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A glimpse of ice sheets in the Early Palaeozoic greenhouse world

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It is a commonly held notion that the Earth had a mild greenhouse climate for much of the Early Palaeozoic, terminated by the Hirnantian Ice Age (c. 434 Ma). Models now predict pCO_2 values of 5x present atmospheric level and a global mean air temperature of 15oC, consistent with δ18O values and zooplankton biogeographical studies that indicate a modern-style "cool" world climate for the Late Ordovician. Did icehouse conditions exist in the earlier Ordovician?

Studiesof depositional architecture from the tectonically quiescent, subpolarGondwana continental margin,in South Africa and Jordan, provide a well constrained sedimentary record of 4th and, 3rd ordereustatic cyclesduring the Floian and Darriwilian. When fourth order sequences are hypothesized to be paced by the long eccentricity 405-kyr cycle the 3rd order sequences are calculated to be $\sim$1.2-myr and broadly correlate with the global eustatic curve. These intervals are separated by sequences of $\sim$2.4-myr duration. In comparison with Mesozoic and Cenozoic we conclude that the $\sim$1.2-myr cycles correspond with long obliquity cycles predominant in icehouse conditions and the $\sim$2.4-myr cycles with the long eccentricity cycle predominant during greenhouse conditions. We propose Floian and Darriwilian Ice Ages, during which, orbitally induced "cold snaps," caused the expansion and amalgamation of small/medium-scale ice sheets. Based on relative sea level changes of 15 – 30m we hypothesize ice sheets of 8-12 x 106 km3.Placing deposition sequence orders into a high resolution temporal framework (i.e. orbital periodicities) provides a method for identifying icehouse periods throughout the Palaeozoic.