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Insights into the Evolution of Seawater Chemistry and Sulfur Cycling during the Early Silurian: Implications for Organic Carbon Accumulation in the Longmaxi Formation, South China

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The Early Silurian Longmaxi Formation in South China preserves black shale sequences that exhibit variations in total organic carbon (TOC) content. These variations are linked to interactions between marine biogeochemical changes and regional tectonic-induced environmental changes. In this study, we integrate graptolite biostratigraphy, carbon isotope chemostratigraphy, and geochemical proxies, including sulfur isotopes, redox-sensitive elements, and hydrographic indicators, from the Yangtze outer and inner shelf to reconstruct paleoenvironmental conditions controlling TOC accumulation.

Our results show that the extraordinarily high TOC (>3 wt.%) interval formed under euxinic conditions with elevated productivity and moderate hydrographic restriction. The subsequent high TOC (2–3 wt.%) interval is linked to anoxic conditions, lower productivity, and stronger restriction. Sulfur isotope ($\delta^{34}S_{py}$) data reveal spatial variations in the sulfur cycle: inner-shelf sites (e.g., Changning) have enriched $\delta^{34}S_{py}$ values (~+8‰), indicating upwelling-derived ^{34}S-enriched H_2S, while outer-shelf locations (e.g., Yichang) show much lower values (~−20‰), suggesting more intense microbial sulfate reduction.

We propose two models for TOC variability. The Sedimentation Rate–H_2S Concentration Model suggests that rapid sedimentation rates and elevated sulfate availability promoted euxinic conditions and enhanced organic matter preservation in inner-shelf settings. In contrast, slower sedimentation in outer-shelf regions led to organic matter decomposition. The Kwangsian Orogeny–Hydrographic Restriction Model connects tectonic uplift with increased hydrographic isolation, reducing sulfate flux, phosphorus regeneration, and shifting the environment from euxinic to anoxic conditions, diminishing TOC accumulation over time.

These findings highlight the importance of tectonically driven changes in seawater chemistry and redox conditions in organic carbon deposition. This study provides new insights into marine biogeochemical cycling during the Early Silurian and contributes to understanding Earth’s spheres interaction in ancient ocean systems.