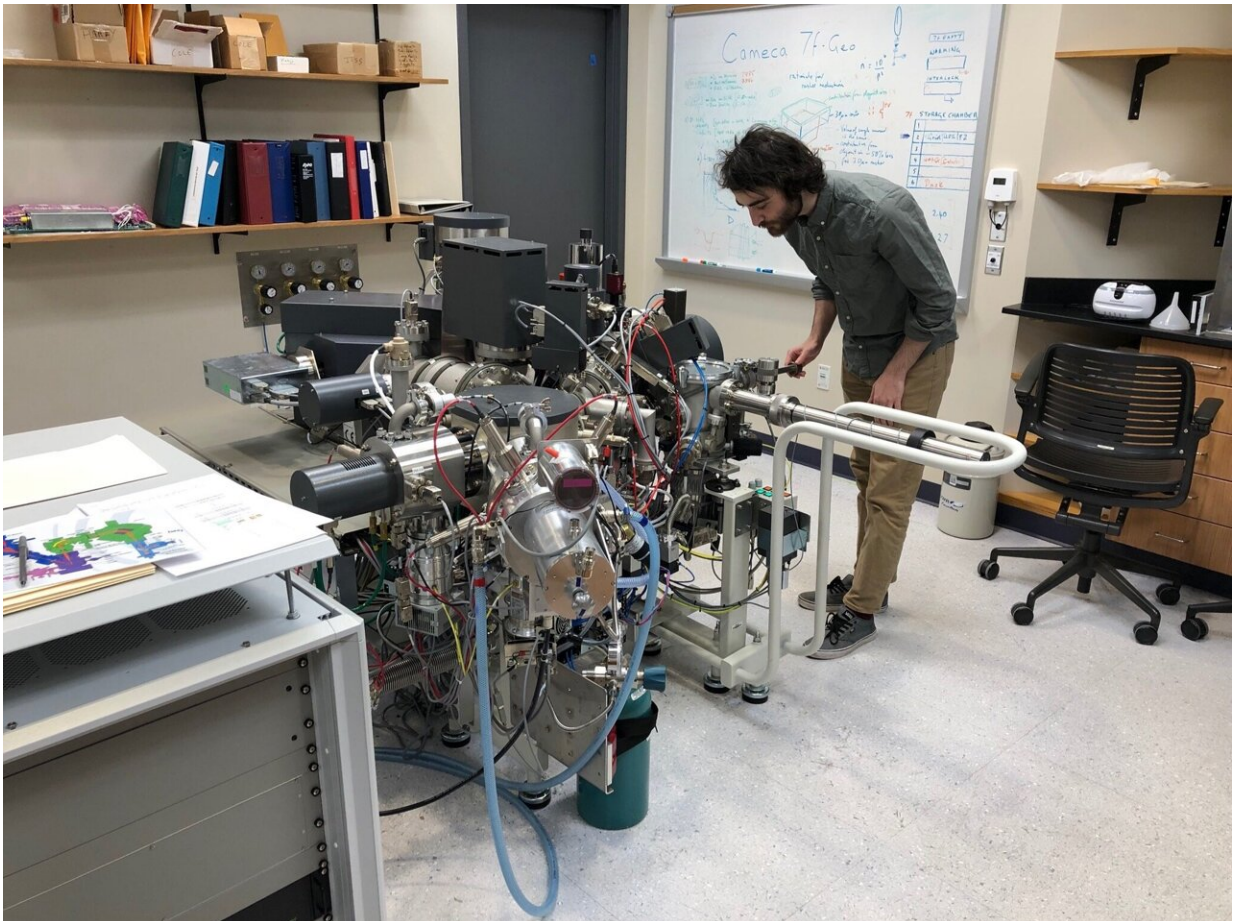


Separating out signals recorded at the seafloor

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Roger Bryant studied ocean floor core samples at the Secondary Ion Mass Spectrometry (SIMS) facility at Washington University in St. Louis during his PhD studies. Bryant and David Fike have used this data to prove a discovery that will fundamentally change how scientists use pyrite sulfur isotopes to study oceanic conditions. Credit: Clive Jones, Washington University in St. Louis

Blame it on plate tectonics. The deep ocean is never preserved, but instead is lost to time as the seafloor is subducted. Geologists are mostly left with shallower rocks from closer to the shoreline to inform their studies of Earth history.

"We have only a good record of the [deep ocean](#) for the last ~180 million years," said David Fike, the Glassberg/Greensfelder Distinguished University Professor of Earth, Environmental, and Planetary Sciences in Arts & Sciences at Washington University in St. Louis. "Everything else is just shallow-water deposits. So it's really important to understand the bias that might be present when we look at shallow-water deposits."

One of the ways that scientists like Fike use deposits from the seafloor is to reconstruct timelines of past ecological and [environmental change](#). Researchers are keenly interested in how and when oxygen began to build up in the oceans and atmosphere, making Earth more hospitable to life as we know it.

For decades they have relied on [pyrite](#), the iron-sulfide mineral known as "fool's gold," as a sensitive recorder of conditions in the [marine environment](#) where it is formed. By measuring the bulk isotopic composition of [sulfur](#) in pyrite samples—the relative abundance of sulfur atoms with slightly different mass—scientists have tried to better understand ancient microbial activity and interpret global chemical cycles.

But the outlook for pyrite is not so shiny anymore. In a pair of companion papers published Nov. 24 in *Science*, Fike and his collaborators show that variations in pyrite sulfur isotopes may not represent the global processes that have made them such popular targets of analysis.

Instead, Fike's research demonstrates that pyrite responds predominantly

to local processes that should not be taken as representative of the whole ocean. A new microanalysis approach developed at Washington University helped the researchers to separate out signals in pyrite that reveal the relative influence of microbes and that of local climate.

For the first study, Fike worked with Roger Bryant, who completed his graduate studies at Washington University, to examine the grain-level distribution of pyrite sulfur isotope compositions in a sample of recent glacial-interglacial sediments. They developed and used a cutting-edge analytical technique with the secondary-ion mass spectrometer (SIMS) in Fike's laboratory.

"We analyzed every individual pyrite crystal that we could find and got isotopic values for each one," Fike said. By considering the distribution of results from individual grains, rather than the average (or bulk) results, the scientists showed that it is possible to tease apart the role of the physical properties of the depositional environment, like the sedimentation rate and the porosity of the sediments, from the microbial activity in the seabed.

"We found that even when bulk pyrite sulfur isotopes changed a lot between glacials and interglacials, the minima of our single grain pyrite distributions remained broadly constant," Bryant said. "This told us that microbial activity did not drive the changes in bulk pyrite sulfur isotopes and refuted one of our major hypotheses."

"Using this framework, we're able to go in and look at the separate roles of microbes and sediments in driving the signals," Fike said. "That to me represents a huge step forward in being able to interpret what is recorded in these signals."

In the second paper, led by Itay Halevy of the Weizmann Institute of Science and co-authored by Fike and Bryant, the scientists developed

and explored a computer model of marine sediments, complete with mathematical representations of the microorganisms that degrade [organic matter](#) and turn sulfate into sulfide and the processes that trap that sulfide in pyrite.

"We found that variations in the isotopic composition of pyrite are mostly a function of the depositional environment in which the pyrite formed," Halevy said. The new model shows that a range of parameters of the sedimentary environment affect the balance between sulfate and sulfide consumption and resupply, and that this balance is the major determinant of the sulfur isotope composition of pyrite.

"The rate of sediment deposition on the seafloor, the proportion of organic matter in that sediment, the proportion of reactive iron particles, the density of packing of the sediment as it settles to the seafloor—all of these properties affect the isotopic composition of pyrite in ways that we can now understand," he said.

Importantly, none of these properties of the sedimentary environment are strongly linked to the global sulfur cycle, to the oxidation state of the global ocean, or essentially any other property that researchers have traditionally used pyrite sulfur isotopes to reconstruct, the scientists said.

"The really exciting aspect of this new work is that it gives us a predictive model for how we think other pyrite records should behave," Fike said. "For example, if we can interpret other records—and better understand that they are driven by things like local changes in sedimentation, rather than global parameters about ocean oxygen state or microbial activity—then we can try to use this data to refine our understanding of sea level change in the past."

More information: R. N. Bryant et al, Deconvolving microbial and environmental controls on marine sedimentary pyrite sulfur isotope

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Provided by Washington University in St. Louis

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