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 multicostata* 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 multicostata*. Radiolarian faunal change before and around the OAE 1a event is analyzed in this study.

キーワード：放散虫化石帯、白亜紀中期、テチィス、海洋無酸素事変
Keywords: radiolarian zonation, Barremian to Aptian, Tethys, OAE 1a

ジュラ系・白亜系境界と放散虫のバイオイベント
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*.

キーワード：ジュラ系・白亜系境界、GSSP、放散虫、進化系列、太平洋
Keywords: Jurassaic/Cretaceous boundary, GSSP, Radiolarians, evolutionary lineage, Pacific

中部日本犬山地域に分布する美濃帯上部三畳系～ジュラ系層状チャートを用いた化石・古地磁気統合層序の確立

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.

キーワード：後期三畳紀、古地磁気層序、化石層序、層状チャート、美濃帯、パンサラサ海
Keywords: Late Triassic, magnetostratigraphy, biostratigraphy, bedded chert, Mino belt, Panthalassa

深海堆積層岩から産するコノドント化石の化学組成の評価：古海洋環境復元ツールへの応用に向けて

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 Conodonta and generally preserves 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 ($^{87}Sr/^{86}Sr$) 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 deepsea 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 shows 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 $^{87}Sr/^{86}Sr$ 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 spectoral interferences caused by REEs absorbed on conodont fossils analyzed in this study.

キーワード：コノドント、チャート
Keywords: conodont, chert

下部三畳系深海チャートギャップの完全な層序復元に向けて
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.

キーワード：遠洋深海相、下部三畳系、岩相層序、コノドント
Keywords: pelagic deep-sea facies, Lower Triassic, lithostratigraphy, conodont

太平洋深海平原におけるバイオターベーション：その古生物学的・堆積学的意義
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.

キーワード：巣穴、生痕化石、生痕学、堆積構造
Keywords: Burrow, Trace fossil, Ichnology, Sedimentary structures