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Analysis of titanium in ancient rocks creates upheaval in history of early Earth

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While previous studies had argued that Earth's crust 3.5 billion years ago looked like these Hawaiian lavas, a new study led by UChicago scientists suggests by then much of it had already been transformed into lighter-colored felsic rock by plate tectonics. Credit: University of Chicago

The Earth's history is written in its elements, but as the tectonic plates slip and slide over and under each other over time, they muddy that evidence—and with it the secrets of why Earth can sustain life.

A new study led by UChicago geochemists rearranges the picture of the early Earth by tracing the path of metallic element titanium through the Earth's crust across time. The research, published Sept. 22 in *Science*, suggests significant tectonic action was already taking place 3.5 billion years ago—about half a billion years earlier than currently thought.

The crust was once made of uniformly dark, magnesium- and iron-rich mafic minerals. But today the crust looks very different between land and ocean: The crust on land is now a lighter-colored felsic, rich in silicon and aluminum. The point at which these two diverged is important, since the composition of minerals affects the flow of nutrients available to the fledgling life struggling to survive on Earth.

"This question has been discussed since geologists first started thinking about rocks," said lead author Nicolas Dauphas, the Louis Block Professor and head of the Origins Laboratory in the Department of the Geophysical Sciences and the Enrico Fermi Institute. "This result is a surprise and certainly an upheaval in that discussion."

To reconstruct the crust changing over time, geologists often look at a particular kind of rock called shales, made up of tiny bits of other rocks and minerals that are carried by water into mud deposits and compressed into rock. The only problem is that scientists have to adjust the numbers to account for different rates of weathering and transport. "There are many things that can foul you up," Dauphas said.

To avoid this issue, Dauphas and his team looked at titanium in the shales over time. This element doesn't dissolve in water and isn't taken up by plants in nutrient cycles, so they thought the data would have fewer biases with which to contend.

They crushed samples of shale rocks of different ages from around the world and checked in what form its titanium appeared. The proportions of titanium isotopes present should shift as the rock changes from mafic to felsic. Instead, they saw little change over three and a half billion years, suggesting that the transition must have occurred before then.

These granite peaks are an example of felsic rock, created via plate tectonics. Credit: Basil Greber

This also would mark the beginning of plate tectonics, since that process is believed to be needed to create felsic rock.

"With a null response like that, seeing no change, it's difficult to imagine an alternate explanation," said Matouš Ptáček, a UChicago graduate student who co-authored the study.

"Our results can also be used to track the average composition of the continental crust through time, allowing us to investigate the supply of nutrients to the oceans going back 3.5 billion years ago," said Nicolas Greber, the first author of the paper, then a postdoctoral researcher at UChicago and now with the University of Geneva.

Phosphorous leads to life

The question about nutrients is important for our understanding of the circumstances around a mysterious but crucial turning point called the great oxygenation event. This is when oxygen started to emerge as an important constituent of Earth's atmosphere, wreaking a massive change on the planet—and making it possible for multi-celled beings to evolve.

The flood of oxygen came from a surge of photosynthetic microorganisms; and in turn their work was fostered by a surge of nutrients to the oceans, particularly phosphorus. "Phosphorus is the most important limiting nutrient in the modern ocean. If you fertilize the ocean with phosphorus, life will bloom," Dauphas said.

The titanium timeline suggests that the primary trigger of the surge of phosphorus was the change in the makeup of mafic rock over time. As the Earth cooled, the mafic rock coming out of volcanoes and underground melts became richer in phosphorus.

"We've known for a long time that mafic rock changed over time, but what we didn't know was that their contribution to the crust has stayed rather consistent," Ptáček said.

More information: Nicolas D. Greber et al. Titanium isotopic evidence for felsic crust and plate tectonics 3.5 billion years ago, *Science* (2017). DOI: 10.1126/science.aan8086

Provided by University of Chicago

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