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Facies architecture and ocean redox structure of a Neoproterozoic clastic shelf:Implications for redox evolution dynamics and elemental cycling

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Reconstructions of Proterozoic Ocean redox conditions frequently utilize iron speciation and redox-sensitive trace-element proxies, that have demonstrated efficacy in identifying the broad redox states of ancient marine environments. However, these proxies are often employed without the integration of basin-scale sedimentological frameworks, despite the significant influence of depositional processes and setting on redox-sensitive geochemical signals. Incorporating process-based facies analysis provides essential environmental context that can refine proxy-based interpretations and enhance assessments of redox heterogeneity. This study integrates process-based facies analysis with redox-sensitive trace-element geochemistry and Iron speciation to evaluate redox conditions prevailing on a Neoproterozoic clastic shelf during the deposition of the Owk Shale Formation, Kurnool Basin, India. The Facies association represents deposition across a shallow marine shelf system, broadly extending from offshore to inner-shelf environments. Fine-grained dark coloured shales dominate distal settings, whereas stratigraphically higher intervals record episodic higher-energy conditions associated with progressive shoaling. This facies framework provides the environmental context necessary to interpret variations in redox proxies across different depositional settings and stratigraphic levels, aiding in determining whether these variations reflect true changes in water-column redox conditions or are influenced by depositional processes and post-depositional alteration. Iron speciation data indicate predominantly suboxic to oxic water column conditions across the shelf, with localized dysoxia in more distal, fine-grained deposits. Fe_{HR}/Fe_T ratios range from 0.16 to 0.66 and vary systematically with depositional setting, having higher values generally associated with offshore facies and lower values in more proximal settings. Consistently, low Fe_{py}/Fe_{HR} values (<0.35) indicate limited pyritization and the absence of sulfidic bottom waters throughout the deposition. Redox-sensitive trace-element concentrations normalized to Al show low to moderate enrichments, with V/Al ~6.53 to 15.29, Mo/Al ~0.051 to 0.336, and U/Al ~0.019 to 0.604. These ranges are consistent with predominantly suboxic to oxic conditions and localized dysoxia, in agreement with iron speciation results. By integrating process-based facies analysis with iron speciation and trace-element proxies, this study demonstrates that redox conditions on Neoproterozoic shelves were spatially variable and closely linked to depositional setting. The results highlight the importance of integrating sedimentological frameworks with geochemical proxies to more robustly resolve redox heterogeneity in Proterozoic shallow-marine systems.