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Spatial Pattern of Marine Oxygenation Set by Tectonic and Ecological Drivers over the Phanerozoic

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Marine redox conditions have profound impacts on a wide range of biogeochemical cycles, but the main controls thereon since the start of the Phanerozoic about 538 million years ago are not well established. We combine supervised machine learning with shale-hosted trace metal concentrations to reconstruct a long-term record of redox conditions in major marine depositional settings. Our results reveal synchronously opposite redox changes in upper ocean versus deep shelf and (semi-)restricted basin settings in several multi-million-year intervals. These changes coincided with biological innovations that altered large-scale oxidant-reductant fluxes (e.g., the mid-Paleozoic spread of land plants; the Mesozoic plankton revolution) and tectonic upheavals that regulated sea-level elevations (e.g., amalgamation and breakup of Pangaea). The redox condition of deep-shelf settings experienced major transitions through the Phanerozoic, from a largely anoxic state in pre-Devonian times buffered by dissolved reductants such as dissolved organic matter and/or ferrous iron, to a transitional state during the Devonian–Carboniferous interval characterized by the inception of persistent oxygen-minimum zones, and subsequently to a redox regime featuring thin oxygen-minimum zones maintained by particulate organic matter. Deep-shelf redox changes are correlated with background extinction rates of marine animals, and mass extinction events were generally more severe during major redox transitions.