THE AMERICAN MINERALOGIST, VOL. 50, MARCH-APRIL, 1965

PRESENTATION OF THE ROEBLING MEDAL TO CLIFFORD FRONDEL

MARTIN J. BUERGER, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

Mr. President, Fellows and Members of the Mineralogical Society of America, and Guests:

The privilege I have today in presenting to you Clifford Frondel as Roebling Medalist is a three-fold pleasure. In the first place, he is one of my early students, and my first graduate student to qualify for the doctorate in crystallography. Secondly, he and his charming consort are close friends of long standing, and finally, it was Clifford Frondel who introduced me as Roebling Medalist in 1958. It is an unusual privilege to return this honorary service.

Frondel was born on January 8, 1907, in New York City. After attending public schools in New York and Bayside, Long Island, and high school in Flushing, he obtained a degree of Geological Engineer from the Colorado School of Mines in 1929, and an M.A. from Columbia in 1936.

Frondel first came to my attention in 1936. It had been evident in the previous year that the number of students taking elementary mineralogy at M.I.T. warranted finding two new laboratory assistants, so I wrote to the geology departments of other universities soliciting candidates. Frondel was one of the applicants and his qualifications assured him of one of these available places. He came to M.I.T. in the fall of 1936 and assumed the usual half-breed role of combined assistant and graduate student. He found himself a member of a close-knit group of eager graduate students whose number exceeded that critical minimum required to make them self-stimulating. These fellow students included William Parrish, Clifford Lord, Victor Lopez, Ely Mencher, and my brother Newton Buerger, each of whom distinguished himself later in mineralogy, geology or education.

As a student, Frondel early recognized that the arrangements of atoms in crystals would eventually provide the key to a rational understanding of the properties and interrelations of minerals. He thus became one of the early recruits to the ranks of the young structural mineralogists then arising. Accordingly, his later writings have a strong structural slant.

Frondel's contributions to mineralogy have been tremendous. He is, of course, known throughout the world for his part in the Seventh Edition of Dana's System. Everyone knows that Volume 3 is entirely his own writing, but it is perhaps not so generally recognized that Volume 2 falls essentially in the same category. His structural influence is clearly seen even in Volume 1, for many regroupings are made there on the basis of re-

lated structural arrangements. Frondel's service to mineralogy through his part in rewriting Dana's system alone entitles him to the recognition we are according him today, for this is now not just a book, it was the first structurally-based integration of all existing mineralogical knowledge.

But if we ignore this monument, we are still impressed by his contribution to mineralogy in the way of journal articles. Judged by numbers of publication alone, Frondel has few peers, for from his pen have flowed some 120 separate papers, of which two-thirds were written without a co-author. In these papers his interests have covered so many topics that it is only possible to call attention to several themes.

An early interest was crystal growth, habit, and attendant phenomena such as incrustations. This theme tended to pervade his output up through his doctoral dissertation, and cropped up again in such theoretical interpretations as "skating crystals."

After receiving his doctorate from M.I.T. in 1939, he was invited by Professor Charles Palache to join the Mineralogical Department of Harvard University as Research Associate. Among his other activities there he found time to begin studying urinary calculi in collaboration with the physician Dr. E. L. Prien, and published occasional papers on their findings. This culminated in a first definitive account of the crystallography and composition of these troublesome stones, and their classic 1947 paper was deemed so important that it evoked 5,000 requests for reprints.

Although the war interrupted his normal activities, it did not suppress his connection with mineralogy. With the title of senior physicist for the War Department, mineralogist Frondel, aided by a small group of co-workers, set up the quartz oscillator-plate industry and provided it with technical assistance; in this general field he incidentally accumulated six patents. He closed this general line of endeavor at the end of the war by editing the "Symposium on Quartz Oscillator Plates" published by *The American Mineralogist* in 1945.

Contact with piezoelectrics involved him in an interesting first in the field of mineral synthesis; he was the first to synthesize that recalcitrant mineral, tourmaline. The caliber of this accomplishment can be put into perspective if I tell you that when Waldemar Lindgren taught economic geology at M.I.T., he offered a doctor's degree to any student who would synthesize tourmaline and describe his experiments on ten pages. But this was not the only pioneering in mineral synthesis to come from Frondel; star rubies and sapphires are also the products of his imagination.

His list of publications is bespeckeled with descriptions of many new minerals; indeed, he has described 35 new species to date, which is prob-

ably a record for all time, and he also discredited many more. More recently, the pressure to find sources of fissionable materials led Frondel to consider the mineralogy and geochemistry of uranium and thorium. He completely revised their mineralogy, and made himself a world's authority in this field.

Frondel has always had a feeling for the timely in mineralogy. During the war it was quartz-crystal technology. When fissionable material was needed, it was the mineralogy of uranium and thorium. Now that planetary exploration is timely, we find him active on the Committee on Lunar Geology. During the last three years he has been involved in the mineralogy of meteorites, in which study he is using that timely tool, the electron probe.

Incidental to all this research activity, he has found time to be a teacher and curator. In 1946 he was appointed Associate Professor at Harvard University, and in 1954, Professor of Mineralogy. He also holds the post of Curator of the Mineralogical Museum. In addition to supervising numerous graduate students, he also teaches two courses in x-ray crystallography and two more in crystal chemistry. With the help of his students, he has, incidentally, built up the world's largest collection of crystal models.

In all these activities, he has always remained a scientist, in the best sense of the word, and a friend and helper to other scientists. Many of us know how he has parted with a rare specimen from Harvard's Museum if it could serve us in a piece of research.

Frondel's service in mineralogy has been recognized by many honors. He was the first American Becke Medalist of the Mineralogical Society of Austria. He is a Foreign Member of the Accademia Nazionale dei Lincei, and of the Deutsche Akademie der Naturforschers, as well as a Corresponding Member of the Natural History Museum of Vienna and the American Museum of Natural History, and Fellow of the American Academy of Arts and Sciences. His Alma Mater of undergraduate days, the Colorado School of Mines, honored him with its medal last June. This Society honored him with its presidency in 1937. It is now about to bestow upon him its highest award, the Roebling Medal.

Mr. President, I take great personal delight in presenting to you, Clifford Frondel.

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ACCEPTANCE OF THE ROEBLING MEDAL OF THE MINERALOGICAL SOCIETY OF AMERICA

CLIFFORD FRONDEL, *Harvard University, Cambridge, Massachusetts.*

President Berry, Professor Buerger, Ladies and Gentlemen:

My interest in minerals began in High School, in the early 1920's, through the enthusiasm of a science teacher. It was immediately sharpened by collecting trips to the Branchville pegmatite, the zeolite locality at Great Notch and to other mineral occurrences in the New York area. The mineral collection of the American Museum of Natural History was an unfailing source of wonders and of information.

The questions of those days—what are minerals, and why do they occur as they do—still press on me. The what and the why are necessarily of equal importance, in the interplay of factual observation and theoretical interpretation that leads us to an understanding of nature, but they are not always of equal interest to the individual. Some take the high road; some, as did I, become descriptive mineralogists. Disregarding road signs later prominently displayed by Martin Buerger, during my graduate years at the Massachusetts Institute of Technology, I have continued in such work.

It is a particular satisfaction to me that this award carries the name and memory of Washington A. Roebling. He exemplifies the discriminating effort of the great private mineral collectors, mostly of the last century, to whom the preservation in museums of the specimen resources of our science is largely owing. The accessibility of these resources to the scientific worker, and their increase and use in ways that best serve mineral science, have been to me matters of concern and effort. In this, and in the coordination and compilation of the descriptive literature of mineralogy that forms my main work, I owe much to my association with Harry Berman and Charles Palache.

The Roebling Medal symbolizes the science that we love and serve. The merit that it carries is created by us all. The Mineralogical Society of America has conferred on me a great honor, that I accept with sincere and humble appreciation.

CLIFFORD FRONDEL

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PRESENTATION OF THE 1964 MINERALOGICAL SOCIETY OF AMERICA AWARD TO WILLIAM SEFTON FYFE

F. J. TURNER, *Geology Dept., University of California, Berkeley, California.*

William Sefton Fyfe, recipient of the Mineralogical Society of America Award for 1964, was born and educated in southern New Zealand. He took his Bachelor's Degree in both geology and chemistry and a Master's Degree in chemistry at the University of Otago, Dunedin, and in 1952 gained his Ph.D. in chemistry. He was lecturer and later reader in chemistry at Otago from 1948 to 1958. During this period he spent 2½ years on leave of absence (1953–1955) working at the University of California, first with J. Verhoogen in Berkeley, and subsequently with G. Kennedy at Los Angeles. From 1959 to the present time he has been on the faculty of the Department of Geology and Geophysics at Berkeley where he currently is professor of geology. His bibliography numbers some 50 items, more than half of which are under his sole authorship.

The value of Fyfe's contribution to mineralogy lies in the fact that he brings to bear upon geologic problems a keenly critical mind backed by wide experimental and theoretical experience in chemistry and an appreciation of pertinent geologic phenomena. Some of his papers are purely chemical. Such are "Isomorphism and Bond Type" (*The American Mineralogist*, 1951) and "The Problem of Bond Type" (*The American Mineralogist*, 1954); these constitute a significant application of theoretical chemistry to mineralogy. Others are critical essays on chemical theory and the philosophy of experimental practice in relation to geochemical problems, especially in the realm of metamorphism. These essays—*e.g.* that on "Hydrothermal Synthesis and Determination of Equilibrium" (*Journal of Geology*, 1960), and his discussion (with D. F. Weill as co-author) on "Treatment of Thermodynamic Equilibrium in Open Systems" (*Geochimica Acta*, 1964)—are especially valuable to the many petrologists like myself, who lack the rigorous training in thermodynamic theory and experimental experience that is so essential in modern petrology and mineralogy. A classic major contribution in this category is Fyfe's critical survey of the theoretical background and then-current experimental data of metamorphic reactions in the chapters that bear his name in *Memoir* 73 of the *Geological Society America* (1958). Although the purpose of the Memoir was to take stock of a changing situation, six years after publication this work stands up remarkably well in the light of subsequent data.

Fyfe has been equally active in the experimental field. Here his published work, dealing with such varied topics as the periclase-brucite reaction, the stability of anthophyllite, synthesis of aluminum silicates and zeolites, and the fusion of peridotites, is characterized by use of ingenious techniques, and rigorous scrupulously honest presentation and interpretation of his results. He presents his conclusions modestly as tentative findings upon to modification or rejection if and when superior data become available.

Fyfe's total contribution has a three-fold value. He has given us new data bearing on problems of metamorphism; his critical essays and excursions into geochemical theory are helpful and informative; his publications in both fields are a source of inspiration to colleagues and students alike.

Mr. President, I introduce to you for presentation of the Mineralogical Society of America Award William Sefton Fyfe.

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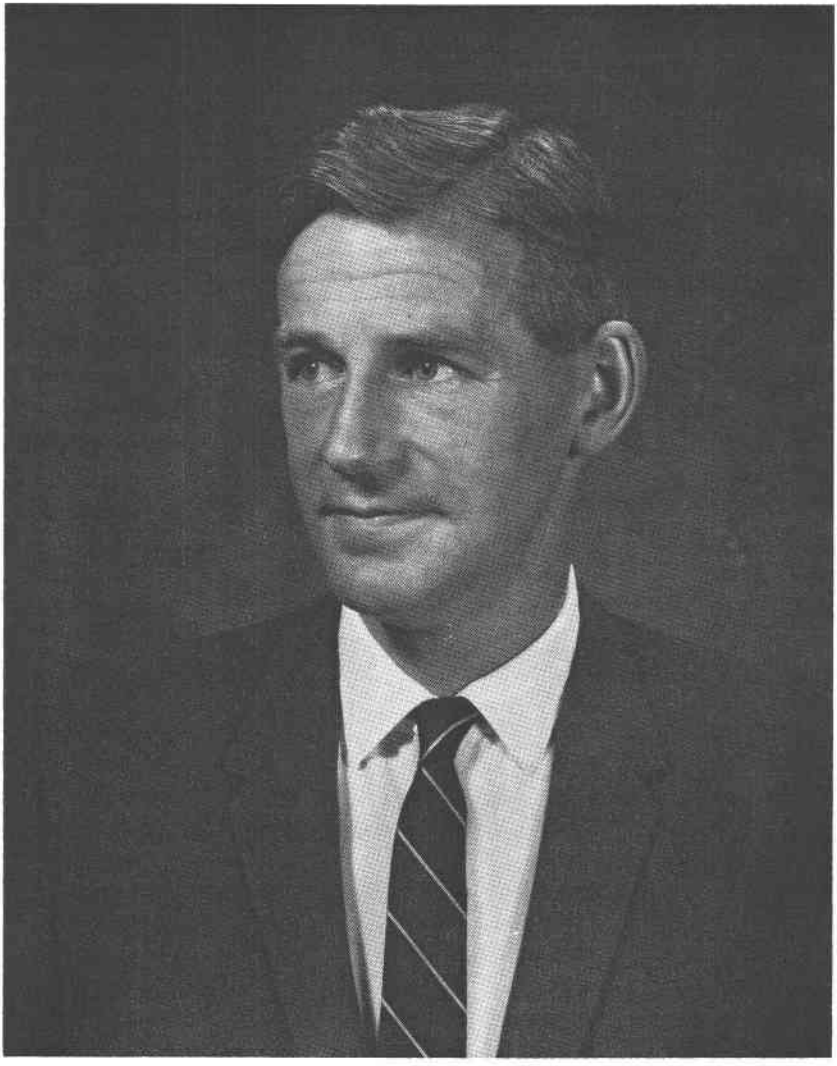
ACCEPTANCE OF THE 1964 MINERALOGICAL SOCIETY OF AMERICA AWARD

W. S. FYFE, *Department of Geology and Geophysics, University of California, Berkeley, California*

Mr. President, Professor Turner, guests, and fellow geologists:

It was a most pleasant surprise to receive a letter from Professor Berry telling me of this award. I think all of us today are impressed, and sometimes depressed, by the obvious insignificance, if not triviality of any individual contribution to modern science. To receive any form of recognition is thus a welcome reassurance. I think, too, that one feels just plain lucky, for with an exponential increase of scientists (perhaps negative in geology at the moment) and not of awards, many who are more deserving must necessarily be unlucky. One also feels that it is just as well that this award is given at an early age for early work. I am sure that many of my contributions will rapidly become a contribution to the best forgotten past.

I was fortunate from the start in being associated with men who were genuinely enthusiastic over geological research. First, at Otago, with W. N. Benson, who, while he might not have qualified for a good lecturer award, did inspire students through his own brilliant research activity in the entire spectrum of geology. Then with Prof. F. J. Turner who tried to teach me mineralogy and also presented a brilliant series of lectures on



WILLIAM SEFTON FYFE

invertebrate paleontology—before he left for Berkeley. Then Prof. C. O. Hutton carried on—before he left for Stanford. At this stage Otago University found itself so geologically naked that I was asked to teach mineralogy myself. But the perturbation of marriage, and the greater opulence of the department of chemistry, caused me to teach chemistry. The oscillation was reversed when I was able to join Professors Turner and Verhoogen at Berkeley and Griggs and Kennedy at U.C.L.A. for a most stimulating three years. I then returned to New Zealand and chemistry and was fortunate in having D. S. Coombs as a colleague and A. J. Ellis as my first Ph.D. student. But I must also pay tribute to a fine group of graduate students, including D. F. Weill, inquisitive and critical, who have done their best to keep me moderately honest.

The evolution of our ideas concerning the formation of rocks and hence much of the history of the entire earth, depends more and more on the integration of detailed observation and laboratory experiment. Today, with modern structural and analytical instrumentation, our ability to observe and describe has achieved new dimensions of detail and significance. The experimenter is more aware of the variables he must consider, the nature of their influence, and the limitations of his own methods. In the last few years we have seen this combined approach solve long-standing problems, and there is no doubt that the next decade will see a great acceleration of this trend particularly in the area of petrology, experimental petrology and geophysics. But the unknowns greatly outnumber the knowns, the guesses outnumber the facts, and a host of fascinating problems lies ahead. Their solution will advance all branches of physical science concerned with the states and reactivity of matter.