree in engineering in 1925, Barrett moved on to the

University of Chicago for graduate education. There he joined the research group of A. H. Compton and became the first scientist to determine the diffraction patterns from individual atoms by measuring the scattering patterns of gases. Barrett earned his Ph.D. in physics in 1928, and in that same year he married Dorothy A. Adams. Their only child, a daughter (Dr. Marjorie A. Barrett Gultepe), followed her father into a scientific career.

After receiving his Ph.D., Barrett was recruited by R. F. Mehl, who led the metals research group at the Naval Research Laboratory (NRL), to work on establishing gamma-ray radiography as a practical nondestructive testing method for large metallic engineering objects. Barrett wrote the first operator's manual for this method and saw it adopted widely by the U.S. Navy and later by others. He subsequently became interested in using X-rays to study structural phase transformations in alloys, and was coauthor with Mehl of many papers on the Widmanstätten structure in alloys, which forms during precipitation from solid solutions. Barrett also applied X-ray diffraction and other radiation techniques to addressing various other problems in physical metallurgy.

When Mehl moved to Pittsburgh in 1932 to join the faculty of the Carnegie Institute of Technology—where he became a professor in the Department of Metallurgical Engineering and director of the Metals Research Laboratory (MRL)—he persuaded Barrett to join him there. During this period, Barrett taught courses on X-rays and physical metallurgy and published research in various fields: a series of investigations on the origin and nature of preferred orientation in metals and alloys; studies of phase transformations, including the changes accompanying age hardening in alloys; and studies of fatigue, slip, and twinning in alloys at various temperatures. He was a pioneer in applying the electron microscope to metal structures, and, with M. Gensamer, published one of the early papers on methods of measuring stresses with X-rays.

Chosen to give the 1944 Annual Lecture of the Institute of Metals Division of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME), Barrett developed and presented a new method of microscopy—a refinement of an X-ray technique previously worked out by W. Berg—that permitted useful magnification up to 100 diameters. This innovation became known in many laboratories as the Berg-Barrett method.

Having written several reviews of different fields in which he had been doing research, Barrett was encouraged to organize them, together with the material he had developed for his teaching, into a book. The result, *Structure of Metals*, filled a need that was acute at the time it first appeared (1943), and it continued to be widely used in the United States and abroad in subsequent editions and translations.

During his 14-year stay (1932–1946) at Carnegie Tech, Barrett came to realize that his interests and ambitions were moving in the direction of more basic research and into a wider range of materials and topics than were being pursued at that time by MRL colleagues. Coupled with the fact that there was also relatively little interaction with chemists or physicists at Carnegie Tech, it is not surprising that he accepted the invitation of first-director Cyril Stanley Smith to join the Institute for the Study of Metals (ISM) at Barrett's alma mater the University of Chicago. There he became a research professor (without formal teaching obligations), enjoyed a long and productive residence there, and officially retired in 1971 with the title of emeritus professor. By that time the ISM had been renamed the James Franck Institute.

During his 25-year tenure (1946–1971) at Chicago, Barrett found many opportunities for challenging contacts with accomplished researchers (several of whom held Nobel prizes), and he immersed himself in a wide variety of projects. For example, he studied X-ray diffraction at low temperatures, discovered the low-temperature phase change in lithium, and explored the structure of all of the alkali metals and various other metals and alloys at temperatures down that of liquid helium (4.2°K). In cooperation with the Argonne National Laboratory, he studied the behavior of uranium in the low-temperature region where strange crystal-structure transformations take place.

As the result of a collaboration with Lothar Meyer and students, Barrett published a series of papers on the crystal structures and phase diagrams of frozen gases, using cryogenic diffraction apparatus that he built specifically for the project—and that he later used as well for numerous other studies of crystal structures and their changes with temperature or deformation. Among other achievements, he determined the crystal structure of oxygen at the lowest temperatures—a significant finding in that the structure and transformations of oxygen had been the subject of uncertainty and controversy for many years.

Barrett also took part in several studies on bismuth, antimony, and arsenic and their alloys at low temperatures, in response to the needs of theoretical physicists for precision data that could only be obtained with X-rays. He did some neutron diffraction experiments on metals as well; and in cooperation with W. White and his assistants Barrett also explored what information could be obtained from crystals through the use of proton-beam diffraction.

In one of these efforts he was actually joined by his daughter, Marjorie, who had by then become a scientific researcher of her own renown, mostly in the fields of ellipsometry and electrochemistry.

As a result of these cryogenic diffraction studies, Barrett expanded his capabilities so as to enable his investigation of the influence of induced plastic deformation on crystal structure changes at very low temperatures, a unique area of research that he pioneered. In one of these efforts he was actually joined by his daughter, Marjorie, who had by then become a scientific researcher of her own renown, mostly in the fields of ellipsometry and electrochemistry.

The years he spent at thee University of Chicago's ISM without formal teaching obligations allowed Barrett not only to pursue the research activities cited above but also to continue widening his contacts with numerous colleagues and institutions in the United States and abroad. He accepted several appointments as visiting professor and several consultancies (see below). He attended numerous conferences and meetings, chaired committees, and presented many invited lectures. He also devoted much time to writing. But while being busy and highly visible in the U.S. scientific circles, he showed little interest in pursuing any major, or permanent, executive responsibilities.

Having interacted and often collaborated with others during his pursuits of very-low-temperature crystal-structure studies and other topics, often alongside other researchers from diverse disciplines, Barrett realized that the various aspects of thermodynamics, the electronic theories of metals, and the concepts of phase stability would be natural parts of a book such as the internationally recognized *Structure of Metals* he first published in 1943. So, for its third edition he decided to look for a collaborator, who turned out to be Ted Massalski, the author of this memoir.

Barrett had been instrumental in arranging a 1954–1956 postdoctoral appointment for me at the ISM. Later, in the 1960s when I was back in the United States at the Mellon Institute in Pittsburgh, he invited me to join him in producing the third and enlarged edition—an offer I couldn't refuse! The result was that Barrett and Massalski's *Structure of Metals* was published in 1966 and followed by a number of reprintings and several foreign-language translations. All together, some 55,000 copies were sold worldwide.

Barrett spent three years (1948–1951) as editor of the *Metals and Alloys Section* of *Structure Reports*, a journal of the International Union of Crystallography, and he was a member of the union's Structure Reports Commission from 1948 to 1953. He was a member of various technical committees, including the Ship Steel Committee of the National Research Council (1948–1962) and the U.S. National Committee on Crystallography (1952–1955).

Barrett served as a consulting metallurgist for various companies, including General Electric, U.S. Steel, the Nuclear Chicago Research Laboratory, and Bell Telephone Laboratories; and for many years he was a consultant to the Argonne National Laboratory.

His visiting professorships were as follows: University of Denver (1961, 1968, 1969, 1970); University of Birmingham, England (1951–1952); Stanford University (1963); Oxford University, England (1965–1966, 1971); University of Virginia (1968, 1970); Georgia Institute of Technology (1973); and Marmara Institute for Scientific and Industrial Research, Turkey (1973).

During his time at Oxford, Barrett published some experiments on the abnormal aftereffect, taught a course normally conducted by William Hume-Rothery, and presented the annual Eastman lecture (1966). With Barrett's usual keen sense of humor, he titled his lecture "On Research that Need Not Be Done," to the delight of the largely student audience. Both Hume-Rothery and Barrett were keen amateur painters, and they exchanged a number of their favorite pictures. At the Marmara Institute, Barrett helped start its X-ray laboratory and gave lectures (which he reassembled years later for X-ray analysis courses he helped teach at the University of Denver).

Honors bestowed upon Barrett during his Chicago years included: Mathewson Medal off the AIME (1950); service as chairman of AIME's Institute of Metals Division (1956); election to the National Academy of Sciences (1967); Edward Demille Campbell Lecturer for the American Society for Metals (1956); honorary life membership in the American Society for Metals (1963); Sauveur Achievement Award of the American Society for Metals (1966); Heyn Medal of the Deutsche Gesellschaft für Metallkunde (1966); fellow of the American Physical Society, American Society of Metals, and AIME; and election to honorary societies in physics (Sigma Pi Sigma), scholastics (Phi Beta Kappa), research (Sigma Xi), and metallurgy (Alpha Sigma Mu).

Earlier, during his tenure at Carnegie Tech, Barrett was awarded the Mathewson medal of the AIME two times (1934, 1944) and the Howe Medal of the American Society for Metals (1939). These awards were for research papers. Later he received the Clamer Medal of the Franklin Institute in Philadelphia for career accomplishments in science and engineering, and he also served as president of the American Society for X-Ray and Electron Diffraction (now called the American Crystallographic Society).

After becoming professor emeritus at the University of Chicago in 1971, Barrett moved to Colorado to become a professor in the University of Denver's Department of Metallurgy (later renamed the Department of Chemical Engineering and Metallurgy). He was also appointed adjunct professor of physics and senior research engineer at the university's Denver Research Institute. There he continued doing research, often with associates, and also some teaching. At this stage of his life, Barrett's research became more focused on applied problems in industry.

Together with L. Trueb, Barrett published a detailed analysis of the internal structure of diamonds; in that work, the preferred orientation and size of the microcrystals embedded in the stones were determined for the first time. The researchers examined details of the microstructure with scanning electron microscopy, electron transmission microscopy, X-ray topography, and metallography.

Meanwhile, Barrett was serving as coeditor of volumes of *Advances in X-Ray Analysis* and was active in the annual Denver Conference on which these volumes were based. Beginning in 1977, he acted as the conference's honorary chairman.

In collaboration with C. O. Ruud and R. Sturm at the Denver Research Institute, Barrett developed an electro-optical X-ray detector and applied it to a range of problems, particularly to the analysis of residual and applied stresses in metals. Together with these and other staff members of the institute, he also applied the X-ray detector in the design of quick, portable, stress-analysis equipment.

With Paul Predecki, Barrett developed an X-ray diffraction method for measuring stresses in polymeric materials. Under the sponsorship of the U.S. Air Force's Office of Scientific Research, the method was further developed; he devised a technique by which all three principal stresses within a homogeneous, or a reinforced, polymeric specimen could be determined. The method was then applied to the measurement of stresses in adhesive joints. Also, he explored the use of an epoxy paint containing diffracting particles as a new way to determine applied (not residual) stresses when it was painted on an object to be tested.

Barrett was appointed by the Organization for Economic Cooperation and Development to present a series of lectures at the new Marmara Institute for Scientific and Industrial Research at Gebze-Kocaeli, Turkey, where he helped start an X-ray laboratory; while in residence there, he also helped other groups in Turkey with their X-ray work. In other travels during his Denver years, Barrett presented numerous lectures on X-ray subjects in Japan and Australia and took part in X-ray conferences in Australia, England, and the United States. Moreover, he was active for several years on the Solid State Sciences Panel of the National Academy of Sciences.

Some honors that Barrett received during his years at the University of Denver included: Gold Medal of the Japan Institute of Metals (1976); honorary membership in the Japan Institute of Metals (1976); Gold Medal of the American Society for Metals (1976); Hume-Rothery Award of the Metallurgical Society of the AIME (1977); and honorary membership in the AIME (1980).

In some places, this memoir has been a rather personal account of Chuck Barrett's life. We first met at the University of Birmingham in England, when I was in my final undergraduate year of majoring in physical and theoretical metallurgy. Characteristically, Chuck befriended me, a young student intensely pursuing his studies, which perhaps reminded him of his own early years. As mentioned earlier, we continued our friendship in Chicago, and later we became involved in a joint writing of the third edition of his renowned book, *Structure of Metals*. We completed working on the proofs at Oxford (1966) in Professor Hume-Rothery's Department of Metallurgy, where Chuck held the visiting appointment of Eastman Professor.

After they moved to Green Valley, Arizona, during the 1980s for their true retirement, and resided in a lovely one-level house bordering a golf course, Chuck and Dorothy continued to enjoy travel, tennis, golf, gardening, music, art, and international friendships. I visited them there a few times and on each occasion Chuck tried to teach me how to practice, and more basically how to understand, what he called the "science and engineering of golf."

ACKNOWLEDGMENTS

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