

Reconstruction of Permian-Triassic ocean redox conditions based on laminae preservation and pyrite framboids from the pelagic Panthalassic Ocean

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Widespread oceanic anoxia has been implicated as an important factor in the Permian -Triassic mass extinction and the delayed recovery of Early Triassic marine ecosystems. This study investigates the composite columnar section of the deep-sea Permian-Triassic boundary section preserved in the accretionary complex in Northeast Japan. This columnar section consists of the Upper Permian bedded chert and siliceous claystone, and overlying the end-Permian to earliest Triassic black claystone. The mass extinction horizon places in the base of the black claystone, and top of the reconstructed black claystone corresponds to 226.7 kilo year after the extinction event based on sedimentation rate estimated by Takahashi et al. (2014). The careful observation of polished cross sections identified thinly laminated structures in the end-Permian to earliest Triassic claystone interval. Our observation on the polished specimen revealed small and well sorted framboids (average diameters are 4 μm and their standard deviations are 1.1 μm) suggesting that sulfidic water column prevailed during the end Permian mass extinction and subsequent time interval corresponding to the overlying 30 cm. Well preserved laminae occur within the same stratigraphic interval, suggesting stagnant benthos activity due to anoxic bottom water condition under sulfidic water column. On the other hand, well preserved laminae appear again in the overlying earliest Triassic horizon, but size of pyrite framboids are not so small (average diameters are more than 7 μm), suggesting anoxic but non-sulfidic water column condition. These facts indicate water column sulfidic episodes sustained for less than 50 kilo years in the pelagic Panthalassa.

Keywords: Permian, Triassic, Mass extinction, Pelagic deep sea, Pyrite Framboids

Redox conditions of late Early Triassic oceanic region around the South Kitakami Microcontinent

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After the end-Permian mass extinction (EPME), biotic recovery required more than 5 million years during the Early Triassic. Evidence of recovery such as the emergence of complex ecosystems and high biodiversity appeared in the late Early Triassic to Middle Triassic (Chen and Benton, 2012). The fossil evidence of a complex food chain was reported from shallow-marine strata of late Olenekian (Spathian), late Early Triassic age, in the South Kitakami Microcontinent that was located in the low-latitude Tethys-Panthalassa border (Ehiro, 2001). These strata belong to the Osawa Formation in the South Kitakami Belt, now distributed in Northeast Japan, and are characterized by well-preserved parallel laminae and the occurrence of the oldest ichthyosaurs (Shikama et al., 1978; Yamanaka and Yoshida, 2007). However, the depositional environment of these strata has been poorly understood. The present study aims to reveal detailed redox conditions in the Spathian shallow marine region around the South Kitakami Microcontinent based on observation of the sedimentary structure (laminae preservation), mode of occurrence of pyrite, and geochemical proxies (redox-sensitive elements). Referring to the type columnar sections described by Kamata and Takizawa (1992), four lithologic sections corresponding to the lower, middle, and upper parts of the Osawa Formation were identified. From these sections, 49 rock samples were collected for thin sections, polished specimens, and geochemical analyses (ICP-AES and ICP-MS). Observation of polished rock specimens indicates that laminae were well-preserved in mudstone from the middle part of the Osawa Formation whereas laminae were not visible in the lowermost and uppermost parts. These trends indicate that the middle part of the Osawa Formation was deposited under conditions of lower benthos activity than the lowermost and uppermost parts. Mode of occurrence of pyrite in the studied sections is divided into euhedral pyrite and aggregations of framboidal pyrite, of which the latter are formed around organic matter. These types of pyrite were observed in almost all the horizons. These modes of occurrence indicate that pyrite formed within the sediment, suggesting a reductive condition during their diagenesis (Wignall et al., 2010; Bond and Wignall, 2010; Gallego-Torres et al., 2013; Wang et al., 2013). Measured concentrations of redox-sensitive elements from bulk samples provide further information on the redox condition. V and U show values close to average upper continental crust (AUCC) value (Taylor and McLennan, 1985) throughout the study sections. Mo values are lower than AUCC in most horizons, but slightly high in the middle part of the Osawa Formation, which is consistent with laminae preservation. Among the modern examples of various redox conditions (Algeo et al., 2009; Tribovillard et al., 2012), the combination of U and Mo concentrations in the Osawa Formation is in agreement with those from the dysoxic condition (not sufficiently oxic but not reaching a strong reductive condition). Accordingly, the depositional environment of the Spathian shallow marine region around the South Kitakami Microcontinent is regarded as possibly reductive, as suggested by low benthic activity, and remaining at the level of a dysoxic condition. It is implied that, after the EPME, recovery of complex marine ecosystems during Early Triassic proceeded under such mildly reducing oceanic environment.

Keywords: late Early Triassic, South Kitakami, redox condition, Osawa Formation

Paleoenvironmental reconstruction by organic matter analyses of Triassic-Jurassic highly mature sediments from North America and Inuyama, Japan.

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Paleoenvironmental reconstruction has been extensively performed using sedimentary organic matter, but paleoenvironmental and paleontological records were hardly preserved in ancient sediments that are of high maturity. In highly mature ancient sediments, a very small quantity of molecular fossils (biomarkers) in solvent extractable components (bitumen) and insoluble organic matter (kerogen, geomacromolecule) are possibly applicable as paleoenvironmental and paleoecological tools. The kerogen has been known to be well preserved as major organic component in ancient sediment. In the present study, we analyzed Triassic-Jurassic highly mature sediments from North America and Inuyama, Japan to improve biomarker and kerogen analyses for reconstructing paleoenvironments, and to examine variations of terrestrial and marine environments during the Triassic-Jurassic.

We used 1) lacustrine sediments (black shales and red sandstones) deposited during Triassic-Jurassic boundary from North America, and 2) Anisian to Toarcian (T-OAE2) pelagic sediments (black shales and cherts) of accretionary zone in Inuyama. Whole rock samples were crushed to a 'rice'-sized (diameter 2-5 mm) grain in an agate mortar. Crushed rock samples (5-10 g) were extracted with ultrasonication, by successive treatment with organic solvents. Thereafter, residues were treated sequentially in a water bath shaker with HCl and HF. We analyzed pyrolysis and thermochemolysis of kerogen by using GC-MS equipped Curie-point pyrolyzer. Thermochemolysis was performed with tetramethylammonium hydroxide (TMAH).

Organic matter in sediments from both North America and Inuyama are confirmed to be of high maturity that were reached oil window. We identified β -carotane (lacustrine algae origin) and 2-methyl hopanes (marine cyanobacteria origin) in sediments from North America and Inuyama, respectively. Interestingly, phenol compounds released from kerogens are mainly detected in black shale from the East Berlin Formation in Hartford basin. These results suggest that terrestrial plant-derived materials were more efficiently transported and deposited by environmental change.

Keywords: Triassic-Jurassic boundary, biomarker, kerogen, thermochemolysis, highly matured sediment

Environmental change and morphological variability in mid-Cretaceous planktic foraminifer, *Muricohedbergella delrioensis*

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The mid-Cretaceous climate maximum (CCM) (approximately 90–98 Ma) is one of the typical examples of the green house intervals. Comparing to the modern Earth system, there must be significantly different interactions between Earth's surface environment and marine biota in this extreme condition. Oceanic Anoxic Events (OAEs), which are accompanied by extinction of surface dwelling microorganisms, e.g. planktic foraminifers, radiolarians, etc., are one of the well known perturbations in the CCM (e.g. Leckie et al., 2002). The other minor events have also been identified in the CCM. For example, mid-Cenomanian Event (MCE) is considered as a precursor event of OAE2 at the Cenomanian/Turonian boundary. However, precise interactions between oceanic surface environment and planktic foraminifers at the MCE are still poorly understood.

We here examined morphological variability, the maximum diameter and the total number of chambers, of the mid-Cretaceous planktic foraminifers, *Muricohedbergella delrioensis*, across the MCE. The specimens were obtained from ODP Site 1258 at Demerara Rise, equatorial Atlantic. Carbon and oxygen isotopic data from the same samples we utilized, published by Moriya et al. (2007), enabled us to compare our results on morphological variability with those isotopic records. The maximum diameter becomes smaller in the sequence younger than the MCE, which is accompanied by decrease in the total number of chambers within a single individual. According to the modern cultivation experiments, the maximum diameter and the total number of chambers become greater with increase in feeding frequency (Bé et al., 1981). These results indicate that *M. delrioensis* older than the MCE might have more feeding opportunity than those younger than the MCE. Additionally, we analyzed a coiling (sinistral/dextral) ratio of *M. delrioensis*. The coiling ratio shows a significant correlation with the oxygen isotopic composition, hence temperature. The correlation between the coiling ratio of *M. delrioensis* and temperature has also been reported by Desmares et al. (2016). Our results reconfirm their implication. Considering modern examples showing genetic discrepancy between sinistral and dextral morphotypes in the species having a correlation between a coiling ratio and ambient temperature (Darling et al., 2006), the coiling direction of *M. delrioensis* might indicate existence of potential cryptic (sub)species.

Bé et al., 1981. Jour. Marine Biol. Ass. UK, v. 61, p. 257-277.

Darling et al., 2006. Paleocyanography, v. 21.

Desmares et al., 2016. Palaeogeogr., Palaeoclimatol., Palaeoecol., v. 445, p. 8-17.

Leckie et al., 2002. Paleocyanography, v. 17, 10.1029/2001PA000623.

Moriya et al., 2007. Geology, v. 35, p. 615-618.

Keywords: Cretaceous, Planktic foraminifer, Morphological evolution

Evaluation of 'paleo' red-tide during the mid-Cretaceous Oceanic Anoxic Event (OAE) 2.

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Red-tide is known as blooming of marine phytoplankton, especially dinoflagellate, under eutrophication, and severely influence on aquatic resources as natural toxins, harmful effects, and depletion of dissolved oxygen. Moreover, evidence for 'paleo' red-tide in the warming period can give understands for occurrence of red-tide associated with global warming in future. Dinoflagellate *Apectodinium* increased during the Paleocene/Eocene Thermal Maximum (PETM) characterized by global warming (Slujis et al., 2007). However, micropaleontological investigation of dinocyst demonstrated that productivity of dinoflagellate presumably decreased as a result of the warming during the mid-Cretaceous Oceanic Anoxic Event (OAE) 2 (Pearce et al., 2009). Paleothermometer such as TEX₈₆ indicate the OAE2 include twice warming and once cooling phases (Forster et al., 2007), and detailed carbon isotope stratigraphy in that interval could enable to comparison between different localities. In this study, we focus on dinoflagellate biomarker (triaromatic dinosteroid) and very small dinoflagellate-like acritarchs, and compare these trends between the Yezo Group (YG; Hokkaido, Japan) and Vocontian Basin (VB; SE France) sediments. Values of dinoflagellate production proxy (triaromatic dinosteroid index; TADS) increase at twice during the OAE2 interval, the onset of 1st build-up phase and from the Trough to 2nd build-up phases, in both YG and VB sediments. These results are synchronous with global warming trend estimated by TEX₈₆ and suggest elevated contribution of dinoflagellate for primary production in different two sections located at NW Pacific and Tethys. Huber et al. (1999) reported 'collapse' of vertical stratification during the warming phase of the OAE2. These changes related to global warming presumably caused enhanced nutrient supply from intermediate and bottom water masses and global expansion of suitable condition for dinoflagellate. Moreover, marine palynomorphs are mainly composed of very small (< 20µm diameter) spiny acritarchs (*Micrhystridium*) in the higher TADS samples in both two sections. It was reported that *Micrhystridium*-accumulated fraction of the Cambrian sediments have high concentration of dinosteane (Talyzina et al., 2000), although the origin of these acritarchs are uncertain. These acritarchs are similar to Gonyaulacoid dinocyst in the morphology and smaller than these cysts, which suggest original species of these acritarch are autotrophic and r strategist such as modern red-tide species. From these results, it is implied that frequent occurrences of red-tides by small dinoflagellate were triggered by global warming and eutrophication, and promoted efficient deposition of organic matter and consequently expansion of anoxic water mass.

Keywords: Cretaceous, Dinoflagellate, red-tide, Oceanic Anoxic Events, acritarch

Draught in the low latitudes and cooling by global soot aerosols led to the mass extinction at the Cretaceous-Paleogene boundary

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The extinction of the dinosaurs at the Cretaceous/Paleogene boundary led to the macroevolution of mammals and appearance of humans. The current hypothesis for the extinction of the dinosaurs is that an asteroid impact at Chicxulub, present-day Mexico, formed condensed aerosols in the stratosphere, which caused the cessation of photosynthesis and global near-freezing conditions. Here, we propose a new hypothesis that latitude-dependent climate changes caused by the soot aerosols in the stratosphere could consistently explain both the extinction of the dinosaurs and the survival of the crocodilians. Our geochemical data show that stratospheric soot aerosols were ejected from the oil-rich area by the asteroid impact and spread globally, coinciding with the devastation of land plants. Our model calculation and biological interpretation indicate that the soot aerosols caused sufficiently colder climates at the mid-high latitudes for several years, inducing the extinction of the dinosaurs and crocodilians in those areas. However, the climate still remained warm enough for their survival and the weak sunlight was still sufficient for plant photosynthesis at low latitudes, but the substantial decreases in precipitation occurred at low latitudes over several years resulting in draught, which may have affected their eventual extinction or survival.

More than 90% species of planktonic foraminifera, which inhabited the global seas, became extinct coinciding with the asteroid impact at the Cretaceous/Paleogene boundary. Our model calculation indicates that the soot aerosols caused 7-11°C, 4-8°C, and 3-6°C cooling at most in the 2 m, 50 m, and 100 m water depths in the low-middle latitude ocean. The rapid global cooling may have caused the marine extinctions.

Keywords: mass extinction, dinosaurs, planktonic foraminifera, Cretaceous-Paleogene boundary, soot, climate

Ontogenetic stable isotope records of Eocene planktic foraminifers: Comparison to modern symbiotic species observation

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Many planktic foraminiferal species in the Eocene epoch are thought to have symbiotic algae in their cytoplasm. Detection of photosymbiosis is achieved from ontogenetic isotopic signature; the $\delta^{13}\text{C}$ of symbiont-bearing species yields more ^{13}C -enriched values than the asymbiotic species, reflecting selective incorporation of ^{12}C by the symbiont photosynthesis. Because foraminiferal tests grow intermittently by adding a new chamber on the preformed test, each chamber holds information of the symbiont photosynthesis at the time of the chamber calcification. Recently, we have proposed chamber-by-chamber isotope analyses to investigate ontogenetic development of the photosymbiotic relationship. Here, we show the preliminary results of ontogenetic trends of isotopic values of Eocene species, and discuss the profiles from our observational results of cultured modern species.

Three Eocene species recovered by IODP Exp. 342 (U1407) were analyzed to examine ontogenetic isotopic profiles; *Morozovella*, *Acarinina* (symbiotic), and *Subbotina* (asymbiotic). Each individual test was dissected into chambers by using a micro-blade, then analyzed by the customized continuous-flow mass spectrometry system that can measure micro-volume carbonate as small as a single chamber.

The $\delta^{13}\text{C}$ values of *Morozovella* and *Acarinina* tended to show the ontogenetic positive shifts until the penultimate chamber. Then the final chamber showed more ^{13}C -depleted $\delta^{13}\text{C}$ value drastically by 0.5–1.0 ‰. In contrast to these species, *Subbotina* showed comparatively ^{13}C -depleted $\delta^{13}\text{C}$ values whole through its ontogeny. We can say that the progressive ^{13}C -enrichment of the chambers $\delta^{13}\text{C}$ with growth, excluding the last chamber, seen in *Morozovella* and *Acarinina* probably reflected the increase of the effect of symbiont photosynthesis. The contrasting relatively constant $\delta^{13}\text{C}$ values through ontogeny seen in *Subbotina* is in good agreement with the known asymbiotic nature of this species. The notable thing is that the last chamber of the two symbiotic species showed comparable $\delta^{13}\text{C}$ value to that of *Subbotina*. It indicates that the two symbiotic species had already lost their symbionts, or their photosynthesis was not active at the time of the last chamber calcification.

Our recent culture experiments of modern species (*Globigerinoides sacculifer* and *Globigerinella siphonifera*) to investigate symbiont photosynthesis through ontogeny showed that the chlorophyll content of the foraminifers, thus the symbiont content, drastically decreased to almost zero at the time or just before the gametogenesis. It sometimes occurred during the last chamber calcification. These modern observations indicate that the more ^{13}C -depleted $\delta^{13}\text{C}$ value in the final chamber in Eocene symbiotic species could reflect the digestion or lysis of symbionts. If so, it can be said that each individual had to acquire the symbionts from the environment at some time during the ontogeny as the modern obligate symbiotic species do.

Keywords: Eocene, Planktic foraminifer, Carbonate stable isotopes, Photosymbiosis

Radiolarian faunal turnover across the early/middle Miocene boundary in the eastern equatorial Pacific Ocean

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The lower to middle Miocene sequence was drilled at IODP Site U1335 (5°18.735'N, 126°17.002'W, water depth 4328 m) in the eastern equatorial Pacific Ocean. In the modern ocean, Site U1335 is located under the North Equatorial Current, and the biogenic silica fluxes to the sea-floor sediments are comparatively high in this area. The sediments recovered from Site U1335 are predominantly nannofossil ooze with siliceous microfossils such as diatoms and radiolarians.

230 morphotypes of radiolarians were identified at this site. Because the low latitude species commonly occurred at this site, the tropical Cenozoic zonation of radiolarians proposed by Sanfilippo and Nigrini (1998) was adopted. The studied sequence was divided into four zones, consisting of the RN2 (the *Stichocorys delmontensis* Interval Zone), RN3 (the *Stichocorys wolffii* Interval Zone), RN4 (the *Calocycletta costata* Interval Zone), and RN5 (the *Dorcadospyrus alata* Interval Zone) at Site 1335. In the standard zonal scheme, the early/middle Miocene boundary corresponds to the top of C5Cn.1n with an age estimate of 16.268 Ma (Pälike et al., 2010; Gradstein et al., 2012). Hence, this boundary was placed at 189.6 mcd at Site 1335.

Radiolarian fauna was divided into three assemblages based on variations in the composition of dominant species: an early Miocene assemblage (20.0 to 16.8 Ma), a transitional assemblage (16.8 to 13.4 Ma) and a middle Miocene assemblage (13.4 to 12.0 Ma). The early Miocene assemblage is characterized by two dominant species of *S. delmontensis*, *S. wolffii*, and *Tholospyris anthophora*. The transitional assemblage consists of three dominant species of *S. delmontensis*, *Calocycletta robusta* group, and *T. anthophora*. The four dominant species of the middle Miocene assemblage present in this assemblage are *Stylodictya* sp. A, *Lophocyrtis aspera*, *Disolenia* spp. and *Collosphaera* spp. The most significant faunal turnover of radiolarians is marked at the boundary between the transitional/middle Miocene assemblages.

Keywords: radiolaria, Miocene, eastern equatorial Pacific

Geologic age of the whale fossil-bearing calcareous float concretion from the Hae River, Hokkaido, Japan, based on radiolarian and diatom analyses

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Radiolarian and diatom fossils have been used to constrain the age of calcareous concretion collected from the Hae River, Hidaka Town, southern central Hokkaido, Japan. The calcareous concretion contains whale fossils and was discovered as a float during the riparian works in 2005. Recovered radiolarian and diatom assemblages indicate the *Lipmanella redondoensis* Zone (9.0 to 7.4 Ma) and the *Rouxia californica* Zone (7.7 to 6.5 Ma), respectively. Thus the concretion can be dated as 7.7 to 7.4 Ma. This age is concordant with the age range of the Nina Formation which is distributed near the locality of the concretion and was previously dated as ca. 10.1 to 3.5 Ma based on the diatom stratigraphy in the surrounding area. We will examine some samples collected from the Nina Formation exposed along the Hae River to confirm the origin of the concretion.

Keywords: whale fossil, Radiolaria, Diatom

The extinct pinniped *Allodesmus* (Mammalia: Carnivora) from the Miocene of Hokkaido, northern Japan, and its implications for phylogeny and postcranial morphology

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Allodesmus is an extinct pinniped that is known from the Middle and Late Miocene of the North Pacific and belongs in the family Desmatophocidae, which became extinct in the early Late Miocene. According to the previous studies, *Allodesmus* has at least five species and is divided into three subgroups: i.e., "Basal", "Broad head" and "Long head" subgroups. However, the phylogenetic study of *Allodesmus* has been limited until now, and therefore, the evolutionary history of the Desmatophocidae is also still unclear. Moreover, a study of postcranial bones of *Allodesmus* nor the Desmatophocidae is almost nothing because of insufficient skeletal material for those taxa.

In this study, we described a specimen of *Allodesmus* (AMP25) collected in 1991 from the Middle Miocene Okoppezawa Formation, Hokkaido, northern Japan. AMP25 contains 83 bones consisting of a skull, fore- and hind-limbs, ribs and vertebrae. To demonstrate the paleobiological importance of this specimen, we performed cladistic analysis to locate the new specimen in the phylogenetic framework. We used PAUP 4.0 and Mesquite 3.03, and then, we based on 97 morphological characters and 15 species, with the enigmatic musteloid *Potamotherium*, and the basal pinnipeds *Enaliarctos* and *Pteronarctos* as out-group.

As a result, previously recognized "Long head" subgroup was supported as a monophyletic group, but the "Broad head" subgroup was not recognized as a monophyletic group in our analysis. As for AMP25, it didn't have any synapomorphy of the "Long head" subgroup and nested with *Allodesmus packardi* and *A. naorai* as unresolved polytomy. On the other hand, AMP25 has an autapomorphy in that the supraorbital process is located at the anterior portion of the interorbital bar in our analysis. From the above and additional observations, we have concluded that AMP25 belongs to an unknown species. Importantly, some postcranial bones of AMP25 also show very different character combination, differentiating it from *A. kernensis* among the Desmatophocidae. In particular, morphology of the calcaneum (that is one of the component of the ankle bones) of AMP25 is remarkably distinguishable from that of *A. kernensis*. For example, the calcaneum of AMP25 is more slender than that of *A. kernensis*, and its peroneal tubercle is more developed than that of *A. kernensis*. These characters were distinguishable not only among the species of *Allodesmus* but among all other pinnipeds. It means that some postcranial characters other than characters that we used for the phylogenetic analysis in this study also have potential phylogenetic values as well as its functional importance.

Keywords: pinnipeds, *Allodesmus*, phylogeny, postcranium

Evaluation of early diagenetic influence on nitrogen isotopes within fossil amino acids:
Towards estimation of ancient food webs

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Compound-specific isotope analysis (CSIA) of nitrogen within amino acids is a relatively new tool to estimate the trophic level of organisms (Chikaraishi et al. 2009; *Limnol Oceanogr Meth*). It would be applicable as a new technique to the trophic and ecological study of fossils. Hard parts (e.g. shells and bones) usually contain amino acids, which can be extracted and identified in a number of previous studies. However, amino acids in fossils would be influenced by diagenesis, including thermal maturation, racemization, and degradation. Thus, it is important to evaluate whether or not the amino acids within the shell keep the original isotopic composition of organisms. Thus, this study aim to evaluate consistency of the estimated trophic level based on the CSIA of amino acids in shells with respect to early diagenesis. We use modern and fossil *Turbo cornutus* (Gastropoda), which is presumably primary consumer, i.e. trophic level should be 2.0. Fossil *Turbo* were obtained from Yuigahama archaeological site (Kanagawa Pref., Kamakura Era, 13-14th century, ca. 800 years ago) and Torihama archaeological site (Fukui Pref., Jyomon Era, ca. 4000 years ago). The modern materials were obtained from Hakui, Ishikawa and Kaneda, Chiba. Some of the modern materials were heated at 200 and 400 °C in oven.

Prior to the isotope analysis, the samples were examined in several ways, including X-ray diffraction pattern analysis, SEM observations of shell microstructures, D/L ratio of amino acids within the shells to evaluate the preservation of the samples. *Turbo cornutus* shell was composed of three layers. Our observation reveal that the outer layer of the shell contaminated by encrusting biota. Middle layer, consists of nacreous structure, sometimes had erosion by microbes. Moreover, microstructures of the modern sample heated at 400 °C were partially dissolved and recrystallized, and no amino acid was found in there. Amino acid composition in these aged samples was similar to the clean modern ones. Based on those results, we used several fossil samples, which remained original microstructures, for the isotope analysis. We also analyzed modern samples, including those heated at 200 °C and invaded by microbes.

As a result, all the samples analyzed show around 1.9-2.3 for the trophic level estimated based on the CSIA of amino acids. It is indicated that the early diagenesis wouldn't affect to the nitrogen isotopes of amino acids in shells at least for 4000 years.

Keywords: Trophic level, fossil, amino acids, stable nitrogen isotope ratios, early diagenesis

Effects of carbonate chemistry and metabolism induced by ocean acidification on stable isotope fractionation in molluscan shell carbonate

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Stable oxygen and carbon isotope compositions of biogenic carbonate have been widely used for many paleoclimate, paleoecological, and biomineralization studies. Oxygen isotope compositions of carbonate, a commonly used proxy of seawater temperature and oxygen isotope compositions of seawater, are also affected by seawater carbonate chemistry, but the knowledge of its dependency on stable isotope fractionation of both synthetic and biogenic aragonite is still limited. It has also been reported that carbon isotope compositions of molluscan shells are affected by carbon isotope compositions of seawater carbonate chemistry and metabolic carbon. Several studies reported effects of ocean acidification on metabolism of molluscs, and thus the metabolic changes could potentially influence the stable isotope compositions of metabolic carbon. Here, we have focused on stable oxygen and carbon isotopic responses of molluscan shells to CO₂-driven seawater acidification for understanding of the contribution of environmental and metabolic effects. Two species of clams (*Scapharca broughtonii*, *Pseudocardium sachalinense*) and two species of abalones (*Haliotis discus discus*, *Haliotis gigantea*) were cultured in seawater chemically manipulated to vary pCO₂ condition using CO₂ control system of the Demonstration Laboratory, Marine Ecology Research Institute (MERI), in Kashiwazaki City, Niigata Prefecture, Japan.

Stable oxygen isotope compositions of *S. broughtonii* had significant negative correlations with pH (-0.48‰ /pH, at 17°C; -0.61‰ / pH, at 25 °C). These of *P. sachalinense*, *H. discus discus*, and *H. gigantea* showed non-significant relationships with pH and small variations (within 1 per mil). The oxygen isotope fractionation in four species of our study are smaller than that of synthetic calcite (-1.42‰ / pH, Zeebe et al., 1999).

The significant negative correlations between stable carbon isotope compositions and pH appeared in *S. broughtonii*, *H. discus discus*, and *H. gigantea* which had non-significant pH effects on calcification, and the slopes of these relationships of shell carbonate were lower than these of dissolved inorganic carbon (DIC) of seawater. We estimated the equilibrium values of carbon isotope compositions at each pCO₂ treatment, and the difference between the carbon isotope compositions of shell carbonate and equilibrium values showed gradual increases of carbon isotope values with decreasing pH in *S. broughtonii*, *H. discus discus*, and *H. gigantea*. Thus, the pCO₂-induced change in metabolism might appear in carbon isotopes of shells of these species as the metabolic effect. On the other hand, in *P. sachalinense* which showed a decrease in calcification in our culture experiment of ocean acidification, the difference between the carbon isotope compositions of shell carbonate and equilibrium values did not indicate a significant pH dependency. This result might be attributable to differences in metabolic responses to acidified seawater.

The findings of our study will contribute to the correction of isotopic paleotemperature of biogenic carbonate and the understanding of acidification effects on metabolism of marine calcifiers.

Keywords: ocean acidification, stable isotopes, mollusca, biomineralization, proxy, pH

Conodonts and other microfossils from the Omi Limestone of the Akiyoahi Belt, Niigata Prefecture

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Although pelagic seas occupy the widest biosphere on earth, we have limited information concerning the Paleozoic ecosystem in the pelagic sea environment. We are now conducting a study to clarify the late Paleozoic ecosystem in pelagic sea environments using microfossils, including conodonts, foraminifers, ostracods, and others. Here we present our preliminary results on the microfossils obtained from the Omi Limestone of the Akiyoshi belt, Niigata Prefecture. The Akiyoshi belt is an accretionary complex that formed in the Permian period. It has a sporadic distribution from northern Kyushu (Fukuoka Prefecture) to the northern part of central Honshu (Niigata Prefecture) (Kanmera et al., 1990). The Akiyoshi belt is characterized by the presence of huge limestone blocks associated with basaltic rocks, which are inferred to have accumulated on a seamount. These limestone blocks are generally massive with no clear stratification and a complete lack of coarse quartz grains (Sano and Kanmera, 1991), which means that deposition occurred at a great distance from the continents. Seamounts are gradually sinking because of cooling of oceanic plates, and associated biota are growing upward to maintain their optimal environmental conditions. Therefore, seamount limestones are presumed to have a record of environmental and biotic changes over the last 100 ma, from the Early Carboniferous to the Middle Permian period. Based on their lithological and biostratigraphical characteristics, these limestones were generally constructed by reef builders, such as corals, bryozoans, algae, brachiopods, ammonites, and others. The organic reef has topographically diversified environments, such as the outer and inner reef, and various species are associated with each environment (Kitsukawa, 1994).

The Omi Limestone is located around the Omi Town, Niigata Prefecture, which is the most northeastern extension of the Akiyoshi belt. It is distributed along the Omi River with a length of approximately 8 km and a width of approximately 2 km (Nagamori et al., 2010). Many previous paleontological investigations have been conducted on the microfossils of the Omi Limestone, including foraminifers (Igo, 1960; Watanabe, 1973; Kobayashi, 1988; Ueno and Nakazawa, 1993), conodonts (Igo and Koike, 1964; Watanabe, 1975), corals (Rowett and Minato, 1968; Yoshida et al., 1987; Yoshida and Okimura, 1992; Niko and Hasegawa, 2000; Niikawa, 2001), brachiopods (Hayasaka, 1918; Tazawa et al., 1983; Tazawa et al., 2004), bryozoans (Sakagami, 1962, 1963), conuralia (Makiguchi, 1993), and others. This aim of this study was to re-examine the conodont biostratigraphy and investigate the Late Paleozoic microfossil fauna recovered from the limestone using the acetic acid method. Limestone samples were systematically collected from the Tomi (Myojyou Cement Co., Ltd.) and Omi mines (Denkikagaku Kogyo Co., Ltd.).

We recovered conodonts, fish teeth, ostracods, smaller foraminifers, bryozoans, sea urchin spines, holothurian sclerites, calcareous algae, and other unidentified fossils. The following conodont genera, indicative of the late Carboniferous Bashkirian-Moscovian time scale, were identified: *Declinognathodus*, *Idiognathoids*, *Idiognathodus*, *Streptognathodus*, *Neognathodus*, *Mesogondolella*, and others. With respect to the limestone lithology, limemudstone and grainstone predominated based on the thin section analysis. Lime mudstone consists of very fine calcareous mud and often contains fossil fragments. Grain stone is characterized by a concentration of fragments and ooids within a sparitic matrix. As these lithological microfacies are continuously observed laterally and stratigraphically, these limestones seem to have been deposited in a back reef environment during the late Carboniferous period. This indicates that the microbiota were diversified in pelagic back

reef environments during this time.

Keywords: microfossil, Paleozoic Era, Akiyoshi Belt, Omi Limestone, conodont

Marine strata and fossils of the Kuwajima Formation, Itoshiro Subgroup of the Tetori Group, in the Setono area, Hakusan City, Ishikawa Prefecture, central Japan

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The presence of marine strata in the Itoshiro Subgroup of the Tetori Group has attracted much attention recently. The marine deposits within the Kuwajima Formation of the Itoshiro Subgroup in the Setono area, Hakusan City of Ishikawa Prefecture, was recognized based on the sedimentary facies analysis and the occurrence of ichnofossils of limuloids (Matsuoka et al., 2009). A tuff bed overlying limuloid ichnofossils indicated an U-Pb age of 130 ± 0.8 Ma (Kusuhashi, 2008). Thus, the marine Kuwajima Formation in the Setono area is one of a few horizons where their stratigraphy, sedimentary environments, and numerical age have been recognized. We conducted the sedimentary facies analysis in this area, and extracted radiolarians and sponge spicules from 2 marine horizons. Radiolarians show drop-like outlines, which are common in the Jurassic and Cretaceous intervals, under an optic microscope. Sponge spicules are mainly composed of diactinal megascleres with blunt to rounded ends. This is the first record of marine microfossils of the middle Early Cretaceous age from the Tetori Group, suggesting the future contribution of radiolarian biostratigraphy and/or paleoenvironmental reconstruction using these fossils to the Itoshiro Subgroup. Other marine to brackish water megafossils from this area are also examined: a shell accumulation of *Myrene (Mesocorbicula) tetoriensis* with a small amount of Ostreidae gen. et sp. indet. in the studied sequence, and a belemnite fossil in sandstone float boulder, which probably suggests the presence of another marine horizon in this area.

Keywords: Tetori Group, Kuwajima Formation, radiolaria, belemnite

Geology and geological age of Upper Cretaceous sequence in the Hobetsu Inasato area, Hokkaido, Japan

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The Cretaceous Yezo Group distributed in the Hobetsu area, Hokkaido, Japan was geologically mapped based on newly surveyed lithological and micropaleontological data. Though the Inasato Formation in this area correlated to Cenomanian, our preliminary study found planktonic foraminiferal species that indicate Turonian or later from the localities previously mapped as the Inasato Formation. Geological map published by Takahashi (2002) is needed to be renewed.

Thirty seven planktonic foraminiferal species belonging to eleven genus were identified in this study. Lithostratigraphic classification shown in the previous study was basically followed but the chronological information from the foraminifera is reflected to renew the map of the west of Hobetsu Dam. The mudstones had been assigned to the Inasato Formation but divided into three formations, as follows: Inasato, Nutapomanai and Osawa formations. They are fault-bounded and some new faults are distinguished and mapped. Occurrence of *Praeglobotruncana delrioensis*, *Rotalipora cushmani*, *Thalmaninella globotruncanoides* among others from the Inasato Formation show that this formation is correlated to the Cenomanian. *Dicarinella canaliculata* and *Marginotruncana marginata* collected from the Nutapomanai Formation show Turonian age of this formation. *Contusotruncana fornicata*, *Globotruncana arca* and *Hedbergella holmdelensis* from the Osawa Formation indicate Coniacian to Santonian, or Campanian age.

Planktonic foraminifera observed here were highly diversified. Many specimens has white or pale yellow in color and were not filled with recrystallized calcite showing good preservation. They are especially preserved in the Osawa Formation. This is exceptional feature in southern Hokkaido. For example, specimen of *C. fornicata* have clear double keels on the peripheral side and opened pore on the surface of the chambers indicating very low degree of recrystallization. Many occurrence of *Dicarinella hanzawai* (Takayanagi) and *Dicarinella japonica* (Takayanagi), which is known as endemic species in Japan were also observed in the formation. Re-description of these species appears to be needed as their morphologies are highly diversified. Exceptionally well preserved nature of the specimen (even umbilical structures can be recognized) indicates the Inasato area suits for such descriptive study.

Keywords: Hokkaido, Hobetsu Inasato, Upper Cretaceous, Inasato Formation, planktonic foraminifera

Variability of *Ciconia boyciana*'s footprints on the homogenous sediment.

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An ichnological experiment using *Ciconia boyciana* was carried out to reveal morphological variability of tracks left on a potter sediment by 2 individual birds. We obtained a total of 56 tracks, for each of which the area, length, width, depth, and volume were measured. The average value of the track area was almost equal to its median value. *Ciconia boyciana* generally left morphologically uniform tracks, suggesting that it controls digit-substrate interaction to keep body balance. A unique anatomical feature is that *Ciconia boyciana* does not leave metatarsal impression, unlike other wading birds. This feature will be useful to identify *Ciconia boyciana* from other trackmakers being similar in body weights and habitats. Track width has a wide range of variability up to 40 %, which can be caused by the linkage of muscles between leg and foot being characteristic to birds. The co-efficient analysis of track geometry reveals that the width and depth of a track have a trade-off relationship to keep a same volume. Application of the theoretical morphology analysis to the track data reveals that the outer digits take a lot of the body weight in *Ciconia boyciana* while walking.

Keywords: foot morphology, *Ciconia boyciana*, classification, track fossils, limb anatomy

Species identification of Spumellaria (Radiolaria) on the basis of the small subunit and internal transcribed spacer region of ribosomal DNA

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Radiolaria are one of the best candidates for time- and environmental-indicators in the modern and past, because their tests have been preserved and the diversity of these morphological species has reflected the water ecosystem in the long Earth history. Although the significance of radiolarian ecology and evolution is well-known issue in paleontology and paleoceanography, the biological studies of radiolarians have been poorly studied so far, especially for the genetics. For the better understanding of the ecology and evolution, the diversity and distribution on the basis of biological species is essential data. However, there is no criterion to identify the biological species of radiolarians by molecular approach. The motivation for this study is setting the delimitation to identify the biological species of radiolarians by molecular data, for the future ecological study.

Identification of the biological species by molecular technique is different among the organisms in consideration of the various types of the reproduction systems: sex and hybridization. Some species identification by genetics are based on molecular distance of the small subunit ribosomal DNA (SSU rDNA) or the secondary structure of the internal transcribed spacer region of ribosomal DNA (ITS1 and 2). In the present study, 232 individuals of five morphological species of spumellarian radiolarians were collected from various environments. I amplified the three gene regions (SSU, ITS1, and ITS2 rDNA) from all collected individuals and examined whether molecular distance of rDNA or secondary structure of ITS2 sequences is useful to identify species in radiolarians. Comprehensive SSU and ITS rDNAs survey clearly show that molecular distance of ITS rDNA is good to identify the species, though it is difficult to set the common delimitation to identify the biological species, among all the spumellarian radiolarians. On the other hand, the secondary structure of ITS2 rDNA have the common threshold for the species identification: below 4 hemi-CBCs (HCBCs: base changes occurring on one side of a double-stranded portion) in a single biological species. The results show that the secondary structure of ITS 2 rDNA could be the criterion for radiolarian species identification.

Keywords: Radiolaria, Internal Transcribed Spacer region, biological species

Robustness of coverage estimators for assessing the completeness of paleontological sampling

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The study on global diversity change requires an adequate method to correct diversity estimates that are readily affected by unevenness of sampling density. The diversity estimates depend on true diversity as well as sampling effort. Therefore, rarefaction to a uniform sample size causes overcorrection of diversity measures which results in an underestimate of diversity particularly when true diversity is high. Alroy (2010) introduced the shareholder quorum subsampling (SQS) method which allows to remove only the effect of sampling intensity without overcorrection. The SQS method needs to estimate the proportion of the total number of individuals belonging to an already observed species in the sample, or sample coverage. The sample coverage can be accurately estimated using Good-Turing frequency estimation when the number of occurrences for each species follows a binomial distribution and the sample size is large enough. In natural community, however, individuals are not evenly distributed among species and often a few species predominate in a community. In addition, a small sample size is common in paleontological studies, especially if we focus on regional or local diversity of a particular taxonomic group. Chao and Jost (2012) proposed coverage-based rarefaction and extrapolation methods using an improved version of the Good's estimator of coverage. The sample coverage can also be estimated using a rarefaction curve calculated from the sample of interest: the final slope of the rarefaction curve represents the probability of encountering an individual hitherto unseen in the sample which is equal to one minus the sample coverage. However, precision and accuracy of the coverage estimators have not yet been fully verified for samples with various sizes from populations with a variety of statistical distribution.

Here I assessed the robustness of the above estimators of sample coverage through a simulation study. 10,000 bootstrap samples with various sizes were taken from the populations that follow logarithmic normal distributions with various sets of parameters. The three kinds of coverage estimators as well as a true coverage were computed for each bootstrap sample. The random error of estimation of the sample coverage was assessed by calculating the standard deviation of true coverage at a fixed value of each coverage estimate. The result of the simulation shows that the precision of any of the estimators examined tends to decrease with decreasing the sample coverage. The random error of estimation is considerably great in the case with a low coverage even if the sample size is pretty large. It also increases fairly as the median of the population increases.

Keywords: paleobiodiversity, completeness of fossil record, rarefaction