QUANTITATIVE ASSESSMENT FOR PARTICLE FLUXES: A LINKAGE BETWEEN MODERN OCEANS AND PALEOENVIRONMENTS

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Particle fluxes using sediment traps have been seriously studied for various microfossil groups in the past decade. We have accumulated substantial amounts of information pertinent to properly interpret the past environments. Characterization of productivity signals in present-day particle fluxes can be significant when it is applied to calculate past productivity levels. A match between fidelity productivity signal and good preservation in a given species is a prerequisite for such a conversion. Since the majority of biogenic silica production is lost due to dissolution mainly at the sea floor and only a minute fraction can be preserved in the fossil record, such a task cannot always be fulfilled. However, when the productivity signal is in solution-resistant taxa such a conversion can materialize. *Denticulopsis seminae*, a pennate diatom taxon, widely occurs in the high latitude North Pacific. It is clearly a productivity and dominant diatom species with relatively good preservation in the fossil record at least in the northeastern Pacific. Quantitative interpretation of paleoproductivity levels will be demonstrated using the flux information of the productivity tracer species.

DISTRIBUTION OF $\delta^{13}$C$_{\text{CO}_2}$ AND TRACE METALS IN THE OCEAN: IMPLICATIONS FOR BENTHIC $\delta^{13}$C AND Cd/Ca RECORDS AS PROXIES FOR INTERMEDIATE-DEPTH NUTRIENT CYCLING AND THE ATMOSPHERE’S PALEOCHEMISTRY

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Continuous accumulation of $^{12}$C$_{\text{CO}_2}$, Cd and biologically cycled nutrients below the pycnocline stabilizes the deep-ocean ($\sigma_0 >$27.7) tracer-nutrient fields, thus leading to monotonic $\delta^{13}$C$_{\text{CO}_2}$-PO$_4$ and Cd-PO$_4$ relationships. In the upper ocean ($26.8 < \sigma_0 < 27.7$), however, these relationships vary as a function of nutrient extraction, Cd- and $\delta^{13}$C$_{\text{CO}_2}$-cycling in the euphotic layer, vertical exchange, and ocean-atmosphere gas exchange. Data collected during the GEOSECS program in intermediate and deep water outcrop areas shows that PO$_4$ intercepts (i.e., preformed PO$_4$) in the tracer-nutrient relationships may vary from ±0 μmol kg$^{-1}$ for the oligotrophic North Atlantic to >1.3 μmol kg$^{-1}$ for the Southern Ocean. That is, while the Cd- and $\delta^{13}$C$_{\text{CO}_2}$ "clocks" are reset to their starting values before surface waters enter the convection-advective pathway, PO$_4$ concentrations may vary significantly thus resulting in marked variations of the tracer-nutrient regression slopes. Dominant factors in defining the $\Delta$S$^{13}$C : $\Delta$PO$_4$ and $\Delta$Cd : $\Delta$PO$_4$ slopes are: (1) efficiency of the marine biota to exhaust nutrients in the surface layer, (2) rate of biotic $^{12}$C$_{\text{org}}$- and Cd-fixation, (3) $^{12}$C-distillation from the surface ocean to the atmosphere, and (4) rate and depth at which tracers and nutrients are recycled.

The effects that differential uptake of cadmium and phosphate in polar surface waters may have on their relative distribution throughout the ocean are illustrated with a 13-box model. In this model, the advective component of the surface water source is estuarine in Antarctic waters and anti-estuarine in the North Atlantic. Because of this, the effects of preformed Cd in each of these regions on the Cd-PO$_4$ pattern are very different. Decreasing the preformed Cd concentration in the North Atlantic has virtually no effect on the Cd distribution elsewhere in the ocean. By contrast, low preformed Cd in Antarctic waters produces a significant alteration to
what would otherwise be a simple linear correlation of Cd and PO₄. In this region, more efficient biological uptake of Cd distills a greater fraction of the upwelling flux into Circumpolar Deep Water and leaves Antarctic Intermediate Water depleted relative to phosphate. As a result, there is a "kink" in the deep-water trend of Cd versus PO₄, with the Indo-Pacific having greater Cd/PO₄ ratios than Atlantic deep water. Intermediate waters, especially in the southern hemisphere, are predicted to have lower Cd/PO₄ ratios than deep waters. The distribution of Cd in Circumpolar and Indo-Pacific deep waters is expected to be more uniform than PO₄, and therefore weaker N-S horizontal Cd gradients in these waters should exist.

The observed deviation of the δ¹³C - PO₄ regressions at intermediate depths in the "eutrophic" Southern Ocean (slope ≥ 1.5, std error=0.09, n=29) from the trend observed in the "oligotrophic" North Atlantic (slope ≤ 1.0, std error=0.09, n=83) suggests importance of air-sea exchange perhaps combined with varying rates of carbonate dissolution which adds to the ΣCO₂ pool and tends to steepen the slope at the high-nutrient end of the ocean Δδ¹³C : ΔPO₄ distribution. Thus even though the mechanics that link δ¹³C and Cd to PO₄ are different, in high-nutrient regimes both tracers show similar deviations from the mean-ocean tracer-nutrient relation in a way that they tend to underestimate nutrient concentrations. The observed variation of the Δδ¹³C : ΔPO₄ and ΔCd : ΔPO₄ relations as a function of the ocean's physical and biological regimes inevitably rises concern about the reliability of foraminiferal δ¹³C and Cd/Ca ratios, especially at shallow-ocean core sites, as paleoceanographic proxies for reconstructing intermediate-depth nutrient levels and the atmosphere's chemistry.