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Memorial of Sterling Brown Hendricks
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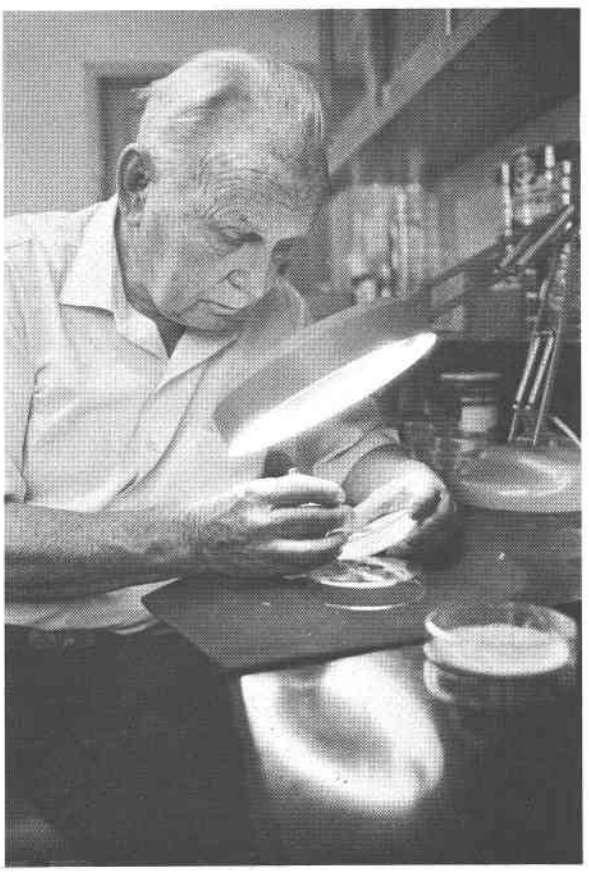
Sterling B. Hendricks was born in Elysian Fields, Texas, on April 13, 1902. He obtained the Bachelor of Chemical Engineering degree from Arkansas State College in 1922, the M.S. degree from Kansas State College in 1924, and his Ph.D. from California Institute of Technology in 1926. From 1922 to 1925 he worked part-time as an assistant in Southern Field Crops Investigations, U.S. Department of Agriculture, and he was an instructor in Kansas State College in 1923 and 1924, and a teaching assistant in CIT from 1924 to 1926. He then worked for one year as a Research Associate in the Geophysical Laboratory of the Carnegie Institution of Washington and for one year in the Rockefeller Institute for Medical Research; during these years he was associated with the pioneer X-ray crystallographer R. W. G. Wyckoff. From 1928 to 1940 he was Chemist in the Bureau of Chemistry and Soils of the USDA; and from 1940 to 1943 Chemist in the Bureau of Plant Industry, USDA. He became Chief Scientist in the Mineral Nutrition Engineering Research Laboratory, Agricultural Research Service, USDA in 1943, holding this position until he retired in 1970. After his retirement he continued to live with his wife in Crystal Spring, Maryland.



Among those scientists associated with the Mineralogical Society of America, Sterling was probably unique in having the broadest field of scientific work. He himself listed as his fields of interest the structural aspects of organic and inorganic chemistry, chemistry and physics of crystal structure, insecticides, phase rule, X-ray diffraction of solids, electron diffraction of crystals and gas molecules, soil chemistry, base exchange, plant physiology, plant nutrition, and photoperiodism. He might have added mineralogy, especially of the clay minerals, micas, and phosphates, metals and intermetallic compounds, and some other subjects. His effectiveness in attacking new problems was without doubt the result in considerable part of his extensive experience in many fields. His earlier publications, including most of those of interest to members of the GSA, are listed in the bibliography; he also published 95 papers on organic chemistry and plant growth.

I first met Sterling in the fall of 1924, when he came to Pasadena to begin his doctoral studies. He was a keen and lively young fellow, full of energy. With his straw-colored hair and freckles, he reminded me of Peck's Bad Boy. A. A. Noyes, the director of the Gates Chemical Laboratory, suggested to

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him that he work on X-ray crystallography, a lively field of research that had been prosecuted in the California Institute of Technology from as early as 1917. Normally he would have been initiated into this field by Roscoe G. Dickinson, who in 1920 had received the first Ph.D. given by California Institute of Technology and in 1922 had taught me the X-ray techniques, but Dickinson was on leave for a year in Europe as a Rockefeller scholar. Sterling accordingly worked with me for one year, thus becoming my first graduate student, and with Dickinson during the second year of his doctoral research.

He first carried out a reinvestigation of the structure of corundum and hematite, which had been studied earlier by W. H. and W. L. Bragg. He found that the aluminum atoms and iron atoms are in very nearly the positions previously assigned to them, but the oxygen atoms are not. The refined structure provided an interesting insight into the nature of the interatomic forces in these crystals. He then determined the structure of sodium azide and potassium azide. Chemists had been unable to decide between a linear structure for the azide (trinitride) ion and the cyclic structure; the X-ray diffraction studies showed that the ion is linear. The other part of his Ph.D. thesis work consisted in the determination of the crystal structures of ammonium, potassium, and rubidium cupric chloride dihydrates, carried out with Dickinson.

This investigation provided the interesting result that the copper atom forms bonds to two chlorine atoms and two oxygen atoms (of the water molecules) with the $CuCl_2 \cdot 2H_2O$ group planar, and the other chlorine atoms at a greater distance. Sterling also worked jointly with Maurice L. Huggins, who was then a post-doctoral fellow in the laboratory, in the investigation of pentaerythritol, $C(CH_2OH)_4$. They agreed with H. Mark and K. Weissenberg that the X-ray data required that the four bonds formed by the central carbon atom were directed toward the same side of the atom, rather than being tetrahedral. In 1927 Hendricks pointed out that there was the possibility that the pyramidal structure was wrong, in that another space group permitted the tetrahedral arrangement of the bonds, but it was not until a decade later that other investigators showed that the carbon atom is in fact tetrahedral in this molecule, as it is in almost all others. During his two years as a doctoral student Sterling carried out another interesting investigation, together with another student, Constant Bilicke. They determined the space group and molecular symmetry of beta-benzene hexabromide and hexachloride, and the refinement of the structures was made later by Dickinson and Bilicke. This early investigation of an organic compound was an important contribution to the chemistry of carbon compounds.

During later years Hendricks made additional contributions to mineralogy, which he had begun with the study of hematite and corundum. Minerals that he investigated include zircon, apatite, gypsum, kaolinite, anauxite, valentinite, alunite, the jarosites, dickite, halloysite, hydrated halloysite, talc, pyrophyllite, vermiculite, chlorite, montmorillonite, nacrite, cronstedite, glauconite, celadonite, gibbsite, endellite, and the micas. His most significant contribution to knowledge may well have been provided by his work on the clay minerals. In the citation by Ian Campbell on the presentation of the Arthur L. Day Medal of the Geological Society of America to Sterling Hendricks, his work on the clays was mentioned in the following words:

> "Sterling Hendricks, an able technician and a masterful and imaginative theoretician, has been in the forefront of those who have given us a rational understanding of these most complex and most important minerals. His elucidation of the structure of layered minerals and his demonstrations of the dependence of clay mineral properties upon structural considerations have been outstanding. Not only has he provided specific data on the kaolin minerals and, with Ross, on the complex montmorillonite group, but he has at the same time developed fundamentals of broad application, as for example in his studies of the polymorphism of the micas and of the nature of the water layer, and in the determination of minerals with disordered structure and of minerals with random layer sequences. He has never been content merely to explain the well-behaved growths in the mineral world, but has gone on to decipher for us some of nature's 'mistakes'."

Among his other contributions I may mention especially the long series of investigations of the crystal structures of alkylammonium halides, beginning in 1928. From his X-ray study of crystals of the mono-alkyl substituted ammonium halides he found that in a number of these crystals the alkyl ammonium ion seems to lie on a four-fold axis of symmetry, a result that apparently excluded the usual staggered chain of carbon atoms and that caused him to suggest that the chain really is straight. Then in 1930 I published a paper on the rotational motion of molecules in crystals and suggested that the chains might be rotating about their long axis at ordinary temperatures, giving the chain an effective infinite

symmetry axis, which is compatible with the X-ray data, and that accordingly Sterling's investigation might not require that the picture of the staggered aliphatic chain be given up. Sterling immediately began a reinvestigation of these crystals, and was able to show that the alkylammonium ion involves a staggered chain of atoms, moving among alternative orientations about the long axis in such a way as to impart a pseudo-tetragonal symmetry to the ion, at room temperature, and that the structure changes at low temperature. He followed this work by investigations of rotational motion of groups in other crystals—ammonium nitrate, calcium nitrate, sodium nitrate, and ammonium chloride, thus providing solid experimental confirmation of the theory.

Sterling did not change much in appearance as he grew older. Even though he was not a small man, I continue to think of him as a pixie, perhaps because of the memory that I have of him as he demonstrated an unusual muscular control—that of wiggling his ears alternately, so that his scalp executed a harmonic motion from side to side. He had a good disposition and got along well with his colleagues. Mountaineering was his avocation. I remember that in 1926 he and Richard M. Badger back-packed for about 100 miles along the Coast Trail through the Santa Lucia Mountains of California, from Cambria to Monterey. Ian Campbell described him as a distinguished mountaineer, credited with the third successful ascent of Mt. McKinley, and noted that he has a number of "firsts" in the British Columbia Rockies, including climbing four previously unscaled heights.

His contributions to science were recognized by a number of awards. He received the Hillebrand Prize of the Chemical Society of Washington in 1937, the Award of the Washington Academy of Sciences in 1942, the Distinguished Service Award of the USDA in 1953, the Arthur L. Day Medal of the Geological Society in 1952, the President's Distinguished Service Award in 1958, the Rockefeller Public Service Award in 1961, and the National Medal for Science in 1975. He was awarded an Honorary LL.D. by Arkansas State University in 1946, and was the President of the Mineralogical Society of America in 1954 and also President of the Society of Plant Physiology.

Sterling B. Hendricks was one of the early American X-ray crystallographers, educated in departments of chemistry rather than of physics, who have applied their knowledge of crystal structure to other fields. He was outstanding in the broad range of his interests and the effectiveness of his work. He died of Guillain-Barre' syndrome, a neurological disease, in Novato, California, on January 4, 1981. He is survived by his wife, Edith, his daughter, Martha O'Neill, and two grandchildren.

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[1] To receive a copy of the complete bibliography, order Document AM-82-193 from the Business Office, Mineralogical Society of America, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Please remit $1.00 in advance for the microfiche.

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