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# Paleoecology of "worm tube" fossils from the Upper Cretaceous Sada Limestone, northern Shimanto Belt, Shikoku, Japan

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The Sada Limestone consists of a cluster of large carbonate blocks intercalated in muddy slope facies of the Upper Cretaceous Nakamura Formation, northern Shimanto Belt, Shikoku, SW Japan. The Sada Limestone is characterized by abundant fossil occurrence of large-sized thyasirid bivalves and worm tube fossils. Thyasirids is one of the representative chemosynthetic bivalves, and its large shell-size and the anomalously dense shell clustering suggest that the Sada Limestone is related to hydrocarbon-seepage activity. The worm tube fossils were reported as Serpula (Tashiro, 1991), but its taxonomy and paleoecology have not yet been fully examined. This study reports shell characters of the worm tubes and mode of their fossil occurrences with some paleoecological comments.

The worm tube fossils are cylindrical, gently curved and sinuous, elongating in nearly vertical direction. The tubes do not branch out nor connect each other, but the tube is independently supported by muddy matrix. The tubes do not taper, but the uppermost margin is frilled. The tube diameter ranges from 2.1 to 8.0 mm with its mode of 5.0-6.0 mm (n= 200), and a maximum length is over 100 mm.

The worm tube fossils are demarcated by a thin calcitic wall, ca. 1mm thick. Individual layers of tube walls were delaminated under microscopic view. The outer surfaces of tube fossils are smooth except for fine growth lines, and have neither collar folds nor longitudinal ornament. The worm tubes frequently form a series of septa inside their tube. The delamination of tube walls is common characters to vestimentifrans, but lack in longitudinal ornament and septa formation disagree with diagnoses of vestimentifran tubes.

The worm tube fossils not only sporadically occur in thyasirids-dominant limestone, but also form dense cluster in muddy micrite (worm tube limestone). The worm tube limestone, over several meters thick, can be laterally traced over 10 m and alternates with thyasirids-dominant limestone.

The worm tube limestone frequently intercalates barren and massive siltstone beds, about several centimeters thick. The barren siltstone beds were maybe mud flow in origin, because they cover the worm tube-rich beds with erosion surface, along which the calcified tubes were cut down and broken. Tube fragments are sometimes concentrated in the basal part of the mud-flow beds. The broken tube fragments in the mud-flow beds are over 5 cm long, and tubes remaining below the erosion surface are over 4 cm.

The worm tube formed a lens-shaped colony, 1 m in diameter and over 30 cm in maximum thickness. The marginal part of the lens-shaped colony was eroded and covered by mud-flow deposits, but its center, 30 cm in diameter, were not covered and protruded above the mud-flow bed.

The polished-slab observation of the tube-rich limestone beds shows that the tube fossils are densely aggregated in the finely brecciated muddy micrite but are rare in gray massive mud with high viscosity.

The results mentioned above suggest that 1) the tubes were not flexible but fragile causing brittle fracture due to mud-flow erosion; 2) the worm tube did not attach to some substrate, but solely stuck firmly into the brecciated muddy sediments with its upper half protruding above the bottom; and 3) they are maybe opportunistic to high sedimentation-rate conditions and sometimes form a colonial hill elevating several centimeters above the surrounding bottom.

Keywords: chemosynthesis, worm tube, methane seepage, Cretaceous, Kochi Prefecture