

Anoxic and iron-rich seawater conditions facilitated reverse weathering: Evidence from the Mesoproterozoic siliceous rocks

**ZHUTONG KE^{1,2}, XIAOYING SHI^{1,2}, LONGFEI SUN¹, BAOZENG XIE^{2,†}, JINXIN CHEN⁴, QUAN ZHONG⁴,
MIN WANG⁴, XINQIANG WANG^{1,3}, LIMIN ZHOU⁵, JIANBAI MA⁶, LEI XU³, AND DONGJIE TANG^{1,3,*}**

¹State Key Laboratory of Geomicrobiology and Environmental Changes, Frontiers Science Center for Deep-time Digital Earth, China University of Geosciences (Beijing), Beijing 100083, China

²School of Earth Sciences and Resources, China University of Geosciences (Beijing), Beijing 100083, China

³Institute of Earth Sciences, China University of Geosciences (Beijing), Beijing 100083, China

⁴Administration of Shennongjia National Park, Shennongjia, Hubei 442421, China

⁵National Research Center for Geoanalysis, Beijing 100037, China

⁶Institute of Vertebrate Paleontology and Paleoanthropology, Beijing 100044, China

ABSTRACT

Enhanced reverse weathering is pivotal for sustaining the persistent ice-free climate during the mid-Proterozoic despite low solar irradiance. Silicon-rich seawater is considered the primary factor driving reverse weathering; however, authigenic clay minerals, the major products of reverse weathering, are not consistently more abundant in siliceous rocks, implying the existence of additional controlling factors. Here, we analyzed Mesoproterozoic siliceous rocks from the ~1.1 Ga Songziyuan Formation of South China, using multiple techniques. The results show that berthierine and stilpnomelane, the dominant authigenic clay minerals, are enriched solely under silica-rich, anoxic, and iron-rich micro-environments. These data support the hypothesis that anoxic, iron-rich conditions may have played a crucial role in promoting reverse weathering, specifically the authigenesis of Fe-bearing clay minerals in silica-rich environments. The predominantly short-term, iron-rich conditions [e.g., Fe(II) > 50 μ M] in the mid-Proterozoic silica-rich ocean may have enhanced reverse weathering and thereby facilitated long-term ice-free climate conditions.

Keywords: Redox sensitive elements, authigenic clay minerals, $p\text{CO}_2$, silicon cycle