



Early Triassic noxious benthic environments in the Lower Triassic, the South Kitakami terrane, northeast Japan

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1 Introduction

The Early Triassic period is characterized by delayed biotic recovery following the end-Permian mass extinction. The existence of a devastated condition and its duration were precisely analyzed by deep-sea sediments; however, its effects on shelf environments wherein most marine organisms were inhabiting are still obscure. The global distribution of contemporaneous devastated shelf sediments implies the widespread diffusion of a noxious condition in shallow marine environments.

Early to Middle Triassic marine sediments (the Inai Group) are known to occur in the South Kitakami terrane, northeast Japan. These sediments unconformably overlie the upper Permian shelf mudstone. On the basis of the biostratigraphical evidence by ammonoids and brachiopods, the group ranges from Smithian to late Anisian in age (Ehiro, 2002). The sedimentary environmental change from fluvial to outer shelf deposited with early Triassic transgression is suggested by previous study (Kamada and Takizawa, 1992). This study aims at reconstructing the Smithian to Spathian sediments deposited from shallow marine to shelf environments by describing the vertical variations in ichnofacies and chemical composition.

2 Methodology

A sedimentary facies analysis was carried out for the Inai Group, prior to laboratory work. Additionally, 33 samples for Smithian-lower Spathian sediments and 47 samples for upper Spathian sediments were collected for geochemical studies. The frequency of bioturbation was estimated under a microscope. The diameters of trace fossil burrows were also estimated. The chemical compositions of the major and trace elements were measured by XRF (X-ray fluorescence).

3 Sedimentary facies, ichnofacies, and chemical composition of mudstone

Smithian to lower Spathian sediments were deposited in shallow marine environments including supratidal ones, while upper Spathian, which was formed in inner and outer shelf environment, is gradually changed from shallow marine sediments. The early diagenetic carbonate nodule in the Smithian-lower Spathian supratidal sediments suggests arid to semi-arid climatic environments. The chemical weathering index of alteration (CIA index; Nesbitt & Young, 1982) in the Smithian-lower Spathian sediments is greater (70-90) than one in the upper Spathian sediments (60-70). The supratidal mudstones include Skolithos-like ichnospecies and the maximum burrow diameter is about 12 mm.

The lower part of the upper Spathian sediments mainly consists of a relatively massive with minor wave-ripple structure-intensely bioturbated calcareous siltstones including numerous burrows in the order of centimeters, suggesting deposition in inner-shelf environments. The lithofacies of the upper part of the upper Spathian sediments mainly comprises HCS sandy siltstones and parallel laminated mudstones with a rare distinct bioturbation in the ascending order. In addition, framboidal pyrite grains forming a laminated structure are observed. The diversity of ichnospecies gently decreases from the lower to the upper part, and the maximum value of the burrow diameter also decreases from 5 mm to 2 mm throughout the upper Spathian except during the episodic flourish of bioturbation.

In geochemistry, the CaO/terrigenous element ratios, showing the productivity by shallow marine calcareous organisms, decrease gradually from the lower to the upper part in the upper Spathian sediments. Conversely, the ratios of Zn and Ni/terrigenous elements indicating the redox condition in benthic environments increase significantly in the upper part of the upper Spathian sediments.

4 Noxious stage in the Spathian in the South Kitakami terrane

In the South Kitakami terrane, the change in the CIA index through the Smithian-Spathian period indicates intense weathering in arid and/or semi-arid climate. Although the weathering condition in the hinterland gradually changed to become more mild in the late Spathian, a distinct reduction in the productivity of shallow marine calcareous organisms and the noxious condition for benthic ecosystems during the later stage of the Spathian period are suggested. A significant reduction in benthic activity accompanied with the enrichment of Ni and Zn continues in upper Spathian sediments, intercalating with episodic flourishing. Thus, the occurrence of noxious and reductive conditions even in the shelf environments was not geologically instantaneous but lasted intermittently given the duration. Since it has been widely interpreted as a consequence of unfavorable environmental conditions throughout the Early Triassic, the intermittent noxious condition in the shelf benthic environments in the South Kitakami terrane is probably related to the large perturbation of carbon isotopes reported from Indian and Chinese contemporaneous sediments (Baud et al., 1996; Payne et al., 2004).