Cd/Ca in planktonic foraminifera of the glacial Southern Ocean

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Since the industrial revolution, 200 years ago, atmospheric carbon dioxide levels have risen by 90 ppmV, an amount equalling the natural variation between the last glacial maximum and pre-industrial values. To predict the fate and influence of anthropogenic carbon dioxide, it is vital to understand the natural controls on the glacial-interglacial variations in atmospheric composition. The biological pump is known to be an important draw-down of carbon dioxide today due to the complete removal of nutrients from the euphotic zone of most surface waters and regeneration at depth. An exception exists in the Southern Ocean today, where the surface waters have high phosphate concentrations indicating incomplete removal of the nutrients either due to very rapid upwelling rates or iron limitation. There is huge potential for glacial carbon dioxide draw-down if the efficiency of the biological pump had been enhanced in the glacial Southern Ocean. Particle proxies suggest that export productivity increased in the glacial subantarctic Southern Ocean (1) but there has been no clear evidence of a lowering of the glacial surface-water nutrients (2).

$\delta^{13}C$ in planktonic foraminifera has been found to be unreliable as a nutrient tracer in surface waters due to a number of factors such as susceptibility to isotopic fractionation during air-sea exchange (3). Cd/Ca in foraminifera, a reliable deep-water nutrient tracer, has been uncalibrated for surface waters and is often present at levels too low for determination by existing methods. We have developed a new isotope dilution, mass-spectrometric method for low-level determination of Cd/Ca in foraminifera which has allowed reliable and accurate planktonic analyses to be made. We have investigated the application of Cd/Ca in planktonic foraminifera for the reconstruction of past surface water phosphate levels. Down-core records of Cd/Ca in *G.Bulloides* covering the last complete glacial cycle have been obtained from a latitudinal transect of cores spanning the present day Subtropical Convergence Zone (SCZ), at approximately 40°S, and the Antarctic Polar Front (APF), at approximately 50°S, in the Indian Ocean sector of the Southern Ocean. In each core there is a striking correlation between the Cd/Ca and the $\delta^{18}O$ of *G.Bulloides* over the last glacial cycle indicating low surface water nutrient levels during the glacials and high nutrient levels during the interglacials. The greatest reduction in nutrient levels occurs in the subantarctic zone of the Southern Ocean, with little change south of the APF, consistent with the export productivity conclusions.

There are two possible explanations for this glacial lowering of surface water nutrients. Firstly the rate of upwelling remains constant but the efficiency of nutrient removal is increased, possibly by iron fertilization due to an increased atmospheric dust fallout in glacial times. Secondly, the glacial Southern Ocean water column became stratified with a stable thermocline allowing the surface water productivity to deplete the nutrients without constant replenishment from upwelling. It is important to distinguish between these two mechanisms as each has a differing potential for glacial draw-down of atmospheric carbon dioxide. A simple box-model following some of the concepts in (4) has been run to resolve which of these two mechanisms is more consistent with the new surface water nutrient data and the existing export productivity conclusions.

References

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