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Molecular Insights into the Spatiotemporal Fate of Minerally Protected Organic Matter across a Land-Ocean Sediment Transect

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Over geological timescales, aquatic sediments serve as a critical sink for organic carbon (OC) sequestering carbon from the atmosphere. Estuarine and coastal sediments receive varying proportions of terrestrial and marine OC input along the land-to-ocean continuum. Adding to this complexity, the preservation of OC from these compositionally different sources is strongly influenced by protective associations with reactive minerals, particularly iron (hydr)oxides and clay minerals. While significant progress has been made in understanding mineral stabilization of OC at the bulk level, molecular insights into the synergistic effects of both iron (hydr)oxides and clay minerals in selectively protecting different OC functionalities under changing environmental regimes remain limited. In this study, the composition, distribution and transformation of minerally protected OC fractions are examined spatiotemporally using spectrometric and spectroscopic methods from the natural laboratory of the St. Lawrence Estuary and Gulf, located in eastern Canada. By tracing geochemical proxies and biomarkers in total, iron-associated, clay-associated, and non-soluble residual OC fractions spanning both oxic and anoxic regimes, this research highlights the characteristics of natural OC within these fractions in surface and deep sediments along gradients of OC inputs and physiochemical properties. The findings of this study provide novel insights into the source-to-sink fate of preserved OC in coastal sedimentary systems, advancing our understanding of carbon interactions and sequestration in dynamic environments.