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The Organic Matter Accumulation in Dynamic Climate Changes Driven by Large Igneous Province during the Carboniferous-Permian Transition: Insights from the NW Junggar Alkaline Paleolake, Northern Pangea

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The Carboniferous-Permian transition (CPT), coinciding with the final assembly of Pangea during the Late Paleozoic Ice Age which is the longest ice age during the Phanerozoic (Montañez and Poulsen, 2013), remains insufficiently documented in mid- and high-paleolatitude regions of northern Pangea. To address this knowledge gap, we conducted a comprehensive geochemical analysis of the Fengcheng Formation (992 m thick; ~302–297 Ma) in the Junggar Basin (paleolatitude ~40°N; Fig. 1a) which is a critical terrestrial archive for understanding lithosphere-climate-hydrosphere-biosphere interactions during this pivotal interval.

The dataset reveals that the initial cold and arid condition characterized by weak chemical weathering, followed by a warming event that peaked at ~298 Ma, marked by intensified continental weathering. This was subsequently succeeded by a renewed cooling period. Notably, these climatic shifts exhibit stratigraphic correlations with contemporaneous CIA records from southern high-latitude Gondwana (e.g., the Karoo Basin) and equatorial regions (e.g., the Yongcheng Basin), as well as atmospheric pCO_2 fluctuations, marine $\delta^{15}N$ excursions, relative sea-level changes, and deglaciations (Fig. 2). The initial warming temporally aligns with the Skagerrak-Centered Large Igneous Province (LIP)-derived CO_2 emissions (Yang et al., 2020; Fig. 1), while the subsequent cooling corresponds to rapid atmospheric CO_2 consumption via accelerated weathering of LIP basalts. These climate transitions fundamentally reconfigured depositional environments and organic matter (OM) compositions through hydrological feedback. Progressive freshening and oxygenation intensified in tandem with the warming period. Moreover, during the warming period, elevated temperatures promoted bacterial biomass dominance over eukaryotic algae and terrestrial plants, and OM contributions from cyanobacteria, methanotrophic bacteria, and zooplankton increased progressively, contrasting with declining inputs from methanogens, halophilic archaea, and both saltwater and green algal groups. Conversely, during the subsequent cooling period, these hydrological dynamics and biotic successions underwent complete reversal, with all previously established trends in organic matter provenance and ecosystem structure being systematically inverted.

References:

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Yang, J., Cawood, P.A., Montañez, I.P., Condon, D.J., Du, Y., Yan, J.X.,Yan, S., & Yuan, D. (2020), Earth and Planetary Science Letters 534, 116074.

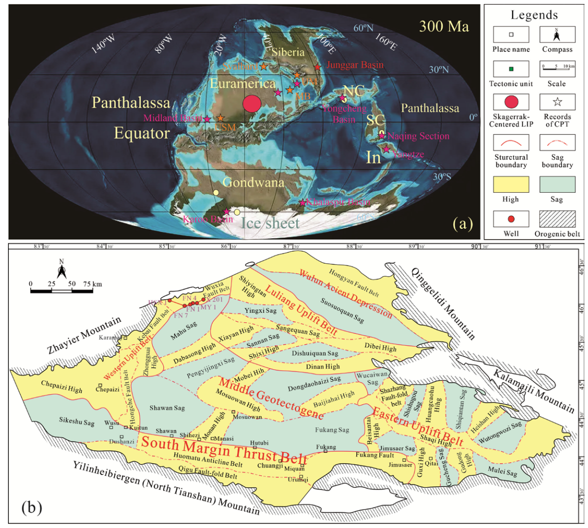

Fig. 1 (a) The location of the Junggar Basin in the paleogeographic map at ca. 300 Ma, and (b) the schematic map of the basin.

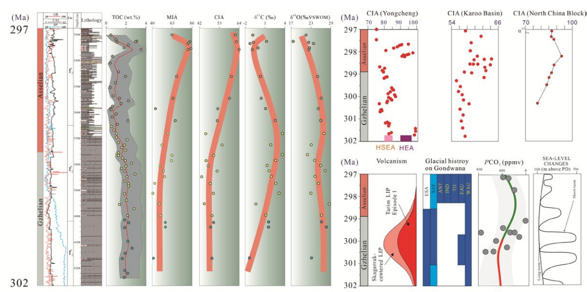

Fig. 2 Distributions of lithology, TOC content, and geochemical data from this study, along with related events and CIA values from other regions.