The Monterey Formation: A window into Miocene oxygen minimum zone expansion

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The Miocene Monterey Formation, an organic-rich deposit found along the coast of California, was deposited under oxygen minimum zones (OMZ) in numerous sediment-starved basins with varying degrees of connection with the open ocean. Though still widely debated, the Monterey's organic-rich nature is thought to have been at least partly responsible for the global positive carbon isotope excursion between ~13 and 18 Ma. This study includes both drill core and outcrop samples from the Santa Maria Basin, a relatively well-connected basin on the outer shelf, and core samples from the San Joaquin Basin, a more restricted setting. Bottom-water redox is constrained by high-resolution iron speciation and trace metal concentrations, which suggest continuously anoxic and occasionally euxinic conditions were achieved in both basins, although these relationships manifest in different ways due to local basin dynamics. Despite being marginal marine basins with varying degrees of restriction, δ^{98}Mo is homogenous (~1‰) and invariant throughout the two basins across redox fluctuations suggested by iron and trace metal concentrations. Invariant Mo isotope signals are rare, even in clearly euxinic sections. One interpretation for this homogeneity is that these deposits are capturing consistent seawater molybdenum values that are different from the modern ocean. If this interpretation is correct, the Miocene global molybdenum inventory must have differed from that present today. Specifically, the isotopic difference could reflect OMZ expansion during Monterey deposition resulting from Pacific Ocean circulation and reducing the aerial extent of seafloor manganese oxide burial. We test this hypothesis through mass balance models to estimate the required change in seafloor oxide burial to account for the observed δ^{98}Mo shift. The Monterey Formation and its organic-rich equivalents may therefore capture a global expansion of OMZs and extent of low oxygen conditions around the Pacific Rim and western Atlantic.