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How did life develop on early Earth? New source of nitrogen discovered

Researchers involving RPTU University Kaiserslautern-Landau, Southwestern Germany, are unraveling mysteries of a bygone era: As part of current studies, they are investigating how life could have developed on the early Earth. Contrary to previous assumptions, it appears that biologically available nitrogen was not a limiting factor.

Living organisms need nitrogen as a central building block for protein formation, for example. However, although our atmosphere contains plenty of nitrogen, neither humans nor the vast majority of plants can absorb it directly from the air. Just like today, early life on Earth was therefore dependent on nitrogen fixation by microbes. In other words, on their conversion of atmospheric nitrogen into nitrogen compounds that living organisms can absorb and utilize.

The details of the processes that took place on Earth billions of years ago are far from known: What were the sources of nitrogen on early Earth? How were they used? And what did this mean for the further development of life? RPTU researcher Dr. Michelle Gehringer is working on precisely these questions. She is a geomicrobiologist - and studies the interactions between microorganisms and geochemical processes.

Nitrogen fixation stable under changing environmental conditions

Under her leadership, a measurement method was recently verified that shows that biological nitrogen fixation remains stable under changing atmospheric compositions. To understand the researcher's approach, it is important to know that nitrogen has two stable isotopes, two different states so to speak, 15N und 14N. Michelle Gehringer explains: “Nitrogen gas is a mixture of the light atom 14N and the heavier atom 15N. When modern microbes use nitrogen in their metabolism, they use these two isotopes in a certain ratio to each other. We measure this by burning nitrogen-containing biomass and collecting the nitrogen gas produced during combustion.”

Michelle Gehringer says: “Until now, it was always assumed that microbes have the same 15N /14N ratio, even though they live under completely different environmental conditions, without oxygen and with a much higher carbon dioxide content. However, no one has yet tested whether this is actually true.” However, since environmental conditions influence metabolic rates, they could presumably also influence the 15N /14N ratio.

The researchers led by Gehringer cultivated cyanobacteria under environmental conditions similar to those of the early Earth, i.e. without oxygen and with a very high carbon dioxide content. “We found that the 15N /14N ratios of the cyanobacteria remain stable. Our results therefore support the assumption that this ratio was the same throughout the Earth's history.”

Nitrogen also absorbed in the form of dissolved ammonium

Building on this, Michelle Gehringer and other researchers – under the leadership of her fellow scientist Dr. Ashley Martin from Northumbria University, UK, and Dr. Eva Stüeken from the University of St Andrews, UK – investigated the nitrogen cycle in ancient stromatolites, i.e. sedimentary rocks of organic origin. The ancient rocks, which were around 2.7 billion years old, contain the dead remains of various microorganisms and can provide the researchers with information about their ecosystems and environmental niches in past times. Michelle Gehringer: "We gained access to pristine, unweathered rock, which we ground into a fine powder and analyzed for nitrogen isotopes."

With the help of the ^{15}N /^{14}N ratio measurements, the researchers discovered that in contrast to modern stromatolites, the organic material of ancient stromatolites was not solely dependent on the biological fixation of nitrogen gas by cyanobacteria. To be more precise, the results of the study point to the additional uptake of nitrogen in the form of dissolved ammonium. "And the most plausible source for this is hydrothermal activity on the sea floor," says Gehringer.

The researchers also looked at sedimentary rocks in a volcanic basin that is also around 2.7 billion years old. Ammonium from hydrothermal sources also proved to be relevant in this system.

So would life on Mars also be possible?

"Until now, it was assumed that life on the early Earth, before the atmosphere was enriched with oxygen, was limited by a lack of biologically available nitrogen." The current studies now prove an additional role of ammonium from deep-sea hydrothermal vents: "With the help of hydrothermal vents, nitrogen did not limit the spread of life on early Earth. Rather, life was able to flourish in both deep and shallow-water marine environments." And according to Gehringer, this enabled the development of a great diversity of microorganisms that we still see today.

What could these findings mean for life on other planets? "Hydrothermal activity has been documented on Mars and probably also takes place on the icy moons in the outer solar system." It is conceivable that processes similar to those on the early Earth took place or are still taking place there.

The studys:

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Between a rock and a green place: Michelle Gehringer studies fossilized life on early Earth to learn more about the evolution of (oxygenic) photosynthesis - the process that makes the oxygen we breath.
Thomas Koziel
RPTU, Thomas Koziel