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Can $^{231}Pa/^{230}Th$ ratios be applied as a paleocirculation proxy? A comparison of dissolved and sedimentary $^{231}Pa/^{230}Th$ in the Atlantic Ocean with modeled water mass age estimates.

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Changes in sedimentary unsupported 231Pa/230Th (Pa/Th) have been widely interpreted to reflect changes in overturning circulation strength; especially in the Atlantic, where the ratio has been used to infer past changes in Atlantic Meridional Overturning Circulation strength and the rate of North Atlantic Deep Water formation. However, applying the ratio as a paleoproxy for ocean circulation is not straightforward due to the dependence of sedimentary Pa/Th on multiple factors, including overlying water mass history, advection, particle flux, particle composition, and nepheloid layers. It is important for climate reconstructions to quantify the extent that each process impacts sedimentary Pa/Th.

To determine if Pa/Th can act as a reliable proxy for water mass ventilation age, which is linked to ocean circulation, we look at Atlantic Ocean dissolved Pa/Th from GEOTRACES GA02 and GA03 alongside compiled sedimentary Pa/Th. We find that any processes impacting deep water dissolved 231Pa and 230Th concentrations do not alter the nuclide ratios, and dissolved Pa/Th does not evolve along water mass trajectories. While deep water dissolved Pa/Th is relatively invariant, sedimentary Pa/Th has high spatial variability, apparently reflecting local scavenging intensity. Also, if the ratio can be used to reconstruct circulation strength, then the spatial distribution of Pa/Th should agree with our understanding of ocean ventilation. A comparison of Atlantic dissolved Pa/Th with deep water mass age estimates from the Ocean Circulation Inverse Model 2 (OCIM) [1,2] shows a lack of correlation. Pa/Th varies between 0.35 and 0.75 over a small range of OCIM ideal mean ages (Fig.1), which disagrees with the conceptual model for the application of Pa/Th as a paleocirculation proxy. Altogether, our results indicate that sediment Pa/Th ratios must be significantly impacted by processes other than deep water ventilation, and Pa/Th should not be interpreted strictly as a circulation proxy until these processes are understood and quantified.

[1] Holzer et al.; Diffusion Controls the Ventilation of a Pacific Shadow Zone above Abyssal Overturning (2021), *Nat Commun 12* (1), 4348.

[2] DeVries, T.; Holzer, M.; Radiocarbon and Helium Isotope Constraints on Deep Ocean Ventilation and Mantle-3He Sources (2019), *Journal of Geophysical Research: Oceans 124* (5), 3036–3057.

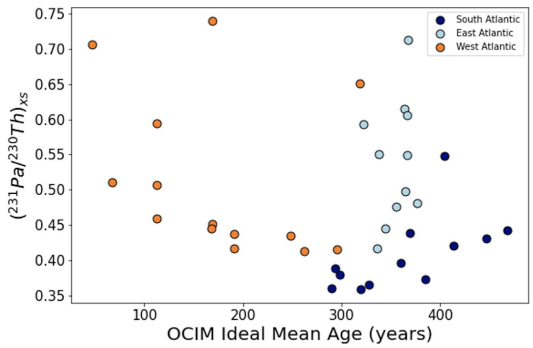

Fig.1: Average dissolved Pa/Th between 2000 m and 4000 m plotted against the average water mass age (ideal mean age output from OCIM model) [1,2] from 2000 m to 4000 m at the location of stations occupied in completing the GEOTRACES GA02 and GA03 sections in the Atlantic Ocean. The datapoint colors represent the different ocean basins: NE Atlantic (light blue), NW Atlantic (medium blue), and SW Atlantic (navy). KN199-04 station 9, an apparent outlier near the NW Africa margin that is significantly impacted by upwelling and Saharan sourced dust fluxes, has been omitted from this figure. Error bars are within the marker for every datapoint.