Evolutionary Accident Probably Caused The Worst Snowball Earth Episode, Study Shows

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For several years geologists have been gathering evidence indicating that Earth has gone into a deep freeze on several occasions, with ice covering even the equator and with potentially devastating consequences for life. The theory, known as "Snowball Earth," has been lacking a good explanation for what triggered the global glaciations.

Now, the California Institute of Technology research group that originated the Snowball Earth theory has proposed that the culprit for the earliest and most severe episode may have been lowly bacteria that, by releasing oxygen, destroyed a key gas keeping the planet warm.

In the current issue of the Proceedings of the National Academy of Sciences (PNAS), Caltech graduate student Robert Kopp and his supervising professor, Joe Kirschvink, along with alumnus Isaac Hilburn (now a graduate student at the Massachusetts Institute of Technology) and graduate student Cody Nash, argue that cyanobacteria (or blue-green algae) suddenly evolved the ability to break water and release oxygen about 2.3 billion years ago. Oxygen destroyed the greenhouse gas methane that was then abundant in the atmosphere, throwing the global climate completely out of kilter.

Though the younger sun was only about 85 percent as bright as it is now, average temperatures were comparable to those of today. This state of affairs, many researchers believe, was due to the abundance of methane, known commercially as natural gas. Just as they do in kitchen ranges, methane and oxygen in the atmosphere make an unstable combination;

in nature they react in a matter of years to produce carbon dioxide and water. Though carbon dioxide is also a greenhouse gas, methane is dozens of times more so.

The problem began when cyanobacteria evolved into the first organisms able to use water in photosynthesis, releasing oxygen into the environment as a waste product. More primitive bacteria depend upon soluble iron or sulfides for use in photosynthesis; the switch to water allowed them to grow almost everywhere that had light and nutrients. Many experts think this happened early in Earth history, between 3.8 and 2.7 billion years ago, in which case some process must have kept the cyanobacteria from destroying the methane greenhouse for hundreds of millions of years. The Caltech researchers, however, find no hard evidence in the rocks to show that the switch to water for photosynthesis occurred prior to 2.3 billion years ago, which is about when the Paleoproterozoic Snowball Earth was triggered.

For cyanobacteria to trigger the rapid onset of a Snowball Earth, they must have had an ample supply of key nutrients like phosphorous and iron. Nutrient availability is why cyanobacterial blooms occur today in regions with heavy agricultural runoff.

Fortunately for the bacteria, Earth 2.3 billion years ago had already entered a moderately cold period, reflected in glacially formed rocks in Canada. Measurements of the magnetization of these Canadian rocks, which the Caltech group published earlier this year, indicate that the glaciers that formed them may have been at middle latitudes, just like the glaciers of the last ice age.

The action of the glaciers, grinding continental material into powder and carrying it into the oceans, would have made the oceans rich in nutrients. Once cyanobacteria evolved this new oxygen-releasing ability, they could feast on this cornucopia, turning an ordinary glaciation into a global one.

"Their greater range should have allowed the cyanobacteria to come to dominate life on Earth quickly and start releasing large amounts of oxygen," Kopp says.

This was bad for the climate because the oxygen destabilized the methane greenhouse. Kopp and Kirschvink's model shows that the greenhouse may have been destroyed in as little as 100,000 years, but almost certainly was eliminated within several million years of the cyanobacteria's evolution into an oxygen-generating organism. Without the methane greenhouse, global temperatures plummeted to -50 degrees Celsius.

The planet went into a glacial period so cold that even equatorial oceans were covered with a mile-thick layer of ice. The vast majority of living organisms died, and those that survived, either underground or at hydrothermal vents and springs, were probably forced into bare subsistence. If correct, the authors note, then an evolutionary accident triggered the world's worst climate disaster.

However, in evolving to cope with the new influx of oxygen, many survivors gained the ability to breathe it. This metabolic process was capable of releasing much energy and eventually allowing the evolution of all higher forms of life.

Kirschvink and his lab have earlier shown a mechanism by which Earth could have gotten out of Snowball Earth. After some tens of millions of years, carbon dioxide would build up to the point that another greenhouse took place. In fact, the global temperature probably bounced back to +50 degrees Celsius, and the deep-sea vents that provided a refuge for living organisms also had steadily released various trace metals and nutrients. So not only did life return after the ice layers melted, but it did so with a magnificent bloom.

"It was a close call to a planetary destruction," says Kirschvink. "If Earth had been a bit further from the sun, the temperature at the poles could have dropped enough to freeze the carbon dioxide into dry ice, robbing us of this greenhouse escape from Snowball Earth."

Of course, 2.3 billion years is a very long time ago. But the episode points to a grim reality for the human race if conditions ever resulted in another Snowball Earth. We who are living today will never see it, but Kirschvink says that an even worse Snowball Earth could occur if the conditions were again right.

"We could still go into Snowball if we goof up the environment badly enough," he says. "We haven't had a Snowball in the past 630 million years, and because the sun is warmer now it may be harder to get into the right condition. But if it ever happens, all life on Earth would likely be destroyed. We could probably get out only by becoming a runaway greenhouse planet like Venus."

Source: California Institute of Technology

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