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Carbon isotopes of ICDP FAR-DEEP Hole 3A: alteration or a signal from atmospheric methane oxidation at the onset of the first Huronian glaciation?

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Biosphere-geosphere interactions are central to understanding the cause of the first, Palaeoproterozoic, low-latitude glaciation. Varied forcing factors include atmospheric CO_2 (greenhouse gas) drawdown resulting from enhanced chemical weathering of silicate rocks because of collisional tectonics; rifting at low latitudes; or a combination of tectonic and environmental factors. These models would all be quite slow to act as they involve the rock cycle, but they do allow for repeat episodes of global freezing. Another driver commonly considered is catastrophic and rapid oxidation of Earth's proposed early methane (greenhouse gas) atmosphere $\sim$2.4 billion years ago. This hypothesis predicts that a record of the rapid transfer of a vast quantity of ^{13}C-depleted carbon from the atmosphere to the oceans should be found in contemporaneous marine carbonates.

Until now, testing of this 'methane oxidation' hypothesis for Earth's first severe climatic deterioration has been precluded by lack of suitable rock types in immediately pre-glacial sections. Only one recently discovered section worldwide is known to include carbonates directly below the glacial diamictites of the first Huronian episode: International Continental Drilling Program FAR-DEEP Hole 3A, which targeted the Polisarka Sedimentary Formation, Imandra-Varzuga Belt, Fennoscandian Russia. The section also includes igneous rocks. Further, from an andesitic ash in the same cores we have obtained a zircon U-Pb ID TIMS age of 2435 Ma, providing a minimum age constraint for these Fennoscandian diamictites and allowing correlation with the first of the three Huronian glacial episodes.

Consistent with predictions of the methane oxidation hypothesis, there are two rapid (estimated ca. 10^5 year duration) negative carbon isotope excursions from 'normal' marine carbonate δ^{13}C values of $\sim$0‰ (VPDB) to low values of -5.4‰ in Hole 3A carbonates in closest proximity to the overlying diamictites. Very strong correlation between decreasing δ^{13}C values and increasing Mg/Ca ratios, consistent with secondary alteration perhaps related to igneous activity, demands explanation: we have yet to rule out a hydrothermal alteration origin for these pre-glacial negative δ^{13}C excursions. Ongoing work on the ICDP FAR-DEEP Hole 3A carbonates offers an opportunity to contribute to resolution of the controversy over the cause of this first "snowball" glaciation in Earth history.