Life's history in iron

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BIF from the Nuvvuagittuq Supracrustal Belt in Quebec, Canada. This belt contains the oldest supracrustals (sedimentary and volcanic rocks) thus far reported. Credit: Ernesto Percoits

A new study examines how Earth's oldest iron formations could have been formed before oxygenic photosynthesis played a role in oxidizing iron.

Geology tells us a great deal about the history and evolution of life on our planet. By studying formations in the rock record, astrobiologists can uncover important clues about the history of habitability on Earth.

Of particular interest to astrobiologists are iron formations, which existed on Earth at key periods in the evolution of life. These sedimentary rocks are made of layers of material that contain at least 15% iron, which is mixed into layers of quartz or carbonate. Geologists recognize two types of iron formations: the Algoma-type and the larger Superior-type.

Algoma-type formations are linked to volcanism deep in the oceans, whereas Superior-type formations were formed near the shore in continental shelf environments and contain few volcanic rocks.

Superior-type formations first appear on Earth in the Late Archean (2.7 billion years ago) – at the same time the continents began to rise. These formations were huge and prevailed until 2.4 billion years ago (the Early Paleoproterozoic).

At this time, the Earth was undergoing big changes, including oxygenation of the atmosphere. Because the Earth was changing so much, the ways in which superior-type formations were created between 2.7-2.4 billion years ago may have also varied – particularly in respect to the time periods before and after the atmosphere became rich in oxygen and photosynthesis became a dominant process on Earth.

After the rise of oxygen, oxygenic photosynthetic bacteria are thought to have played a big role in the creation of iron formations. But how were iron formations made before advent of oxygenic photosynthesis?

The new study addresses this question by examining how iron deposition could have occurred without biology (a process known as abiological iron deposition).

One mechanism for abiological iron deposition is a reaction in the atmosphere that creates hydrogen peroxide (a well-known powerful oxidant), which can then oxidize ferrous iron in seawater. Researchers modeled how much hydrogen peroxide could have been produced in the Eoarchean atmosphere of the Earth in order to see if this process could have played a major role in creating ancient iron formations.

According to the paper, published in Geobiology, the amount of hydrogen peroxide simply wasn't enough to account for the iron formations we now see in the geological record.

"What we concluded is that, by discounting hydrogen peroxide oxidation, anoxygenic photosynthetic micro-organisms are the most likely mechanism responsible for Earth's oldest iron formations," Ernesto Pecoits of the Université Paris Diderot and lead author on the study told astrobio.net.

Microorganisms that photosynthesize in the absence of oxygen assimilate carbon by using iron oxide (Fe(II)) as an electron donor instead of water. While oxygenic photosynthesis produces oxygen in the atmosphere (in the form of dioxygen), anoxygenic photosynthesis adds an electron to Fe(II) to produce Fe(III).

"In other words, they oxidize the iron," explains Pecoits. "This finding is very important because it implies that this metabolism was already active back in the early Archean (ca. 3.8 Byr-ago)."

More information: Pecoits et al. (2014) "Atmospheric hydrogen peroxide and Eoarchean iron formations." *Geobiology*, DOI: 10.1111/gbi.12116