

## 飼育実験とマイクロCT技術にもとづく放散虫の生態学的・形態学的研究 Ecological and morphological analysis of radiolarians based on laboratory culture and X-ray micro-CT technology

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Living radiolarian researches have provided us with fundamental data on radiolarian ecology including feeding behavior, symbiosis, and parasitism. These researches together with detailed morphological analysis are expected to expand our understandings of past pelagic environments. Detailed observations of feeding behavior of laboratory cultured radiolarian specimens make it possible to understand the relationship between skeletal morphology and feeding behavior. Four types of feeding strategy well correspond to skeletal morphology in extant radiolarian taxa. High diversity of radiolarian skeletal morphology is partly related to having a variation in feeding strategies. The wide variation in feeding behavior means that radiolarians occupy several kinds of ecological niches in marine environments. We can infer feeding behavior of extinct radiolarian group based on their skeletal morphology. Once we recognize the role of radiolarians in food web in the modern ocean environments, we can apply it to reconstruct marine ecosystem in the past. Fluctuation in morphological diversity of radiolarian skeletons is well documented in fossil records. This fluctuation can be interpreted as change in the number of ecological niches in the marine eco-system through time. Recently developed X-ray micro-CT and layered manufacturing technology is essential for detailed morphological analysis of radiolarian skeletons.

キーワード: 放散虫, 飼育実験, X線マイクロCT技術, 詳細形態解析, 遠洋域

Keywords: radiolaria, laboratory culture, X ray micro-CT technology, detailed morphological analysis, pelagic realm

## First record of Late Jurassic radiolarians from eastern Heilongjiang Province, NE China First record of Late Jurassic radiolarians from eastern Heilongjiang Province, NE China

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The early study of the Nadanhada geology began in 1930s by Japanese geologists (Yabe and Ohki, 1957). In 1957 Chinese and Russian scientists made joint geological research in the Ussuri River region, and confirmed the occurrence of Upper Triassic, Lower and Middle Jurassic rocks on the basis of fossil evidence (Wang, 1959), and they came to the conclusion that the Mesozoic mobile belt developed from a geosyncline in the northeastern continental margin of East Asia.

Based on fossil records of Late Palaeozoic fusulinids the Nadanhada Range was considered as a Palaeozoic geosyncline which extends from the northeast Sikhote-Alin region (Li et al., 1979). But the sporadic and irregular distribution of rock formations with various age fossils (Carboniferous and Permian fusulinids in limestone, Triassic conodonts in bedded chert, Triassic, Early and Middle Jurassic radiolarians in bedded chert and siliceous shale and Late Jurassic to Early Cretaceous bivalves, a *Buchia* fauna), strongly suggest the melange characters of the Nadanhada geology. It together with the Mino and Western Sikhote-Alin terranes formed a single superterrane before the opening of the Japan Sea (Kojima, 1989).

Recent studies showed that the Dajiashan Formation, cropping out in the Zhenbaodao-Dajiashan area, southern Nadanhada Terrane, yields a middle-late Early Cretaceous *Aucellina* Fauna (Wang et al., 1995). Furthermore, the purported Early Jurassic ammonites of the Dajiashan Formation (Li, 1996) are also similar to those of the *Pseudohoplaceras* ammonite fauna from the Lower Cretaceous Longzhaogou Group. All these sparked an interest in restudying the palaeontology and biostratigraphy of the Dajiashan Formation and its underlying deposits.

Well preserved Middle-Late Jurassic radiolarian faunas are encountered in four samples from the black mudstone of the Dalinqiao Formation, which was originally dated to Late Triassic-Early Jurassic by the Geological Survey of Heilongjiang Province of China. These radiolarian faunas consist of 45 species and subspecies in 28 genera and are assigned to two radiolarian zones, i.e. the Middle Jurassic (late Bathonian to early Callovian) *Striatojaponocapsa conexa* Zone and the Late Jurassic (Kimmeridgian) *Hsuum maxwelli* Zone. The new fossil record of Late Jurassic radiolarians makes it possible to reconstruct the geological history of the Nadanhada Range in northeastern China.

キーワード: radiolarians, biostratigraphy, Middle Jurassic, Late Jurassic, Eastern Heilongjiang Province, China

Keywords: radiolarians, biostratigraphy, Middle Jurassic, Late Jurassic, Eastern Heilongjiang Province, China

## オスミウム同位体比に基づく拓洋第五海山における鉄マンガクラスト成長速度の時間・空間変化

### Temporal and spatial variation in growth rates of Fe-Mn crusts from the #5 Takuyo Smt using osmium isotope compositions

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A ferromanganese crust (Fe-Mn crust) records geochemical information of ambient seawater and is known as a useful material for deciphering the paleocean environmental changes throughout the Cenozoic period (e.g., Klemm et al., 2005; Burton, 2006). Based on the osmium (Os) isotope stratigraphy, recent studies proposed that a growth rate of the Fe-Mn crust was changed significantly and that its variation in the growth rate was attributable to global ocean environmental changes (Klemm et al., 2005; Li et al., 2008; Meng et al., 2008). However, due to the lack of detailed studies constraining the temporal and spatial variations in the growth rate of Fe-Mn crusts, the linkage between their growth rates and marine conditions is still poorly understood.

Here, we report the temporal and depth variations in the growth rate of Fe-Mn crusts on the basis of the Os isotope composition. Our samples were collected systematically from the Takuyo Daigo Seamount (#5 Takuyo Smt) by ROV Hyper Dolphin / RV Natsushima (NT09-02 Leg.2 cruise) with manipulator and underwater diamond saw. The Os isotope compositions of two Fe-Mn crust samples collected from 1440 and 2987 mbsl exhibit a similar trend and their values are almost the same as the seawater Os isotope record from present to 12 Ma, demonstrating that the growth rates of Fe-Mn crusts from the #5 Takuyo Smt are constant regardless of sea depth. This is consistent with the growth rate determined by the Be-10 dating method. However, in the older part (bottom part in the side of basement rock) of Fe-Mn crust collected from 1440 mbsl, the Os isotope compositions have a large deviation from the seawater Os isotope record. Moreover, the Fe-Mn crust collected from 2987 mbsl totally lacks the section older than 12 Ma. These results suggest that (1) the existence of the growth hiatus older than 12 Ma, recognized in the previous studies (Klemm et al., 2005; Li et al., 2008; Meng et al., 2008) or (2) the bottom part of Fe-Mn crust older than 12 Ma at 2987 mbsl was simply eroded and disappeared by land slide of the #5 Takuyo Smt.

The present study is the first attempt to comprehend the spatial/depth variation in the growth rate of Fe-Mn crusts using the Os isotope stratigraphy. It is turned out that the growth rate of Fe-Mn crusts collected from different depth is constant and sedimentary age determined by Os isotope composition is consistent with that of the Be-10 dating method. In the future research, we will conduct the Os isotope geochronology to various Fe-Mn crust samples from various localities and elucidate whether or not the growth hiatus is related with the global ocean environmental changes.

キーワード: オスミウム同位体, 古海洋環境, マンガクラスト, 成長ハリエタス

Keywords: osmium isotope, paleoceanography, ferromanganese crust, growth hiatus

## Fe-Mn クラストから新生代海水の化学進化を解読する Deciphering the chemical evolution of the Cenozoic seawater using ferromanganese crust

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We report the secular variation in the Os concentration and isotope ratio from the Middle Miocene to present using Fe-Mn crust samples collected from the Takuyo Daigo Seamount. Both the Os/Fe ratio and Os isotope ratio increased exponentially toward present. Based on the flux calculation using a simple box model, these increase tendencies can be almost explained by the increase of riverine Os flux to the ocean and the present seawater Os mass is estimated to be ca. 1.85 times the size of that in 10 Ma. Therefore, the seawater Os mass may not be constant through the Earth history and a Fe-Mn crust is one of the most appropriate materials to unravel the chemical evolution of the paleo-seawater.

キーワード: Fe-Mn クラスト, 海水, 化学進化, Os 組成, 拓洋第五海山, 太平洋

Keywords: ferromanganese crust, seawater, chemical evolution, Os geochemistry, Takuyo Daigo Seamount, Pacific Ocean

## 白亜紀における大規模火山活動と地球環境変動のリンク ~ 遠洋性堆積物から読み取地球内部ダイナミクスと環境変動 ~ Linkage between Massive Volcanic Events and Global Extreme Climatic Events in the Cretaceous Period

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Causal linkages between massive volcanic events and extreme climatic events have long been discussed. However, little has been understood about the mechanisms of these linkages. Recent developments of heavy metal isotope analyses such as lead (Pb) and osmium (Os) enable us to reconstruct detailed volcanic events from marine sedimentary records. Based on these isotopic records, we have investigated temporal relationship between massive volcanic events associated with large igneous provinces (LIPs) and Mesozoic extreme events such as Triassic-Jurassic mass extinction, and mid-Cretaceous Oceanic Anoxic Events (OAEs). We present an overview of our recent works on 1) end-Triassic mass extinction (200 Ma), 2) Early Aptian OAE-1a (120 Ma) and 3) end-Cenomanian OAE-2 (94 Ma) and their linkages with Central Atlantic Magmatic Province, Ontong Java Plateau and Caribbean/Madagascar LIPs, respectively.

Marine sediments deposited across the early Aptian OAE-1a show two prominent negative shifts of seawater osmium isotopic ratios, suggesting duplicate inputs of unradiogenic osmium from the mantle. The lead isotopic record suggests that the main part of the Ontong Java Plateau was formed by deep submarine eruptions. On the other hand, marine sediments deposited across the end-Cenomanian OAE-2 interval indicate an abrupt shift of Pb isotopic ratios, suggesting an increased supply of volcanic Pb via subaerial eruption. Our data indicate strong consistency between magmatic events and extreme climatic events for both OAE-1a and OAE-2, although the eruption processes differ. A more precise discussion of the causal mechanisms between these events will be presented in the near future.

## 赤道太平洋東部地域における中期中新世以降の生物生産性および底層水循環変動 Surface Productivity and bottom water circulation changes in the Eastern equatorial Pacific

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Integrated Ocean Drilling Program Expedition 320/321 Pacific Equatorial Age Transect (PEAT I and II) was carried out to recover complete paleoceanographic record in the Eastern equatorial Pacific during Cenozoic. Especially clarifying accumulations of biogenic carbonates and carbonate compensation depth (CCD) fluctuations were one of the highest priorities in these expeditions. The cruise we attended (PEAT II) were recovered cores from two locations (Sites 1337 and 1338) to understand equatorial paleoceanography since middle Miocene in the Pacific. In this study, we performed geochemical analysis in order to reveal the bottom water hydrography in the eastern Equatorial Pacific from the middle Miocene to Holocene.

The cores U1337 and U1338 were pelagic sediments composed of calcareous chalk with laminated diatom bulbs. Inorganic carbon (IC) and total organic carbon (TOC) was analyzed shipboard using coulometry and CHN analyzer. IC contents of core was 0-99% and 30-90% through the cores in U1337 and U1338, respectively and indicated mostly good preservation of calcium carbonates. On the other hand, the carbonate crash representing anomalous decreasing of carbonate accumulation was detected both sites at Middle-Late Miocene (ca. 11-9 Ma), and it affected more strongly in U1337 rather than U1338. TOC contents was mostly very low (~0.1%) through both cores but showed 0.3 - 0.5% in some layers that were indicated laminated diatom concentrated layers. It suggested that frequent productivity changes had occurred during middle - late Miocene.

Trace metal analysis was performed for benthic foraminifers in core U1338 to understand deepwater temperatures and other geochemical properties. *Cibicides mundulus* and *Oridorsalis umbonatus* were used for Mg, Sr, Mn/Ca analysis. Mg/Ca showed that 0.4 - 1.5 mmol/mol through the core. This fluctuation showed similar trend with global  $\delta^{18}O$  fluctuations of benthic foraminifera. It suggests that bottom water temperature was affected with global climate changes related to ice volume effects.

Keywords: PEAT, Eastern equatorial Pacific, Middle Miocene, CCD, benthic foraminifera, bottom water circulation

## オマーンオフィオライトにおける上部白亜系スヘイラ層の岩相層序と放散虫化石年代 Lithostratigraphy and radiolarian age of the Upper Cretaceous Suhaylah Formation of the Oman Ophiolite

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オマーンオフィオライトの噴出溶岩上には、遠洋性堆積物であるスヘイラ層が分布している。スヘイラ層は、下位よりアンバー（メタリフェラス堆積物）、赤色頁岩・チャート、ミクライト質石灰岩から構成される。本層については、Fleet and Robertson (1980) などにより詳しく研究され、その分布域、溶岩層との関係および堆積環境の復元が行われた。放散虫化石については、Tippit et al. (1981) により後期白亜紀 Cenomanian 前期～Santonian の放散虫化石が報告された。しかし、放散虫化石の詳細な層序分布は不明であり、報告された化石の産出層準も限られたものである。また、これ以降は放散虫による生層序学的研究は行われていない。本研究では、遠洋性堆積物の発達史とそこに記録された放散虫の進化・変遷を明らかにすることを目的とし、オマーンオフィオライト北部の Wadi Jizzi 地域においてスヘイラ層の岩相層序の記載と生層序学的検討を行った。

Wadi Jizzi 地域は、スヘイラ層の模式地となっており、下位よりアンバー、チャートを挟む赤色頁岩、ミクライト質石灰岩から構成される。アンバーは金属光沢のある暗赤紫色を呈する。層厚は3～8 m である。赤色頁岩はメタリフェラス堆積物から漸移し、下部は暗赤紫色、上部へ行くほど赤色となる。上部ではチャートの挟みも卓越するようになる。層厚は3～12 m とセクションにより変化する。ミクライト質石灰岩は、下部の1 m 程が赤褐色を呈し、上部へ行くにつれて灰緑色となる。しかし、セクションによっては、下部から上部まで一律に赤色である。葉理構造が発達し、葉理に沿って板状に割れる。層厚は9 m 以上である。

Wadi Jizzi 地域において、3つの放散虫化石群集を認識した。群集Aは、赤色頁岩中のチャートから産出した *Thanarla pulchra* (Squinabol), *Guttacapsa biacuta* (Squinabol) などから構成され、Cenomanian 後期の群集である。群集Bは、赤色頁岩とミクライト質石灰岩に認められる。 *Rhopalosyringium scissum* O'Dogherty, *Dictyomitra formosa* Squinabol などから構成され、Turonian 前期の群集である。群集Cは、ミクライト質石灰岩から産出したもので、 *Mylocercion* sp., *Schadelfusslerus* sp. などから構成される。本群集は Turonian を示すと考えられる。これらの結果から、ミクライト質石灰岩直下の赤色頁岩中には Cenomanian/Turonian 境界が存在すると考えられる。

キーワード: オマーンオフィオライト, スヘイラ層, 放散虫, 上部白亜系

Keywords: Oman Ophiolite, Suhaylah Formation, radiolarians, Upper Cretaceous

## オマーンオフィオライト・ヒルチ地域の噴出溶岩層上における後期白亜紀遠洋性堆積物と放散虫化石

### Late Cretaceous pelagic sedimentary rocks on the extrusive rocks of the Oman Ophiolite and their radiolarian age

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The Oman ophiolite, a member of the Tethyan ophiolites, crops out over 600 km long and up to 150 km wide in the Oman Mountains. The ophiolite suite consists of mantle peridotites, gabbros, a sheeted dyke complex, and extrusive lavas overlain by pelagic sediments. The basaltic rocks have been subdivided into three volcanic units: the V1 lava with the N-MORB signature, the V2 lava formed by intra-oceanic volcanism, and the V3 lava generated by intra-plate seamount magmatism (Ernewein et al., 1998). Pelagic sediments with metalliferous sediments (umber) commonly occur at the boundaries between these volcanic units. We are now reinvestigating radiolarian biostratigraphy of the pelagic sediments, and here we present newly-obtained Turonian radiolarians from micritic limestone overlying the V2 lava.

Radiolarian study for the micritic limestone was conducted in "South of Wadi Hilti" section, located in an area about 40 km west of Sohar. At this section, the radiolarian-bearing micrites with a total thickness of 6 m conformably overlie the uppermost part of the V2 lava. In this section, basaltic rocks of the V3 lava thrust over the micrite. The micritic limestone is thinly bedded (3 to 5 cm thick) and light brown in color in the lower part and red in the upper part. Numerous radiolarian shells can be observed in the muddy matrix of micrite but they are commonly calcified. Total 11 samples were collected from this section for radiolarian biostratigraphic analyses. Well-preserved radiolarians were recovered from two samples of red micrite. From these samples, we recovered *Dictyomitra formosa* Squinabol, *Pseudotheocampe tina* (Foreman), *Amphipyndax stocki* (Campbell and Clark), *Myllocercion* sp., and *Rhopalosyringium scissum* O'Dogherty. According to O'Dogherty (1994), the first appearances of *P. tina* and *R. scissum* are near the base of Turonian. Thus, these radiolarians are assignable to early Turonian or slightly younger age.

Very recently, the details of volcanostratigraphy and geochemical features for the upper part of the V2 lava including boninite are becoming clearer (S. Miyashita, pers. comm.). Compilation of the present result, in combination with the volcanostratigraphy and future reinvestigation of radiolarian biostratigraphy across a much wider area, will provide essential information on age constraints and formation process of the Oman ophiolite.

キーワード: オマーンオフィオライト, 後期白亜紀, 放散虫, 遠洋性堆積物

Keywords: Oman Ophiolite, Late Cretaceous, radiolarians, pelagic sedimentary rocks