Researchers find new information about 'Snowball Earth' period

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It is rather difficult to imagine, but approximately 635 million years ago, ice may have covered a vast portion of our planet in an event called "Snowball Earth." According to the Snowball Earth hypothesis, the massive ice age that occurred before animal life appeared, when Earth's landmasses were most likely clustered near the equator, precipitated relatively rapid changes in atmospheric conditions and a subsequent greenhouse heat wave. This particular period of extensive glaciation and subsequent climate changes might have supplied the cataclysmic event that gave rise to modern levels of atmospheric oxygen, paving the way for the rise of animals and the diversification of life during the later Cambrian explosion.

But if ice covered the earth all the way to the tropics during what is known as the Marinoan glaciation, how did the planet spring back from the brink of an ice apocalypse? Huiming Bao, Charles L. Jones Professor in Geology & Geophysics at LSU, might have some of the answers. Bao and LSU graduate students Bryan Killingsworth and Justin Hayles, together with Chuanming Zhou, a colleague at Chinese Academy of Sciences, had an article published on Feb. 5 in the *Proceedings of the National Academy of Sciences*, or *PNAS*, that provides new clues on the duration of what was a significant change in atmospheric conditions following the Marinoan glaciation.

"The story is to put a time limit on how fast our Earth system can recover from a total frozen state," Bao said. "It is about a unique and rapidly changing post-glacial world, but is also about the incredible resilience of life and life's remarkable ability to restore a new balance between atmosphere, hydrosphere and biosphere after a global glaciation."

Bao's group went about investigating the post-glaciation period of Snowball Earth by looking at unique occurrences of "crystal fans" of a common mineral known as barite (BaSO4), deposited in rocks following the Marinoan glaciation. Out of the three stable isotopes of oxygen, O-16, O-17 and O-18, Bao's group pays close attention to the relatively scarce isotope O-17. According to Killingsworth, there aren't many phenomena on earth that can change the normally expected ratio of the scare isotope O-17 to more abundant isotope O-18. However, in sulfate minerals such as barite in rock samples from around 635 million years ago, Bao's group finds large deviations in the normal ratio of O-17 to O-18 with respect to O-16 isotopes.

"If something unusual happens with the composition of the atmosphere, the oxygen isotope ratios can change," Killingsworth said. "We see a large deviation in this ratio in minerals deposited around 635 million years ago. This occurred during an extremely odd time in atmospheric history."

According to Bao's group, the odd oxygen isotope ratios they find in barite samples from 635 million years ago could have occurred if, following the extensive Snowball Earth glaciation, Earth's atmosphere had very high levels of carbon dioxide, or CO2. An ultra-high carbon dioxide atmosphere, Killingsworth explains, where CO2 levels match levels of atmospheric oxygen, would grab more O-17 from oxygen. This would cause a depletion of the O-17 isotope in air and subsequently in barite minerals, which incorporate oxygen as they grow. Bao's group has found worldwide deposits of this O-17 depleted sulfate mineral in rocks dating from the global glaciation event 635 million years ago, indicating an episode of an ultra-high carbon dioxide atmosphere following the

Marinoan glaciation.

"Something significant happened in the atmosphere," Killingsworth said. "This kind of an atmospheric shift in carbon dioxide is not observed during any other period of Earth's history. And now we have sedimentary rock evidence for how long this ultra-high carbon dioxide period lasted."

By using available radiometric dates from areas near layers of barite deposits, Bao's group has been able to come up with an estimate for the duration of what is now called the Marinoan Oxygen-17 Depletion, or MOSD, event. Bao's group estimates the MOSD duration at 0 – 1 million years.

"This is, so far, really the best estimate we could get from geological records, in line with previous models of how long an ultra-high carbon dioxide event could last before the carbon dioxide in the air would get drawn back into the oceans and sediments," Killingsworth said.

Normally, carbon dioxide levels in the atmosphere are in balance with levels of carbon dioxide in the ocean. However, if water and air were cut off by a thick layer of ice during Snowball Earth, atmospheric carbon dioxide levels could have increased drastically. In a phenomenon similar to the climate change Earth is witnessing in modern times, high levels of atmospheric carbon dioxide would have created a greenhouse gas warming effect, trapping heat inside the planet's atmosphere and melting the Marinoan ice. Essentially, the Marinoan glaciation created the potential for extreme changes in atmospheric chemistry that in turn lead to the end of Snowball Earth and the beginning of a new explosion of animal life on Earth.

While previous work by Bao's group had advanced the interpretation of the strange occurrence of O-17 depleted barite just after the Marinoan glaciation, there was still much uncertainty on the duration of ultra-high CO2 levels after meltdown of Snowball Earth. Bao's discovery of a field site with many barite layers gave the opportunity to track how oxygen isotope ratios changed through a thickness of sedimentary rock. As the pages in a novel can be thought of as representing time, so layers of sedimentary rock represent geological history. However, these rock "pages" represented an unknown duration of time for the MOSD event. By using characteristic features of the Marinoan rock sequence occurring regionally in South China, Bao's group linked the barite layer site to other sites in the region that did have precise dates from volcanic ash beds. Bao's group has succeeded in estimating the duration of the MOSD event, and thus the time it took for Earth to restore "normal" CO2 levels in the atmosphere.

"To some extent, our findings demonstrate that whatever happens to Earth, she will recover, and recover at a rapid pace," Bao said. "Mother Earth lived and life carried on even in the most devastating situation. The only difference is the life composition afterwards. In other words, whatever humans do to the Earth, life will go on. The only uncertainty is whether humans will still remain part of the life composition."

Bao says that he had been interested in this most intriguing episode of Earth's history since Paul Hoffman, Dan Schrag and colleagues revived the Snowball Earth hypothesis in 1998.

"I was a casual 'non-believer' of this hypothesis because of the mere improbability of such an Earth state," Bao said. "There was nothing rational or logic in that belief for me, of course. I remember I even told my job interviewers back in 2000 that one of my future research plans was to prove that the Snowball Earth hypothesis was wrong."

However, during a winter break in 2006, Bao obtained some unusual data from barite, a sulfate mineral dating from the Snowball Earth period that he received from a colleague in China.

"I started to develop my own method to explore this utterly strange world," Bao said. "Now, it seems that our LSU group is the one offering the strongest supporting evidence for a 'Snowball Earth' back 635 million years ago. I certainly did not see this coming. The finding we published in 2008 demonstrates, again, that new scientific breakthroughs are often brought in by outsiders."

Bao credits his research ideas, analytical work and pleasure of working on this project to his two graduate students, Killingsworth and Hayles, as well as his long-time Chinese collaborators. Bao brought Killingsworth and Hayles to an interior mountainous region in South China in December 2011, where the group succeeded in finding multiple barite layers in a section of rocks dating to 635 million years ago. This discovery formed a large part of their analysis and subsequent publication in *PNAS*.

"Nothing can beat the intellectual excitement and satisfaction you get from research in the field and in the laboratory," Bao said.

More information: www.pnas.org/content/early/201 … 213154110.1.abstract

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