Recognizing the termination of the Late Paleozoic Ice Age Early Permian phase

Charles M. Henderson*†[1], Daniel Calvo Gonzalez[2], and Benoit Beauchamp[2]

[1]Department of Geoscience, University of Calgary, 2500 University Drive, NW Calgary Alberta T2N 1N4 – Canada

[2]Department of Geoscience, University of Calgary – Canada

Abstract

The Permian Time Scale is nearly finished with only the base-Kungurian GSSP remaining to be decided. The base-Sakmarian and base-Artinskian GSSPs have been recently ratified at points that differ somewhat from previous traditional levels, making this a good time to review how these boundaries affect correlation of Late Paleozoic Ice Age (LPIA) phases. Interpolation of radio-isotopic ages place the base-Permian (base-Asselian Stage) at 298.9 Ma, the base-Sakmarian at 293.5 Ma, the base-Artinskian at 290.1 Ma (or 290.5 Ma by different interpolation) and base-Kungurian at _˜283 Ma. These boundaries approximate maximum flooding intervals as is generally the case when boundaries are defined by conodonts. Many workers have correlated a Carboniferous-Permian interval of widespread ice-sheets as Kasimovian to mid-Sakmarian age. However, a mid-Sakmarian age for the termination of widespread ice-sheets would now correlate with the base of the Sakmarian in the newly ratified time scale. Published radio-isotopic ages from the Parana Basin of southern Brazil suggest a terminal late Carboniferous (300-299 Ma) deglaciation. In addition, a major transgression near the base of the Copacabana Formation at Cochabamba, Bolivia dates to about 299-298 Ma. Deposits and published ages from the Kalahari and Karoo basins of Namibia and South Africa also correlate with this event, but two younger deglaciation events at _˜295 Ma (mid-late Asselian) and at 282 Ma (early Kungurian) also occur. All of these dates fit within a framework of transgressive-regressive sequences (T-R), transgressive systems tracts (TST), astronomically tuned cyclothems and conodont biostratigraphy established from the Robledo Mountains of southern New Mexico to the high Canadian Arctic on Ellesmere Island, where the Kasimovian to Asselian interval is characterized by numerous 405 Kyr cyclothems that provide a distinct banded pattern in outcrop within our study region. This pattern is interrupted by major flooding events of longer duration 3rd order T-R sequences. We have demonstrated that cyclothems from approximately Kasimovian to mid-Asselian exhibit facies relationships that point to sea-level fluctuations on the order of 100 metres, but late Asselian cyclothems are associated with sea-level fluctuations of only _˜30-40 metres. The difference is interpreted to reflect the potential ice-volume. A 3rd order T-R sequence boundary that is astronomically tuned to 294.9 Ma separates these units at Carlin Canyon Nevada and the Canadian Arctic. The maximum flooding surface (MFS) of the overlying T-R sequence correlates with the base-Sakmarian stage at 293.5 Ma. This MFS is probably the most significant flooding event during the Early Permian and in many sections the overlying progradational platform is mid-Artinskian. In more proximal sections a

*Speaker

†Corresponding author: cmhender@ucalgary.ca

significant MFS separates Sakmarian and Artinskian carbonate platformal successions. The late Asselian TST with smaller amplitude cyclothems and base-Sakmarian MFS represent the primary far-field signature to recognize the termination of widespread ice sheets and must be associated with major $pCO2$ rise and global warming. This interval can also be recognized by major changes in conodont faunas. Although the warm-water taxon *Sweetognathus* first evolved earlier in the Asselian, it underwent a major species diversification near the base-Sakmarian in association with the extinction of the genus *Streptognathodus*. Species of *Streptognathodus* distinguish many biozones from the Kasimovian to Asselian, but it is ecologically replaced by *Sweetognathus* in Sakmarian and younger Permian; this provides an additional key signature to correlate the termination timing of major cyclothems associated with the main phase of the LPIA. Until recently, cyclothems in Kansas USA were correlated to be as young as early Artinskian, but the co-occurrence of abundant *Streptognathodus* and an older *Sweetognathus* homeomorph species indicate a late Asselian age. Following this event, the ice-volume in the Karoo and in Australia must have been insufficient to affect far-field facies distribution to clearly allow recognition of high-frequency cyclothems. However, the base-Kungurian boundary may be associated with the last deglacial transgression at 282 Ma.

Keywords: Early Permian, LPIA timing, Streptognathodus extinction, Sweetognathus, cyclothems