Anti-freeze for snowball Earth

Does complex life stop the planet freezing over? Andy Ridgwell investigates.

There is a Gary Larson *Far Side* cartoon showing penguins and a polar bear together on an ice floe. Spot anything wrong? Of course – polar bears live in the Arctic while penguins live in the Antarctic, with warm climates in between. Ice stretching from the Arctic to Antarctic is impossible. Or is it?

The geological record of the late Precambrian, around 600 million years ago, tells us huge glaciers gouged the landscape and deposited layers of crushed rock debris thousands of meters thick. So far so ordinary – the Earth has had many cold periods since then. Each time glaciers have left tell-tale marks on the landscape. But in the Precambrian, glaciers seem to have deposited sedimentary rocks in the tropics. We know this because even though the continents have since moved, we can read a rock's original latitude from tiny magnetic fields imprinted when it formed.

If the coast near the equator had glaciers, most of the planet must have been frozen. From space, the Earth would have looked like a giant snowball. There is evidence that this wasn't a one-off and something similar had happened several times before. However, the last 'snowball' catastrophe occurred at about the time complex multi-cellular animal life first appeared on Earth. So might there be a link between evolution and extreme climate changes?

At the University of East Anglia I studied how carbon cycles through living systems, and how carbon dioxide in the atmosphere is regulated (*Planet Earth* summer 2002 p6-7). More recently, working with experts on Precambrian geology at the University of California in Riverside, I began to see a fundamental difference in the carbon cycle in modern and ancient times.

The difference involves life. In the modern ocean, some microscopic marine plants (phytoplankton) and animals (zooplankton) use chemicals dissolved in sea water to make protective shells out of the mineral calcium carbonate. These tiny organisms can have a big effect, sometimes turning the ocean surface milky-white when vast blooms form. When the plankton die, their bodies settle on the ocean floor. In shallow seas, this is how chalk rocks are formed.

In the deep sea, calcium carbonate can dissolve, and over thousands of years the rate these shells dissolve helps regulate ocean chemistry and the amount of atmospheric carbon dioxide. But back in the Precambrian, life had not yet thought about building shells, and there would have been no carbonate shell 'regulator' to help keep things running smoothly. Could this have something to do with why recent ice ages weren't as cold as those in the Precambrian?

'Earth would have looked like a giant snowball.'

I modelled how carbon cycles through the atmosphere, ocean, and sedimentary rocks. Remove the organisms in the surface ocean that lock up calcium carbonate, and atmospheric carbon dioxide is not so well regulated anymore. Carbon dioxide can drop so low, and the Earth cool so much, that ice would creep from the poles down to the equator. There would be the greatest ice age the Earth ever experienced.

Once organisms that use calcium carbonate became widespread in the ocean, carbon dioxide in the atmosphere would have been better regulated and the Earth could no longer 'snowball'. Perhaps we are only here because the recent ice ages that our caveman ancestors had to live though were not too cold.

Carbon dioxide from burning fossil fuels is now making the ocean more acidic and environmental conditions more difficult for organisms that lock up calcium carbonate in shells and skeletons. Recent reports of declining coral reefs might be showing there is already a problem. So what are the implications for future climate? This type of complex issue, involving interactions between climate, carbon cycling, and living organisms responding to global change is just what NERC's new programme Quantifying the Earth System (QUEST) aims to tackle.

I am now testing my theories using the GENIE Earth system model (part of NERC's e-Science programme), which represents carbon cycling as well as ocean and atmosphere circulations, and will soon be able to show how ice sheets grow and decay. This will give a much better idea of how important calcium carbonate-forming plankton are in regulating climate and maintaining conditions suitable for complex life like you and me.

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This work was recently described in the journal Science *in an article called* Carbonate deposition, climate stability, and Neoproterozoic ice ages.