Rare fossilized algae, discovered unexpectedly, fill in evolutionary gaps

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The field team breaks for lunch after a morning of fossil-hunting in the Wernecke Mountains of the Yukon Territory in Canada. The ridge they're sitting on is made of shales of the Dolores Creek Formation, where Maloney and her colleagues collected fossilized algae. Credit: K. Maloney

When geobiology graduate student Katie Maloney trekked into the mountains of Canada's remote Yukon territory, she was hoping to find microscopic fossils of early life. Even with detailed field plans, the odds of finding just the right rocks were low. Far from leaving empty-handed, though, she hiked back out with some of the most significant fossils for the time period.

Eukaryotic life (cells with a DNA-containing nucleus) evolved over two billion years ago, with photosynthetic algae dominating the playing field for hundreds of millions of years as oxygen accumulated in the Earth's atmosphere. Geobiologists think that algae evolved first in freshwater environments on land, then moved to the oceans. But the timing of that evolutionary transition remains a mystery, in part because the fossil record from early Earth is sparse.

Maloney's findings were published yesterday in *Geology*. She and her collaborators found macroscopic fossils of multiple species of algae that thrived together on the seafloor about 950 million years ago, nestled between bacterial mounds in a shallow ocean. The discovery partly fills in the evolutionary gap between algae and more complex life, providing critical time constraints for eukaryotic evolution.

Although the field site was carefully chosen by Maloney's field team leader, sedimentologist Galen Halverson, who has worked in the region for years, the discovery was an unexpected stroke of luck.

"I was thinking, 'maybe we'll find some microfossils,'" Maloney said. The possibility of finding larger fossils didn't cross her mind. "So as we started to find well-preserved specimens, we stopped everything and the whole team gathered to collect more fossils. Then we started to find these big, complex slabs with hundreds of specimens. That was really exciting!"

Determining if traces like the ones Maloney found are biogenic (formed by living organisms) is a necessary step in paleobiology. While that determination is ultimately made in the lab, a few things tipped her off in the field. The traces were very curvy, which can be a good indicator of life, and there were visible structures within them. The fact that there were hundreds of them twisted together sealed the deal for her.

Few people would likely have noticed the fossils that day.

On the right, a slab of gray shale sample. Two black boxes mark places where fossilized algae are present; those are shown on the left. The fossils are reddish-brown marks, curving and broken into segments, on a gray rock background. Credit: K. Maloney.

"We were really lucky that Katie was there to find them because at first glance, they don't really look like anything," Maloney's advisor, Marc Laflamme, said. "Katie is used to looking at very weird looking fossils, so she has a bit of an eye for saying, 'This is something worth checking out.'"

Maloney and her colleagues in the field wrestled the heavy slabs into their helicopter for safe transport back to the lab at the University of Toronto-Mississauga. She, Laflamme, and their collaborators used microscopy and geochemical techniques to confirm that the fossils were indeed early eukaryotes. They then mapped out the specimens' cellular features in detail, allowing them to identify multiple species in the community.

While Maloney and her coauthors were writing up their results, they were confident they had found the first macroscopic specimens from this critical time period. During the peer review process, though, they received word from a collaborator that another group in China had made a similar discovery at about the same time—macrofossils from a similar period. That did not dissuade them.

"What's a few hundred million years between friends?" Laflamme laughed. "I think our fossils have more detail, which makes them easier to interpret... They're beautiful. They're huge, they're well detailed, there's anatomy. Your eyes are just drawn to them."

Ultimately, having two sets of macrofossils from approximately the same time can only improve the timeline of eukaryotic evolution, serving as critical calibration points for DNA-based biologic dating techniques. The new fossils also push back the time when algae were living in marine environments, indicating that evolution had already occurred in lakes on land. But for Maloney, an expert in sedimentology, they also raise questions about what gets preserved in the rock record and why.

"Algae became really important early on because of their role in oxygenation and biogeochemical cycles," Maloney said. "So why does it take them so long to show up reliably in the fossil record? It's definitely making us think more about animal ecosystems and whether or not we're seeing the whole picture, or if we're missing quite a bit from a lack of preservation."

The whole project has been engaging for Maloney, who pivoted to algae from more recent biota. "I never expected to be fascinated by algae," she said. "But I was pleasantly surprised as I started investigating modern algae, finding what an important role they play in sustainability and climate change—all these big issues that we're dealing with today. So it's been amazing contributing to algae's origin story."

This fieldwork was carried out with permits on traditional lands of the First Nation of Na-Cho Nyak Dun with their consent.

More information: Katie M. Maloney et al. New multicellular marine macroalgae from the early Tonian of northwestern Canada, *Geology* (2021). DOI: 10.1130/G48508.1

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