The redox history and nitrogen cycle in the pelagic Panthalassic deep ocean during the double-phased extinction interval across the Paleozoic-Mesozoic transition

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The end-Permian mass extinction, the largest catastrophic perturbation in the Phanerozoic life history, comprises two distinct extinctions; the first one across the Guadalupian-Lopingian (G-L) boundary and the second one across the Permian- Triassic (P-Tr) boundary. The appearance of prolonged global-scale anoxia during this interval was likely unfavorable for most animals and marine ecosystems. In order to constrain oceanic redox conditions and biological activity, carbon isotope ratios and redox proxies were measured in many sections; however, most of these studies have been undertaken on the sections from the Tethys Ocean, a region covered only 10-15% of the area of the global-ocean, and ignored the larger part of central Panthalassa, comprising 85-90% of the area of the Permian to Triassic global-ocean. The Permo-Triassic deep-sea pelagic cherts preserved in the on-land exposed Jurassic accretionary complex in Japan are ideal material for paleoenvironmental studies; however, the linkage between marine redox history and biological activity in the mid-Panthalassic deep ocean has not been well understood owing to limited data-set. We collected shales partings of bedded cherts of the Guadalupian to earliest Induan ages exposed at the Gujo-Hachiman section in central Japan. We determined the organic carbon ($\delta^{13}C_{org}$) and nitrogen ($\delta^{15}N_{TN}$) isotopic ratios, and major, trace and rare earth element abundances of the shales, in order to clarify changes in the redox history and nitrogen cycle in mid-Panthalassa for the double-phased mass extinction across the Paleozoic-Mesozoic transition.

Little enrichments of Mo, V, U, and TOC were detected from the Guadalupian to Lopingian shales, suggesting that the mid-Panthalassic deep ocean was dominated by an oxic-suboxic condition across the G-L transitional zone. In addition, the $\delta^{13}C_{org}$ and $\delta^{15}N_{TN}$ values across the G-L transitional zone exhibit little fluctuation, and the former is almost the same as those obtained from adjacent bedded cherts. In contrast, a negative $\delta^{15}N_{TN}$ shift and the extensive ocean euxinia are recognized in the Tethyan shallow marine strata. These lines of evidences indicate that the development of euxinia and nitrogen-limited conditions were limited only to shallow shelf domains of the Tethyan Ocean and had little influence to the mid-Panthalassic deep ocean across the G-L boundary.

High abundances of U, V, and Mo in the Induan black mudstones indicate the appearance of anoxic conditions in mid-Panthalassa. The $\delta^{13}C_{org}$ values during the Induan show a similar pattern to that reported in other deep-sea sites. On the other hand, the $\delta^{15}N_{TN}$ values in the Induan mudstones range from -2.0 to 0.7‰. These low $\delta^{15}N_{TN}$ values together with the emergence of anoxic condition suggest that a relative predominance of nitrogen fixation, which in turn means a nitrogen-limited condition in the mid-Panthalassa. Our $\delta^{15}N_{TN}$ profiles are similar to those reported from other P-Tr boundary sections, such as eastern Panthalassic and Tethyan Oceans. Therefore low $\delta^{15}N_{TN}$ values during the Induan was likely a global signature, and we concluded that the protracted oceanic nitrogen depletion during the Induan would have acted as an environmental stress on shallow and deep-sea biota.

Keywords: mass extinction, Panthalassa, organic carbon isotopes, nitrogen isotopes, redox-sensitive elements

