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High-Resolution Geochemical Profiles Provide New Insights into Controls on Organic Matter Accumulation in the Middle and Upper Devonian Horn River Group

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Summary

Organic matter (OM) accumulation in black shales is primarily controlled by dilution, preservation, and bioproductivity. Anomalous perturbations of these controls can be recorded as oscillations in concentrations of certain elements that make them useful as proxies for detrital flux, biogenic flux, and redox conditions. In this study, we applied biogenic silica (Si_{bio}) as the proxy for bioproductivity, Al and Ca for siliciclastic and carbonate inputs, S/Fe for redox states, and total organic matter (TOC) for estimate of buried OM in the middle and upper Devonian Horn River Group, Canada. We built a high-resolution dataset (~ 2 mm vertically) by combining EDXRF and hyperspectral (infrared) imagery analyses for 175 core slabs; each ~ 7-10 cm long. The dataset was calibrated by the whole rock analyses of ICP-MS and LECO combustion. This approach enables us to distinguish immediate triggers for organic matter accumulations, when more coarsely spaced sampling yields apparently simultaneous shifts in redox and bioproductivity proxies, potentially related to the development of feedback loops among these three parameters.

We identified 3 patterns in our millimeter-resolution profiles. In one pattern, seen in many examples, Si_{bio} or S/Fe systematically correlates with TOC, indicating bioproductivity or redox conditions as the primary control on organic matter burial, where previous studies with 1 m-spaced samples identified apparently synchronous variation of proxies in profiles. Similarly, dilution of OM by siliciclastics (or carbonate) is indicated by negative correlation of Al (or Ca) concentration with TOC and varied Si_{bio}/TOC ratios. A second pattern seen in some organic-lean intervals during sea-level lowstand deposition shows a positive correlation between Si_{bio} with Al but a negative correlation with S/Fe, demonstrating that the terrigenous nutrient flux stimulated bioproductivity, and that low sea-level primarily increased the depth of the chemocline. A third pattern present in some sections shows that biogenic silica leads or lags to S/Fe profile by ~ 1.5-3 mm offsets, indicating the development of redox-bioproductivity feedback loops. The offsets indicate the time required feedback loops to develop, approx. 50-150 yr, based on the average sedimentation rate of the Horn River Group.

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