J. LAURENCE KULP AND GEOCHEMISTRY AT COLUMBIA

While Maurice Ewing applied physics to geology, J. Laurence Kulp blazed his own trail—infusing chemistry into the discipline to create a scientific "Garden of Eden."

In the pioneering postwar years of earth sciences research at Columbia, "two distinct scientific kingdoms existed," says Wallace Broecker '53C '58GSAS, now the Newberry Professor of Earth and Environmental Sciences. "The dominant one was Maurice Ewing's geophysics and marine geology realm. But running strong and independently was the isotope geochemistry program of J. Laurence Kulp."

"The early 1950s were heady days in the field of geology, which was being revitalized and transformed by an invasion of physicists and chemists with new techniques inspired by wartime research," Broecker says. "While Ewing blazed one trail, unleashing modern physics onto the study of the earth, Kulp just as eagerly rushed to infuse chemistry into geology, opening up wholly new and hitherto unexplored lines of inquiry."

The key to this rapidly blossoming field of geochemistry was dating—using the natural radioactivity of certain elements in rocks and water. These elements have known half-lives—the time required for one-half of a quantity of "parent" isotopes to decay into more stable "daughter" isotopes. A specimen's age can be computed by measuring the relative amounts of daughter isotopes and remaining parent isotopes. "Analyzing samples gives you a 'when,' providing a good start to figuring out a 'how,'" says Broecker.

In 1949 Kulp had gone to Willard Libby's laboratory to learn Libby's Nobel Prize-winning radioactive carbon-14 dating method. He brought the technique back to Lamont, perhaps the first lab to apply it to geology. Carbon-14, incorporated into all organic matter, offered a built-in clock to date plant and animal material. But the periodic chart contained an alphabet of isotopes, from beryllium to uranium, that allowed scientists to date and trace a variety of processes occurring throughout the earth system.

Knowing where and when isotopes entered oceans, lakes, or rivers, for example, geochemists could begin to track circulation patterns in these water bodies. They could use isotopes to study gas exchanges between ocean and atmosphere and to unravel the oceans' role in regulating the planet's climate. They measured isotopes in seafloor sediments, volcanic seafloor rocks, fossilized coral reefs and glacial ice to learn how Earth's climate changed, how the earth system operates, and how it might respond in the future.

"When we first started out, the field was wide open," Broecker reminisces. "There were so many interesting questions ripe for plucking. The lab was open 24 hours a day, seven days a week, anytime anybody wanted to come in and work. Exciting new results poured in weekly and everyone in our group discussed them spiritedly and freely, all of us equals in a field too young to have developed a hierarchy. . . . It was a scientific Garden of Eden."

In 1953, they began to measure occasional spikes of high radioactivity, which at first they blamed on "bugs" in their still-nascent techniques and equipment.

"Then it hit us," Broecker says. "Could it be we were picking up traces of fission products wafting over to New York from atomic tests that had recently begun at the Nevada test site? Sure enough, we were."

Soon after, Kulp's mentor, Libby, who was a member of the Atomic Energy Commission (AEC), called a meeting of high-level scientists to discuss the potentially harmful ramifications of radioactivity released into the atmosphere by nuclear weapons tests.

LAMONT- DOHERTY EARTH OBSERVATORY

"Kulp had the temerity to volunteer that the Lamont lab could prove that low levels of strontium-90, an isotope produced by atomic bombs, could be measured accurately enough to track nuclear fallout," Broecker says.

A critical AEC meeting was scheduled three weeks later, so the Columbia geochemists worked around the clock. They successfully measured radioactive strontium in soil, a calf bone, and Wisconsin cheese. They showed that radio-strontium had settled onto soil and had been incorporated into grass, which was eaten by cows that produced milk for the cheese. Eventually humans would eat that cheese, as well as vegetables grown in soil. Concern grew that radioactive strontium might be absorbed into human bone, inducing cancer-causing mutations, especially in growing children. Further, strontium retained its radioactivity for thirty years and it remained airborne long enough to be carried over wide distances, making strontium-90, as Libby put it, as ubiquitous as sunshine.

"Thus 'Project Sunshine' was launched to understand the fate of radio-strontium, radio-cesium, and other nuclear fallout isotopes," Broecker says. "Over the next decade, nearly 10,000 samples of human bone samples, mostly from cadavers from countries on all continents arrived [at Lamont], at what came to be known as 'Kulp's Kitchen,' where they were cremated into ash and tested for strontium-90 content. The study, in many ways, launched a Lamont tradition in geochemistry of tackling global environmental questions: Its objective was to determine how much strontium-90 ended up in human skeletons in people of different ages, locales, and dietary regimes all over the world. The results, published by Kulp, Walt Eckelmann, and Arthur Schulert, clearly helped persuade politicians to negotiate the treaty banning atmospheric testing of nuclear weapons.

"As the 1950s drew to a close, Kulp's original geochemical children dispersed to populate positions at major universities, oil companies, and industries and to spawn ever-branching new generations in the ever-widening field," Broecker says. In the early 1960s, Kulp and two former Columbia students started a business, Isotope Inc., leaving Columbia geochemistry in Broecker's hands. The tradition of boldly tackling environmental questions has never slowed down. Here are some highlights:

Since the 1960s, Taro Takahashi '57GSAS, a Doherty senior research scientist, has spearheaded efforts to find out how the vast oceans absorb and store the greenhouse gas, carbon dioxide—a critical factor for understanding and managing potential global warming.

Meanwhile, Broecker and his students, analyzing isotopes from seafloor sediments, corals and elsewhere, launched successful, ongoing quests to understand the driving forces and mechanisms behind the ice ages and other climate changes.

In the 1970s, Broecker co-led an ambitious fundamental study of the world's oceans: the Geochemical Ocean Sections Study, or GEOSECS. Over a decade, scores of geochemists from major oceanographic laboratories roamed the world's oceans, measuring for the first time the distribution of assorted isotopes, elements, and compounds throughout the oceans. They used them as tracers to map and measure the deep circulation of the ocean and to reveal other previously unknown ocean processes. To this day, GEOSECS results still provide the underpinning for virtually all studies of marine chemistry.

Also, in the 1970s, Columbia scientists and students helped launch pioneering studies to identify the impact of metal pollutants, acid rain, and other factors on lakes. They proved that phosphates supplied nutrients that dramatically disrupted lake ecosystems, which led to the banning of phosphates in detergents. Today, the Columbia graduate students who conducted these experiments hold key environmental positions.

Columbia also turned its geochemical attention to rivers, as Professor James Simpson and his students sought to understand the circulation, sedimentation, and chemical processes of the rapidly deteriorating Hudson River. They studied the spread of highly toxic polychlorobiphenyls (PCBs) spilled into the upper Hudson by General Electric and played a large role in campaigns to curtail the dumping of sewage and other pollutants.

Meanwhile, Columbia "hard-rock" geochemists, originally led by Paul Gast, explored geochemical processes within the solid earth. In recent years, Professor David Walker designed and built his own laboratory device to simulate the enormous pressure conditions deep inside the earth, which he and his students used to shed light on dynamics within Earth's mantle. Professor Charles Langmuir and his students became known for their work on volcanism and the volcanic processes that create new seafloor.

In the 1980s, Broecker combined his research on climate and ocean circulation in a stunning new theory: the Great Ocean Conveyor. In brief, he proposed that Earth's global circulation of the oceans has changed in the past and could again in the future. Because the oceans circulate heat around the planet like the ducts that circulate heat throughout your house, any disruption in ocean circulation has huge impacts on Earth's climate. The theory had strong repercussions. Today, scientists around the world continue to search for clues to reconstruct how Earth's oceans and climate operated in the past and to identify how they could change abruptly or dramatically in the future.

At Columbia, for example, Peter Schlosser, Vinton Professor of Earth and Environmental Engineering and chair of the H. Krumb School of Mines, leads efforts to measure tritium and helium-3 to track cold, dense waters that sink deep into the ocean and propel the Ocean Conveyor. Martin Stute, now adjunct associate research scientist at Lamont, pioneered a technique measuring noble gas concentrations in aquifers to determine air temperatures thousands of years ago. Lamont scientist Pierre Biscaye uses telltale isotopes in tiny particles trapped in glacial ice to reveal ancient atmospheric dust levels and winds patterns. Tanzhuo Liu, associate research scientist at Lamont, analyzes micron-thin coatings on desert rocks to reconstruct wet and dry cycles. Assistant Professor Sidney Hemming analyzes lead and argon isotopes in grains of rocks that were frozen into the bases of advancing glaciers, carried out to sea, deposited on the ocean floor and buried by subsequent sediments—to chronicle dramatic climate shifts in the past that launched iceberg armadas.

"Fifty years after J. Laurence Kulp established the geochemistry group, it thrives with a continuing infusion of bright young men and women," Broecker says. "Their ideas have always been given equal status with those of more senior people, and in that spirit of cooperation and excitement, first engendered by Kulp, we continue to uncover fascinating and important new clues that further our understanding of how our planet works."

—Laurence Lippsett