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Decoupling of Redox Conditions Between the Surface and Deep Ocean Over the Early Middle Ordovician

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The Ordovician Period witnessed a profound milestone in biospheric evolution—the so-called 'Great Ordovician Biodiversification Event' (GOBE) marked by an almost threefold increase in species diversity. Although the biological trends are well documented, the environmental trigger of the GOBE remains less clear. A recent study using the thallium isotopic approach (ε^{205}Tl) suggested a progressive oxygenation in the global marine realm during the Middle-Late Ordovician, potentially linking the biological radiation to a turnover in marine chemistry (Kozik et al., 2023, *Glob. Planet. Change.*). However, the peak of biodiversity associated with the GOBE occurred slightly earlier—in the early Darriwilian (Middle Ordovician), and the redox conditions at that time remained unresolved, which motivated us to explore their potential cause-and-effect relationships.

Here, we focus on a shale-dominated drill core taken in Sweden that spans the early Darriwilian to constrain marine chemistry from a global perspective using the Tl isotopic tool. Our iron speciation data suggest that the local redox was predominantly oxic with only episodic anoxia in the water column, consistent with the trace metal and manganese (Mn) concentration data. Surprisingly, the ε^{205}Tl (= ~-2) of the samples tied to oxic deposition are the same as data from samples deposited under anoxic bottom waters. The suggestion is that even oxic sediments might track the coeval water-column ε^{205}Tl, perhaps because they were characterized by low Mn concentrations indicative of negligible local MnO_2 burial. This possibility suggests an expanded utility for the proxy, which is traditionally applied to anoxic sediments. Importantly, the high ε^{205}Tl values of our samples reveal that the deep oceans during the early Darriwilian were still characterized by prevailing anoxia. This possibility stands in contrast to the coeval shallow marine settings where higher I/Ca values in carbonates compared to the periods before and after suggest pronounced oxygenation (Lindskog et al., 2023, *Nat. Geosci.*). In light of these results, we argue that the redox conditions in the surface and deep oceans were strongly decoupled over this critical time window. That said, our results do not rule out a contribution to the GOBE from rising oxygen given that marine animals diversified primarily in the shallow settings.