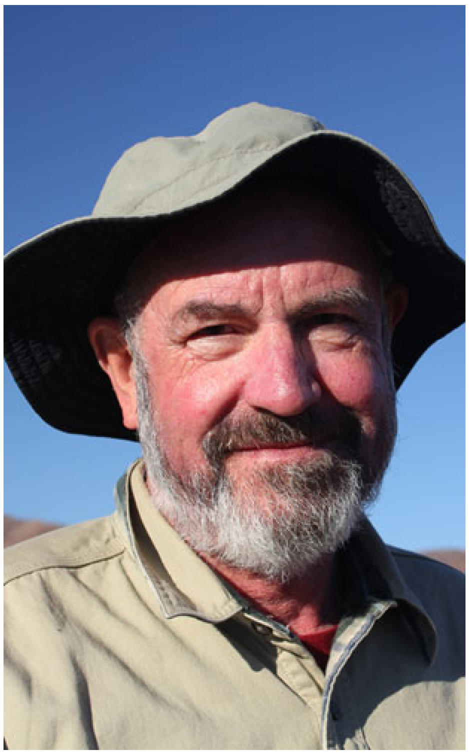
Summoned From the Depths

Geobiologist Roger Summons analyzes organic material in rocks found deep inside Earth, looking for evidence of how life originated and evolved on our planet—and possibly on Mars.

By Anna Azvolinsky | March 1, 2014



ROGER E. SUMMONS
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PHOTO BY PHOEBE A. COHEN

In 1979, Roger Summons was a research officer at the Australian National University (ANU) in Canberra studying photosynthesis and the structure of plant hormones. His perspective on science was about to change, thanks to two visitors to the university from California. The first was UC San Diego biologist Andrew Benson—one of the three scientists who elucidated the fixation of carbon in photosynthesis (known as the Calvin-Benson-Bassham cycle). Summons was charged with managing the logistics of Benson's sabbatical in Australia to ensure it was a fruitful one.

Benson took Summons on the young researcher's first field trip—to the Great Barrier Reef, where the two conducted studies on the accumulation of arsenic in marine algae and invertebrates. "It was observing him at work and discussions with him about how science works that changed my perspective completely," Summons recalls.

A short time later, at the Australian Institute of Marine Sciences in Queensland, Summons met earth scientist Preston Cloud of UC Santa Barbara. Cloud was studying the beginnings of life on Earth by coordinating discoveries about early microfossils with Earth's geological record. He was particularly concerned with how and when oxygenated oceans created an environment conducive to the evolution of complex life. "Cloud gave a seminar, and I was just in awe of the work. It was the first time I came in contact with a researcher who was integrating biology, chemistry, and geology to come up with ideas that had never been previously appreciated."

Back at the ANU, Summons invited Cloud to give a seminar on the origin of oxygenic photosynthesis on Earth to his plant physiology colleagues. "Here is this guy talking about how the Earth has changed over billions of years, and he is talking to scientists who are interested in what happens at the surface of a leaf when the sun comes up every day! The time scales could not be more different."

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Influenced by Cloud, Summons applied to join the Baas Becking Geobiological Laboratory at the Bureau of Mineral Resources in Canberra, kicking off his career as a geobiologist studying how life on Earth evolved as its environment changed.

Here Summons talks about the random path of his early career, getting hooked on microfossils, and whether there could be life on Mars.

Summons Surmounts

Country life. Summons grew up in a small country town west of Sydney, Australia. "It was an industrial town with coal mines, a small-arms factory, and woolen mills, but it was really at the end of its industrial life after World War II," Summons remembers. He attended a small high school with hands-on science classes that sparked his interest. "We had to really engage in the laboratory right away, learning to titrate and measure things. I really enjoyed this 'doing' of science much more than sitting in math class—and I was better at it."

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Phytochemical surveys. After receiving a bachelor's degree from the University of Wollongong, which was then a college within the University of New South Wales, Summons stayed there to pursue a PhD in chemistry. For his doctoral work he analyzed the chemical structures of plant compounds using nuclear magnetic resonance spectroscopy and mass spectrometry. "Because of the diverse and unusual flora in Australia, there was a great interest in exploring plants and discovering unique compounds with physiological activity."

Carpe diem! At the end of graduate school, Summons was offered a postdoctoral fellowship at the University of Cambridge in the U.K. But then chemist Berthold Halpern moved to Wollongong from Stanford University and something unexpected happened to Summons. Halpern studied exobiology—the search for life beyond Earth—and was also interested in improving detection of metabolic diseases in newborn babies. Both of these very disparate topics rely on analyses using coupled gas chromatography–mass spectrometry (GCMS), a method used to identify substances found in a sample after separation by gas-liquid chromatography, in which Halpern was an expert. "'You don't want to go to Cambridge to study natural products,' Halpern told me. 'You want to go to California and try something different,'" Summons remembers. "I was mulling this over, and the next thing I know is that I have a letter from Stanford with an unsolicited postdoc offer." Summons seized the opportunity, spending the next two months writing his thesis and packing his bags for California. "This was a life-changing experience for me because it was the first tangible opportunity to engage in research beyond the world of organic chemistry."

Technology boom. At Stanford, Summons worked with Alan Duffield on the analysis of organic components in blood and urine using GCMS, just as the method was coming into vogue for studying life-science problems. "In those days, connecting a gas chromatograph to a mass spectrometer was a very new thing," says Summons. There was suddenly unprecedented access to a lot of data, and processing the data required the advent of computerized mass spectrometry. "We were working on both the analysis and efficient ways to process the information. I was developing methods to study amino acids and other biomolecules."

Productive meandering. As a graduate student and postdoc, Summons had no clear focus, instead doing what came easily and what was offered to him. "I basically analyzed other people's samples," he says. "I just liked working in the lab, analyzing things, and I was reasonably good at it." After his time at Stanford, he went back to Australia for another postdoc at the ANU "I spent over eight years in total analyzing plant hormones, identifying new structures and developing new quantification methods."

Super Summons

Chemical fossils. Through Cloud, Summons met geologists and microbiologists at the Baas Becking Geobiological Laboratory and landed a position to establish a program in organic mass spectrometry. "This was my first job where I had responsibility to independently define a research program," says Summons. The many experiences and influences he had acquired by working with world-renowned geologists and biologists put him in a position to combine biology, chemistry, and geology. Summons analyzed rock samples for the presence of trace organic molecules that signaled the presence of life during critical periods of Earth's history. His work demonstrated that it was possible to detect complex organic compounds—called biological marker compounds, or "biomarkers" for short—in oil and rock, linking them to specific organisms that had thrived on Earth in the past. This analysis of molecules harboring information about the organism that made them was a relatively new way to study evidence of life on Earth, complementing the use of the fossil record.

A new beginning. After working as a research scientist at Baas Becking Laboratory and Geoscience Australia, the government's national geological survey, for 18 years, Summons wanted to return to academic pursuits and seek new challenges. His research at Geoscience had become increasingly less basic, more applied, and more bureaucratized. In 2001, he accepted a professorship in geobiology at MIT. "The idea that the Earth we have today is not just a result of rock cycles—chemistry and physics—but is very much a function of the interaction of these things with biology was not widely appreciated," says Summons. "When I went to MIT, our program was one of the first geobiology initiatives in the U.S." The boom in geobiology over the last decade can be traced to a few insightful individuals who supported research and education programs on the topic, particularly the nonprofit grant-issuing Agouron Institute, says Summons. The growth of the discipline is also partly attributable to the availability of genomics tools to study the evidence of microbes in Earth's surface environment as well as in the oceans and their underlying sediments. "Paleobiology used to be largely about documenting fossils that are visible to the naked eye. But there are now many other lines of evidence that, from the beginning, the Earth has been influenced by the life that has inhabited it, including the chemical, isotopic, and molecular signals that are produced and that accumulate within sedimentary rocks. Once scientists realized the depth of that interaction, geobiology really began to flower."

The source of life. Summons is now studying how biogeochemical cycles have changed over the billions of years of Earth's history, making early life possible. "This is a problem that I have worked on for many years. We have tectonic cycles that have resurfaced the Earth, as well as the carbon, water, nitrogen, phosphorous, and trace-element cycles. We are trying to understand how and when these cycles changed from operating on a local scale to a global scale."

Samples to call his own. Only recently have geologists had access to fresh core samples from deep inside Earth. "For years, we were studying drill cores discarded by industry. Often these samples would be exposed to the elements for months, and it was difficult to know whether they had been contaminated. The geobiology community now appreciates the importance of accessing fresh rocks that have not been influenced by weathering."

Earth and beyond. At MIT, Summons joined one of the first teams funded by the NASA Astrobiology

Institute (NAI), and he is currently leading a new five-year project that aims to understand how complex life developed on Earth and how its record becomes preserved in sedimentary rocks. The research will be applied to analyzing data from the Mars *Curiosity* rover, one of whose goals is to reconstruct the planet's history of habitability. "We are trying to understand to what degree the environment controls the preservation of the geobiology record. Rather than a clear glass window, what we have are little holes through which we can peer and find evidence of life from the past, both on Earth and, potentially, on Mars." Summons and a postdoc are working at reproducing the chemical behavior of Martian sedimentary rocks based on evidence collected by Mars rover missions. "We infer the types of chemistry of Mars soils and produce and test the behavior of these compounds. This helps the bigger team narrow down possible conditions on Mars." One of *Curiosity*'s missions is to search for organic carbon to address whether there is now or could have been life on Mars. The project, says Summons necessitates an extraordinary number of talented and dedicated scientists. "There are many, many steps to get a single data point."

The big question. "My personal opinion is that there is currently no tangible evidence that Mars is alive. But we probably have not yet looked at enough types of rocks to know whether it was ever alive in the past. With more data, we may be able to infer whether Mars was ever wetter and warmer." Smaller than Earth, Mars almost certainly had a heavier atmosphere at some point, says Summons. "When it lost its atmosphere and its water is a significant question that we cannot answer yet."

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Ready for a challenge. "I recommend that anyone in science change their career a couple of times during their working life," says Summons. "There is something about giving yourself a challenge that stimulates the scientific mind. There are plenty of 'lifers' I know who have been at a single institution and have very successful careers. But for me, reinvention has been the path of discovery that has been enriching."

Summons Surmises

Adventures in California. "The move to Stanford from Wollongong was only the second time I had ever been on an airplane. My wife and I were married for about 18 months by then and had been living near our parents. This was really embarking on a scientific and a life adventure for the two of us."

Go with the flow. "It was a slow journey of enlightenment for me. I was a student and a postdoc for a long time. Early on, everything I did was colored by a very narrow range of experiences and understanding. I did science in my early career, but I had no clear goal at first. Now so many college, graduate students, and even high school students that I see have strong career path ideas, which is wonderful."

Chance encounters. "The biggest and best moments in my career have been as a result of serendipitous collaborations with people I met at meetings, or who would visit the lab."

A scientist is not an island. "We live in a very interesting time in terms of the way science is developing from a more individual pursuit to one that is tackled by large groups of scientists. A prime example is the NASA Mars Science Laboratory mission. The problems we try to solve are ever-increasingly large and complex. No individual has all of the knowledge and skills to address the problems and questions of science—it needs to be done through collaborations."

Greatest Hits

- Developed methods for analyzing complex organic samples using gas chromatography–mass spectrometry.
- Developed computational techniques for detecting amino acids in meteorite samples to study whether life could have existed, or has existed, on planets other than Earth.
- Discovered that green sulfur bacteria (photosynthetic obligate anaerobes) thrived in the oceans during the Paleozoic Era, 300 million years ago, providing evidence for the existence of anaerobic conditions near the surface of ancient seas.
- Developed molecular proxies for oxygenic photosynthesis to study the biogeochemistry of the Precambrian.
- Produced a significant body of work on the bacterial lipids known as bacteriohopanepolyols (BHPs), including occurrences in the environment and in ancient sediments and petroleum.

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