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Western equatorial Pacific productivity and carbonate dissolution over the last 550 kyr: Foraminiferal and nannofossil evidence from ODP Hole 807A

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Abstract

We analyzed foraminiferal and nannofossil assemblages and stable isotopes in samples from ODP Hole 807A on the Ontong Java Plateau in order to evaluate productivity and carbonate dissolution cycles over the last 550 kyr (kilo year) in the western equatorial Pacific. Our results indicate that productivity was generally higher in glacials than during interglacials, and gradually increased since MIS 13. Carbonate dissolution was weak in deglacial intervals, but often reached a maximum during interglacial to glacial transitions. Carbonate cycles in the western equatorial Pacific were mainly influenced by changes of deep-water properties rather than by local primary productivity. Fluctuations of the estimated thermocline depth were not related to glacial to interglacial alternations, but changed distinctly at ~280 kyr. Before that time the thermocline was relatively shallow and its depth fluctuated at a comparatively high amplitude and low frequency. After 280 kyr, the thermocline was deeper, and its fluctuations were at lower amplitude and higher frequency. These different patterns in productivity and thermocline variability suggest that thermocline dynamics probably were not a controlling factor of biological productivity in the western equatorial Pacific Ocean. In this region, upwelling, the influx of cool, nutrient-rich waters from the eastern equatorial Pacific or of fresh waters from rivers have probably never been important, and their influence on productivity has been negligible over the studied period. Variations in the inferred productivity in general are well correlated with fluctuations in the eolian flux as recorded in the northwestern Pacific, a proxy for the late Quaternary history of the central East Asian dust flux into the Pacific. Therefore, we suggest that the dust flux from the central East Asian continent may have been an important driver of productivity in the western Pacific.

Keywords: paleoproductivity; thermocline; carbonate dissolution cycles; benthic foraminifera; nannofossils; eolian processes; western equatorial Pacific Ocean

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1. Introduction

Research on paleoproductivity has received much attention because of the possible link between atmospheric CO_2 concentrations and organic productivity in the oceans. Pleistocene productivity records have become a focus of research in order to understand fluctuations of CO_2 and other greenhouse gases preserved in polar ice (Petit et al., 1999; EPICA community members, 2004; Siegenthaler et al., 2005; Spahni et al., 2005). There are many processes to influence atmosphere CO_2, including physical, chemical and biologically-linked processes (Prentice et al., 2001), but the surface phytoplankton productivity, a part of the biological pump which probably plays a central role in the global carbon cycle, may have played a key role in changing glacial–interglacial atmospheric pCO_2 levels (Archer et al., 2000a,b; Bopp et al., 2003). The history of sea surface productivity in the western equatorial Pacific is poorly known, and results from a small number of available records are highly inconsistent. For example, the record of combustion oxygen demand (COD) over the last 400 kyr (core RNDB 74P, water depth 2547 m, Ontong Java Plateau) does not display an obvious down-core trend (Perks and Keeling, 1998). COD may provide an approximation of the organic carbon content of sediments, but sediment above lysocline (~3300 m; Prentice et al., 1993) may contain organic carbon too low to be reliably measured. In Core C4402 (water depth 4402 m, West Caroline Basin, Fig. 1a), however, organic carbon has a relatively high concentration because of strong carbonate dissolution, and both organic carbon and biogenic silica increased during the last 330 kyr (Hodaka et al., 1998).

Quantification of productivity changes is important for understanding the global carbonate cycles on both glacial–interglacial and longer timescales, because carbonate production is linked to primary productivity. There is still no agreement on the interpretation of carbonate cycles on glacial–interglacial time scales even after a half-century long endeavor (Thomas et al., 2000). Carbonate concentration in sediments is affected by multiple factors including carbonate production, carbonate dissolution and dilution by siliceous and/or terrigenous particles. Arrhenius (1988) argued that carbonate cycles in the equatorial Pacific were caused by the differences in biogenic production rates between glacial and interglacial periods, but Berger (1973) maintained that carbonate cycles were largely caused by changes in the rate of carbonate dissolution. Berger's opinion is supported by the finding that carbonate accumulation rates did not increase in response to the higher productivity during the last glacial relative to the late Holocene productivity in the western equatorial Pacific (Herguera, 1992). Wu et al. (1991) considered that more than half of the total amplitude of the observed carbonate cycles was due to lysocline fluctuations in the western equatorial Pacific. However, it still remains an open question to what degree variations of productivity are involved and what their implications are.

On a longer timescale, globally increased pelagic carbonate production was proposed as a primary candidate driver for the mid-Brunhes severe dissolution event, which occurred about 600 kyr ago and lasted for approximately 400 kyr (Barker et al., 2006). Together with a period of enhanced carbonate preservation centered at about 900 kyr, it formed a 500-kyr carbonate cycle (Becquey and Gersonde, 2002). The mid-Brunhes dissolution event has been identified in many places of the Atlantic, Pacific, Indian, and Southern Oceans as well as the Red Sea from <1000 m to abyssal depths (Barker et al., 2006). In the western equatorial Pacific, however, this severe dissolution event occurred at depths below the lysocline (Wu et al., 1991) and is not detectable above the lysocline using foraminifer fragment ratios (Le and Shackleton, 1992). Although the cause of this distinct dissolution pattern along depth profile is still unknown, it was unlikely to have resulted from carbonate production in the Western Pacific Warm Pool, a region with relative small spatial variability of carbonate production.

The mid-Brunhes dissolution event was temporally coincident with the mid-Brunhes climate event, characterized by a more zonal circulation in the northern hemisphere and intensified atmosphere and ocean circulation in the southern hemisphere. The mid-Brunhes climate event was terminated by a global southward migration of the polar and subtropical fronts; therefore, more glacial conditions became prevalent in the northern hemisphere and more interglacial conditions in the southern hemisphere (Jansen et al., 1986). Accompanying the redistribution of global heat during the front southward migration, the wind intensity in both northwestern (Hovan et al., 1991; Janecek and Rea, 1985) and central equatorial (Chuey et al., 1987) Pacific changed from a pattern of high amplitude, low frequency fluctuation to a pattern of fluctuation at lower amplitude and higher frequency. The change of wind intensity may have caused some dramatic changes in other climatic subsystems such as oceanic circulation, mixing, nutrient distribution and global total primary productivity. Carbonate preservation was probably just one aspect of these changes, although there is by far no evidence to substantiate the suggested link between the two mid-Brunhes events (e.g., Farrell and Prell, 1989).