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Dynamic Carbon–Sulfur Cycling and Weathering Feedbacks in the Early Cambrian Ocean: Insights from Potassium Isotopes

MS. LIU WILLOW YANG, TAO YANG AND JIN WANG
Nanjing University

The early Cambrian witnessed dramatic shifts in marine chemistry linked to Earth's sphere interactions, yet the drivers of seawater C–S cycling remain debated. We present a multi-proxy study (major/trace elements, Fe speciation, $\delta^{13}C_{carb}$, $\delta^{13}C_{org}$, $\delta^{34}S_{py}$, and $\delta^{41}K$) of the Luojiacun Section, China (Cambrian Stage 2-3, Yangtze Block) to unravel seawater evolution and weathering-climate feedbacks. Stratigraphic correlation using δ^{13}Ccarb links the section to the ZHUCE event. Weathering proxies (CIA_{corr}, CIW, ICV, A–CN–K diagram) reveal three phases: Phase 1 (intense weathering), Phase 2 (moderate weathering), and Phase 3 (weathered sources with K recycling). Redox evolution, reconstructed via redox-sensitive element, Fe speciation and Mo-U covariation, transitions from suboxic (Phase 1, transgression) through euxinic (Phase 2, hiatus) to oxic-suboxic conditions (Phase 3, regression). Crucially, coupled $\delta^{13}C_{carb}$–$\delta^{34}S_{py}$ trends and $\Delta^{13}C_{org\text{-}carb}$ shifts (+36 to +30 ‰) demonstrate dynamic C–S cycling: Phase 1 shows decoupled C–S with stable δ^{34}Spy, whereas Phase 2 exhibits coupled $\delta^{13}C_{carb}$–$\delta^{34}S_{py}$ excursions. $\delta^{41}K$ variations (-1.10 to -0.46 ‰) correlate with weathering phases, highlighting terrestrial inputs (e.g., nutrient fluxes, sulfate delivery) as key controls on marine productivity, sulfate reservoirs and the seawater stratification structure. This work establishes continental weathering as a critical bridge between lithospheric evolution and marine biogeochemical cycles during marine paleoenvironment evolution.