Transitions of redox state and nutrient status in the Southern Ocean since the last glacial: Evidence from speciation analyses of C, Fe, and P in sediments at the Conrad Rise

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The Southern Ocean, a high-nutrient, low-chlorophyll region, has played an important role in regulating global climate system. The Southern Ocean became suboxic during the last glacial period (~40 to 19 kyr ago) and changed to oxic toward Holocene. In order to elucidate changes in the redox state and nutrient status of the seawater caused by sea ice, we performed C, Fe and P speciation analyses of the marine sediments (COR-1bPC) recovered in 2010 at the Conrad Rise in the Southern Ocean (KH10-7 cruise).
Thirty-seven samples were quantified for five P-bearing species (P_{abs}, P_{Fe}, P_{auth}, P_{det} & P_{org}) by modified SEDEX method of Ruttenberg (1992) and four Fe-bearing species (Fe_{HCl}, Fe_{carb}, Fe_{ox} & Fe_{mag}) by the method of Poulton et al. (2005). The abundance and the stable isotope compositions of organic carbon were measured using EA-irMS at Center for Advanced Marine Core Research, Kochi University. Average content of P_{det}, which represent the continent flux, in the dark colored (last glacial) sediments was 0.004 wt.%. Conversely, that in the light colored (interglacial) sediment was 0.002 wt.%. The $\delta^{13}C_{org}$ values in last glacial period (avg. = −23.63 ‰) was isotopically lighter than those in the interglacial period (avg. = −21.73 ‰
). These results suggest that the Conrad Rise (54.2 °S) was covered by sea ice during the last glacial period. Suppression by sea ice of atmosphere-ocean interactions would have decreased dissolved oxygen concentration and gradually created suboxic condition. Fluctuating contents of P_{Fe} and Fe_{ox} indicate occurrence of short-term oxidation events during the last glacial period. In the deglacial period, abundance of C_{org} decreased but that of all P-bearing phases, Fe_{HCl}, and Fe_{ox} abruptly increased to the maximum value. This suggests that melting of the sea ice would have increased P and Fe nutrient supply to the surface ocean and dissolved oxygen supply to the deep ocean, leading to enhanced decomposition of organic matter and drastic changes into oxic conditions. Such environmental changes would have been due to southward migration of Antarctic Circumpolar Current (ACC). Speciation analysis of C, Fe and P in sediments is a powerful tool toward reconstruction of redox and nutrient states in the ocean.

