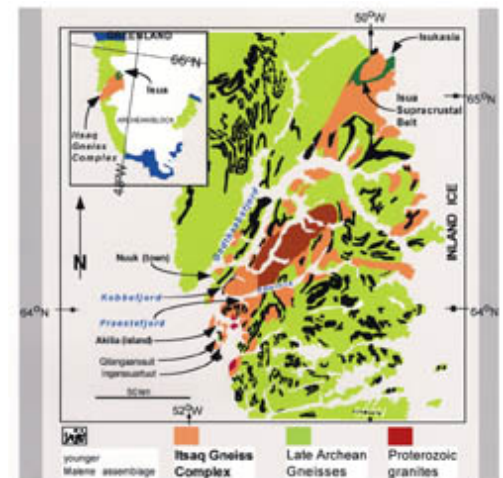




## When Did Life on Earth Begin? Ask a Rock.

*By: David Tenenbaum*



Generalized geologic map showing extent of early Archean (3770-3900 c) Itsaq Gneiss Complex in southern West Greenland (adapted from Nutman et al., 1984, 1996). Oldest sedimentary rocks and associated gneisses are along coast, represented by island of Akilia, and are intruded in places by Proterozoic Qorqut granites.

*Credit: GSA Today*

Does the first evidence of life date to 3.85 billion years ago (Ga), or 3.65 Ga? A 200-million-years discrepancy may seem trivial almost 4 billion years after the fact. And yet scientists continue to debate whether some of the oldest rocks ever found date to 3.85 Ga, or "just" 3.65 Ga.

The discrepancy matters because the rocks, however old they are, indicate that life already existed at the time they formed. The dispute is not just a matter of how early life began, however, but under what conditions: The earlier date was during the tail end of an asteroid storm called the "late heavy bombardment," while the later date was after the bombardment ceased.

When Did Life on Earth Begin? Ask a Rock.

For astrobiology, the issue could hardly have greater weight. What conditions allowed life to emerge? How quickly after the planet coalesced from primordial dust and gas did chemicals organize themselves into self-replicating, evolving systems — into life? And what evidence of that early life would remain after billions of years?

The debate concerns samples of graphite — a form of carbon used in pencil leads — from the snowy, barren wastes of western Greenland. In 1979, German geologist Manfred Schidlowski first argued that ratios of carbon isotopes from the rocks were a relic of organic matter. The issue has been contested with renewed vigor since 1996, when Stephen Mojzsis, a geologist at the University of Colorado, published a study of microscopic samples of carbon from the same area.

The samples were found in black, fine-grained, highly deformed rocks that started out as ocean-floor sediments. Marine sediments receive a continual rain of matter — both organic and inorganic — from the water, so they are a good place to look for the remains of past life.



Aerial photograph of BIF locality on Akilia, looking east; sediments are bounded by amphibolites and intruded by gneissic sheets up to 3850 million years old.

*Credit: GSA Today*

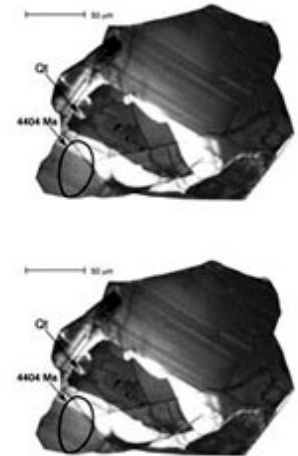
The debate over the sediments has two parts: What is the evidence for life? And how old are the rocks containing it?

Rocks of this age are not likely to contain conventional fossils — to date, the oldest undisputed fossils appear in rocks from 3.2 Ga. Fossils in older rocks would have long since been destroyed by eons of heat, pressure and deformation. In searching for the oldest life, Mojzsis observes, "you have to look to the chemical record, on the principle that life changes the chemistry of its surroundings in a predictable way."

The chemical record of ancient life, found in so-called "chemofossils," is reflected in the ratio of isotopes, with carbon being particularly useful. Carbon exists in nature in more than one form. Normally, carbon-13 (C-13, with atomic weight 13), is much rarer than C-12. However, biological processes concentrate C-12, so when organic debris falls to the ocean floor, the C-12 to C-13 ratio rises still further in the sedimentary rock that forms. That ratio is preserved even in rocks that formed billions of years ago.

The percentage differences are small, but distinctive, says Craig Manning, a geologist at the University of California at Los Angeles. "In the modern world, the only way you can generate such a high ratio of carbon-12 relative to carbon-13 is if some sort of fractionation [or preferential use of carbon-12] occurs in living organisms."

When Did Life on Earth Begin? Ask a Rock.



Microscopic view of a zircon crystal determined to be 4.4 billion years old making it the world's oldest known terrestrial material. Zircon is a mineral commonly used to determine the geological age of rocks. Chemical analysis of this grain suggests that the Earth was cool enough to have water, a hydrosphere and, possibly, life much earlier than previously thought.  
*Credit: John W. Valley*

Manning, who helped map Akilia Island, Greenland, where the possible 3.85 Ga sediments were found, says ancient life is "the simplest explanation" for their carbon ratios.

The isotopic evidence may be ancient and subtle, but it's convincing to John Valley, a professor of geology at the University of Wisconsin–Madison who has a lot of experience dating ancient rocks. High C–12 to C–13 ratios, he says, "when present in sufficient quantity, are very strong evidence of organic activity, although I don't use the word 'proof.'"

But do the rocks that held the carbon really date to 3.85 Ga? Rock of sedimentary origin cannot be dated directly. However, it's possible to deduce a minimum age by dating any igneous "intrusions" that have cut through the sedimentary rock. These intrusions can be dated by the presence within them of crystals called zircons. And because the intrusions were deposited after the sedimentary rock, knowing the age of the zircons gives a minimum age of the sedimentary rock.

Geochronologists depend on zircons. Mojzsis, for example, calls them "nature's timekeepers." Zircons crystallize from molten igneous rock as it cools. When they first crystallize, zircons contain uranium, a radioactive element that slowly decays to lead. But until the decay process begins, lead is absent. Because all the lead they now contain originally must have been uranium, the ratio of uranium to lead reflects the time since the zircons formed – since the igneous rock cooled.

Thomas Krogh, who helped develop the uranium–lead zircon dating method at the Royal Ontario Museum in

Toronto, says that even if the zircons are reheated, as happened at least once to the Greenland samples, they retain a "memory" of the first crystallization. Even more than 3.5 billion years later, uranium–lead dating is accurate to within a few million years, Krogh adds.

But because the Greenland rocks were severely deformed during billions of years of geologic turmoil, their age sequence – which rocks were laid down first, which later? – is confusing. Obviously, accurate zircon dating can help determine the age of the sedimentary rocks only if the age relationship of the various rocks is known accurately.



A rock sample from Akilia Island off the coast of Greenland.

*Credit: CNN*

During summer, 2000, Manning, Mojzsis and Mark Harrison of UCLA performed a detailed survey of Akilia Island. "All the previous claims were based on an old kind of mapping," Manning says. "You [can't] just stand there with notebook and sketch what you see. Given the magnitude of the claims, it was extremely important to lay out a grid and map at more detailed scale."

After two weeks of mapping, he says, "We did discover a good crosscutting relationship" among the rocks. The 3.85 Ga figure, he adds, "is indisputable, as far as we're concerned." This new research has been submitted for publication.

While Manning, Mojzsis and Krogh all think the 3.85 Ga age is correct, Stephen Moorbath, a geologist at Oxford University contends that the rocks were most likely deposited about 3.65 to 3.70 Ga. This more recent dating would explain the absence of the element iridium – rare on Earth but common in asteroids – or any other signs of asteroid impacts, such as surface turbulence.

Due to the paucity of evidence, the detailed interpretation of life from ancient samples may always remain controversial, yet the very existence of samples moves the discussion of ancient life from the realm of speculation and theory into the realm of experimentation. In other words, says Mojzsis, it enters the realm of science.

"The geological record of Earth is the baseline from which we can investigate evidence of past environments on any other planet. On Earth, we call a spacecraft a Toyota Land Cruiser, and a sample return mission can return hundreds of kilograms to the world's best labs."

Ancient zircons, he adds, "are intrinsically exciting because they help us understand the early Earth. These studies provide an important feature for any scientific discussion: data."

---

## Related Web Pages

Vestiges of a Beginning: Clues to the Emergent Biosphere Recorded in the Oldest Known Sedimentary Rocks  
Greenland Rocks Tell New Tale of Life on Earth  
Ancient Crystal Questions Earth's History