論文内容の要旨

High-resolution reconstruction of the deep-water environment and its relation with shallow-water environment during the End-Permian to the Early Triassic: Implication for the cause and consequence of ocean anoxia at the P/T boundary

ペルム紀末－三畳紀前期における深海域の環境変動の高解像度復元および浅海域の環境変動との関連性：P/T 境界海洋無酸素事変の原因と結果への示唆

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High-resolution and nearly continuous lithostratigraphic reconstruction of pelagic sequence from the latest Permian to the Early Triassic was conducted for the first time based on the detailed geologic mapping and lithostratigraphic correlation in Ubara and Inuyama areas, southwestern to central Japan to establish the continuous lithostratigraphic sequence of pelagic sediments in superocean Panthalassa during the latest Permian and the Early Triassic.

For the reconstructed sequence, measurement of carbon isotopic ratio of organic carbon ($\delta^{13}C_{org}$) was carried out. In order to establish the higher-resolution age model for the reconstructed pelagic sequence of the uppermost Permian to the Lower Triassic, we correlated $\delta^{13}C_{org}$ profiles in Ubara and Inuyama areas with high-resolution carbonate carbon isotopic ratio ($\delta^{13}C_{carb}$) profiles of shallow marine carbonate sequences in South China based on the similarity in general variation patterns with age constraints given by radiolarian and conodont biostratigraphy. The result

demonstrates that positive and negative excursions in the $\delta^{13}C_{org}$ profiles in both areas and $\delta^{13}C_{carb}$ profiles in south China are correlatable, thus providing high-resolution time scale for the pelagic sequence of Panthalassa. It is also worth to note that the age model for the Inuyama area suggests a drastic increase in sedimentation rate during the late Smithian, which should have been caused by the increase in terrigenous input to the ocean.

Using continuously sampled slabs obtained from the reconstructed pelagic sequences in Ubara and Inuyama areas, we reconstructed changes in the bottom-water oxygenation condition in the deep-sea environment based on the degree of lamina preservation observed on soft X-ray radiographs so as to reveal the extent, duration, and periodicity of the anoxic condition. The observation revealed that anoxic condition of the bottom-water in Ubara area occurred periodically with the duration of 10^3-10^4 years and the repeated period of 10^3-10^4 years during the latest Changxingian to the earliest Griesbachian, corresponding to the time interval of 0.3-0.4Myr. In Inuyama area, repeated emergence of anoxic condition of the bottom-water with the duration of 10^4 years and the repeating period of 10^4 years occurred from the middle to late Smithian, corresponding to the time interval of approximately 0.2Myr.

The size frequency distribution of pyrite framboids was also examined using polished samples under a scanning electron microscope to identify the occurrence of small-sized (approximately 5 micrometer in general) pyrite framboids indicative of water column euxinia. Based on the identification of stratigraphic intervals with small framboidal pyrite, bottom-water euxinia occurred with the repeating intervals of 10^4-10^5 years from the latest Changxingian to the earliest Griesbachian in Ubara area, and with the repeating intervals of of 10^3-10^4 years from the the middle to late Smithian in Inuyama area. In Ubara area, sulfur isotopic composition of small framboidal pyrite was measured by NanoSIMS. The result shows$\delta^{34}S$ value of approximately -23‰, which is obviously lighter than those of diagenetic pyrites (generally heavier than -15‰), confirming that

small framboidal pyrite were formed under euxinic condition in the water-column.

The Co/Al_2O_3, V/Al_2O_3, and Mo/Al_2O_3, which tend to be high in sediments deposited under anoxic bottom water environment (Trivovillard *et al*., 2006), show high ratios in the upper part of the black shale unit in Ubara area and Co/Al_2O_3 and V/Al_2O_3 exhibit high ratios in the lower part of the gray bedded argillaceous chert unit in Inuyama area. Although there are some scattering, these ratios tend to be high in intervals in the upper part of the black shale unit in Ubara area and the lower part of the gray bedded argillaceous chert unit in Inuyama area, which were identified as anoxic on the basis of LPI, confirming the validity of our reconstruction on variation of bottom water oxygenation level based on LPI and presence of small framboidal pyrite.

We conducted the correlation of environmental changes between deep-water of Panthalassa and shallow-water of Tethys using carbon isotope stratigraphy to explore the mechanism of anoxia and its linkage with the mass extinction. The result suggests that the horizon with small pyrite framboids and bioturbation, which is immediately above the laminated interval, in pelagic siliceous sequence of Central Japan seems to be correlated with the horizon interpreted as photic zone anoxia which is immediately followed by the horizon of mass extinction in the shallow carbonate sequence across the P/T boundary in South China. Whereas the horizon with small pyrite framboids and well-preserved lamination in pelagic siliceous sequence of Central Japan seems to be correlated with the horizon interpreted as cyanobacterial expansion in shallow water Tethys. These results suggest that the upwelling of anoxic deep-water could have caused the photic zone anoxia and mass extinction at least in the shallow-water at the P/T boundary, while cyanobacterial expansion at least in the shallow-water possibly contributed to euxinic condition in deep-water following the photic zone anoxia event. The result in Inuyama area also suggests that the laminated interval with small pyrite framboids in the middle Smithian seems to be correlated with immediately below the horizon which is interpreted as the occurrence of anoxia and faunal turnover of ammonoids from the upper

Smithian to the Smithian/Spathian boundary in South China and India. These results imply that the anoxic/euxinic bottom-water in the pelagic deep-sea could have contributed to the occurrence of anoxia and faunal turnover in the shallow-water through the ocean circulation.

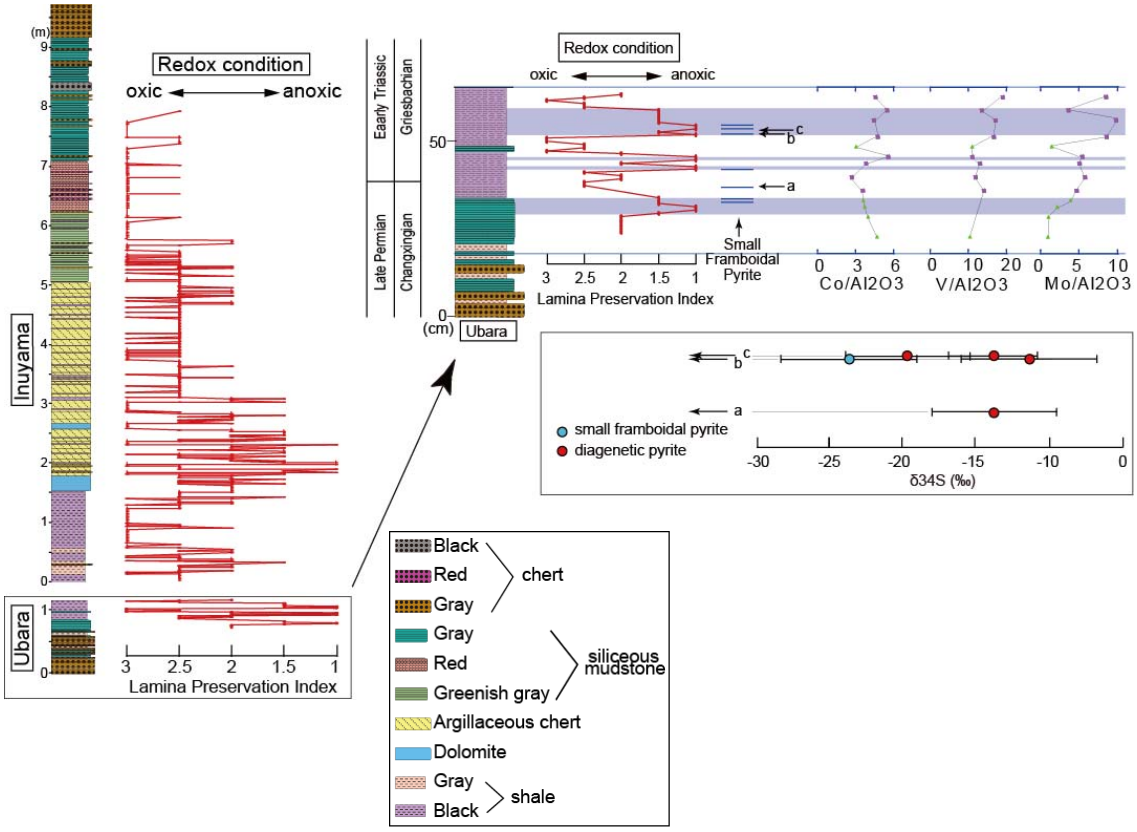

Figure. Temporal changes in bottom-water oxygenated condition in Ubara area and Inuyama area based on the lamina preservation index and the observation of small framboidal pyrite. Results of sulfur isotope analysis of small framboidal pyrite and diagenetic pyrite are also indicated.