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Improved paleoenvironmental interpretations at the intersection between paleontology and biogeochemistry

T. W. Lyons

University of California, Department of Earth Sciences, Riverside, CA United States (timothy.lyons@ucr.edu, +1-(0)951-8273106)

Paleoenviromental reconstructions, particularly those focused of oxygen levels in the ancient ocean, often rely on geochemical or paleoecological approaches but too infrequently exploit the added strength that comes with a combined approach. Trace metal, organic biomarker, and iron paleoredox proxies do well in distinguishing between ancient oxic water columns and anoxic, Fe-rich (ferruginous) and anoxic, sulfidic (euxinic) settings. Molybdenum isotope approaches may even allow us to estimate the amount of hydrogen sulfide in the ancient seawater. Where the challenges often arise are at intermediate redox states marked by episodes of only transient anoxia/euxinia where diagnostic geochemical end-member enrichments are muted. Unfortunately, rapid detrital sedimentation and depleted seawater metal inventories under anoxic/euxinic conditions on basin and ocean scales can yield similarly tempered metal enrichments. Intermediate geochemical signatures can also mark conditions of extremely low bottom-water oxygen (often referred to as 'suboxic') but with sulfide confined to the pore fluids and a lack of appreciable and persistent Fe availability in the water column. Also possible are protracted episodes of true anoxia that lack Fe or sulfide in the water column because of limited availability of the organic matter required to drive bacterial Fe and sulfate reduction. In contrast, benthic ecological relationships, both trace and body fossil, are very sensitive to redox fluctuations at the low oxygen end, even brief episodes of oxygenation, and across subtle spatiotemporal redox gradients, although they are not readily effective at distinguishing between ferruginous and euxinic bottom waters.

The talk will explore the mechanistic underpinnings of some of the most important geochemical proxies and then view their relative strengths and weaknesses in light of the added insight gleaned via coupled paleoecological analysis. Beyond stronger interpretations of Phanerozoic paleoenvironments using the combined approach, subtle variations in chemical tracers can be calibrated with refined paleoredox resolution using fossils and extrapolated back to Precambrian intervals predating the evolutionary appearance of animals. Oxygen deficiencies of varying degree likely dominated most of the Precambrian marine record. Additional topics to be discussed are new and refined geochemical proxies that work best under intermediate redox states. Another interesting intersection of Fe and trace metal proxies and biology lies with the clear fingerprints of depositional settings with abundant free hydrogen sulfide in the pore fluids, often right at the sediment-water interface, but with oxygen in the bottom waters. Independent recognition of such conditions would have important impact on our interpretations of infaunal and epifaunal animal communities, including those that thrive at redox interfaces in symbiotic partnership with thiotrophic and methanotropic bacteria.