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Biogeochemical cycling of phosphorus in the 45˜50Ma Arctic Ocean: Constraints from speciation analysis (IODP Exp302)

HASHIMOTO, Shunta[1*], YAMAGUCHI, Kosei E.[1], TAKAHASHI, Kozo[3]

[1]Department of Chemistry, Toho University, [2]Department of Chemistry, Toho University, NASA Astrobiology Institute, [3]Department of Earth and Planetary Sciences, Kyushu University

The modern Arctic Ocean plays a key role in regulating global climate system, because it is a site of high albedo by sea ice and of deep water formation as a driving force of thermohaline circulation through which heat and nutrients are transported. However, the Arctic sea ice did not always exist in the past. Integrated Ocean Drilling Program (IODP) Expedition 302 Arctic Coring Expedition (ACEX) has revealed that the seawater temperature was substantially high (10˜14^{o}C) and no sea ice was formed before 45Ma when sea ice started to form (e.g., Brinkhuis et al., 2006; Moran et al., 2006; Marz et al., 2010). In a warm Arctic Ocean, the thermohaline circulation was weak enough to stagnate the deep ocean and to develop anaerobic environment, like the modern Black Sea. Nutrient recycling is likely to have been much different from that of today. In order to clarify the geochemical cycle of phosphorus, a bio-essential nutrient element, we performed sequential extraction analyses for different forms of phosphorus using ACEX samples. We utilized a method modified after Schenau et al. (2000), which is based on a SEDEX method by Ruttenberg (1992) where phosphorus-bearing species in sediments are chemically extracted into five different forms; (1) absorbed P, (2) Fe_{oxide}-P, (3) carbonate fluorapatite (CFAP) + $CaCO_3$-P + hydroxylapatite (HAP), (4) detrital P, and (5) organic P. In the method of Schenau et al. (2000), the above (3) was divided into two phases: non-biological CFAP and biological HAP and $CaCO_3$-P.

Our working hypothesis is as follows: If the Arctic Ocean was warm and closed by surrounding continents, the seawater would have stratified and become anaerobic, where bacterial sulfate reduction was active. Phosphorus in the sediment would have been preserved mainly as organic P that likely originated from decay of plankton. Fe oxide-P is considered to be less important as a sink of P, because free Fe would have been depleted due to extensive pyrite formation (Ogawa et al., 2009). CFAP could be an important sink of P because its abundance increased with increasing age and depth (Fillippelli and Delaney, 1996). If continental weathering was enhanced by an increase in rainfall in a warm climate during the 49˜48 Ma Azolla Event, increased weathering flux of phosphorus would have enhanced primary productivity.

Keywords: IODP, ACEX, SEDEX method, Phosphorus phase