ASU professor 'follows the elements' to understand evolution in ancient oceans

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In the search for life beyond Earth, scientists 'follow the water' to find places that might be hospitable. However, every home gardener knows that plants need more than water, or even sunshine. They also need fertilizer – a mixture of chemical elements that are the building blocks of the molecules of life. Scientists at Arizona State University are studying how the distribution of these elements on Earth – or beyond – shapes the distribution of life, the state of the environment and the course of evolution.

Ariel Anbar, a professor in ASU's Department of Chemistry and Biochemistry and the School of Earth and Space Exploration in the

College of Liberal Arts and Sciences weaves together threads from geoscience, chemistry, biochemistry and biology in his article published in the Dec. 5 issue of *Science*. The "Perspectives" article reviews what we know about changes in the availability of some key nutrients in the oceans over the sweep of geologic time and suggests future directions for research.

"The history of our planet is like a natural laboratory of 'alternative worlds,'" says Anbar. "The chemical composition of the oceans has changed dramatically over billions of years. Elements that are abundant today were once scarce, and elements that are scarce today were once abundant. So Earth's ancient oceans are a good place to go if we want to understand how organisms and ecosystems evolve to cope with changing abundances of elements. Studying the ancient oceans also stretches our minds to imagine what we might find someday in alien oceans on other worlds."

Visiting billion-year-old oceans is not so easy, however. Anbar explains that biogeochemists cannot directly sample oceans of the past but make inferences about their compositions by examining sedimentary rocks that were deposited on ancient sea floors. For example, the ocean floor rocks from the first half of Earth history include massive deposits of iron oxide – essentially, rust. Those rusty rocks tell us that the oceans in those days were rich in dissolved iron. Today, iron is so scarce in seawater that organisms living in vast areas of the oceans are literally starved for this biologically essential element. These organisms have evolved clever strategies to find and capture this key nutrient.

But Anbar stresses that iron is only one of many critical nutrient elements to consider. Sulfur, nitrogen, phosphorus, copper, zinc, nickel and even obscure elements like molybdenum are all essential nutrients whose abundances have gone up and down in the oceans over geological time. These changes are a consequence of increases in the amount of oxygen in the atmosphere and oceans.

Different elements are important in different ways for biological processes that affect the environment. As a result, Anbar says that changes in ocean chemistry probably had many unusual consequences in Earth history. For instance, he points to a suggestion made by a colleague, Professor Roger Buick of the University of Washington, that changes in the availability of copper could have affected the amount of the gas nitrous oxide – so-called 'laughing gas' – in the atmosphere. The idea follows from the fact that copper is present in the reaction center of the enzyme that bacteria use to convert nitrous oxide to ordinary nitrogen gas. Buick proposes that copper-poor oceans could have led to a 'laughing gas' atmosphere between 1.8 and 0.7 billion years ago. "Ironically, it's no laughing matter," says Anbar. "Nitrous oxide is a powerful greenhouse gas. It may be that copper scarcity helped keep the Earth warm at that time."

Anbar is most excited by the possibility that changes in ocean chemistry affected the makeup of life itself. "Take iron, for example," he contemplates. "It's needed by virtually every organism on the planet. Is that because the basic biochemistry of life on Earth developed in the iron-rich oceans of Earth's distant past? Or is it because the chemical properties of iron are so special that evolution would have selected for it even if it was always rare?"

The answers to such questions will come from continued study of the past combined with research into how the use of elements by organisms is affected by changes in element abundances in their environment. Much of this biological work will take place at ASU in a project Anbar is undertaking with Profs. James Elser and Susanne Neuer in the School of Life Sciences, Everett Shock in the School of Earth and Space Exploration and the Department of Chemistry and Biochemistry, and other ASU scientists. That effort is supported by a new, $7 M grant from the NASA Astrobiology Institute. "NASA is really interested in the idea that they should 'follow the elements' in addition to water when searching for life out there," says Anbar. "They recognize that ASU is an exceptional place for such research."

Source: Arizona State University