The composition of glacial Antarctic Circumpolar Deep Water and its role in driving changes in atmospheric carbon dioxide

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Circumpolar Deepwater (CPDW) comprises the major portion of the Antarctic Circumpolar Current, and as such acts as a conduit connecting the deep waters of the major ocean basins. The composition of CPDW lies at a critical intermediate point between the nutrient-depleted waters formed in the North Atlantic and the nutrient-rich waters that fill the deep Pacific and Indian oceans. CPDW is the source for much of the water that upwells to the Antarctic polar front; therefore, its composition plays a key role in setting both the nutrient and carbon dioxide levels of Southern Ocean surface waters (Broecker and Peng, 1989).

The important role CPDW plays in the global ocean circulation and chemistry has motivated paleoceanographers to establish the composition of glacial CPDW, principally via the oxygen and carbon isotopic composition and Cd and Ba contents of benthic foraminifera shells from deep-sea cores (Boyle, 1992; Charles and Fairbanks, 1992; Lea, 1993; Oppo *et al.*, 1990). The available data for Cd and carbon isotopes do not appear to reveal a coherent picture of glacial CPDW composition. This has been an impediment to progress aimed at reconstructing the glacial deep-ocean circulation and establishing the role changes in oceanic thermohaline circulation played in driving lower atmospheric carbon dioxide during glacial periods (Broecker, 1993).

In a new study (Lea, in review) I have determined Cd/Ca and Ba/Ca in benthic foraminifera shells from core RC13-229, which lies in the deep Cape Basin (South Atlantic) at a site predominantly bathed by CPDW. I use the modern oceanic relationships between Cd and Σ_{CO_2} and Ba and alkalinity to reconstruct changes in the carbon dioxide composition of CPDW. Calculated results suggest that the composition of glacial CPDW is broadly consistent with atmospheric carbon dioxide history (Table 1).

The results of this study suggest that changes in Circumpolar Deepwater composition brought about by modulations of the thermohaline circulation can directly influence atmospheric carbon dioxide, via upwelling of CPDW to Southern Ocean surface waters (Broecker and Peng, 1989). However, because the observed trends in CPDW Ba and Cd composition are dissimilar, they cannot obviously be explained by changing inputs of nutrient (also Ba and Cd) depleted North Atlantic Deep Water to the Southern Ocean. Thus, a key challenge is to search for ocean circulation or chemical changes that could reasonably account for the observed paleochemical trends.

References

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TABLE 1. ΣCO_2, alkalinity and P_{CO_2} calculated from RC13-229 paleochemical data

	Cd/Ca μmol/mol	ΣCO_2 μmol/kg	Ba/Ca μmol/mol	Alkalinity equiv/kg	pCO_2† μatm	pCO_2,Vostock μatm
Holocene, stage 1	0.165	2277	2.93	2398	268	262
LGM, stage 2	0.154	2261	3.35	2417	213	196

†P_{CO_2} is calculated using ΣCO_2 and alkalinity from Cd/Ca and Ba/Ca, respectively. The values are adjusted to surface equivalent values assuming a constant Southern Ocean biological pump. Temperature and salinity are estimated from oxygen isotope data (Oppo *et al.*, 1990).

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