Use of sedimentary trace-metal concentration data to constrain hydrographic conditions in ancient marine systems

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Sedimentary Mo concentrations, $[\mathrm{Mo}]_s$, have been widely used as a proxy for benthic redox potential owing to generally strong enrichment in organic-rich marine facies deposited under anoxic conditions. A detailed analysis of $[\mathrm{Mo}]_s$-TOC covariation in modern anoxic marine environments and its relationship to ambient water chemistry suggests that (1) $[\mathrm{Mo}]_s$ is not related in a simple manner to benthic redox potential, for which it can serve as only a rough indicator, and (2) patterns of $[\mathrm{Mo}]_s$-TOC covariation can provide paleohydrographic information, e.g. regarding the degree of restriction of the subchemoclinal watermass and temporal changes thereof related to deepwater renewal [1]. These inferences are based on data from four anoxic silled basins (the Black Sea, Framvaren Fjord, Cariaco Basin, and Saanich Inlet) and one upwelling zone (the SW African Shelf). The silled basins represent a spectrum of degrees of deepwater restriction, as reflected in their residence times (ranging from <10 y for Saanich Inlet to ~2000 y for the Black Sea) and aqueous Mo concentrations ($[\mathrm{Mo}]_{aq}$, ranging from 80-100% of the seawater concentration for Saanich Inlet to 3-5% for the Black Sea). Restriction-related differences in water chemistry are recorded in the sediment as variation in the quantity of Mo accumulated per unit organic carbon, $[\mathrm{Mo}]_s$/TOC, which ranges from ~45±5 for Saanich Inlet to ~4.5±1 for the Black Sea. This reflects control of $[\mathrm{Mo}]_s$ by the concentration of aqueous Mo, $[\mathrm{Mo}]_{aq}$, the latter being depleted in silled basins through sedimentation without adequate resupply via deepwater renewal. Consequently, at timescales associated with deepwater renewal in silled basins, $[\mathrm{Mo}]_s$ may be positively correlated with benthic redox potential—antithetic to the prevailing paradigm. Sedimentary trace-metal concentration data may provide information about other aspects of ancient restricted marine systems as well. Patterns of covariation between $[\mathrm{Mo}]_s$ and other trace metals have the potential to reveal secular changes in the chemistry of restricted watermasses and the operation of particulate shuttles that enhance the rate of delivery of authigenic Mo to the sediment-water interface.

[1] Algeo & Lyons (2006) *Paleoceanography* **21**, PA1016.

Deoxygenation of Permo-Triassic oceans: The role of elevated continental weathering fluxes

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Oceanic anoxia was widely developed in the latest Permian to Early Triassic interval (Wignall & Twitchett (1996), Isozaki (1997)). Geochemical evidence suggests that global climates warmed abruptly during this interval (Retallack (1999), Retallack & Jahren (2008)) and paleoceanographic modeling has demonstrated that such warming would have led to (1) lower dissolved oxygen levels in seawater, and (2) a reduced latitudinal temperature gradient, which would have suppressed overturning circulation and deepwater formation (Hotinski *et al.* (2001), Kiehl & Shields (2005)). An additional factor may have been increased nutrient availability, stimulating primary productivity and leading to a higher sinking flux of organic matter. Although the extant evidence for changes in primary productivity in Permian-Triassic marine systems is mixed (Martin (1996), Knoll *et al.* (2007)) the inference of higher nutrient availability is supported by evidence of an abrupt increase (~7X global average) in bulk accumulation rates in shallow-marine systems during the latest Permian, reflecting elevated continental weathering fluxes (Algeo & Twitchett [1]). This increase is accompanied by a pronounced shift toward more clay-rich marine sediments, indicating an enhancement of chemical weathering relative to physical weathering and, hence, an elevated flux of nutrients. Regional variation in the intensity of anoxia in Permian-Triassic marine systems is consistent with increased nutrient availability—in the Panthalassic Ocean, depletion of dissolved oxygen was focused with the oxygen-minimum zone rather than on the deep-sea floor (Algeo *et al.* [2]), consistent with an increase in surface-water productivity.

[1] Algeo & Twitchett (2010) *Geology*, submitted February 2010. [2] Algeo *et al.* (2010) *Geology* **38**, 187–190.