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# Zinc isotope evidence for global carbon cycling and stepwise cooling during the onset of late Paleozoic Ice Age

**YUTIAN ZHONG**[1,2], JITAO CHEN[1], SHENG-AO LIU[3], CHENGSHUAI YUAN[4], BIAO GAO[1], TERRY ISSON[5], BO CHEN[1], GENMING LUO[6], QINGYI SHENG[1], XIANGDONG WANG[7] AND WENKUN QIE[1]

[1]Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences

[2]University of Chinese Academy of Sciences

[3]China University of Geosciences, Beijing

[4]Research Institute of Petroleum Exploration and Development

[5]University of Waikato

[6]State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences

[7]State Key Laboratory for Mineral Deposits Research, School of Earth Sciences and Engineering and Frontiers Science Center for Critical Earth Material Cycling, Nanjing University

Presenting Author: ytzhong@nigpas.ac.cn

The earliest Carboniferous saw a critical climate transition from the Devonian greenhouse to the late Paleozoic icehouse climate state, which is featured by a worldwide, mid-Tournaisian positive carbon isotope excursion (TICE). Regardless of uncertainties in single versus double peaks in carbonate carbon isotope record ($\delta^{13}C_{carb}$), the TICE was thought to have caused by increased organic carbon burial, the underlying mechanism of which, however, remains controversial.

Zinc (Zn) is a vital micronutrient for organisms, and Zn isotopic compositions ($\delta^{66}Zn$) of seawater are mainly controlled by marine primary productivity and continental weathering, which are tightly connected to global carbon cycling. Thus, Zn isotope has the potential to disentangle the interlinked processes during the TICE event. Here, we present the first carbonate $\delta^{66}Zn$ record, in combination with other geochemical data, from two widely separated, well-preserved carbonate dominated successions (Malanbian and Xiasi) from the northeastern Paleo-Tethys Ocean region (South China Block). During the TICE interval, the coupled $\delta^{66}Zn$ and $\delta^{13}C$ profile delineates two peaks, indicating that the TICE event is a two-phase carbon cycle perturbation. Both phases are attributed to enhanced marine primary productivity, which was stimulated by increased micronutrient supply from continental weathering and oxidation of previously buried organic matter, respectively. Consequently, the two-phase, enhanced productivity and the resultant organic matter burial could have led to a stepwise climatic cooling.