

Radiolarian zonation of Barremian to Aptian interval and its constraint on oceanic anoxic event 1a (OAE 1a)

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Based on the phyletic evolution of *Aurisaturnalis* and *Turbocapsula*, two radiolarian zones have been defined: the *Aurisaturnalis carinatus* Zone and the *Turbocapsula costata* Zone. The *Turbocapsula costata* Zone is subdivided into the *Turbocapsula costata multicosata* Subzone and the *Turbocapsula costata costata* Subzone. These zones are defined by evolutionary first appearance bio-horizons (EFABs), which are more reliable than the first and the last occurrence bio-horizons over wide areas. This zonal scheme can be used for identifying episodes, such as OAEs, in the pelagic realms.

These zones are established by the radiolarian biostratigraphic study ranging from the latest Barremian to the Aptian of a pelagic sequence (section BB1) near Babazhadong in southern Tibet. The strata are dominant by siliceous mudstone and chert. No fossils other than radiolarians can be obtained from the strata. Umbria–Marche sedimentary sequence was accumulated in the Middle Jurassic to Eocene at bathyal depths, in a relatively isolated pelagic basin. The lower Cretaceous units are composed of the whitish to medium grey pelagic limestones and dark grey to black cherts nodules or layers of the Maiolica Formation, overlain by the polychrome marls of the Marne a Fucoidi Formation. The section of Gorgo a Cerbara in the northern Umbria–Marche Basin has been constrained by magnetostratigraphy, planktic foraminiferal, and calcareous nannofossil biozones.

Radiolarian biostratigraphic study on pelagic basin of Umbria–Marche can provide better age-constraints for radiolarian zonation and is necessary to testify the applicability of the zonation. Totally, 52 samples from the section BB1 and 15 samples from section Gorgo a Cerbara have been collected for radiolarian biostratigraphic study.

During this period, black shale layers (OAE 1a) were deposited in marine secessions in the Mediterranean Tethys. However, no black shale layers are recorded in the siliceous sequence in southern Tibet.

Comparison of radiolarian assemblages from sections of Gorgo a Cerbara and BB1 proves that this zonation is useful in the whole Tethys. The Early Aptian OAE 1a is located between the first appearance bio-horizon of the genus *Turbocapsula* and the EFAB of *T. costata multicosata*. Radiolarian faunal change before and around the OAE 1a event is analyzed in this study.

Keywords: radiolarian zonation, Barremian to Aptian, Tethys, OAE 1a

Jurassic/Cretaceous boundary and radiolarian bioevents

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The Global Boundary Stratotype Section and Point (GSSP) of the Jurassic/ Cretaceous (J/K) boundary is the last among the GSSPs in the Phanerozoic. It will be defined the base of the Berriasian Stage. The definition was decided as the evolutionary first appearance biohorizon of *Calpionella alpina* by the Berriasian Working Group in the International Subcommission on Cretaceous Stratigraphy. Unfortunately, the primary marker cannot be found in the Pacific and circum-Pacific areas since the distribution of *Calpionella* is limited to the western Tethys regions. To determine the base of the Berriasian outside of the western Tethys, alternative proxies are needed. Radiolarians are good candidates for determining the J/K boundary. Evolutionary series of several radiolarian lineages across the J/K boundary are reviewed and suitable bioevents, which are approximate to the J/K boundary, are proposed. These lineages include the genera *Eucyrtidiellum*, *Cinguloturris*, *Ristola*, *Hemicryptocapsa*, and *Pseudodictyomitra*.

Keywords: Jurassic/Cretaceous boundary, GSSP, Radiolarians, evolutionary lineage, Pacific

Integrated biostratigraphy and magnetostratigraphy of the Upper Triassic to Lower Jurassic bedded chert sequences from Inuyama area, central Japan

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The stratigraphic record of several catastrophic events has been recently recognized in the Upper Triassic bedded chert successions from the Jurassic accretionary complex in Japan. Although their stratigraphic record is particularly important for understanding the impact of global catastrophic events in the Late Triassic, this process has been hampered by the poor age control for the cherts. The ages of the Triassic bedded cherts were predominantly determined from the radiolarian biostratigraphy, however, the accurate calibration of chronostratigraphic stages and substages has been developed using ammonite and conodont biostratigraphies and magnetostratigraphy. In order to calibrate the Upper Triassic radiolarian zonation with the standard Triassic timescale, the conodont biostratigraphic and magnetostratigraphic studies are required in the pelagic chert successions in Japan. Here, we present the conodont biostratigraphy and magnetostratigraphy established in exactly the same sections that Sugiyama in 1997 used as the type sections for his radiolarian biozones. The stratigraphic intervals from the Carnian to the Hettangian in his sections H, N, Q and R in the Inuyama area, central Japan were examined.

Based on recent conodont taxonomy and the stratigraphic distribution of marker species, eight conodont zones were defined: *Paragondolella? tadpole* interval Zone, *Quadralella tuvalica* interval Zone, *Epigondolella quadrata* interval Zone, *E. triangularis* interval Zone, *Mockina postera* interval Zone, *Mockina bidentata* interval Zone, *Misikella hernsteini* interval Zone, and *Misikella posthernsteini* interval Zone. These were correlated with the coeval radiolarian zonation established by Sugiyama in 1997, and comparable to that in British Columbia, the Pizzo Mondello section, the Steinbergkogel section, and other sections in southwest Japan.

Magnetostratigraphic results delineate 20 substantive normal and reverse magnetozones, defined by measurement of 357 samples. Although the magnetostratigraphic data in the vicinity of the early-late Carnian boundary is the first record from the marine section, the magnetostratigraphy of samples in Carnian-Rhaetian interval was well correlatable with that of Tethyan marine sections. This correlation implies that the bedded chert of Inuyama area was deposited in the Northern Hemisphere, assuming that the rocks in the Tethyan marine sections were deposited in the Northern Hemisphere. The correlation of the magnetostratigraphic data also suggests that loss of the stratigraphic record at the Triassic-Jurassic boundary (TJB) in the study sections, possibly due to structural erosion or hiatus. The intercalibrated conodont-radiolarian biostratigraphy and magnetostratigraphy from the studied sections accurately calibrates the radiolarian zones in Japan with standard chronostratigraphic stages and substages.

Keywords: Late Triassic, magnetostratigraphy, biostratigraphy, bedded chert, Mino belt, Panthalassa

Evaluation of chemical composition of conodont fossils in pelagic sedimentary rocks for application to reconstruction of paleo-seawater condition

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Conodont fossils are one of the best materials for reconstruction of paleo-seawater information. They are tooth-like phosphatic organs of the extinct group of marine animals Conodontia and generally preserve chemical information of paleo-seawater better than other carbonate fossils. Their chemical and isotope compositions have been used for paleo-environmental reconstruction; for example, their REE patterns and strontium isotopes ($^{87}\text{Sr}/^{86}\text{Sr}$) are used for estimation of paleo-redox conditions and paleo-weathering intensities, respectively. All of the prior researches on chemical composition of conodont fossils have focused on fossils from shallow marine carbonate rocks. However, geochemical researches on conodont fossils from pelagic deep-sea sediments have not been conducted so far. Herein, this study aims to evaluate the chemical composition of conodont fossils from pelagic deep-sea sedimentary rocks and establish methods of paleo-environmental reconstruction using the conodont fossils.

We collected pelagic deep-sea sedimentary rocks (chert and siliceous claystone) ranging from the Lower to Upper Triassic pelagic deep-sea strata from the Inuyama area, Aichi Prefecture, Central Japan. Collected samples were cracked parallel to the bedding planes into small "chips" and conodonts were found on the surface of these "chips" by careful observation under a stereoscopic microscope. In this method, any acid such as HF acid is not used in order to avoid elemental leaching during the extraction procedure. Conodont specimens were embedded in 1-inch diameter Petropoxy 154 resin, then polished on their surface with diamond paste (#60000).

Elemental mapping analysis of major elements by Electron Probe Micro Analyzers (EPMA) on the polished fossil specimens revealed their major components are Ca, P and F (24:14:5 in molar ratio), suggesting that they preserve their initial main elemental composition of apatite. The cathodoluminescence (CL) images and elemental mapping of minor elements by EPMA indicate that REEs were concentrated in ~10 μm -thick apatite layers at the outer margins of cracks and albid crowns of all analyzed conodonts. The results of laser ablation inductively coupled mass spectrometry (LA-ICP-MS) also indicate the existence of REE-rich layers at the rims of conodont albid crown and cracks. Some parts of the REE-concentrated layers show euhedral shape implying that they are probably authigenic apatite precipitation after deposition of fossils. The REE concentrated layers are considered to be the main host of conodont REEs.

Values of Ce-anomaly (Ce/Ce^*) of the conodont fossils from the studied sections showed a stratigraphic variation through Lower to Upper Triassic, which is consistent with the shift of anoxic to oxic paleo-seafloor conditions previously reported by geochemical analysis of whole rock from the same section. Formation of Mn oxide at oxic seafloor-condition can explain positive Ce-anomalies of the variation (Takahashi et al., 2015; Fujisaki et al., 2016). In addition, Y/Ho of all conodont samples were 25~30 which is the value of terrigenous sediments. These results imply that, under anoxic condition, conodont fossils record REEs of terrigenous sediments, and under oxic condition they record those of terrigenous sediments and Mn-oxides.

Measured $^{87}\text{Sr}/^{86}\text{Sr}$ of conodont fossils using laser ablation multi collector inductively coupled plasma mass spectrometry (LA-MC-ICP-MS) were slightly higher than sea-water values predicted from shallow marine bioapatite, probably because of the spectral interferences caused by REEs absorbed on

conodont fossils analyzed in this study.

Keywords: conodont, chert

Towards the establishment of a complete lithostratigraphy of the Lower Triassic deep-sea chert gap

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Carboniferous to Jurassic pelagic deep-sea sediments that accumulated in the pelagic Panthalassa Ocean are mostly dominated by bedded chert, which contains abundant radiolarian tests (Matsuda and Isozaki, 1991). However, the Lower Triassic interval is characterised by grey and black siliceous claystone instead of bedded chert (the deep-sea chert gap) (Ishiga and Yamakita, 1993; Isozaki, 1997). Previously, it has been believed that siliceous claystone was deposited because of diminished radiolarian production during oceanic anoxia: black siliceous claystone of the uppermost Permian to Induan was assumed to reflect oceanic anoxia related to the end-Permian mass extinction, and grey siliceous claystone below and above it was assumed to represent a less prominent oxygen depletion (e.g. Isozaki, 1997). Contradictory to this hypothesis, the estimation of burial fluxes of clastic material and biogenic silica in the Spathian (upper Olenekian) siliceous claystone dominant lithofacies implies that the increase in the flux of clastic material, rather than decreased radiolarian production, was the origin of the deep-sea chert gap (Muto et al., JpGU meeting 2016). Furthermore, black siliceous claystone has recently been reported from the lower Spathian (Yamakita et al., Annual meeting of the Paleontological Society of Japan 2016) and the Lower-Middle Triassic boundary (Muto et al., JpGU meeting 2015), indicating that black siliceous claystone is not confined to the uppermost Permian to Induan interval of the deep-sea chert gap. Despite these recent advancements, compilation of lithostratigraphy covering the entire deep-sea chert gap has not been conducted to date. In this study, the lithostratigraphy of previously reported sections covering the deep-sea chert gap, along with new data from the Ryugadake section in Kyoto Prefecture are compiled. In the Ryugadake section, an approximately 2 m thick black siliceous claystone of unknown age is apparently overlain by an approximately 20 m thick grey siliceous claystone dominant lithofacies of upper Spathian age. The compiled sections are constrained by conodont biostratigraphy, which provides the biostratigraphic framework to correlate between distant sections.

The compilation of the lithostratigraphy of the deep-sea chert gap reveals three main features that were previously undernoted:

Firstly, black siliceous claystone occurs in multiple regions in the lower Spathian and probably across the Lower-Middle Triassic boundary. This implies that oxygen-poor depositional condition similar to that detected from the Induan black siliceous claystone is likely to have occurred in the early Spathian and at the Lower-Middle Triassic boundary.

Secondly, the thickness of the Griesbachian (lower Induan) to Smithian (lower Olenekian) interval also predicts a high sedimentation rate compared to bedded chert. The combined thickness of this interval seems to be at least over 15 m, which would mean a linear sedimentation rate greater than 6.7 m/Myr, higher than that of Middle Triassic to Lower Jurassic bedded chert (1.4 m/Myr; Ikeda and Tada, 2014). This implies that increased flux of clastic material to the pelagic realm was a phenomenon characteristic during the entire Early Triassic, not just the Spathian.

Thirdly, there is considerable lateral variation in the lithofacies of the deep-sea chert gap. The upper Spathian of the Ryugadake section is mostly composed of grey siliceous claystone dominant lithofacies with thin intercalations of black siliceous claystone and almost no chert. The contemporaneous interval in the Tsukumi composite section in Oita Prefecture is composed mainly of red and grey siliceous claystone dominant lithofacies with thin intercalations of grey chert and almost no black siliceous claystone. The

lateral variation in lithofacies must be taken into account when the sedimentary record of the pelagic deep-sea sections is used to investigate regional or global scale palaeo-environment.

Keywords: pelagic deep-sea facies, Lower Triassic, lithostratigraphy, conodont

Bioturbation in the Pacific abyssal plain: its paleontological and sedimentological implications

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Abyssal plain is the largest single marine ecosystem on Earth and contains abundant benthic fauna living on and in the seafloor sediment such as gastropods, bivalves, polychaetes, echinoderms, and crustaceans. The benthic fauna are important in the seafloor environments, because they mix sediments, disrupt microstratigraphy, and influence the biogeochemistry of seafloor sediment. The process of biomixing of sediment is known as bioturbation. The abyssal plain is characterized by low-sedimentation rate thereby being heavily disturbed by bioturbation. Hence, investigating nature of bioturbation is essential for further understanding on organism–sediment interactions, and is also important for sedimentology and paleontology. In this presentation, we review previous biological and ichnological studies on the abyssal plain settings, and show preliminary result of our ongoing research project on bioturbation and biogeochemical cycles under different settings on organic carbon input to the seafloor in the Pacific abyssal plain.

Keywords: Burrow, Trace fossil, Ichnology, Sedimentary structures

InterRad 15 in Japan (22-17 October, 2017) and outreach items for radiolarians

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InterRad is the international association of radiolarists. The 15th InterRad meeting will be held in Japan during 22-27 October in 2017. The InterRad is returning to Japan after 23 years since the InterRad 7 was held in Osaka in October, 1994. On the occasion of this international meeting, we are planning to do something in enhancing a degree of recognition of radiolarians. It is essential for any academic associations to introduce relevant topics into society. Several items are being newly produced in relation to the InterRad 15. They include enlarged models of radiolarian shell, play cards using scanning electron microscope images of radiolarian shell, and T-shirts with radiolarian printed on. The T-shirt is produced in collaboration with an artist Mr. Moria.

Keywords: InterRad, Radiolaria, Outreach item, Enlarged model, Card game, T-shirt

High precision X-ray CT morphometry of microfossils for scientific validations

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Recent three dimensional (3D) morphometrics bring tremendous contributions for natural sciences. In the field of earth sciences, the acquisition of 3D morphometrics is rapidly increasing for the purpose of precise analysis of morphology of geological materials, especially for microfossils. In this study, we are trying to acquire the high resolution microtomography of microfossils by using the Microfocus X-ray Computed Tomography (MXCT). The combination of MXCT technique and high-precision X-ray detectors realize submicron-scaled morphology of microfossils without destruction on both the outer and the inner structures, therefore it is useful for classification, evolutions and functional morphology on microfossils.

The materials used in this study were microfossils from deep-sea sediments collected by the Deep Sea Drilling Project (DSDP) and Ocean Drilling Project (ODP) and other materials in modern ocean. So far, we already achieved the 3D microtomography for some species on foraminifers, radiolarians, diatoms and pteropods from each geological ages. In this presentation, we will show the reconstructed 3D images of the above specimens and discuss about the essentials for scientific validation on micropaleontological studies. In addition, we will discuss about 3D printing models by using the above 3D data for educational purposes.

Keywords: Microfossils, Microfocus X-ray CT, 3D morphometry, Three dimensional models

Preliminary report on Permian radiolarians from the Ashio terrane in Hachioji Hills, eastern Gunma prefecture, central Japan

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The Ashio terrane, a Jurassic accretionary complex, is distributed over the Ashio Mountains in the North Kanto region, central Japan. Hachioji Hills in eastern Gunma Prefecture is located at the southwest end of the Ashio Mountains, and the Ashio terrane is exposed at the hills. However, there is a few studies that focus on the Ashio terrane in Hachioji Hills. I have surveyed the Ashio terrane in the Ashio Mountains, including that in Hachioji Hills, since 2016.

I discovered Permian radiolarian assemblages from red bedded cherts of the Ashio terrane in Hachioji Hills. Previously, Middle Jurassic radiolarians occurred in the mudstones of Ashio terrane in Hachioji Hills; however, Permian radiolarian occurrences have never been reported from Hachioji Hills.

The assemblages contain *Pseudoalbaillella sakmarensis* Kozur. This species occurred in the *Pseudoalbaillella lomentaria* Assemblage Zone and *Albaillella sinuata* Range Zone of the middle Cisuralian, lower Permian.

The Ashio terrane in Hachioji Hills has been considered to be extension of the Kiryu-Kurohone Unit distributed over the Kiryu and Kurohone areas. However, the Kiryu-Kurohone Unit contain no Permian cherts according to the previous studies. Our result suggests that the Ashio terrane in Hachioji Hills belongs to other unit in the Ashio Mountains.

Keywords: Permian radiolaria, Ashio terrane, Jurassic accretionary complex, Hachioji Hills, Gunma Prefecture

Lithology and age of Middle Paleozoic siliceous-clastic strata related to the opening of the Paleo-Tethys in the Klaeng area, Rayong Province, southeastern Thailand

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The Devonian continental-margin to deep-water facies in Thailand provides important information about the marine environmental change during the opening of the Paleo-Tethys (Hara et al., 2010). In the present study, Devonian siliceous and clastic rocks, exposed at Laem Krabang Phet, approximately 20 km southwest of Klaeng, Rayong Province, southeastern Thailand (Kamata et al., 2015), were examined in terms of lithostratigraphy and geologic age. The strata of the study section are subdivided into the following three rock-facies: black carbonaceous mudstone, sandstone, and chert (Unit I), felsic tuff, tuffaceous sandstone, tuffaceous chert, and chert (Unit II), and siliceous mudstone associated with various lithologies (chert, black carbonaceous mudstone, sandstone) (Unit III).

From near the locality where we studied, Kamata et al. (2015) reported *P. cladophorum* and some entactiniid species such as *S. cf. pusilla*. They concluded that this fauna is probably referable to the Middle-Late Devonian. We collected over 50 samples including black carbonaceous mudstone, chert, tuffaceous chert, felsic tuff and siliceous mudstone from the study section, with the aim of determining detailed biostratigraphic age. As a result, we recovered moderately well-preserved radiolarians from gray to dark gray chert of Unit II and black siliceous mudstone of Unit III. The radiolarian fauna from both samples has similar species composition, including *T. minax*, *T. vetusta*, *T. davidi*, *T. elegans*, and *T. echinata*. *Trilonche minax* and other *Trilonche* species are the representative species of the *T. minax* assemblage (Aitchison et al., 1999). Based on the age calibration by Aitchison et al. (1999), the fauna of our samples can be assigned to latest Givetian to early Frasnian (latest Middle Devonian to early Late Devonian).

Kamata et al. (2015) suggested that the lithological assemblage in the study section is dissimilar to that of the Devonian part of the Fang chert (Chiang Dao area of northern Thailand), which is related to the opening of the Paleo-Tethys (Hara et al., 2010). However, the result of the present study shows that the stratigraphy consisting of black carbonaceous mudstone of Unit I and overlying fine-grained siliceous and tuffaceous rocks (Unit II) is similar to that of black shale and overlying siliceous shale and tuffaceous chert in the Chiang Dao area of Hara et al. (2010).

Keywords: Paleo-Tethys, Devonian, Radiolaria