三畳紀古世後期における南部北上古陸周辺海域の酸化還元環境

Redox conditions of late Early Triassic oceanic region around the South Kitakami Microcontinent

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After the end-Permian mass extinction (EPME), biotic recovery required more than 5 million years during the Early Triassic. Evidence of recovery such as the emergence of complex ecosystems and high biodiversity appeared in the late Early Triassic to Middle Triassic (Chen and Benton, 2012). The fossil evidence of a complex food chain was reported from shallow-marine strata of late Olenekian (Spathian), late Early Triassic age, in the South Kitakami Microcontinent that was located in the low-latitude Tethys-Panthalassa border (Ehiro, 2001). These strata belong to the Osawa Formation in the South Kitakami Belt, now distributed in Northeast Japan, and are characterized by well-preserved parallel laminae and the occurrence of the oldest ichthyosaurs (Shikama et al., 1978; Yamanaka and Yoshida, 2007). However, the depositional environment of these strata has been poorly understood. The present study aims to reveal detailed redox conditions in the Spathian shallow marine region around the South Kitakami Microcontinent based on observation of the sedimentary structure (laminae preservation), mode of occurrence of pyrite, and geochemical proxies (redox-sensitive elements). Referring to the type columnar sections described by Kamata and Takizawa (1992), four lithologic sections corresponding to the lower, middle, and upper parts of the Osawa Formation were identified. From these sections, 49 rock samples were collected for thin sections, polished specimens, and geochemical analyses (ICP-AES and ICP-MS). Observation of polished rock specimens indicates that laminae were well-preserved in mudstone from the middle part of the Osawa Formation whereas laminae were not visible in the lowermost and uppermost parts. These trends indicate that the middle part of the Osawa Formation was deposited under conditions of lower benthos activity than the lowermost and uppermost parts. Mode of occurrence of pyrite in the studied sections is divided into euhedral pyrite and aggregations of framboidal pyrite, of which the latter are formed around organic matter. These types of pyrite were observed in almost all the horizons. These modes of occurrence indicate that pyrite formed within the sediment, suggesting a reductive condition during their diagenesis (Wignall et al., 2010; Bond and Wignall, 2010; Gallego-Torres et al., 2013; Wang et al., 2013). Measured concentrations of redox-sensitive elements from bulk samples provide further information on the redox condition. V and U show values close to average upper continental crust (AUCC) value (Taylor and McLennan, 1985) throughout the study sections. Mo values are lower than AUCC in most horizons, but slightly high in the middle part of the Osawa Formation, which is consistent with laminae preservation. Among the modern examples of various redox conditions (Algeo et al., 2009; Tribovillard et al., 2012), the combination of U and Mo concentrations in the Osawa Formation is in agreement with those from the dysoxic condition (not sufficiently oxic but not reaching a strong reductive condition). Accordingly, the depositional environment of the Spathian shallow marine region around the South Kitakami Microcontinent is regarded as possibly reductive, as suggested by low benthic activity, and remaining at the level of a dysoxic condition. It is implied that, after the EPME, recovery of

complex marine ecosystems during Early Triassic proceeded under such mildly reducing oceanic environment.

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