Taking the temperature of the ancient earth

March 8 2011, By Tony Fitzpatrick

(PhysOrg.com) -- A new technique has allowed scientists to pin down the timing of ancient glaciations, linking them more firmly to two bursts of extinction.

A team of researchers, including earth and planetary scientists from Washington University in St. Louis, for the first time has been able to reconstruct both ocean temperature and general ice thickness of massive glaciers during one of the biggest mass extinctions in history hundreds of millions of years ago.

The extinction, which occurred between 445 and 443 million years ago in the Late Ordovician Period, is one of the five biggest mass extinctions in Earth history, wiping out an estimated 75 percent of simple marine species.

The Ordovician glaciation is the only one that coincides with a major mass marine extinction. Shedding light on this ancient event can help reveal clues about the interplay between evolution, climate and environment.

David Fike, PhD, Washington University assistant professor of earth and planetary sciences in Arts & Sciences, along with his post-doctoral researcher David Jones, PhD, and colleagues from the California Institute of Technology (Caltech), gathered carbonate rock samples from the Quebec, Canada area and east-central Missouri that date back to the Late Ordovician, when all of the present mid-continental United States was a shallow ocean.

David Fike, PhD, assistant professor of earth and planetary sciences, holds a 443-million-year-old slab of Ordovician limestone from Anticosti Island in Quebec that is sprinkled with the fossilized remains of marine creatures killed during a cooling pulse. Work he and his colleagues did using a new paleothermometer recently linked a double cooling pulse at the end of the Ordovician period to a double mass exintinction in ancient oceans.

They used mass spectroscopy to analyze the chemistry of the fossilized marine animal shells in the carbonates and plied a new type of "paleothermometer," developed by John Eiler, PhD, of Caltech, to determine the average temperatures of the Late Ordovician oceans.

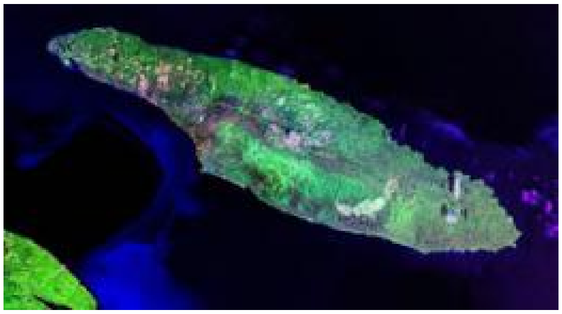
Eiler's technique measures the extent to which heavy isotopes of carbon and oxygen bond to one another in the carbonate (CO,-) portion of ancient limestone rather than to the sea of light isotopes in which they swim. The proportion of these heavy-isotope bonds is sensitive to the temperature at which the rock formed; the lower the temperature, the greater the clumping. Clumping thus forms the basis for a simple paleothermometer that can be used to take the temperature of ancient climates.

Previously to get a temperature estimate of ancient climates, researchers would measure the oxygen isotope composition of the carbonate samples. Oxygen 16 is preferentially evaporated from colder oceans, leaving the slightly heavier oxygen 18 behind in seawater. When the shells of animals form from elements in seawater, they record this oxygen isotope signal. However, temperature can be derived from oxygen isotope ratios only if the ratios in both the rock and the seawater are known.

"The problem is: In old rocks we don't have any water, so what was done was to measure one thing (shells) and guess the other (water)," said Fike. "With clumping there is no guess work involved. We end up getting two measurements in one, the temperature and the isotope composition of the ancient ocean which lets us infer yet another, the size of the ice sheets. It's the best way to reconstruct temperature, and it allows us to go back in time to understand how climate has been changing in ways that we could never do before."

Results were published recently in the Feb 18th issue of *Science*.

PHYS.ORG



Satellite image of Anticosti Island, an island at the opening of the St. Lawrence River in Quebec, Canada, where most of the samples were taken. The island is an ideal limestone hunting ground because recent glaciation removed weathered rocks from the surface, exposing fresh strata that had never undergone deep burial or geothermal heating, which might have changed their isotopic composition.

Their analysis reveals a relatively short-lived cooling of sea waters by five degrees Celsius (nine degrees Fahrenheit) and the existence of ice sheets that were as much as two times the extent and depth of the last period of glaciation, some 20,000 years ago during the Pleistocene. The ice sheets, the researchers estimate, eventually became as large as 150 million cubic kilometers (km).

Previous estimates of ice sheet volume ranged from roughly 50 to 250 million cubic km; duration estimates ranged from 35 million years to less than one million years, and it was anybody's guess how much sea surface temperatures in the tropics cooled.

Now, this is not your father's Earth. At the time, the northern hemisphere was entirely ocean and what passed for continents were positioned on the equator including North America and the supercontinent called Gondwana, which began on the equator and extended to the South Pole. Marine life almost exclusively occupied shallow areas such as reefs, akin to the modern-day Great Barrier Reef.

"This is the first direct reconstruction of how much ice was on land and the first recording of temperature change during the end of the Ordovician," said Fike, who ran mass spectrometry measurements samples from Anticosti Island in Quebec in his laboratory as part of this study. "It's a valuable record that dramatically enhances our understanding of the ocean and the climate system during this time."

The extinction of marine species such as brachiopods, trilobites and conodonts, quaint beasts fossilized in limestone, seems to have come in two separate bursts, said Fike, unlike the extinction of the dinosaurs, the best known extinction that came in one massive swoop. And evidence for the extinction long has elicited debate over how it happened.

Limestone laid down in the aftermath of the second pulse of extinction includes surviving brachiopods, bryozoans and trilobites. They were the fortunate few. Two-thirds of all brachiopods and bryozoans perished in the double extinction as did 75 percent of marine species in total.

"The first pulse of extinction is associated with the onset of intense glaciation and could be due to a variety of reasons," said Fike. "Maybe it just got colder and organisms couldn't handle it. Another thing that you see going into a glacial period where you're taking water from the ocean and putting it on land is a drop in sea level, so it's likely that most of the shallow seas, such as the one covering much of North America, fell, and that would have hit those organisms' habitat space hard.

"The second pulse comes at the end of this intense glaciation. And we think that's associated with organisms that had adapted to the cold and suddenly the sea level rises and you're going out of the glacial period and temperatures get a lot hotter, and clearly some organisms are not happy with that. So, you have this intriguing two-pulse mass extinction that now can be directly related to the emergence and the end of this big burst of glacial activity that we see."

Provided by Washington University in St. Louis