Paleoclimate Evolution Driven by Astronomical Forcing in the Early Cretaceous Songliao Basin, Northeast China

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Early Cretaceous climate and environmental change remain speculative and disputed, due in large part to time scale uncertainties and a lack of information on terrestrial environments. Recent exploration of the Songliao Synrift Basin, NE China, which is one of the largest and long-lived Cretaceous continental basins in the world with a continuous 10-km thick sequence of strata, provides a new opportunity to improve the Early Cretaceous time scale and study terrestrial climate change. Understanding the evolution of the basin, including the climatic and environmental changes that affected sediment deposition, is key to identifying the forces that led to the carbon burial and preservation, leading to today's oil and gas reserves in the basin. We have conducted cyclostratigraphic analysis on natural gamma-ray logs from extended boreholes in the terrestrial Songliao Basin. The target is the Lower Cretaceous Shahezi Formation (K_1S), a 836-m-thick succession with black mudstone, siltstone, gravel-bearing sandstone and conglomerate, together with meter-scale black coal units distributed throughout the upper part of the formation. Time series analysis of the gamma-ray logs from selected boreholes reveals power spectra that are consistent with Earth's astronomical frequencies of precession, obliquity and orbital eccentricity, providing strong evidence for astronomically driven climate change in this Early Cretaceous basin. The results also indicate that black coal coincides with short eccentricity minima that exceed a threshold. The cyclic evolution of the lithology indicates a paleo-lake and surrounding environment that expanded and contracted repeatedly. We infer that astronomical forcing influenced paleo-lake level: climate was warm and humid with high eccentricity, and cold and dry with low eccentricity. Based on the interpreted astronomical cycles and other available chronostratigraphy, we conclude that the age of K_1S is from early Valanginian to late Hauterivian with a duration of approximately 10 million years. The formation may also reflect the well-known transient cooling Weissert Event in the mid-Valanginian as evidenced by marine glendonites at Svalbard Island accompanied by polar ice.