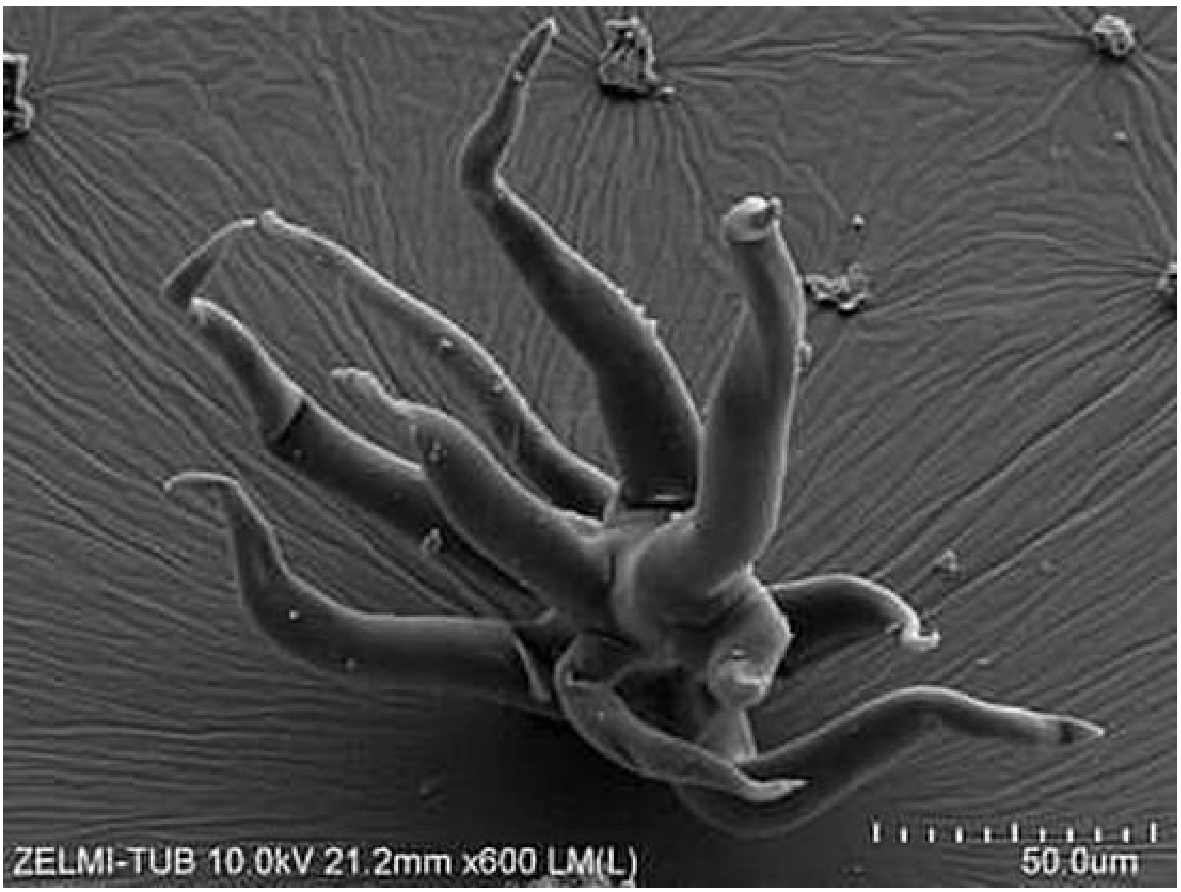
Discovery of oldest 3D-preserved microorganisms

July 24 2023, by Stefanie Terp



Rare, previously unknown forms of organisms Credit: Technische Universität Berlin

For the first time ever, researchers have been able to study the form of microorganisms from the early days of evolution some 1.5 billion years ago. These microorganisms are of exceptional importance for our understanding of the development of early life.

Researchers from Technische Universität Berlin, the National Academy of Sciences of Ukraine, the Museum of Natural History Berlin and the National Museum of Natural History in Luxembourg have discovered the oldest, three-dimensionally preserved microfossils on Earth to date on minerals from the Volyn quartz mine near the city of Zhytomyr (Ukraine). The findings are published in the journal *Biogeosciences*.

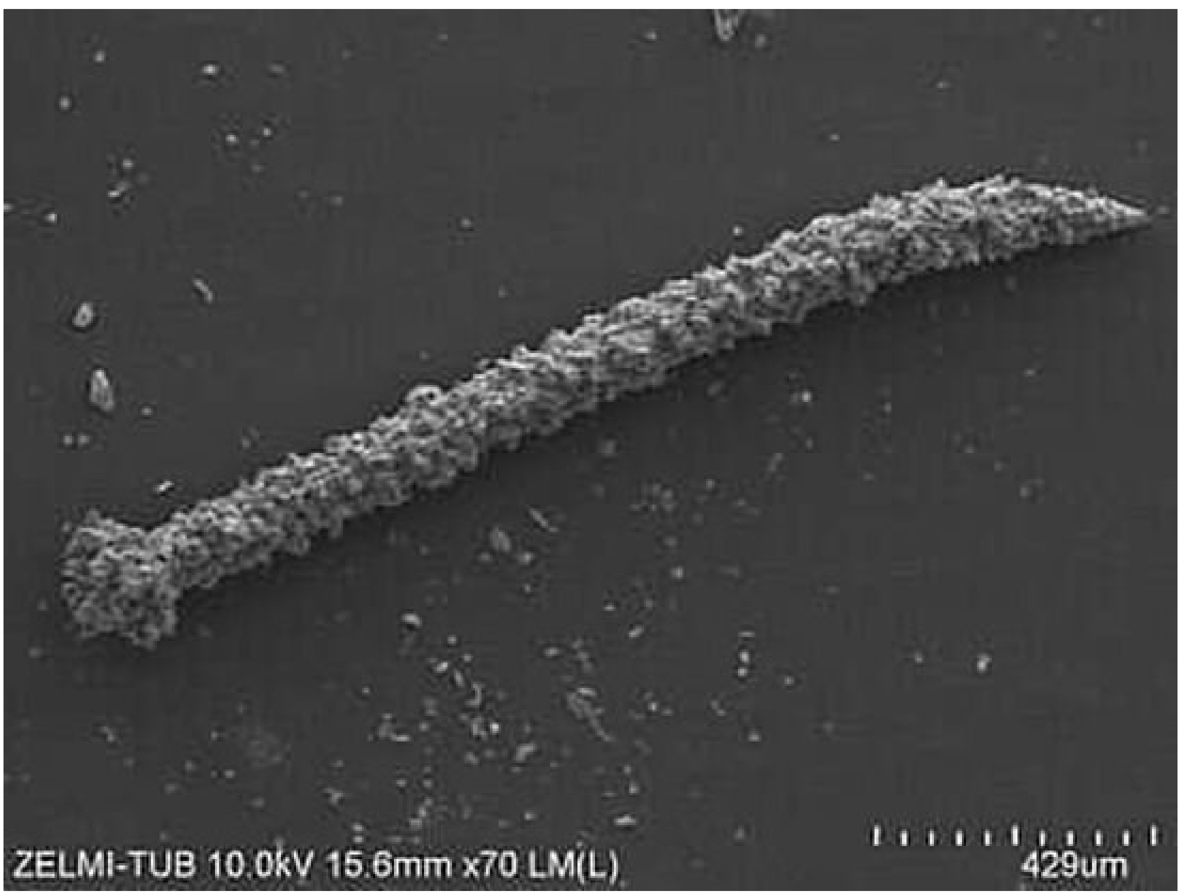
Their original form was preserved by a micrometer-thin layer of aluminum silicate, which could only form as a result of a special set of geological circumstances. Most of previous evidence of Precambrian microorganisms was based on indirect methods such as characteristic imprints in the rock or the detection of biological degradation products.

"It's fascinating that here, for the first time, we are able to study the fossils of primordial microorganisms under a scanning electron microscope. We were actually looking to study beryl and topaz from the mine. What we have found now is far more valuable than any gemstones," explains Professor Emeritus Dr. Gerhard Franz of the Institute of Applied Geosciences at TU Berlin.

This is because the finds are the first fossilized microorganisms dating back to what is referred to as the "boring billion," the first seemingly uneventful billion years before the Precambrian Revolution. "Only then, about 600 million years ago, did evolution produce skeletons made of calcium carbonate or phosphate; invertebrates such as clams, corals or snails emerged, and then vertebrates with backbones. Real fossils with preservable skeletons only became possible as a result of this biomineralization."

Because living organisms had no skeletons more than 600 million years ago, they could not actually preserve their form—which is why very little is known about this period. It was mainly only in sedimentary rocks, i.e., former deposits on sea floors, that carbon remains of the microorganisms were preserved, which were then destroyed by millions of years of mechanical deformation. And it is only because life forms prefer the lighter carbon isotope ^{12}C to the heavier variant ^{13}C that it has been possible to speculate at all that this was once biological material.

It is only recently that researchers found for the first time biological compounds such as cholesterol in rocks in Australia, that are 1.5 billion years old and that directly suggest primordial life forms. In other rocks, the early microorganisms have left only faint imprints, from which it is difficult to discern their form.



Scanning electron microscope images of filamentous organisms. Credit: Technische Universität Berlin

The first images of primordial microorganisms: Filaments, spheres and tentacles

"What we are looking at now under our electron microscope are mostly fibrous structures. Either thin filaments that branch out, or thick ones that have small protrusions or dents," Franz explains. The thickness of the objects varies between 10 and 200 micrometers and their length is up to several millimeters, sometimes with a thin channel in the middle.

This means these primordial microorganisms can also be seen with the naked eye. What is particularly exciting is that the researchers also found a few previously unknown forms of microorganisms. These had shell or spherical-shaped structures or tentacle-like branches.

Some of the fossilized organisms resemble fungi

"By analyzing the carbon isotopes ^{12}C and ^{13}C, we have also been able to prove that our finds must once have been living creatures," Franz explains. The age of the finds was measured using a special isotope method, which resulted in a minimum age for the fossils of 1.5 billion years. The researchers also detected the substance chitosan in certain filamentous objects using infrared spectroscopy, as well as the elements bismuth and tellurium using an electron microscope.

"This all points to a fungus-like organism," Franz says. However, that would only apply to some of the finds, he adds. "From the other fossilized microorganisms, we can at least assume that they must have been single or multicellular organisms with distinct cell structures."

These probably lived with the fungi in a common ecosystem.

Subterranean life preserved by a geyser

The location of the fossilized primordial microorganisms on granite rock in a quartz mine suggests both their way of life and the reasons for their exceptionally good state of preservation. "Even today, microorganisms live up to three kilometers deep in the Earth's crust," Franz explains. They live there—without sunlight—on substances such as phosphorus, nitrogen or carbon dioxide, some of which are dissolved in water and migrate downward from above through fissures and crevices or are already present there.

The microorganisms obtain the energy they need for their metabolism from chemical processes on minerals. In the granite caverns of the Volyn quartz mine, such colonies of microorganisms were apparently already present near the Earth's surface 1.5 billion years ago. And because granite contains a lot of fluorine, strongly corrosive hydrofluoric acid was formed underground in interaction with water and heat, which dissolved a lot of aluminum and silicon.

Like a geyser, this solution shot into the caverns from time to time, covering the microorganisms with a micrometer-thin layer of aluminum silicate. "Of course, the microorganisms died as a result—but they were also perfectly preserved," says Franz.

The history of the finds

"As is so often the case in science, the history of our find owes a lot to coincidence," he reports. "The main reason my predecessor, Professor Klaus Langer, initiated the cooperation with Ukraine back in the days of perestroika was to support researchers in the still young, independent

Ukraine. The interesting gemstone finds in the Volyn quartz mine came as a nice surprise for the working group."

When Franz started out as the new head of the academic chair years later, he one day detected some strange fibers on the beryls when examining them under an electron microscope. Over the years, and with the help of rock samples from different museums, that's how the discovery got rolling.

"Nevertheless, today we are only at the beginning. Further investigations and possibly new finds will be able to tell us even more about the primordial microorganisms, especially about previously unknown forms on the continents, and not just in the sea," says Franz.

This could provide new insights into the early development of life on Earth, but perhaps also into the development of life under extreme conditions on other planets.

More information: Gerhard Franz et al, The Volyn biota (Ukraine)—indications of 1.5 Gyr old eukaryotes in 3D preservation, a spotlight on the "boring billion, *Biogeosciences* (2023). DOI: 10.5194/bg-20-1901-2023

Gerhard Franz et al, Fossilization of Precambrian microfossils in the Volyn pegmatite, Ukraine, *Biogeosciences* (2022). DOI: 10.5194/bg-19-1795-2022

Provided by Technische Universität Berlin