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THE HAWLEY MEDAL FOR 1989 TO CECIL J. SCHNEER

Ladies and Gentlemen,

The Hawley Award is presented annually to the author of the paper judged to be the best of those published in the previous year's volume of *The Canadian Mineralogist.*

It is my privilege to present the Hawley Award for 1989 to Professor Cecil J. Schneer for his contribution entitled "Symmetry and morphology of snowflakes and related forms". The citation prepared by the jury reads as follows:

"Classical crystallography excludes five-fold rotational symmetry, because a unit cell with such symmetry cannot be translated so as to fill space. Recently, however, five-fold rotational symmetry has been observed in X-ray diffraction films of rapidly crystallized alloys. These crystalline structures have been modeled by means of Penrose tilings, which make use of two different unit-cells to fill space, and may possess five-fold rotational symmetry.

Schneer's contribution to this problem is a new class of symmetry operations based on self-similar scaling and hierarchic invariance. In the point-symmetry case, these operations involve dilational recursive expansion about a fixed point, using a generative pattern and a point-group symmetry, and they result in crystalline structures that do not fill space. Three-dimensional Penrose tilings are shown to be a nondilational type of self-similar scaling that does fill space.

As examples of dilational point-symmetry, Schneer describes and analyzes the morphology and structure of silver iodide flakes, snowflakes and viruses. If recursion is unlimited, these structures may approach fractal dimensionality and properties.

Schneer's paper provides a new way to describe and classify crystalline ordering phenomena at the micrometer scale, where rapid growth of crystals at conditions remote from equilibrium may result in profoundly exotic morphology and symmetry. Five-fold rotation and translational symmetry are shown to be compatible. Although the thermodynamic implications of this new approach have yet to be fully explored, we believe Cecil Schneer to be a very worthy recipient of the Hawley Award for 1989."

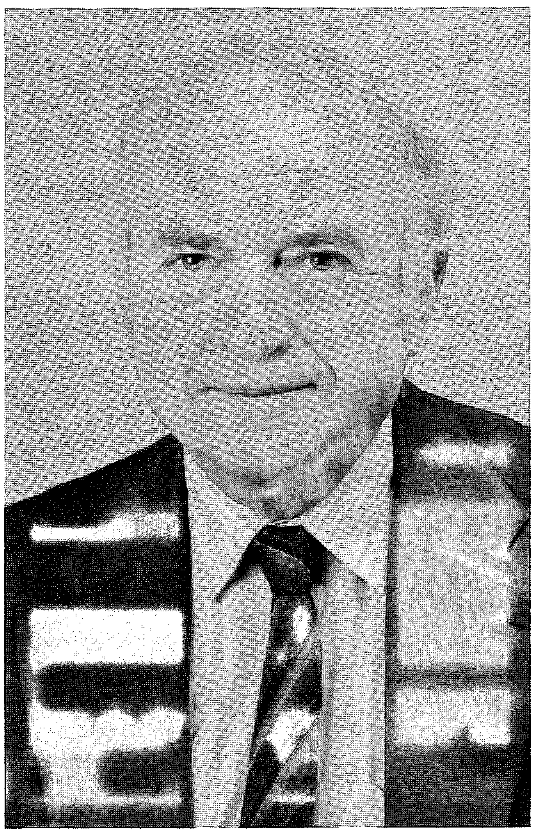
The author of this year's award-winning paper is a native of Far Rockaway, New York. He received his bachelor's and master's degrees from Harvard University, and his Ph.D in mineralogy from Cornell. He has been on the faculty of the University of New Hampshire since 1954, where he is now Emeritus Professor.

Cecil Schneer has compiled an extensive publication record in crystallography and mineralogy, especially in the thermodynamics of phase transformations, crystal morphology and structure, and hierarchic symmetry. He has also been actively engaged in the study of the history of science since his days at Cornell, and his two didactic texts "The Evolution of Physical Science" and "Mind and Matter" have just been republished.

J.M. Duke
President

Mr. President, Ladies and Gentlemen:

It is a decided honor to be here today to receive the Hawley Medal for my paper on the symmetry of snowflakes and related forms. It is particularly gratifying to win your approval for my attempt at



CECIL J. SCHNEER

expanding the boundaries of crystallography to include the natural world of the mineralogist. For my degree at Cornell I read not only geology with Bill Holser, but history of science with Henry Guerlac. They came together in von Laue's introduction to the Crystallographic Union's Anniversary volume, which traced the beginnings of atomic crystallography to Johann Kepler's "New Year's Gift of Hexagonal Snow" of 1609. Kepler had ignored Euclid's proof limiting the regular solids to the Platonic five and demonstrated two additions, a challenge to the revealed truth of geometry that haunted me for forty years. The dilational symmetry of my paper in *The Canadian Mineralogist* relates Kepler's additions to the Platonic solids, with their forbidden five-fold symmetry, to Kepler's snowflakes with their orthodox hexagonal symmetry as prescribed by "material necessity" (his newly discovered geometry of close-packing).

My thesis research was an explanation of polytypism as a cooperative phenomenon analogous to ferromagnetism. Its publication in *Acta Crystallographica* won me the X-ray equipment to attempt the diffraction analysis of phase transformation in real time. I had tried to work with zinc sulfide, which was known to exhibit the polytypic behavior of silicon carbide, but both compounds required relatively high temperatures. I turned to silver iodide, which is isostructural with ZnS and an analog of ice. AgI went through structural hoops at easily manageable temperatures; I showed that the analogy with ferromagnetism was complete, up to and including the hysteresis behavior.

This work brought me the opportunity to spend a year growing crystals at Georg Busch's Festkorper Institute at Zürich. Busch advised me to start with Rochelle salts. It was quick and easy, he told me, and in a pinch you can use it as a laxative. I was interested in the relationship of morphology to crystal structure. We wrote programs for Fourier analysis using morphological rather than diffraction data. It amounted to getting rough maps of the atomic structure by counting the numbers of times that different faces appeared on the crystals of a given species. This work, which provided quantitative extension of the Bravais–Donnay–Harker relations, brought me the encouragement and assistance of Gabrielle and José Donnay.

The love of travel planted in my first job as mining geologist at Morococha, Peru found expression for many years in my pursuit of conferences and field trips. A casual invitation on an English mine dump during the 1966 IMA led me to a year at Milan and an enduring romance with Italy and all things Italian. I have not mentioned in all this the influence of my wife, an art historian and part-time Africanist. It was in her behalf that our itineraries, geographic and intellectual, encompassed Australian pictographs and the Viennese Pinakotheque. The first time we travelled in Italy, we entered on a compromise arbitrated by my daughter, one museum or church to one volcano. Through their eyes, I learned to see that there was nothing more real, more 'natural' displayed by a classical Greek statue than by an Eskimo carving or a Mayan frieze.

About five years ago, as I began to slip into retirement, I came upon accounts of Mandelbrot's fractals, accounts which I read with horror because they challenged my lifelong preoccupation with what Friedel had termed "the reticular hypothesis". Instead of the periodicity, the rigorous order, and the security of kinetic–molecular theory, Mandelbrot's work invoked a world that was but a mote in the eye of the Buddha, a mathematics of singularities and infinities, a physics of effects totally disproportionate to causes. It was immediately applicable to snowflakes, those least limits of the fractal distribution of H_2O in the atmosphere. Ichiro Sunagawa invited me to Japan to discuss my morphological maps of atomic periodicities, but I arrived with talk of nonlinear iterative functions, and found them already there in the studies of quasicrystals. Back in New Hampshire, I resurrected my 30-year-old flakes of AgI, put them under an electron microscope and discovered to my very great surprise that the world on the scale of the micrometer was neither an extrapolation upward of the world of X-ray diffraction, nor an extrapolation downward of the world at the scale of the visible.

My geological career spanned major revolutions in thought. I lived through the first, crustal mobilism, without particularly appreciating what was going on. For the second, natural history's declaration of independence from the linear laws of physics, I was already involved by my early association with iterative structures, the polytypes, by my preoccupation with morphology and the reticular hypothesis, and by the long years with Kepler's and Leonardo's solids. It has always been one cathedral to one volcano.

I thank the editor of the Journal, the members of the selection committee, and the officers and members of the Mineralogical Association of Canada for this gracious recognition of my work.

Cecil J. Schneer
University of New Hampshire