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Transition to glacial state through the lower Carboniferous and impact of orbital forcing on sedimentary records and anoxia expansion

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The lower Carboniferous is marked by the onset of the Late Paleozoic Ice Age (LPIA), one of the most severe and longest in Earth history, with a duration of nearly 100 million years [1]. The onset of the glaciation is associated with bursts of anoxia of different magnitudes through the Tournaisian and Visean stages (in the lower Carboniferous). These anoxic events are the Lower Alum Shale (LASE [2]) at the base of the middle Tournaisian, The Tournaisian Carbon Isotope Excursion (TICE, also called KOBE [3]) in the middle Tournaisian, and the Visean Carbon Isotope Excursion (VICE [4]). The particularity of these anoxic events is their development during a relatively cold period and their longer durations (5-10 Myr) compared to most other anoxic events. Clues have been accumulated pointing to the possibility that anoxia and glaciation may have been paced by changes in Earth's orbit parameters ([5], [6], [7], [8]). These changes are the astronomical (Milankovitch) cycles (Eccentricity, Obliquity, and Precession) with specific durations. They impact the incoming solar radiation and seasonal contrasts, hence global climate. Cyclostratigraphy (The identification of astronomical cycles in the geological record) is the tool to establish a chronological framework (ATS) of the lower Carboniferous in order to reach precise estimates for the duration of these anoxic events. This precise timing is essential to get a better understanding of the climate response to astronomical forcing in the early Carboniferous. We also intend to delve into Milankovitch forcing related to ice age evolution and to understand the connection of anoxic events with climate dynamics and orbital forcing. In addition, precession and obliquity cycles are directly related to the Earth-Moon distance (and the length of the day). Through our study, we will provide a duration of precession and obliquity cycles which would allow to provide the Earth-Moon distance and length of the day for this period. Therefore, five geologic sections have been selected in the Namur-Dinant basin in Belgium and one section in Germany. Sections will undergo a high-resolution sampling then multiple analyses will be applied (major and trace elements, total organic carbon (TOC), and stable carbon isotopes($\delta^{13}C$)). Different cyclostratigraphic techniques will be applied (e.g., MTM, ASM, TimeOpt, COCO, EHA) on specific paleoclimate proxies to build the chronostratigraphic framework. In fine, precession and obliquity cycles are directly related to the Earth-Moon distance (and the paleo-length of the day). Through our study we will provide a duration of precession and obliquity cycles which would allow us to provide the Earth-Moon distance and length of the day for this period, marked by a period of resonance of oceanic dissipation [9]. The study aims to deepen our understanding of the carboniferous ice age, its triggers, and Earth's intricate climatic mechanisms.

[1]Crowley & Baum 1991. [2] Rakociński et al., 2021. [3] Yao et al., 2015. [4] Liu et al., 2019. [5] Batenburg et al., 2019. [6] Batenburg et al., 2023. [7] Christine et al., 2020. [8] De Vleeschouwer et al., 2017. [9] Farhat et al., 2022.