Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

BPT24-01 Room:202 Time:May 24 11:00-11:15

Three types of cold-seep carbonates from Miocene sediments in the Shin'etsu basin of the Japan Sea region

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During the opening of the Japan Sea in the early to middle Miocene, deep sedimentary basins were formed by rapid subsidence. The Neogene sediments, which deposited in these basins and are now exposed in the Japan Sea borderland, host carbonate blocks associated with fossil vesicomyid bivalves, suggesting that cold seeps have prevailed in the Japan Sea since its formation. Although some of them are interpreted to be methane-seep carbonates (Ishimura et al., 2005; Amano et al., 2010), many vesicomyid-bearing carbonates in this region remain geochemically unstudied. Researches on geochemical and physical properties, and evolution of the cold seep in the Japan Sea are prerequisite for further understanding of the cold seep system in this region under different tectonic setting from that of the Pacific side subduction zone.

This study investigated the textures, stable isotopic compositions of carbon and oxygen, and biomarker contents of the carbonate concretions associated with vesicomyid fossils from three localities in the Neogene Shin'etsu sedimentary basin. Three distinct types of cold seep carbonates are observed in this basin, as follows.

At Loc. 1, Sorimachi in Matsumoto City, pebble- to cobble-sized small concretions are scattered with articulated vesicomyid fossils, *Adulomya* sp. A, in the dark-grey siltstone of the middle Miocene Bessho Formation exposed along the Hofukuji River. They are mainly composed of micritic low-Mg calcite. The low δ^{13}C values (− 34.6 to − 23.6 ‰) and a lipid biomarker pentamethylicosane (PMI) extracted from the micrite suggest that these concretions are derived from anaerobic oxidation of methane (AOM), and they can represent a diffuse methane seep.

At Loc. 2, Nakanomata in Joetsu City, a float of concretion yielding disarticulated and fragmented vesicomyid fossils, *Adulomya* sp. C, as well as bathymodiolin mussels, *Bathymodiolus akanudaensis*, was found along the Nakanomata River where alteration of fine sandstone and siltstone of the upper Miocene Nodani Formation crops out. The concretion is considered to be derived from the Nodani Formation based on the diatom fossil assemblage. It is composed of micritic aragonite crosscut by abundant vein-like voids and cavities rimmed with acicular aragonite crystal aggregates. The low δ^{13}C values of them (− 41.1 to − 23.8 ‰), and the presence of PMI and crocetane in the micrite suggest that the concretion is derived from AOM, and interpreted to have been formed by rapid and active methane seepage.

At Loc. 3 which is close to Loc. 2, pebble-sized small concretions and pipe-like concretions are contained with articulated and disarticulated vesicomyid fossil, *Calyptogena pacifica*, in the dark grey siltstone just below oily sandstone of the upper Miocene Nodani Formation. They are composed of micrite and bladed to fibrous calcite lining voids. The δ^{13}C values of them are − 24.8 to − 13.2 ‰, and typical biomarkers of anaerobic methanotropic archaea such as PMI and crocetane are absent in the micrite. These concretions are considered to be sulfate reduction- or oil-derived, and may represent a non-seep, sulfide-rich habitat or an oil seep. Analyses of carbon stable isotopes of these biomarkers would provide further evidence for it.

The difference among these three types of carbonate concretions from the Neogene Shin'etsu sedimentary basin suggests the variety of seepage rates, intensity, or source material of the cold seeps which prevailed there. Such environmental variation is also represented in associated faunal compositions. During the middle to late Miocene, the stress field of the Japan Sea region was tensional (Sato, 1994; Takano, 2002), and it is suggested from this study that geochemically and physically different cold seeps developed under tensional stress field within a limited interval of time and space in this time in the Japan Sea region.

Keywords: Japan Sea, Shin'etsu basin, Miocene, cold seep

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Oligocene-Miocene cold-seep from Shimanto accretionary complex: Focused on formation process of the cold-seep

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Many modern cold-seeps have been found along landward slopes of trenches or troughs where accretionary prisms frequently formed. However very limited studies have been done on cold-seep in accretionary prisms. Thus, we have only limited knowledge on formation processes, cross-sections, and relationship between chemosynthetic fauna and the geochemical cycles of cold-seeps formed in accretionary prisms. Matsumoto and Hirata (1972) reported visicomyid and thysirid bivalves, modern counterparts of both of which are known as chemosynthetic bivalves, from carbonate nodules from Muroto City, Kochi Prefecture, where composed in accretionary complex (Taira et al., 1980). However, the locality has not been fully studied. This study aims to reconstruct formation process and cross-section of the cold-seep in accretionary complex setting.

The late Oligocene to early Miocene limestone body, containing chemosynthetic bivalves, yielded in mudstone of in the Hioki Complex, which is part of accretionary complex of the Southern Shimanto Belt. The limestone body, ca. 4 m in maximum diameter, is subdivided into three parts. The lower part is composed of mixed mudstone and concretionary part, which is composed of calcite microspar, in lower part. Middle part is composed of microsparry calcite. Upper part shows chaotic texture, which is composed of micrite, radially grown calcite, microspar and sparry calite. Paragenetic sequence can be observed as micrite, radial calcite, microspar and sparite in ascending order. The chaotic structures are often found in ancient and modern cold seep carbonates. Only the upper part contains fossil bivalves. δ13C of the authigenic carbonate cements range from -38.5 to -10.6 ‰ (VPDB). These lower carbon isotopic composition indicate the carbonate formed under influence of anaerobic oxidation of methane. Fossil bivalves occurred only in the upper part. Those are mainly composed of Vesicomyidae, Thyasiridae, Lucinidae and Solemyidae. Those bivalves are known as chemosynthetic bivalves. Aforementioned evidences indicate the rock is a cold seep deposit.

Based on distribution pattern of textures, paragenetic sequence of minerals and mode of occurrence of fossils, we interpreted formation processes of the cold-seep deposits as follows. 1) Starting of cold seep. Carbonate ions and hydrogen sulfide contents in pore water in close proximity to the sea floor were increased. On the sea floor, chemosynthetic community, mainly vesicomyid bivalves, was started to form. 2) Activity of cold seep was increased and more authigenic carbonate precipitation occurred. During the carbonate precipitation, but before completely solidified, pore fluids and/or gasses broke up micritic sediments and formed chaotic texture. At this stage, chemosynthetic community was flourished. 3) With decrease of cold seep activity, microspar formed. 4) Sparite precipitated in remaining pore spaces.

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Vesicomyid fossils from the Lower Pleistocene Imaizumi Sandstone and Conglomerate Member

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Vesicomyid fossils have been known to occur from the Imaizumi area, northern Miura Peninsula (Shikama and Masujima, 1969; Utsunomiya et al., 2014; Jimbo et al., 2015), where the lower Pleistocene Imaizumi Sandstone and Conglomerate Member (Eto, 1986) of the Nojima Formation is exposed. From the sandstones of this member, Utsunomiya et al. (2014) reported vesicomyid fossils from a sediment gravity flow deposit, and considered that they had been transported from the southern area on the basis of the imbrications and long axis arrangements of the fossils within the bed, and Jimbo et al. (2015) reported vesicomyid fossil fragments from the basal portion of a channel fill conglomeratic sandstone attaining 9 m in the single bed thickness. We observed four vesicomyid fossil localities (locs. 1-4) including those reported by Utsunomiya et al. (2014) (loc. 2) and Jimbo et al. (2015) (loc. 1) and clarify in this report all of the vesicomyid fossils occurring from the Imaizumi Sandstone and Conglomerate Member had been reworked and transported by sediment gravity flows, judging from their modes of fossil occurrences.

The Imaizumi Sandstone and Conglomerate Member is composed of the successions of a submarine fan. This fan show an overall upward coarsening in sequence, its basal part consists mainly of the alternation of sandstones and muddy sandstones, sandstones increase gradually in upward successions (locs. 2-4), and its most upper part is composed of a channel fill deposits interpreted as a topset of the fan (loc. 1).

At the loc. 1, vesicomyid fossil fragments occur in the basal part of a channel-fill conglomeratic sandstone in association with shallow water molluscan fossils (Jimbo et al., 2015) and are interpreted that they had been transported by a sediment gravity flow originated in shallow waters. Locs. 2-4 occur in sandstones and muddy sandstones alternation part of the successions that are interpreted as the mid-fan of the submarine fan sequence. In those localities, vesicomyid fossils occur in a pebbly course-grained sandstone bed that grades into fine-grained sandstone (loc. 2; Utsunomiya et al., 2014), in course-grained sandstone bed that grades into medium-grained sandstone (loc. 3), or three course-grained sandstone beds that grade into medium-grained sandstone (loc. 4). Many shells of the locs. 2-4 are fragmented, and no articulated shell occurs. Their commissure planes of the valves arrange parallel nearly to the beddings and both convex-down and convex-up positions are observed in nearly the same amount. No authigenic carbonates, associated frequently with the cold-seep depended fossil assemblages, are found in the four fossil localities described above. Those occurrences clearly show that they had been transported from their original habitats.

The fossil occurrences summarized above suggest that there were no methane seepage when the Imaizumi Sandstone and Conglomerate Member was deposited, at least in the area where the member is exposed now.

Keywords: Kazusa Group, Pleistcene, Vesicomyid, Miura Peninsula

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The mode of occurrence of a fossil chemosynthetic assemblage from the Pliocene Takatoriyama Pyroclastics Member

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We discovered an exposure in which vesicomyid, lucinid and thyasirid bivalves occur abundantly, near the Takatoriyama, northern Miura Peninsula, Pacific side of central Japan. This exposure, 9.5 m in outcrop width and 5.5 m in height, consists mainly of tuffaceous medium- to coarse-grained sandstones and conglomerates, with minor amount of tuffaceous muddy sandstones and coarse ash tuffs, of the Pliocene Takatoriyama Pyroclastics Member, Ikego Formation, Miura Group. Authigenic carbonates massively to weakly develop in concordant well with beddings in the exposure.

The bivalve fossils occur sporadically or aggregately in seven horizons and their shells may be dissolved entirely. The bivalve aggregated horizons show two types in their occurrences: (1) disarticulated shells are dominated with minor amount of shell fragments, and (2) articulated and disarticulated shells occur in nearly the same amount. We measured the orientations of commissure plane of the bivalves. The commissure planes of articulated shells show both the alignments of the parallel and nearly perpendicular to the bedding planes, and those of disarticulated shells align nearly parallel to the beddings.

Considering estimated water depth of Takatoriyama Pyroclastics Member (between 500 and 1000 m) (Eto et al., 1987), we interpret that the disarticulated and some articulated shells with alignments parallel nearly to the bedding planes, had been reworked by physical disturbances, probably in bottom currents or sediment gravity flows. The articulated shells preserved perpendicular nearly to the beddings may be interpreted to have retained their life positions in spite of such high energy depositional environments evidenced by coarse grained substrates. Utsunomiya et al. (2015) reported an *in situ* vesicomyid-dominated cold-seep assemblage from Urago Formation, a conformably overlain formation of the Ikego (Utsunomiya et al., 2012), of the Kazusa Group. The Urago assemblage occurs in association with ^{13}C-depleted authigenic carbonates in cross-bedded or massive sandstones, and the bivalves occur mostly in disarticulated conditions with minor amount of articulated ones some of which are preserved normal nearly to the beddings in their commissure planes. Utsunomiya et al. (2015) considered they were preserved in their life positions. The modes of fossil occurrences reported herein are similar to those of the Urago.

Keywords: fossil chemosynthetic assemblage, Miura Group, Pliocene, Ikego Formation, Takatoriyama Pyroclastics Member

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Comparison of fossil echinoderms from Upper Cretaceous cold seep environments between Japan and central United States

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Echinoderms were thought to be rare in a cold seep or hydrothermal vent environments and had not been considered as a member of the chemosynthetic community until recent years (Grassle 1985; Laubier 1989; Desbruyéres et al. 2006), whereas echinoderms are one of the main groups in marine invertebrates especially in deep sea. In the last 10 years, some species of echinoderms have been reported as a member of the modern chemosynthetic community (Pawson and Vance, 2004; Stöhr and Segonzac, 2005). However ecology of these echinoderms and the process of adaptation to environments of cold seep or hydrothermal vent still remain to be clarified. The purpose of this study is 1) to clarify the process of adaptive evolution of echinoderms associated with a cold seep environment and 2) to discuss to what extent the life of the echinoderms was related to reducing substances from cold seeps.

Fossil echinoderms from seep carbonate have been reported from some localities (Gaillard et al., 2011; Landman et al., 2012). Fossils from coeval two formations, one is the Pierre Shale (South Dakota, USA) and the other Osoushinai Formation (Hokkaido, Japan), both the upper Campanian have been studied to compare regional differences of these localities and to discuss the factors that cause such differences.

From the Pierre Shale, at least 5 species of echinoderms are found, comprising mainly crinoids and irregular echinoids. The crinoids from South Dakota have unique morphology, suggesting that these crinoids had adapted to environment of cold seeps (Hunter et al., in progress). On the other hands, from Osoushinai Formation, only 1 species crinoid was found. The carbonates associated with cold seeps are found as boulders and include tube worms and crinoid columnals. The crinoids from Hokkaido are assigned to the family Isocrinidae, very common to ”normal” non-seep environments and thus are not regarded as the specialized form for a seep environment.

To discuss the degree of linkage between echinoderms and methane released from cold seeps, the stable carbon isotope ratio (δ^{13}C) of echinoderm skeleton were measured. Before analyzing δ^{13}C, microstructure of echinoderm skeleton was observed with a polarizing microscope to estimate the degree of diagenesis, and spots of the skeleton considered to be not strong effect of diagenesis were measured selectively. As a result, the crinoids from both the Pierre Shale and Osoushinai Formation have almost comparable to or lower δ^{13}C values than seep carbonate matrix around the fossils. The effect of diagenesis is not fully examined at this stage, but these results suggest that the crinoids from both localities had lived nearby cold seep environments. Therefore, it is thought that the crinoids from the Pierre Shale were adapted to cold seep environment with highly specialized morphology, and the Isocrinidae from Osoushinai Formation lived around cold seeps at least but they did not change them morphology notably.

Keywords: chemosynthesis community, cold seep, echinoderms, paleoecology, stable carbon isotope

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Confirmation of chemosynthetic activities of Bathymodiolus septemdierum through laboratory culture

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Submarine volcanic activities circulate seawater between bottom water and interstitial water around hydrothermal vent. The heated water absorb carbon dioxide, methane, sulfur dioxide, hydrogen sulfide (H_2S) and others originated from magmas. Chemosynthetic ecosystem is distributed around these thermal vent. Many volcanic activates has been found around the Japanese archipelagos. Chemosynthetic biology earn living energy by the organisms what has symbiotic bacteria in their body with these volcanic gases. Deep-sea bivalve Bathymodiolus septemdierum have been hosting some sulfur oxidizing bacteria in their gills. The bacteria have ability to synthesize such organic compounds as sugars from inorganic carbon source. Many questions have been still remaining about the emergence and maintenance mechanisms of such symbiotic relationship between host animal and bacteria. Even though the development of laboratory culture techniques of such chemosynthetic bivalves are very useful approach to understand the detailed ecology and for further experiments, the technique is not developed very well. Our research group try to set chemostat water bath up with hydrogen sulfide to keep B. septemdierum as live. We try to use the culture system to evaluate the bivalves can keep their symbiotic bacteria to make much longer life time in laboratory. The activity of symbiotic bacteria has been tested by the uptake ability of ^{13}C labeled inorganic carbon into their body.

Individuals of *B. septemdierums* are captured during dive series of ROV Hyper-dolphin system of two cruises of R/V Natsushima operated by Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in April of 2012, in March of 2013 and in April of 2014. The samples are collected around Myojin-Sho submarine volcano on the Izu-Ogasawara Ridge (1224-1285m depth). Collected samples were kept under 4 ℃ water tank in an on-board low-temperature room till the end of cruise. Then, the individuals are immediately transfer to on-land laboratory water tank after cruise to avoid the unfavorable environment. The water tank has been designed as chemostat system with H2S supply to maintain symbiotic bacteria of deep-sea chemosynthetic animals. The individuals are cultured in this system for three months and fourteen months respectively. Here, previous study shows the symbiotic bacteria disappeared within three months without H_2S source. Therefore, we prefer to confirm the bacteria hopefully maintained more than three months in our chemostat system or not. For the purpose, carbon isotope labeling experiments were carried out to clarify the symbiotic bacterial activity. The carbon isotope will be taken by *B. septemdierums* if the symbionts are active. We compare the carbon isotopic uptake between under H2S positive and under H_2S negative (control) conditions. Meantime, dissolved oxygen (DO) of each cultivation was monitored to check health and activity of individuals. The results show the labeled ^{13}C was taken into organic matter in both gills and foot especially under H_2S positive condition. The isotopic measurement of compound specific carbon isotopes in fatty acid show positive result. By this result, we consider the labeled carbon should be incorporated to the cell membrane of host animal. We summarize the symbiotic bacteria have been maintained for fourteen months in the chemostat system.

Keywords: deep-sea biology, chemosynthetic ecosystem