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Controls of redox-dependent P cycling on the Namibian margin in past and present

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A constituent of most biological macromolecules, phosphorus (P) is an essential nutrient that controls marine primary productivity on geological timescales. Constraining the short- and long-term mechanisms that control redox-dependent P cycling is essential considering the global trend of increasing ocean deoxygenation.

In the Benguela Upwelling System, high nutrient availability and primary productivity boost biological O_2 demand, resulting in seasonal shelf anoxia (<100 mbss, O_2 < 5 µmol L^{-1}) and a perennial oxygen minimum zone (OMZ) on the continental slope (200-400 mbss, O_2 ~ 50 µmol L^{-1}) offshore Namibia. In the organic-rich, reducing shelf sediments, where large amounts of P are buried and phosphorites form, sulphide-oxidizing bacteria (SOB) are thought to play an important role in P burial, but we have limited understanding of P cycling and benthic-pelagic coupling.

In 2019, we collected water column and surface sediment samples (0-50 cm) along a redox transect from the Namibian shelf and slope to explore early diagenetic P cycling. On-board surface sediment incubations and chemical analysis of pore waters and sediments (including sequential phosphorus, sulphur and iron extractions) were performed to elucidate redox-dependent P cycling around the sediment-water interface. In addition, a 10-meter-long sediment core recovered from below the perennial OMZ (750 mbss) provides a long-term (~100,000 years) record of the (de)coupling of depositional conditions and P cycling in relation to climate and OMZ variability.

Our results show that SOB can play a crucial role in early diagenetic cycling and benthic release of PO_4^{3-} and other solutes such as toxic H_2S. However, spatial heterogeneity in benthic microbial communities introduces significant variability in sediment chemistry and P cycling, under seemingly similar (anoxic) bottom-water conditions. The slope sediment from below the OMZ is also rich in organic matter, but the close, SOB-driven coupling between P and S cycling was not observed. In addition, relatively stable P concentrations compared to variable productivity and redox proxies throughout a 100,000-year record suggest a decoupling of P burial from organic matter deposition and redox conditions. Overall, these findings may significantly refine our understanding of the redox-dependent cycling and burial of P in upwelling systems over long and short timescales.