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The 2011 Benjamin Franklin medal in Earth and Environmental Science presented to Jillian F. Banfield

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Abstract

The Franklin Institute, Philadelphia, Pennsylvania, awards the 2011 Benjamin Franklin Medal in Earth and Environmental Science to Professor Jillian F. Banfield for her pioneering work in the fields of geochemistry and environmental microbiology, in particular her discoveries of the underlying principles of mineral formation and alteration by microbes and her efforts to advance the understanding of the form, composition, and distribution of minerals in the presence of living organisms.

Introduction

Professor Banfield is recognized as a leader in the application of electron microscopy techniques, especially high-resolution transmission electron microscopy (HRTEM), to investigate the mechanisms of crystal growth and alteration in minerals. Combined with her deep knowledge and understanding of mineralogy and crystal chemistry, she and her colleagues used HRTEM methods to elucidate the detailed mechanisms of mineral alteration reactions, including reactions important to understanding metamorphic phase changes and environmental deposition and weathering of minerals.

Working from her foundation of HRTEM expertise and knowledge of mineralogy and crystal chemistry, Banfield also established herself as a leader in understanding the

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processes by which micro-organisms mediate mineral alteration, including weathering reactions, crystal growth, and microstructure development.

In subsequent work, drawing on rapid advances in genomics, Banfield and the team of co-workers she assembled tackled the problem of understanding natural microbial communities and their metabolic relationships with their environment. This work is especially significant because most wild micro-organisms remain uncultivated. While many challenges remain, the Banfield team showed that the combination of microscopy and whole-genome "shotgun" sequencing could reveal details of the genetic basis for the energy pathways of micro-organisms and their communities, thus pointing the way for more discoveries relevant to biology, ecology, and geology.

Technical background

Three lines of investigation characterize the intellectual flow of Banfield's scientific career to date. The first line of investigation involves abiotic processes, that is, natural processes that do not involve living organisms. Her work in this line is based on crystal chemistry and electron microscopy and has included mechanisms of mineral weathering and alteration, studies of microstructure and disorder in mineral crystals, phase stability and transitions in minerals, bulk and surface properties of minerals, and the structure and behavior of mineral nanoparticles. This line originates with her BSc honors thesis (mid-1980s) and continues in some of her most recent publications. The second line of investigation brings microbiology to bear on questions of mineral weathering and alteration leading to an understanding of microbial mediation of those processes and the coupling of microbial and geochemical processes. This line can be traced from the mid-1990s to recent publications. The third line of investigation links the methods of genomics to her studies of microbially mediated mineral weathering and alteration and has led to important discoveries of how natural microbial communities interact with their environments.

Banfield's first publication in 1985 reported work from her BSc honors thesis with Richard Eggleton at Australian National University. In this work, we see two important contributors to her long-term success. The first is a mastery of crystal chemistry. The research was an investigation of the alteration of biotite to chlorite. Biotite is an iron-rich mica, the "black mica" commonly occurring in granite, and chlorite is a mineral formed by alteration of biotite. Both biotite and chlorite are layered or sheet-like aluminosilicate structures, but the layering patterns and crystal chemistry are different. Banfield's knowledge of crystal chemistry led her to propose a reaction stoichiometry expressed in unit cells of the mineral structures that fit the observed changes in the structures. The second contributor to her long-term success is her mastery of electron microscopy technique. For this work, Banfield used transmission electron microscopy (TEM), not the high-resolution technique she was able to adopt in later work, but it was sufficient to make the necessary observations in altered crystal structures to substantiate the proposed reaction stoichiometry. She was later able to return to this research using HRTEM and refine the reaction model proposed in 1985.

After completing an MSc at ANU with Eggleton, continuing her work on the alteration of granite, Banfield moved to Johns Hopkins University to join David Veblen's research group, where she encountered advanced high-resolution transmission electron microscopy (HRTEM) and analytical electron microscopy (AEM) instruments and flourished. Some of her work with Veblen included studies of structure and disorder in mineral crystals, but her