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Paleoecology of Neogene vesicomyids from Niigata, Japan and their adaptations to geochemical environments of cold seeps

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Living vesicomyid bivalves are known to adapt to different hydrogen sulfide concentration and various habitats such as methane seeps, hydrothermal vents, whale falls, and petroleum seeps depending on species. Fossil vesicomyids are reported especially from Neogene seeps worldwide, but their adaptations to the geochemical environments of ancient seeps, which can help to understand the diversity and evolution of them, remain unrevealed. This study examined the paleoecology of fossil vesicomyids and geochemical environments of seeps to which they adapted by investigating their modes of fossil occurrence and geochemistry and petrography of seep carbonates from the two Neogene seep localities in Niigata Prefecture.

The lower Pliocene part of the Kurokura Formation mainly consists of gray to dark gray siltstones which deposited in upper bathyal depth. At the riverside cliff of Echido River at Matsunoyama-Matsuguchi, Tokamachi City, pebble-sized carbonate concretions are contained in 60 cm-thick massive gray siltstone. Fossil vesicomyids, *Archivesica kannoi*, are contained in the concretions some of which are gradually bounded by surrounding siltstone. A large individual (ca. 90 mm length) and surrounding small individuals (ca. 20 mm in the mean length) of *A. kannoi* are contained in the same concretions with various other bivalves, gastropods, and scaphopods which are not unusual to the modern cold-seep communities. Lucinid bivalves are contained in surrounding siltstone and burrows filled with carbonates are also observed in the siltstone. Concretions are mainly composed of micritic Mg-calcite, containing abundant pyrite crystals, and stable carbon isotopic compositions of them are very low values (-43.3 to -27.1 ‰ vs. PDB), showing their derivation from methane, whether they contain fossils or not. Only fossil-bearing concretions contain clast-like carbonates (ca. 5 mm in diameter) which are triangular or oval-shaped in cross section and composed of many fine dolomite crystals surrounded by Mg-calcite matrices in thin section. Dolomite formation is related to the removal of dissolved sulfate by sulfate reduction, thus it may suggest active produce of hydrogen sulfide. It can be concluded that *A. kannoi* was adapted to the habitat where hydrogen sulfide concentration was relatively higher due to more active sulfate reduction than surroundings, or pumping activity of *A. kannoi* supplying sulfate was active enough to promote active sulfate reduction.

The upper Miocene Nodani Formation consists of alternation of gray sandstone and dark gray siltstone which deposited in upper bathyal depth as submarine fan turbidites. At the river cliff of Nakanomata River at Nakanomata, Joetsu City, pebble-sized carbonate concretions are contained in dark gray siltstone just below gray, oily sandstone. Fossil vesicomyids, *Calyptogena pacifica*, are contained in these concretions or surrounding siltstone. Some of them are preserved in life position. Fossils and concretions are contained in a narrow range of 30 cm wide and 5 cm thick, and pipe-shaped carbonate concretions are contained parallel to bedding in siltstone 50 cm below. These concretions are mainly composed of micritic calcite and carbon isotopic values of them are moderately low (-21.7 to -13.2 ‰), suggesting their derivation from crude oil. In thin section, the fossil-bearing concretion contains many micritic peloids. Central void space of pipe-shaped concretion is fringed with bladed calcite which also shows low carbon isotopic value (-22.6 ‰), suggesting that these pipes acted as conduits of seepage. *C. pacifica* lives in the Recent methane seeps, but it is suggested that this species was also adapted to narrow-ranged, local petroleum seep in the Miocene.

Keywords: vesicomyids, Neogene, sulfide concentration, petroleum seep