A rule of N2 fixation region for ocean nitrogen cycle in the past 120 kyr

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Introduction

Nitrate is a significant nutrient for growth of phytoplankton in the ocean. In most of the oceans, primary production is restrained due to deficiency in supply of nitrate. Therefore, nitrate pool in the oceans is interpreted to be one of factors controlling capacity of primary production. The nitrate pool is primarily controlled by fluxes of N2 fixation, riverine input, and denitrification. However, there is a possibility that each flux was varied in past and the varying fluxes might affect capacities of nitrate pool and primary production. Although past denitrification rates in the Arabian Sea and Eastern Tropical Pacific (ETP) have oscillated in a scale of few thousand years, the flux of N2 fixation which adds new nitrogen into the surface waters has not yet been understood. In this paper, we document a history of N2 fixation in the Sulu Sea in the western equatorial Pacific region, and discuss a rule of N2 fixation region for ocean nitrogen cycle in the past 120 kyr.

Results and discussion

The age model for the SUP8 was based on the foraminiferal delta18O chronology for G. Sacculifer and three AMS14C dates of foraminiferal tests, applying SPECMAP timescale. Depositional period of the SUP8 covered over the past 85 kyr. TOC varied from 0.11 to 0.46 wt%, which was lower than TOC in adjacent marginal sea sediments. Glacial TOC during 70-12 ka increased up to 3 times compared to those of interglacial values. Furthermore, glacial delta13C also increased from interglacial values of -20 to glacial values of -18permil in sync with increases in glacial TOC. Alkenones contents (biomarker of specific haptophyte algae) have a good, positive correlation with TOC. Primary production, therefore, is interpreted to have been enhanced during glacial ages. The delta15N varied within a range of 3.2-6.1permil, but there was not an obvious trend responded to glacial-interglacial cycles in the delta15N. The average delta15N value over the 85 ka was 4.8permil, which was isotopically lighter than nitrate delta15N (5.5-6.1permil) of the Pacific Intermediate Water [Higginson et al., 2003]. delta15N variability treated by 3-points running mean showed that delta15N values at MIS-3 (50-35 ka) were more depleted than those of MIS-2.

The present Sulu Sea is characterized by no upwelling and surface stratification due to the intrusion of low-saline surface waters from the South China Sea. Nitrate in the surface waters, therefore, is almost depleted in yearly basis. In such condition, it is expected that sinking particulate organic matter (POM) from the surface water has an equivalent delta15N value to subsurface nitrate because phytoplankton completely utilize nitrate supplied from subsurface. However, in the Sulu Sea delta15N values of sinking POM in the sediment traps at 50-m and 150-m deep were 4.3-5.9permil. Since delta15N of subsurface nitrate in the Sulu Sea is inferred to be within a range of 5.5-6.1permil of the PIW, lighter delta15N values of POM are interpreted to reflect an influence of N2 fixation. Indeed, N2 fixing cyanobacterium is widely observed in the SCS, Sulu Sea, and Celebes Sea [Gomez et al., 2005]. Thus, N2 fixation is partly contributed to supply of nitrate to the photosynthetic system in the Sulu Sea. If this mechanism occurs in the past Sulu Sea, isotopically lighter delta15N documented from MIS-3 reflect enhanced N2 fixation. Although N2 fixation rates and its distribution are interpreted to be depend on iron concentrations supplied from aeolian dust, the oscillation in the Sulu Sea N2 fixation showed N2 fixation was more efficient than during MIS-2 when dust contents increased. Furthermore, during MIS-3 denitrification rates were increased in the Arabian Sea and ETP, and therefore oceanic nitrate must be decreased. Our finding suggests that the enhancement of N2 fixation in the Sulu Sea during MIS-3 responded to the decreased oceanic nitrate pool.