Billions of years ago, microbes were key in developing modern nitrogen cycle

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(PhysOrg.com) -- As the world marks the 200th anniversary of Charles Darwin's birth, there is much focus on evolution in animals and plants. But new research shows that for the countless billions of tiniest creatures - microbes - large-scale evolution was completed 2.5 billion years ago.

"For microbes, it appears that almost all of their major evolution took place before we have any record of them, way back in the dark mists of prehistory," said Roger Buick, a University of Washington paleontologist and astrobiologist.

All living organisms need nitrogen, a basic component of amino acids and proteins. But for atmospheric nitrogen to be usable, it must be "fixed," or converted to a biologically useful form. Some microbes turn atmospheric nitrogen into ammonia, a form in which the nitrogen can be easily absorbed by other organisms.

But the new research shows that about 2.5 billion years ago some microbes evolved that could carry the process a step further, adding oxygen to the ammonia to produce nitrate, which also can be used by organisms. That was the beginning of what today is known as the aerobic nitrogen cycle.

The microbes that accomplished that feat are on the last, or terminal, branches of the bacteria and archaea domains of the so-called tree of life, and they are the only microbes capable of carrying out the step of adding oxygen to ammonia.

The fact that they are on those terminal branches indicates that large-scale evolution of bacteria and archaea was complete about 2.5 billion years ago, Buick said.

"Countless bacteria and archaea species have evolved since then, but the major branches have held," said Buick, a UW professor of Earth and space sciences.

He is the corresponding author of the research, which appears in the Feb. 20 edition of *Science*. Lead author is Jessica Garvin, a UW Earth and space sciences graduate student. Other authors are Ariel Anbar and Gail Arnold of Arizona State University and Alan Jay Kaufman of the University of Maryland. The work was funded by NASA and the National Science Foundation.

The scientists examined material from a half-mile-deep core drilled in the Pilbara region of northwest Australia. They looked specifically at a section of shale from 300 to 650 feet deep, deposited 2.5 billion years ago, and found telltale isotope signatures created in the process of denitrification, the removal of oxygen from nitrate.

If denitrification was occurring, then nitrification - the addition of oxygen to ammonia to form nitrate - also must have been taking place, Buick said. That makes the find the earliest solid evidence for the beginning of the aerobic nitrogen cycle.

"What this shale deposit has done is record the onset of the modern nitrogen cycle," he said. "This was a life-giving nutrient then and remains so today. That's why you put nitrogen fertilizer on your tomato plants, for example."

The discovery gives clues about when and how the Earth's atmosphere became oxygen rich, Buick believes.

Geochemical examination of stratigraphic samples from the core indicates that atmospheric oxygen rose in a temporary "whiff" about 2.5 billion years ago. The whiff lasted long enough to be recorded in the nitrogen isotope record, then oxygen dropped back to very low levels before the atmosphere became permanently oxygenated about 2.3 billion years ago.

It is unclear why the oxygen level declined following the temporary increase. It could have been that the oxygen was depleted rapidly as it reacted with chemicals and minerals that had not been exposed to oxygen previously, Buick said. Or something could have halted the photosynthesis that produced the oxygen in the first place.

But it seems clear, he said, that the tiniest creatures played a crucial role in completing the nitrogen cycle that life depends on today.

"All microbes are amazing chemists compared to us. We're really very boring, metabolically," Buick said.

"To understand early evolution of life, we have to know how organisms were nourished and how they evolved. This work helps us on both of those counts," he said.

Provided by University of Washington

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