Geophysical Research Abstracts
Vol. 12, EGU2010-6250, 2010
EGU General Assembly 2010

The Late Ordovician crisis: the Large Igneous Province hypothesis tested by global carbon cycle modeling.

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The causes of the well-known Late Ordovician-Hirnantian glaciation remain largely debated. This global cooling event is generally attributed to a severe decrease of atmospheric pCO_2 during a time of general greenhouse climate but its duration is not fully determined. The climate perturbation is synchronous with one of the biggest biotic crisis of the Earth history. Some authors have shown that, considering the Ashgillian paleogeography, a drop in pCO_2 below a threshold of 8x to 10x PAL (Present Atmospheric Level) may induce a decrease in temperature in high latitudes so that the installation of an ice-sheet on Gondwana could be possible. Such a process requires an intensification of silicate weathering and/or organic carbon burial that are the two major processes potentially driving a decrease in atmospheric pCO_2 at the geologic time scale.
The Late Ordovician is known to be a period of high mantellic activity marked by a lack of reversal magnetic field and high volcanic activity. Barnes (2004) and Courtillot and Olson (2007) link this process to a superplume event that may give rise to continental basalt flooding. In the present study, we tested this hypothesis with a global carbon cycle numerical box-model coupled with an Energy Balance Climate Model. The Model is an upgrade of that used by Grard et al. (2005) to simulate the environmental impact of the Siberian traps at the P/T boundary. The configuration of the box-model has been set using the Late Ordovician paleogeography. In each oceanic box, the model calculates the evolution of carbon, phosphorus and oxygen concentrations and alkalinity. It also calculates atmospheric pCO_2, atmospheric and oceanic $\delta^{13}C$.
We tested different scenarios of Large Igneous Province (LIP) emplacements and organic carbon cycle interactions simulating atmospheric pCO_2 drops of amplitude large enough to produce the Hirnantian glaciation. We show that the hypothesis of low latitude LIP well accounts for the Late Ordovician climate perturbations with a global warming event (the Boda Event of Fortey and Cocks, 2005) prior to the development of the Hirnantian maximum cooling. Our simulations furthermore show that a 600 000 km^2 continental trap localized at the equator is the minimum configuration required to reach the 8x PAL atmospheric pCO_2 threshold.