

Distribution and internal structure of the nodules occurring in Shimanto sedimentary rocks, Muroto Peninsula, Shikoku

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Nodules are known to occur within the alternate layers of sand and mud stones in Muroto Peninsula, Shikoku. Those nodules apparently have been formed within the deep-sea sediment of the trench, the timing and the details of their formation, however, is not known. This report describes the occurrence of the nodules within the alternate layers of sand and mud. The occurrence and the cross-sectional observation of the nodules both support that the nodules are trace fossils and they formed within compacted layers of mud underneath the surface of the sea floor.

Spatial distribution and occurrence of the nodules were observed within an outcrop of alternate layers of sand and mud. The alternate layers were straight, with no evidence of large deformation associating the accretion. The thickness of the mud stone layer and the sand stone layer was approximately 10 cm and 2 cm, respectively. The size of the nodules was around 3 to 5 cm (radius). Nodules occurred in many different layers. Most nodules were found in groups within the same mud layer, located at a certain depth from the surface of the mud. Sand layers sometimes showed upward curvature above the nodules, indicating that the nodules formed before the compaction terminated.

Occurrence of the nodules and the relation between their mother rocks were described. Larger part of the nodules showed no clear boundary between the mother rocks. Nodules occurring in the layers with evidence of large deformation often showed boundary with certain thickness.

Observation of the cross-section of the nodules revealed that the materials within the nodules were not very much different from the materials in the mother mud stone. Calcite crystals occurred in the nodules but the areal fraction of calcite was comparable in and out of the nodules (5 to 10 %). Some of the nodules showed radial pattern of dark and light part, with slightly larger amount of calcite in the lighter part. Microveins of calcite were often found within the nodules and in the mud stone layers. Many of the nodules showed pyrite grains (<500 micrometer) with rounded triangular and quadrangular shape scattered within. These pyrite grains tended to occur near the calcitic microveins. Pyrite grains with framboidal structure (<10 micrometer) were also found in the nodules.

The sectional structure of the nodules of Tertiary Muroto Peninsula has been compared to that of the nodules that have just been growing on the deep sea floor of Japan sea. The modern nodules were rimmed with large (~4mm) calcite crystals. None of the Muroto nodules had such rim.

The occurrence, together with the cross-sectional observation of the nodules, indicate that the nodules in Muroto Peninsula did not form near the surface of the sea floor, but formed within layers of mud which had compacted to some extent. Radial pattern of dark and light part was found within the cross-section of the nodules. No evidence of concentric growth pattern was found. It is not likely that the nodules started growing on some small biotic core and gradually grew larger. The concretion of sediments seems to have started within a fixed space from the very start.

Keywords: nodule, Shimanto belt, mudstone layer, pyrite, trace fossil

Diffuse methane seep in the upper bathyal zone from the lower Pliocene Tamugigawa Formation, Niigata Prefecture

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"Diffuse seeps" are characterized by scattered occurrences of small carbonate concretions and cold-seep bivalve fossils, and interpreted to be caused by ephemeral and weak fluid flow (Nesbitt et al., 2013). Although they are expected to preserve infaunal or semi-infaunal fossils *in situ* in the sediments not fully cemented with carbonates and also help to understand how seeping fluids diffuses through low permeable sediments, they have not been well described and studied compared with large methane-seep carbonate bodies.

In the Japan Sea borderland, some fossil vesicomid bivalves occur from the Neogene marine sediments associated with small carbonate concretions, which suggest diffuse cold seeps. This study reports an ancient diffuse methane seep from the lower Pliocene Tamugigawa Formation in Niigata Prefecture. At Matsunoyama-Matsuguchi, Tokamachi City, various shaped, pebble-sized small carbonate concretions are scattered with vesicomid, lucinid, and thyasirid bivalve fossils in the grey siltstone exposed along the Koedo River. The shapes and distributions of the concretions as well as fossils were recorded by drawing a sketch of the outcrop, and the carbon and oxygen stable isotopic compositions of some concretions were analyzed and plotted on the sketch. The molluscan fossils from this outcrop consist of remarkably diverse taxa, such as protobranch bivalves, naticid, buccinid, and other small gastropods, and scaphopods as well as cold-seep bivalves including vesicomids. Infaunal lucinids and thyasirids occur in the upper part of the outcrop as articulated valves retaining their living positions. The vesicomid bivalves, including at least two species, *Archivesica kannoi* and *Calyptogena cf. pacifica*, constitute only 27% of the species composition (n=54). The low abundance of vesicomids and also the presence of naticid drill hole suggest relatively shallow environment (cf. Kiel, 2010; Amano et al., 2010), consistent with the inferred depositional depth of the Tamugigawa Formation based on molluscan fossil assemblage (upper bathyal zone, 200-500 m: Amano et al., 1991; Amano, 1994). The concretions occur mostly in the middle part of the outcrop and they are irregular-shaped, globular, funnel-shaped, or tortuous like burrows. They are light grey colored, or dark grey colored in the lowermost part of the outcrop, and composed of micritic low-Mg calcite. The $\delta^{13}\text{C}$ values of them are low (-46.0 to -24.3 ‰), suggesting that they are mainly derived from anaerobic oxidation of methane (AOM), which is also suggested by the presence of a lipid biomarker pentamethylcosane (PMI) in the micrite. The concretions contained close to one another or in about the same horizon in the outcrop have similar $\delta^{13}\text{C}$ values (± 6 ‰), which may suggest that they formed in the same AOM zone. It is concluded that this outcrop represents a diffuse methane seep in a relatively shallow environment, upper bathyal zone, in the early Pliocene where seeping fluids diffused through some pore spaces such as burrows in the silty sediment. It may be possible to recognize ancient AOM zones in outcrops of diffuse seeps by analyzing the isotopic composition of each concretion scattered in the outcrop as this study.

Keywords: diffuse methane seep, Niigata, Pliocene, upper bathyal zone

Thermal effect for distribution of deep-sea chemosynthetic faunas

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Temperature is an important factor affecting the distribution and life-history traits of marine animals. Deep-sea hydrothermal vent is a suitable environment to examine ecological differences related to temperature, due to the steep temperature gradients in their vicinity. We will discuss thermal effects for distribution of deep-sea chemosynthetic faunas based on the recent results from rearing experiments.

We conducted rearing experiments using two hydrothermal vent shrimps, *Shinkaicaris leurokolos* and *Alvinocaris longirostris*, because these two species shows different distribution near hydrothermal vents; centrally-distributed *S. leurokolos* and peripherally-distributed *A. longirostris*. The rearing experiment was conducted under atmospheric pressure, with a temperature range of 5-30 °C, to demonstrate a difference in thermal effects on egg hatching and larval activity between the two shrimp species.

The incubation period (duration before hatching) became shorter when temperature is higher in both species, while the optimal hatching temperature was higher in *S. leurokolos* than in *A. longirostris*. Hatched larva were negatively buoyant, but normally-developed larvae could actively swim and stay suspended in the mid- or surface-water layers of the culture plates, in both species under the present experimental conditions. While no larvae settled or metamorphosed into juveniles under the present conditions, frequency of abnormal morphology was different according to temperature between the two species, i.e. the frequency was high under high temperature in *A. longirostris* and low under high temperature in *S. leurokolos*. Therefore, reproductive frequency and larval dispersal abilities of the two shrimps seemed to be differed by temperature conditions where the shrimps prefer. These results indicate that temperature is an important factor controlling life-history traits of vent shrimps.

It is widely known that temperature affect metabolic rate of animal. In addition to the present rearing conditions, several studies revealed temperature effects on ecologies of deep-sea chemosynthetic fauna including hydrothermal vent fauna. Accumulation of the information on the thermal effects on the present chemosynthetic fauna will help our understanding of ecology of fossil chemosynthetic fauna, based on temperature reconstruction.

Keywords: hydrothermal vent, Alvinocarididae, rearing experiment

Current status and problems of studies on ancient fossil chemosynthetic communities

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Nearly 40 years has been past from the first finding of novel ecosystem (chemosynthetic ecosystem) from deep-sea hydrothermal vent along Galapagos Rift. Since the discovery, the chemosynthetic ecosystems have been found not only from vents but also around cold-seeps, whale falls and sunken drifted woods. The ancient chemosynthetic communities have also been recognized and dozens of researches have been reported from various ages and areas. Up to now, we have roughly known temporal changes of chemosynthetic communities. Many interesting hypotheses for the evolution of chemosynthetic communities have been proposed from both paleontological and modern biological sides. However, many problems and/or conflictions have been recognized. For examples, recognition of ancient chemosynthetic communities especially depended on whale carcasses and sunken wood, confliction between molecular divergent ages and fossil record, and incomplete records of temporal and spatial distribution of fossil record. This presentation will summarize current status of studies on chemosynthetic communities, and propose some scopes to understand better evolutionary history of chemosynthetic communities.

Keywords: chemosynthesis-based ecosystem, evolution, fossil assemblage, Mesozoic, Cenozoic, Extreme environment