New study challenges old views about evolution of early life

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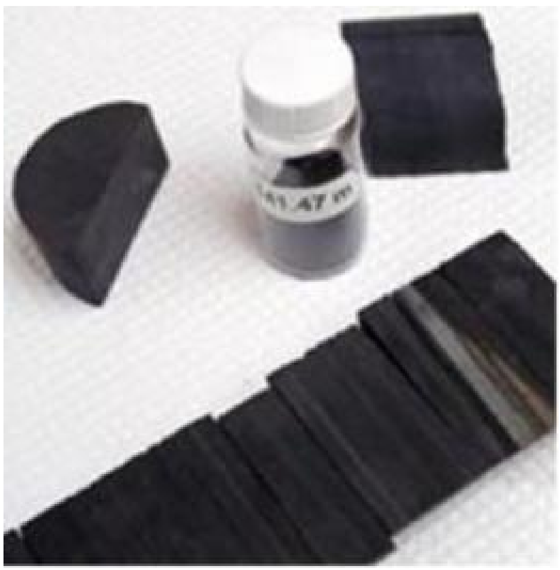

Organic-rich shale samples, such as these from the 2.5-billion-year-old Mount McRae Shale from Western Australia, were analyzed for their zinc contents. The results confirm that the early ocean was not Zn-lean and that other controls must be invoked to explain the protracted appearance and proliferation of eukaryotic life. Credit: Arizona State University

A research team led by biogeochemists at the University of California, Riverside has tested a popular hypothesis in paleo-ocean chemistry, and proved it false.

The fossil record indicates that eukaryotes—single-celled and multicellular organisms with more complex cellular structures compared to prokaryotes, such as bacteria—show limited morphological and functional diversity before 800-600 million years ago. Many researchers attribute the delayed diversification and proliferation of eukaryotes, which culminated in the appearance of complex animals about 600 million years ago, to very low levels of the trace metal zinc in seawater.

As it is for humans, zinc is essential for a wide range of basic cellular processes. Zinc-binding proteins, primarily located in the cell nucleus, are involved in the regulation of gene transcription.

Eukaryotes have increasingly incorporated zinc-binding structures during the last third of their evolutionary history and still employ both early- and late-evolving zinc-binding protein structures. Zinc is, therefore, of particular importance to eukaryotic organisms. And so it is not a stretch to blame the 1-2-billion-year delay in the diversification of eukaryotes on low bioavailability of this trace metal.

But after analyzing marine black shale samples from North America, Africa, Australia, Asia and Europe, ranging in age from 2.7 billion years to 580 million years old, the researchers found that the shales reflect high seawater zinc availability and that zinc concentrations during the Proterozoic (2.5 billion to 542 million years ago) were similar to modern concentrations. Zinc, the researchers posit, was never biolimiting.

Study results appear online Dec. 23 in *Nature Geoscience*.

"We argue that the concentration of zinc in ancient marine black shales is directly related to the concentrations of zinc in seawater and show that zinc is abundant in these rocks throughout Earth's history," said Clint Scott, the first author of the research paper and a former UC Riverside graduate student. "We found no evidence for zinc biolimitation in seawater."

Scott, now a research geologist with the U.S. Geological Survey, explained that the connection between zinc limitation and the evolution of eukaryotes was based largely on the hypothesis that Proterozoic oceans were broadly sulfidic. Under broadly sulfidic conditions, zinc should have been scarce because it would have rapidly precipitated in the oceans, he explained.

"However, a 2011 research paper in *Nature* also published by our group at UCR demonstrated that Proterozoic oceans were more likely broadly ferruginous—that is, low in oxygen and iron-rich—and that sulfidic conditions were more restricted than previously thought," said Scott, who performed the research in the lab of Timothy Lyons, a professor of biogeochemistry and the principal investigator of the research project.

The research team argues that ferruginous deep oceans, combined with large hydrothermal fluxes of zinc via volcanic activity on the seafloor, maintained high levels of dissolved zinc throughout the oceans and provided a relatively stable marine reservoir of the trace metal over the past 2.7 billion years.

"The key challenge in understanding the early evolution of life is recognizing the environmental conditions under which that life first appeared and diversified," Lyons said. "We have taken a very direct approach that specifically tracks the availability of essential micronutrients, and, to our surprise, zinc supplies in ancient seawater were much higher and less variable than previously imagined.

"We can imagine for the first time," he quipped, "that zinc supplements were not on the shopping lists of our early eukaryotic ancestors, and so we better find another reason to explain the mysterious delay in their rise in the ocean."

Provided by University of California - Riverside