Transient rise of atmospheric O_2 levels and marine shelf oxygenation at ~1.36 Ga

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We conducted a comprehensive investigation of paleoredox, paleoproductivity and seawater sulfate levels of the ~1.4-1.32-Ga Xiamaling Formation in the shallow Hougou and mid-depth Huangtugui sections in the Yanshan Basin (North China). Integrated Fe-trace metal data suggest that bottom-water redox condition mainly underwent a three-stage evolution: (1) suboxic (-oxic), (2) predominantly anoxic, and (3) oxic. Integrated productivity proxies (TOC, P/Al, and EFs of Cu-Zn-Ni) and depositional system (elemental enrichment patterns) suggest varying productivity during deposition of the Xiamaling Formation, with high productivity fueled mainly by intense upwelling. In combination with published data from the deeper Xiahuayuan section, a new stratigraphic correlation framework was developed for the Xiamaling Formation based on the coeval upwelling event with existing lithostratigraphic correlation framework. Within this new framework, integrated Xiamaling pyrite $\delta^{34}S$ records ($\delta^{34}S_{py}$) suggest a rise in marine sulfate concentrations and atmospheric O_2 levels (to >0.4 % PAL) at ~1.36 Ga, which was supported by $\delta^{34}S_{py}$ record of the coeval Velkerri Formation (North Australia). Furthermore, strong spatiotemporal redox heterogeneity was observed in the ~1.4-1.32-Ga Yanshan basin, which can be explained by a transient productivity-driven shelf oxygenation model. In this model, at low atmospheric oxygen levels, increasing surface productivity in shelf areas due to elevated nutrient supplies not only intensified bottom-water anoxia through organic matter export but also enhanced oxygenation of the ocean-surface layer through photosynthetic O_2 release. Our model helps reconcile conflicting observations concerning Mesoproterozoic marine redox conditions and provides new insights into the nature of putative Mesoproterozoic atmospheric and oceanic oxygenation events.