

Osmium isotope composition in the deep pelagic Panthalassa ocean during the Toarcian Oceanic Anoxic Event

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The Toarcian Oceanic Anoxic Event (T-OAE) represents one of the most significant paleo-environmental perturbations in the Phanerozoic, which resulted in marked disruption to both the climate system and marine ecosystem. The causes for this widespread deposition of organic carbon-rich sediments under the reducing condition are still controversial. Several mechanisms have been proposed to explain the occurrence of T-OAE including; abrupt seawater warming, an increase in continental weathering rates, enhanced rates of biotic turnover, atmospheric pCO₂ changes, and ocean acidification. In particular, volcanic activities in the large igneous Karoo-Ferrar province have been considered as the most fundamental trigger for the Toarcian perturbations. Radiogenic Os isotope compositions of sedimentary rocks are useful for estimating the influx from both ancient basaltic magmatism and continental weathering. However, the relationship between biotic crisis, anoxic event, and the volcanic activity in the deep pelagic environment is still ambiguous because of the lack of detailed Os isotope records during T-OAE. In this study, we reconstructed a detailed lithological column in the Inuyama area where the Pliensbachian to Toarcian deep-sea cherts well crop out along the Kiso river. For Os isotope analysis, we collected 12 chert samples from a section where two black bedded chert intervals T-OAE1 and T-OAE2 were observed.

The rock powder was spiked with ¹⁹⁰Os and ¹⁸⁵Re prior to digestion. The sample was digested by CrO₃-H₂SO₄ in a sealed Carius tube at 240 °C for more than 48 hours. Subsequently, Os was separated by solvent extraction using CCl₄ and back-extracted from CCl₄ into HBr, followed by the final purification using the micro-distillation method. The Os isotope ratios were determined by N-TIMS at Tokyo Tech. Re-bearing solution after the CCl₄ extraction was stored in a Teflon vessel, and Cr⁶⁺ in the solution was completely reduced to Cr³⁺ by the addition of ethanol in order to avoid the disturbance of the elution profile of the following chromatography due to the coexistence of Cr⁶⁺. After this process, Re was purified by chemical separation using an anion exchange resin, and the isotopic composition was determined using a quadrupole-type ICP-MS at Tokyo Tech. The Os and Re concentrations were determined by the isotope dilution method.

The Re and Os abundances in 12 chert samples across T-OAE varied from 2.1 to 128.6 ng/g, and from 32.8 to 2284.3 pg/g, respectively. The ¹⁸⁷Os/¹⁸⁸Os ratio in the samples before T-OAE1 decreased from 0.44 to 0.27, resulting in the minimum value of 0.24 at the onset of T-OAE1. However, the ¹⁸⁷Os/¹⁸⁸Os ratio increased abruptly to be 0.77 towards the end of T-OAE1, and decrease down to 0.30 at the interval between T-OAE1 and T-OAE2. During T-OAE2, the ¹⁸⁷Os/¹⁸⁸Os ratio gradually increased up to 0.56. Take into account organic carbon isotope record in the same section by Grocke et al. (2011), we envisage the following scenario for the cause of Os and C isotopic variation during T-OAE observed in the chert samples: The Karoo-Ferrar volcanic activity induced an anoxic condition, which resulted in negative ¹⁸⁷Os/¹⁸⁸Os before T-OAEs. The Karoo-Ferrar volcanism released significant amount of CO₂, which triggered the global warming and continental erosion during T-OAE1. Subsequent gradual increase of Os isotope ratios most likely reflects its aftermath. These indicate that the Karro-Ferrar volcanism played an important role for inducing anoxic condition and global warming during Toarcian in the deep pelagic Panthalassa ocean.

Keywords: Toarcian Oceanic Anoxic Event, deep pelagic Panthalassa ocean, osmium isotope, Karoo-Ferrar volcanism