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Global Cooling, Mass Extinction and a Carbon Cycle Disruption

In the late Ordovician the atmospheric CO_2 was greater than present day. Yet, roughly 445 million years ago, in a stage known as the Hirnantian, an ice-sheet managed to grow on the supercontinent Gondwana that would change Life on Earth. The sudden ice-age led up to the second greatest mass extinction event that killed 85% of all species. Uncertainty remains how an ice-age could take hold in a greenhouse world. The erosion of a large igneous province that removed CO_2 from the atmosphere has been suggested, but no geological proof is preserved. The palaeogeographic configuration was however favorable for the expansion of an ice-sheet, as Gondwana covered the South Pole.

Land was still barren of life in the Hirnantian Stage of the Ordovician. The fauna in the seas was adapted for a warm climate and unprepared for a global cooling that would have dire consequences. In the start of the glacial, temperature decreased, ice-sheets expanded on Gondwana and the global sea-level fell. As a consequence, many species went extinct. Some genera managed to survive and even thrive in the cooler climate, such as the characteristic *Hirnantia* brachiopod fauna. But this was just the first phase of the mass extinction. At the end of the glacial, as the ice-sheets melted, the global-sea level increased. The cold and less saline meltwater in the ocean caused the water to become stratified. As a response, anoxia (depletion of oxygen), spread and killed many species in the second phase of the mass extinction. The two phases combined, constitutes the second largest mass extinction in earth's history and is known as the Late Ordovician Mass extinction.

The geological record of this time is fragmented. Fossil evidence reveals a changing fauna. Glacial deposits in Africa and South America, once a part of the supercontinent Gondwana, reveals the extent of the ice-sheet. A major disruption in the carbon cycle is revealed in the increase of stable isotope $\delta^{13}C$.

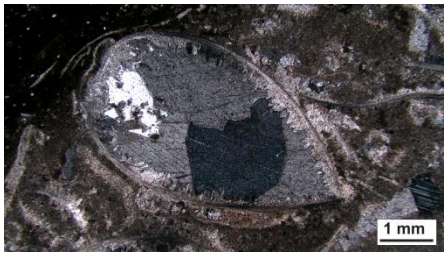

Figure shows a *Hindella sp.* brachiopod fossil of the *Hirnantia* fauna, which thrived in the cool climate. Found in the drill core from Gotland.

The carbon anomaly in a drill core from Gotland

In a recently drilled core from Southern Gotland, the $\delta^{13}C$ isotope of the Hirnantian were analysed and the rock and fossils were studied. The core revealed a complex history of changing sea-levels due to the glaciation. The strata of the Hirnantian were bound between two unconformable surfaces in the bottom and top, indicating two episodes of ice-sheet growth with an interglacial between. Brachiopod fossil, of both the cool water thriving *Hirnantia* fauna and a later post-glacial fauna co-occurred within the core. However, they did not appear consecutively as would be supposed. The $\delta^{13}C$ isotope values showed a large increase in values in the Hirnantian strata. The peak values are associated with transgressive strata, meaning sediments deposited during the sea-level increase. This study of southern Gotland, as it was 445 million years ago, is a piece in a greater puzzle to understand the climate change and mass extinction of the late Ordovician.

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