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Exciting Frontiers Await at Scientific Boundaries
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An example from the Deep Carbon Observatory

Robert M. Hazen

Great opportunities lie at unexplored boundaries among scientific disciplines. Compelling examples abound in the earth sciences — scenarios of planetary formation and differentiation, models of the evolution of oceans and atmospheres through deep time, the plate tectonics revolution and ongoing efforts to understand life's origins — all of which required the integration of evidence from many specialties. Yet most scientists spend most of their lives engrossed in specialized nooks. Every so often an opportunity arises that lets us break out of our specialties, to join together and start new endeavors. The Deep Carbon Observatory is a prime example of one such endeavor.

Fifteen years and more than $15 million in NASA funding later, an expanding Carnegie team is at the center of the burgeoning field of astrobiology.

My career, until recently, was a model of scientific specialization. For a quarter-century, my research at the Carnegie Institution of Washington, D.C., had focused on high-pressure crystal chemistry of rock-forming minerals. A steady flow of government funding, and an equally steady output of specialized experimental results, justified this effort. Life was good.

In 1989, while still at Carnegie, I also joined the faculty of George Mason University in Virginia to work with physicist and science writer James Trefil on a new science curriculum for nonscience majors. Jim and I advocate connecting the physical and life sciences into a single course — a philosophy espoused in our popular bestseller "Science Matters: Achieving Scientific Literacy" and in an undergraduate textbook, "The Sciences: An Integrated Approach." In these books, we emphasize a few overarching scientific ideas — such as energy, atoms, forces and evolution — that transcend disciplinary boundaries.

Yet for several years, what we advocated in the classroom didn't affect what I did in the lab. I delved into ever-more-nuanced details of high-pressure crystal chemistry. But an epiphany came in 1995, when I finally realized two important facts. First, one's research career is finite — lasting a few decades at most. Second, some scientific questions are more important, more fundamental than others. High-pressure crystal chemistry, I decided, while fascinating, was not at the nexus of any big unanswered question. It was time to try something new.

The geochemical origins of life quickly rose to the top of my to-do list. A few years earlier this fundamental question had taken an unexpected twist, when rich ecosystems were discovered in the deep, dark, volcanic environs of seafloor "black smokers." Several scientists posited a deep, high-pressure, high-temperature origin of life, but no group had yet tested those ideas experimentally. The Carnegie Institution's Geophysical Laboratory was well-equipped to handle such questions, and we had just hired organic geochemist George Cody. At first it was just George, veteran petrologist Hatten S. Yoder Jr. and me. We explored a few aspects of these uncharted waters and found that organic synthesis, including the production of key biomolecules, could have occurred at the vents. Now, 15 years and more than $15 million in NASA funding later, an expanding Carnegie team is at the center of the burgeoning field of astrobiology.

My switch to origins research has paid other significant dividends. Aware of our efforts, the Alfred P. Sloan Foundation approached us in 2008 about the possibility of funding an international program related to the origins of life within Earth's crust. We countered with an ambitious proposal to study all aspects of deep carbon — the cornerstone element of life — from the crust to the core, including deep organic synthesis and deep life.

The result is the Deep Carbon Observatory, a new 10-year program to achieve fundamental advances in our understanding of carbon's chemical, physical and biological roles in the planet. This international effort has already recruited hundreds of researchers in more than two dozen countries.

Carbon is an astonishingly versatile element, profoundly important to ongoing concerns about energy and resources, the environment and climate, health and the science of materials. Yet we remain quite ignorant of the chemical, physical and biological roles of carbon in our planet. Current estimates of Earth's store of carbon vary by a factor of 30. The nature and extent of major mantle and core carbon repositories are even more uncertain. We don't know the speciation of deep carbon-bearing fluids or how those fluids move within and between the mantle and crust. Ongoing debates rage about the extent to which hydrocarbons and other organic species might be produced abiotically in the crust and upper mantle, and whether such processes may have played a role in life's origins. A growing body of evidence hints at a vast subsurface microbial biosphere, but we have yet to discover the nature and limits of deep life.

As we embark on this new research adventure, we invite scientists of every background to join us.

As we embark on this new research adventure, we invite scientists of every background to join us. Visit https://dco.gl.ciw.edu to see where you might fit in. The 10-year goals of the Deep Carbon Observatory are ambitious, but with the combined efforts of the international research community, we aim to achieve a transformational understanding of carbon's chemical and biological roles in Earth.

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