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Latitudinal variations in intermediate depth ventilation and biological production over northeastern Pacific Oxygen Minimum Zones during the last 60 ka

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A B S T R A C T

Mechanisms affecting past variability in the Oxygen Minimum Zone (OMZ) in the Eastern Tropical North Pacific (ETNP) are poorly known. We analyzed core MD02-2524, obtained from the Nicaragua Margin in the present ETNP OMZ for major and minor elements (titanium (Ti), brome (Br), silicon (Si), potassium (K), and calcium (Ca)) using an X-ray Fluorescence (XRF) core scanner, and redox-sensitive trace elements (uranium (U), molybdenum (Mo), and nickel (Ni)) determined by ICP-MS. The U and Mo content was higher during the deglaciation than during the Holocene and the last glacial maximum, whereas enrichment was not observed for Ni, an element closely associated with organic matter. High-resolution XRF scanning indicated that the Ca-based carbonate content had millennial-scale variability inversely correlated with Br-based organic matter and Si/K-based opal content during the last glacial period. The available data suggest no clear regional trend in biological productivity during the last deglaciation, but significant local variability in the coastal eastern equatorial Pacific. The trace element enrichment and the lack of a concomitant increase in biogenic phases indicated that an enhanced ETNP OMZ, at least between 15°N and 12°N at a water depth of 500–900 m, was principally caused by a reduced oxygen supply driven by oceanic circulation to the Nicaragua Basin during the deglaciation. The observed patterns can be interpreted as the distinct changes in the oxygenation state of northern and southern water masses at intermediate depths.

We also found evidence for a decoupling between local productivity and pore water oxygenation for several millennial-scale events during Marine Isotopic Stage 3, indicating that remote oxygen consumption and/or oceanic ventilation impacted OMZ intensity. Multi-millennial scale variations of the productivity at Papagayo upwelling cell displayed an opposite trend from productivity at the Costa Rica Dome, in relation with the latitudinal shift of the Inter Tropical Convergence Zone (ITCZ). Latitudinal variations of the OMZ intensity reflected the relative influence of the northern and southern intermediate water masses whose oxygenation was driven by high latitude climates and productivity over the intermediate water pathway.

1. Introduction

The northern edge of the Oxygen Minimum Zone (OMZ) for the last glacial period in the Eastern Tropical North Pacific (ETNP) has been intensively studied over the past few decades. Most previous studies have found evidence of millennial-scale variability of the OMZ in relation to abrupt climate variability as observed in the north Atlantic Ocean with oxygen depletion occurring during interstadial events rather than stadials (also called Dansgaard–Oeschger variations or DO) and Heinrich events (H) (Dean et al., 1997; Cannariato and Kennett, 1999; Hendy and Kennett, 2000; Hendy et al., 2002; van Geen et al., 2003; Hendy et al., 2004; Ortiz et al., 2004; Hendy and Pedersen, 2005; Dean, 2007; Cartapanis et al., 2011). Changes in marine productivity, induced by wind-driven upwelling variations, and ventilation of the water column (dissolved oxygen transport by oceanic advection) have been proposed to modulate past OMZ variability through oxygen consumption and inputs (van Geen et al., 2006). Even if productivity change was the main factor modulating the OMZ off the coast of Baja California (e.g. MD08 at 23°N, Cartapanis et al., 2011, proxies and modeling studies indicate that intermediate depth ventilation in the northeastern Pacific Ocean was at least partly related to the formation/oxygenation/extension of North Pacific Intermediate Water (NPIW, Fig. 1; see also Fig. 7A) (Hendy and Pedersen, 2005;

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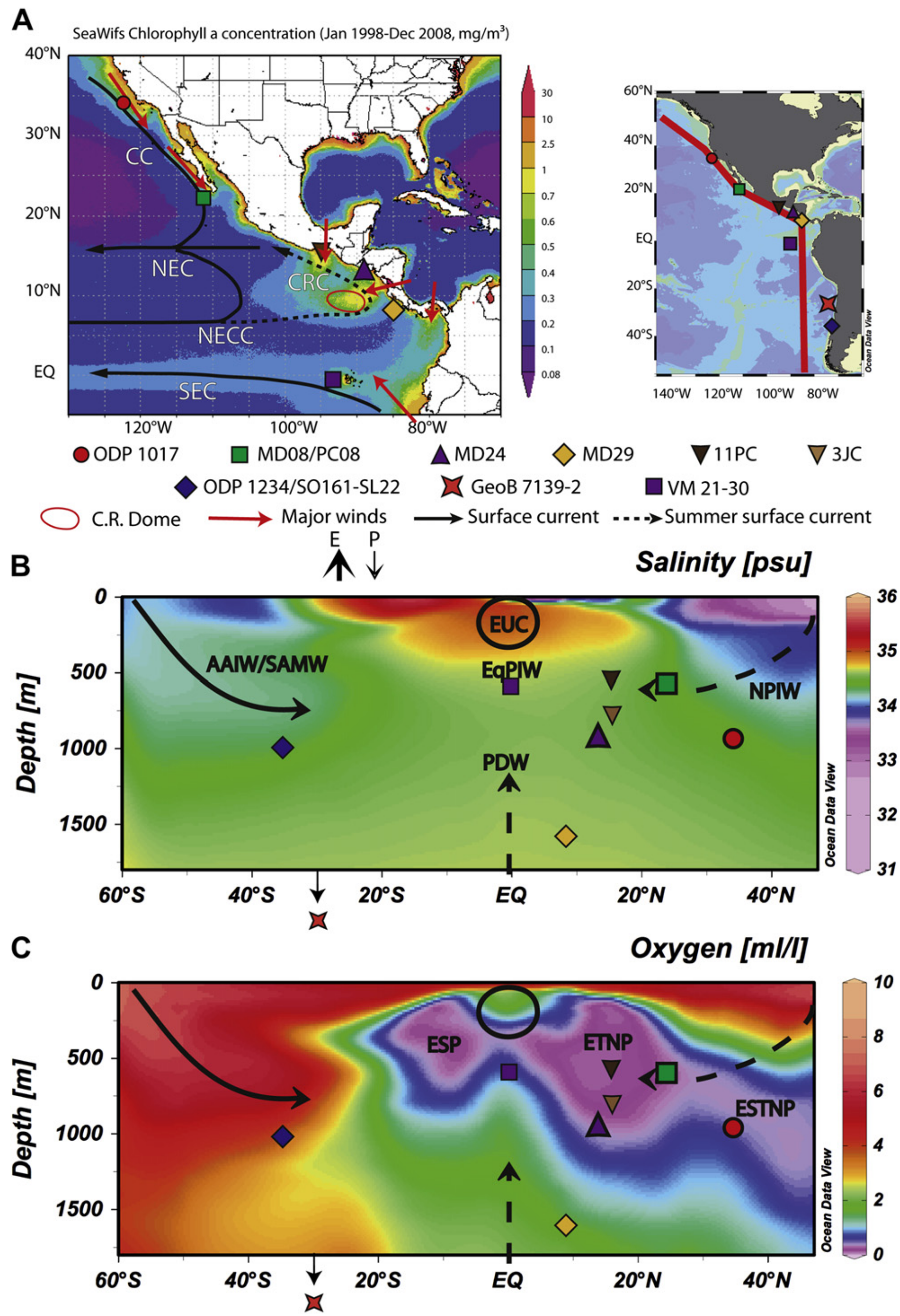

Fig. 1. A) Mean Seawifs Chlorophyll-a content estimations from January 1998 to December 2008, in mg/m^2. The main surface currents are indicated with black arrows (CC for the California current, NEC for the North Equatorial Current, NECC for the North Equatorial Counter Current, and SEC for the South Equatorial Current). The main winds that drive winter coastal upwelling are shown with red arrows. The position of the cores discussed in the text and the mean position of the Costa Rica Dome (following Figure 11 in Fiedler, 2002) are also indicated. B) The salinity transect taken along the eastern Pacific Ocean Margin (500 km wide, right upper panel). The following major water masses are shown: NPIW for North Pacific Intermediate Water, EqPIW for Equatorial Pacific Intermediate Water, SPMW for South Pacific Mode Water, AAIW for AntArctic Intermediate Water, and PDW for Pacific Deep Water. C) The oxygen content obtained along the eastern Pacific Ocean Margin (right upper panel). The position of the OMZ in the Eastern Tropical North Pacific (ETNP), the Eastern SubTropical North Pacific (ESTNP), and the Eastern South Pacific (ESP) are shown. Core sites quoted in the text are indicated, as follows: ODP1017 (34°32′N, 121°6′W, 955 m, Hendy et al., 2004; Hendy and Pedersen, 2005); MD08 (MD02-2508; 23°27′N, 111°35′W, 606 m Cartapanis et al., 2011) and PC08 (23°5′N; 111°6′W, 705 m, Marchitto et al., 2007); 11PC (15°71′N, 95°29′W, 574 m, Hendy and Pedersen, 2006); 3JC (15°65′N, 95°28′W, 740 m, Hendy and Pedersen, 2006); MD24 (MD02-2524, 12°00′N, 87°54′W, 863 m, this study); MD29 (MD02-2529, 8°12′N, 84°07′W, 1619 m, Romero et al., 2011); VM21-30 (1°13′S; 89°41′W; 617 m, Stott et al., 2009) ODP1234 (36°13′S, 73°40′W, 1015 m, Muratli et al., 2010) and SO161-SL22 (36°13′S; 73°40′W, 1000 m, De Pol-Holz et al., 2010); and GeoB 7139-2 (30°12′S; 71°58′W, 3267 m, De Pol-Holz et al., 2007). Data for A were obtained from the Giovanni online data system, developed and maintained by the NASA GES DISC (Acker and Leptoukh, 2007). B and C were generated using the Ocean Data View software (http://odv.awi.de) from the World Ocean Atlas 2005 dataset (http://www.nodc.noaa.gov/OC5/WOA05/pr_woa05.html). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)