Climate-related changes in export production off the Pacific coast of Mexico during the last deglaciation

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Naturally occurring radionuclides such as ^{230}Th, ^{231}Pa and ^{10}Be are removed from the ocean by scavenging onto particles. Due to their differing sensitivities to particle composition and particle flux, ^{231}Pa/^{230}Th and ^{10}Be/^{230}Th ratios measured in marine sediments can be used to trace past changes in biological productivity of the ocean.

Climate-related changes in the ocean's oxygen minimum zones

A striking feature of abrupt climate change during the last glacial period is the correlation between temperature proxy records from Greenland ice cores and the intensity of the oxygen minimum zone (OMZ) in the eastern North Pacific Ocean (Ortiz et al., 2004) and the Arabian Sea (Altabet et al., 2002). Oxygen concentrations decreased during warm interstadial periods, much like conditions today, whereas oxygen concentrations were much greater during cold stadials and the Last Glacial Maximum. Intensification of the OMZ is manifested in several proxies, including concentrations in sediments of organic carbon and of redox-sensitive trace elements, as well as in nitrogen isotope indicators of denitrification.

Various investigators have attributed these features to either 1) changes in the supply of oxygen associated with the ventilation of intermediate water mass, or 2) local changes in productivity, as a result of ocean-atmosphere reorganizations, such as is seen during El Niño events today in the eastern North Pacific. Whereas evidence for changes in the intensity of the OMZ is unequivocal, most sedimentary proxies cannot discriminate between the two proposed causes because the impact of low bottom-water oxygen concentrations on the composition of marine sediments (e.g., carbon concentration; trace metal enrichment) is generally indistinguishable from that of high biological productivity and associated organic rain rates.

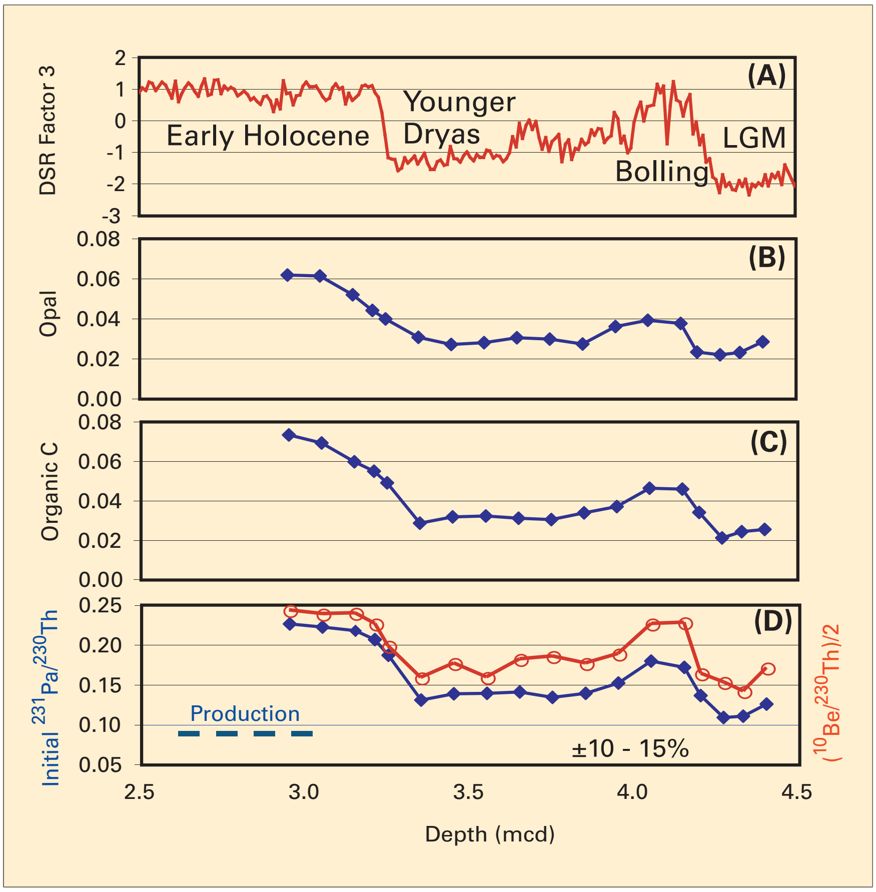

*Figure 1: Records from piston core MV99-PC08 (23.5°N, 110.6°W, 700 m) covering the period from ~6 to ~16 ka BP. (**A**) Diffuse spectral reflectance (DSR) factor 3, which is representative of the organic carbon content of the sediments (from Ortiz et al., 2004). (**B&C**) Preserved fluxes (g cm^{-2} kyr^{-1}) of opal and organic carbon evaluated using the ^{230}Th normalization method (Francois et al., 2004). (**D**) Decay-corrected unsupported ^{231}Pa / ^{230}Th (activity ratio; diamonds) and ^{10}Be / ^{230}Th (10^9 atoms/dpm, divided by 2 to put them on the same scale as Pa/Th; circles).*

New geochemical proxies link OMZ changes to biological productivity

Natural radionuclides can help resolve this. Due to the differential solubilities of the radionuclides, ^{231}Pa/^{230}Th and ^{10}Be/^{230}Th ratios increase with increasing particle flux (Kumar et al., 1995), which, in turn, is regulated by biological productivity. These ratios have the advantage that they are insensitive to the concentration of dissolved oxygen. However, they are sensitive to changes in particle composition (e.g., the ratio of clay to biogenic particles or the ratio of carbonate to opal (Chase et al., 2002)) as well as to changes in particle flux (productivity). Therefore, although these ratios do not provide a unique and unambiguous paleoproductivity tracer, they are a valuable component of a multiproxy study because their sensitivities to changing environmental parameters are orthogonal to the sensitivities of other paleoproductivity proxies.

Concentrations of ^{231}Pa, ^{230}Th, ^{10}Be and biogenic constituents were measured in sediments from a piston core recovered from within the OMZ off the southern tip of Baja California (Mexico). Across the last deglaciation, we find that ^{230}Th-normalized fluxes (Francois et al.,

2004) of opal and of organic carbon were positively correlated with the high organic carbon content of sediments deposited during warm periods (Bølling and Holocene; Fig. 1). We find elevated $^{231}Pa/_{230}Th$ and $^{10}Be/^{230}Th$ ratios during warm periods as well (Fig. 1), indicating that increased productivity must have contributed to the higher preserved fluxes of opal and carbon at those times.

Conclusions

While these results do not rule out changes in the ventilation of intermediate waters, they do provide clear evidence for changes in biological productivity and the export flux of biogenic particles. Enhanced productivity during warm events reflects a shoaling of the nutricline, an increase in upwelling-favorable winds, or some combination thereof.

Note

Data used in this study will be available in the NOAA Paleoclimatology data base at: www.ncdc.noaa.gov/paleo/paleo.html

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Is there a pervasive Holocene ice-rafted debris (IRD) signal in the northern North Atlantic? The answer appears to be either no, or it depends on the proxy!

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Introduction

One of the most cited papers (271 citations by June 2006) on Holocene climate change is the 2001 paper by Bond and colleagues (2001), which argued for a pervasive ~1500 yr signal in the delivery of hematite-stained quartz (HSQ) sands to sites at or beyond the historic limits of observed drift ice (Fig. 1) (we use the term "drift ice" to denote any mixture of glacier icebergs or various forms of sea ice). To critically examine the hypotheses set forth in Bond et al. (2001), we selected a series of cores for analysis of ice-rafted debris (IRD). These cores were collected from sites that are much more within the historically known limits of drift ice (Fig. 1), hence lie to the north of the sites examined for HSQ. Two of the cores are exceptionally well dated (Moros et al., 2006) and the other two have sufficient age control to examine the Holocene trends in IRD.

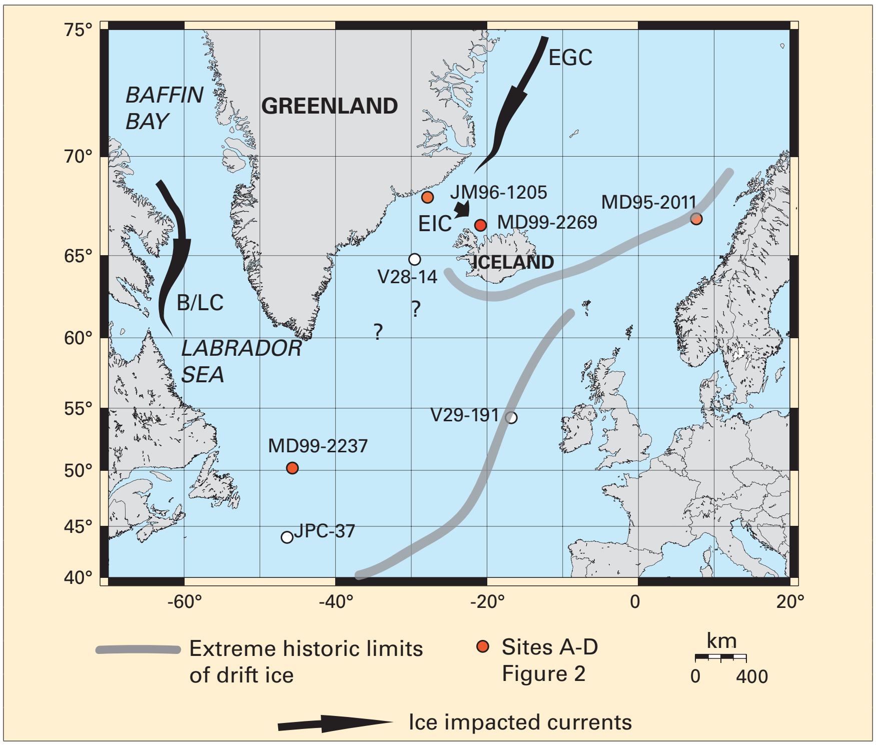

Figure 1: Location of cores used in this study (red circles) and cores reported by Bond et al. (2001). Historic maximum limits of drift ice are shown based on data from the International Ice Patrol (www.uscg.mil/LANTAREA/IIP/home.html) and the Norsk Polar Institute (acsys.npolar.no/ahica/quicklooks/looks.htm). Arrow labels: EGC = East Greenland Current; B/LC = Baffinland and Labrador Current; EIC = East Iceland Current.

Methods

There is no single working definition of IRD (Andrews, 2000); the variations in sediment carried by drift ice are often defined on the basis of grain-size or on some aspects of provenance (i.e. mineralogy) (Ruddiman, 1977; Andrews et al., 1989; Andrews et al., 1997; Bischof,