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Redox Evolution and Organic Matter Preservation in Organic-Rich Marine Shales of the Água de Madeiros Formation, Lusitanian Basin (Portugal): Insights from Pyrite Framboids and Organo-Mineral Associations

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This study investigates the morphology, size distribution, and microstructural characteristics of pyrite framboids and their spatial associations with organic matter in organic-rich marine shales from the Água de Madeiros Formation (Lower Jurassic), Lusitanian Basin, Portugal. Our objective is to reconstruct depositional redox conditions and post-depositional diagenetic alteration of the studied interval. So far, the study identified abundant framboidal pyrites with an average diameter between 1 and 5 µm. They occur as polyframboidal aggregates composed of morphologically rounded framboids (<10 µm) interconnected by randomly oriented microcrystals. The predominance of small framboids and their limited size variability suggests syngenetic to early diagenetic pyrite formation under euxinic conditions, likely within or immediately below the sulfate-reduction zone shortly after sediment deposition. Transmission electron microscopy (TEM) confirmed the presence of enlarged spheroidal framboidal aggregates with fine-grained internal textures. Element analyses identified Fe and S as the principal constituents of the framboids, with minor oxygen suggesting localized post-depositional oxidation or redox fluctuations during burial. TEM observations also demonstrated intimate nanoscale spatial associations between pyrite and organic matter-rich domains. The strong spatial correlation between framboidal pyrites and organic matter suggests sulphur-mediated OM stabilization during early diagenesis. It is hypothesized that sulphide mineralization and organo-mineral encapsulation limit microbial degradation. Overall, these observations indicated euxinic conditions during initial deposition, followed by redox variability during diagenesis. Ongoing research on polyframboidal pyrite aggregates, together with their associations with organic matter, aims to provide robust proxies for reconstructing redox dynamics.