論文の内容の要旨

論文題目

Stratigraphy and palaeoenvironmental record of Lower Triassic deep-sea sedimentary rocks deposited in the pelagic Panthalassa

（パンサラッサ遠洋域で堆積した下部三畳系深海堆積岩の層序と古環境記録）

氏名　武藤俊

The pelagic deep-sea sediments deposited in the Panthalassa during late Paleozoic to early Mesozoic times are dominated by bedded radiolarian chert, except for the Lower Triassic interval, which is composed of claystone dominant lithofacies: the deep-sea chert gap. In addition to the absence of bedded chert, the deep-sea chert gap is characterised by the occurrence of organic-rich black claystone at the end-Permian mass extinction (EPME) horizon. Therefore, the deep-sea chert gap potentially holds information on perturbations in the global silica and carbon cycles that began at the EPME and continued for the 5 Myr of the Early Triassic. However, information on its lithostratigraphy was highly fragmentary. This thesis attempted to clarify the complete lithostratigraphy of the Lower Triassic deep-sea chert gap, and to evaluate its record of perturbations in the silica cycle and the carbon cycle in the aftermath of the EPME.

Based on field investigations of nine sedimentary sections and conodont biostratigraphic investigations, in addition to compilation of previous studies, I established an almost complete lithostratigraphy of the deep-sea chert gap. The established lithostratigraphy of the deep-sea chert gap revealed the presence of chert beds, intercalated in or alternating with claystone beds, especially in the Olenekian interval. In addition, I discovered that black claystone is not restricted to the EPME horizon, and also occurs as dominant lithofacies in the lower Spathian and across the Olenekian-Anisian boundary (OAB). Furthermore, linear sedimentation rates (LSR) were estimated for the

deep-sea chert gap by projecting U-Pb ages from shallow-marine sections using conodont biostratigraphy. The LSR of the deep-sea chert gap is > 7.4 m/Myr (5.8–10 m/Myr accounting for errors of radiometric age) from the EPME horizon to the lower Spathian, > 6.8 m/Myr (5.9–7.9 m/Myr accounting for errors of radiometric age) from the lower Spathian to the OAB and > 4.8 m/Myr (3.9–6.2 m/Myr accounting for errors of radiometric age) from the OAB to the Aegean-Bithynian substage boundary (ABB). These values are significantly higher than the LSR of Middle Triassic to Lower Jurassic bedded chert in the Inuyama area (1.5–1.7 m/Myr).

The organic matter burial flux (OMBF) in the deep-sea chert gap was estimated based on measurements of total organic carbon content (TOC), including data from previous studies. The estimated OCBF in the deep-sea chert gap is 30 $g/Myr \cdot cm^2$ (10–80 $g/Myr \cdot cm^2$) from the EPME to the early Spathian, 10 $g/Myr \cdot cm^2$ (4–20 $g/Myr \cdot cm^2$) from the early Spathian to the OAB and 20 $g/Myr \cdot cm^2$ (6–40 $g/Myr \cdot cm^2$) from the OAB to the ABB. These values are two orders of magnitude higher than that in bedded chert, and are comparable to upwelling zones in the modern ocean. The high OCBF in the deep-sea chert gap is interpreted as a result of high sediment accumulation rate, in addition to bottom water anoxia and/or high export production. Furthermore, assuming a relatively constant LSR, the highest OCBFs in the deep-sea chert gap in black claystone-dominant intervals are likely to be 500 to 1000 times that of bedded chert. Such an increase in OCBF probably occurred under the combined effects of high sediment accumulation rates, bottom water anoxia and high export production. The OCBF estimates were compared with secular changes in carbon isotope values of carbonates ($\delta^{13}C_{carb}$) using conodont biostratigraphy and profiles of carbon isotope values of organic matter ($\delta^{13}C_{org}$) in the deep-sea chert gap including data from previous studies. The comparison showed that the extremely high OCBFs coincided with rising $\delta^{13}C_{carb}$, suggesting that the high OCBF in the low latitude pelagic Panthalassa played a significant role in the removal of dissolved inorganic carbon form the atmosphere-ocean system. Indeed, extrapolation of the OCBF in black claystone dominant intervals to the area between 10°N and 10°S of the pelagic Panthalassa accounts for 10–30% of the total OCBF in the typical Phanerozoic ocean.

In order to clarify the origin of the clay-rich sedimentary rocks of the deep-sea chert gap, biogenic silica burial flux (BSBF) and clastic material burial flux (CMBF) in the deep-sea chert gap were calculated and compared with those in bedded chert. BSBF and CMBF were calculated using the content ratio of clastic material and biogenic silica within the deep-sea sediments based on the contents of SiO_2 and Al_2O_3 measured by X-ray fluorescence analysis. BSBF in the deep-sea chert gap is > 810 g/cm^2·Myr (240–1740 g/cm^2·Myr) from the EPME horizon to the lower Spathian, > 930 g/cm^2·Myr (510–1480 g/cm^2·Myr) from the lower Spathian to the OAB and > 680 g/cm^2·Myr (360–1190 g/cm^2·Myr) from the OAB to the ABB. CMBF in the deep-sea chert gap is > 1190 g/cm^2·Myr (580–2260 g/cm^2·Myr) from the EPME horizon to the lower Spathian, > 950 g/cm^2·Myr (510–1550 g/cm^2·Myr) from the lower Spathian to the OAB and > 620 g/cm^2·Myr (270–1060 g/cm^2·Myr) from the OAB to the ABB. Compared to estimated BSBF and CMBF in the Middle Triassic to Lower Jurassic bedded chert (420 g/cm^2·Myr and 140 g/cm^2·Myr, respectively), BSBF is increased at least by a factor of 2 and CMBF is increased at least 7 by a factor of in the deep-sea chert gap. Consequently, the origin of the deep-sea chert gap was identified as an anomalous increase in clastic material, most likely aeolian dust, to the pelagic realm. The increased CMBF may have been a result of expansion of arid regions due to the pole-ward expansion of the Hadley Cell under hothouse conditions in the Early Triassic. The increase in BSBF was probably a result of increased continental weathering, which is consistent with strontium isotope ($^{87}Sr/^{86}Sr$) records in South China and Iran.

A plausible causal relation between the high OCBF, BSBF and CMBF in the deep-sea chert identified in this study and environmental perturbations reported for the Early Triassic is as follows. Climatic warming caused the expansion of arid areas through the pole-ward expansion of the Hadley Cell, and also an increase in chemical weathering of the continents. The expansion of arid areas led to the increase in aeolian dust flux to the pelagic Panthalassa, resulting in high CMBF. Increased continental weathering resulted in increased dissolved silica and nutrient flux to the oceans. Increased dissolved silica flux resulted in increased BSBF, which in concert with high accumulation rate of aeolian dust, enhanced the burial efficiency of organic carbon by shielding. Increased nutrient flux to the oceans led to increased export production in the pelagic Panthalassa, which resulted in episodic oxygen depletion in the bottom water. In addition to high nutrient flux, the increase in aeolian dust flux may have been an essential factor that supported high export production by fertilising the pelagic ocean with iron. A combination of high sediment accumulation rates, high export production and episodic bottom water anoxia resulted in a dramatic increase in OCBF.