The Upwelling Myth and Phosphate Accumulation in a Semi-enclosed Basin: Counterarguments from the Phosphoria Formation, Wyoming and Idaho, USA

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The Permian Phosphoria Formation (late Leonardian to Guadalupian) in the northwestern United States is comprised of anomalously large accumulations of phosphorite, organic-rich siltstones and mudstones, carbonates, and bedded chert. Deposition occurred along a westward-deepening carbonate ramp within the Phosphoria Sea, an epicontinental marine embayment along the northwestern margin of Pangea. The Phosphoria Formation has been reported to source several oil fields in Wyoming containing up to 32.9% total organic carbon locally. Most previous investigations focused on geochemical and basin modeling approaches to characterize the Phosphoria Formation. They attributed the deposition of the Phosphatic Meade Peak Member of the Phosphoria Formation to marine upwelling based on the presence of abundant phosphate, organic matter, and silt, coupled with modeled basin hydrography and wind patterns. Our study focuses on fine-scale stratigraphic relationships and microfacies analysis within the Meade Peak member in order to better understand controls on deposition and the mechanisms responsible for phosphorite accumulation. Our results suggest that silt-sized quartz, previously attributed to eolian input into the basin, was more likely transported by marine processes as it shows traction structures such as ripples and intense marine bioturbation. The phosphatic units are often coarse-grained, show small-scale cross bedding and erosional contacts reflecting significant reworking and sedimentation in a relatively shallow-water, high-energy regime. This contrasts with the traditional upwelling model for marine phosphorites that envisions a tranquil oxygen minimum zone to accumulate significant amounts of phosphates. Thus, upwelling as a cause for depositing these Permian phosphates seems extremely unlikely. It is also not supported by the sheltered nature of the basin, protected from the open ocean by an island arc in the west. Our study successfully shows that large amounts of phosphates can be accumulated in inland seas within a high-energy environment without upwelling as a major driving process.