

Stratigraphy and sedimentary facies of the Late Jurassic Nakanosawa Formation, Somanakamura Group: Facies changes from wave-dominated siliciclastic facies to lagoonal carbonate facies and their significance

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The Somanakamura Group, distributed along the eastern margin of the Abukuma Mountains from Minami-soma City to Soma City, Fukushima Prefecture, is one of infrequent well-exposed successions of the Middle Jurassic to lowest Cretaceous strata in Japan. It constitutes of 1) Awazu, 2) Yamagami, 3) Tochikubo, 4) Nakanosawa, 5) Tomizawa, 6) Koyamada Formation in ascending order. Because the marine (1,2,4,6) and fluvial (3,5) strata are alternated, the Somanakamura Group records the sedimentary cycles of fluvial, shallow-marine, lagoonal sedimentary environments along the eastern margin of paleo-Asian continent. The Nakanosawa Formation includes dark gray lagoonal limestone in the upper Koike Limestone Member regarded as the Torinosu-type Limestone typically known in Shikoku, Southwest Japan, and the Torinosu-type bivalve fauna mainly from the lower Tatenosawa Sandstone Member. The Nakanosawa and Koyamada formations are correlated with the Kimmeridgian to Tithonian, and Berriasian, respectively, based on ammonite biostratigraphy.

Resulting from the correlation of sedimentary facies distribution along six well-exposed study sections, the Tatenosawa Member about 100 to 150 m thick forms a coarsening-upward succession above the underlying fluvial sandstone of the Tochikubo Formation with a sharp and flat erosional ravinement surface, composed of five sedimentary facies associations (FA) in ascending order, 1) FA-E: granule-bearing coarse to medium sandstone (transgressive lag); 2) FE-D: alternated hummocky cross-stratified fine sandstone and bioturbated fine sandstone/sandy siltstone (lower shoreface to inner shelf); 3) FA-C: trough cross-stratified medium to coarse sandstone (upper shoreface); 4) FA-B: bioturbated fine sandstone with bivalve shell beds (inner bay); 5) FA-A: carbonate sandstone to limestone (carbonate lagoon). This facies trend indicates continuous shallowing and regressive changes of sedimentary environments under wave-dominated shallow sea after the rapid transgression following the fluvial setting of the Tochikubo Formation.

The Koike Limestone Member (FA-A) 30 to 50m thick generally constitutes of five repetitive successions of oncoid facies with swarmed bivalve and nerineid gastropod shells and nodular facies bearing in situ coral. These successions suggest that five at least minor relative sea-level changes possibly less than 20 m amplitude occurred from wave-dominated barriers and nearby to stagnant central lagoon and the further coastward area.

The formation contains four type of bivalve fossil beds each of which has an unique association: E) Shell concentrations with a basal transgressive lag and d) *Protocardia tosensis* - *Plagiostoma enormicosta* Association; D) Scatterd shells in HCS fine sandstone and c) *Astarte sakamotoensis* - *Nipponitrigonia sagawai* Association; B) Lenticular shell concentrations in calcareous silty sandstone and mix of b) *Neocrassina subdepressa* - *Protocardia tosensis* Association and *Gervillia tatenosawaensis* - *Pinna* cf. *mitis* Association; A) Patchy shell concentrations in silty limestone and a) *Pteria masatanii* - *Trichites* sp.

Association.

Based on the recognized facies successions, their inferred sedimentary environments, and bivalve facies changes, interpreted sequence stratigraphy, the Nakanosawa Formation can be interpreted as a third-order depositional sequence formed by a series of transgression and subsequent regression during the late Jurassic time. Furthermore, we consider the paleogeographic significance of the Nakanosawa Formation as well as the Torinosu-type Limestone and Torinosu-type bivalve fauna.

Keywords: Jurassic, sequence stratigraphy, paleogeography, Somanakamura Group, Nakanosawa Formation, Northeast Japan