

# 新たな系統樹の提案 “Bacteria-first” : 生命誕生場は海ではなく陸

## Newly proposed “Bacteria-first” phylogenetic tree of life with landmass and not ocean being the mother of life

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プロゲノム、LUCA、コモノムといった単語は、提案者によって少しずつ定義が異なるが、我々の最も古い祖先を指す言葉である。このような最古祖先の生物は現在の地球上には当然存在していないが、最古生命の手がかりはゲノムの中に残されていると多くの生物学者は考えている。現在までの研究で、リボソームRNAの構造を手掛かりに、生命は、古細菌、真正細菌、真核生物の3つに区別されているが、最古の生物はいったい何だったのか？

一般的に、古細菌は真正細菌より古いと考えられている。これは、古細菌が初期地球に似た還元的環境をより好むのに対し、多くの真正細菌は酸化環境に棲息していることが理由である。古細菌の生息場としては、中央海嶺熱水系が示されており、中でも超好熱菌は系統樹の根元に近いところに位置する。水素発生型の還元的熱水系が発見された後は、多くの人が、生命誕生場として中央海嶺熱水系を考えるようになった。

しかし、生命の誕生が現在の生息場で起きたとは限らない。たとえば、陸上の還元場で誕生した生物が、中央海嶺熱水系の還元場に移動したとも考えられる。実際に、冥王代の地球表層（陸上）では自然原子炉間欠泉内部に還元場があり、そこでは還元ガスの濃集が可能だった。つまり、生命誕生場が還元場であったというなら、陸上の還元場が生命誕生場だったと説明することもできる。実際に真正細菌の系統樹の根に近いところでは、好熱性細菌や硫黄細菌が位置することがわかっており、真正細菌の中でも古いものは、超還元環境に生息していたことを意味している。

生命誕生の条件を考えてみると、いくつかの鍵となるのは、淡水の供給、窒素や栄養塩の供給、さらに周期的環境などがあげられる。冥王代の海洋は、重金属元素に富む超酸性かつ超高塩分の化学組成を持つうえに、生物の体に必須である窒素の供給もないことから、生命誕生場とはなりえないことは明らかだ。一方で、冥王代の原初大陸には、これらの条件を満たす場があり、それが自然原子炉間欠泉である。

そこで、ここでは系統樹の新たなモデルとして、“Bacteria-first”モデルを提案したい。このモデルは、陸上の自然原子炉間欠泉で三段階進化によって生命が誕生したとするモデルに基づいている。Petrov(2014)は、リボソームをもとに古細菌は真正細菌よりも若いことを推察したが、これは我々のモデルに矛盾しない。生命の起源研究における次の目標は、おそらくRNAリボソームになるだろう。中央海嶺に棲息する古細菌のRNAリボソームが真正細菌のそれと類似しているか否かは非常に重要なポイントである。そして、古細菌が先か、真正細菌が先かの議論は、今後、レトロポゾン（サイン）法などを適用し遺伝子の平行移動を取り除いた形で進めていく必要がある。

キーワード：生命の起源、真正細菌起源、リボソームRNA

Keywords: origin of life, Bacteria-first, Ribosomal RNA

## 前期太古代のレンズ状微化石における形態の多様性は初期生命の種分化の証拠か？

### Can speciation of early life be evidenced by morphological variation of Early Archean lenticular microfossils?

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Organic-walled lenticular microstructures up to 100  $\mu\text{m}$  along the major dimension were discovered from Early Archean (3.4 Ga) cherts of the Strelley Pool Formation in the Pilbara Craton, Western Australia (Sugitani et al., 2010, 2013). They have been extensively studied multi-disciplinarily, including classical microscopic observation, palynology, scanning electron microscope (SEM), transmission electron microscope (TEM), Raman spectroscopy, and secondary ion mass spectroscopy (SIMS) (Lepot et al., 2013; Sugitani et al., 2015a; Williford et al., 2015). Their biogenicity is now well established and appears to be widely accepted; however, their biological affinities are still poorly understood. Here we once keep away from this issue, and focus on their morphological variation in the context of taxonomy, base on new data of lenticular microfossils from the two remote localities of the 3.4 Ga Strelley Pool Formation, one in the Goldsworthy greenstone belt and the other in the Panorama greenstone belt.

The two fossil localities of the 3.4 Ga Strelley Pool Formation in the Goldsworthy and the Panorama greenstone belts are distinct in lithostratigraphy and trace element characteristics of fossil-bearing black cherts, suggesting that they represent different environments of habitat. Fossil-bearing black chert in the Goldsworthy greenstone belt had probably deposited in a terrestrial hydrothermal system, whereas that in the Panorama greenstone belt did in marine setting, probably intertidal to subtidal zone (Sugitani et al., 2013, 2015b). Measurement of major and minor dimensions of their polar views of over 1000 specimens indicates that lenticular microfossils from these two localities are statistically distinct in ellipticity. Although SPF lenticular microfossils are thought to have had reproduced by binary fissions, higher ellipticity of the Panorama specimens cannot be explained by vegetative growth of circular type that dominates the Goldsworthy population, because there is no correlation between ellipticities and major dimensions. Also taphonomy cannot explain the difference in ellipticity between two populations. Considering that both the elliptic and circular types have a common body plan (lenticular body and surrounding flange), the two populations of different ellipticities likely represent subgroups of the same taxon. Namely, the SPF lenticular microfossils have a common ancestor and thus could be the earliest evidence for speciation, possibly through adaptation to different environments. Although how the difference of ellipticity worked is unclear so far, we assume that it was related to different hydrodynamics of the habitats.

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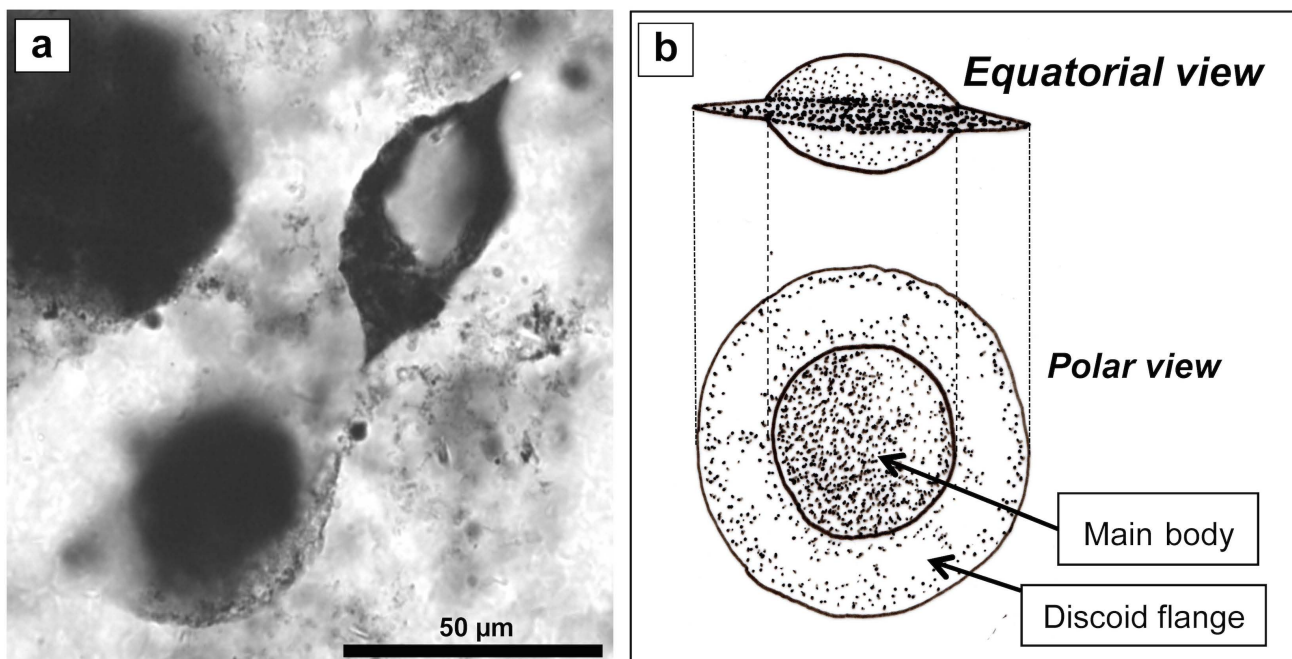
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キーワード：太古代、微化石、初期生命、形態、種分化

Keywords: Archean, microfossils, early life, morphology, speciation



## 深海相ペルム紀-三疊紀境界層に記録された鉄・モリブデンの化学種記録 Reduced iron and molybdenum in the end-Permian sulphidic sedimentary rocks

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The presence of reduced iron (Fe) and significant increases in molybdenum (Mo) concentration in sedimentary rocks have been taken as evidence of reducing and highly reduced sulphidic depositional conditions, respectively. We performed extended X-ray absorption fine structure (EXAFS) analyses of Fe and X-ray absorption near edge structure (XANES) and Mo in lithified silicic sedimentary rocks from the pelagic deep-sea Permian–Triassic boundary section to determine their oxidation states and the bonding environments of the host phase of each element. The most dominant Fe-bearing minerals were pyrite and illite. Ferric minerals such as hematite were absent, which suggested reducing depositional and/or post-depositional conditions throughout the Permian–Triassic transition. On the other hand, tetravalent and hexavalent Mo (Mo(IV) and Mo(VI), respectively) were observed in the studied section by the XANES analysis. It is impossible to rule out the oxidative weathering in the outcrop and/or following experimental procedures for the presence of Mo(VI)-O species. However, Mo(IV)-S species dominates in the end-Permian horizons, which suggests that any post-depositional oxidative effect did not occur significantly at least for these samples and originated from sulphidic depositional environment with following diagenetic effects. Considering features of matured rock samples, preservation of Mo(IV) species would be helped by molybdenite formation during thermal late diagenesis and dense cementation by silicic materials forming matured sedimentary rocks. The absolute concentrations of Fe hosted in pyrite (Fe-pyrite) and S-bonding Mo(IV) (Mo(IV)-S) increased in the siliceous claystone beds just below the mass extinction boundary. However, the Fe-pyrite concentrations decreased while those of Mo(IV)-S species increased across the mass extinction boundary. This trend reflects decreased reactive Fe in bottom waters, likely caused by massive pyrite formation and increased reduced Mo(IV) under the prolonged stagnation of sulphidic deep water and ambient continental margin regions at the end-Permian.

キーワード : iron、molybdenum、X-ray absorption near edge structure (XANES)、X-ray absorption fine structure (XAFS)、the end-Permian mass extinction、pelagic deepsea

Keywords: iron, molybdenum, X-ray absorption near edge structure (XANES), X-ray absorption fine structure (XAFS), the end-Permian mass extinction, pelagic deepsea

## 北西パンサラッサ海域のトアルシアン期酸化還元状態と海洋生物への影響：西中山層における研究

### Toarcian redox history and biotic response in NW Panthalassic margin: Multiproxy analysis of the Nishinakayama Formation

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The early Toarcian (Early Jurassic) oceanic anoxic event (T-OAE) was a significant palaeoenvironmental perturbation that led to marked changes in ocean redox condition and ecosystem. This event is characterized by the widespread occurrence of a ~3–7‰ negative excursion in the carbon-isotope ( $\delta^{13}\text{C}$ ) composition of marine organic and inorganic matter and terrestrial plant material. In addition, one of the distinct phenomena during the early Toarcian is the abrupt rise of  $p\text{CO}_2$  and consequent global warming, which led to enhanced hydrological cycles and ocean anoxia. Despite such global impacts of the event, the precise palaeoenvironmental and palaeoecological changes during the event from sections outside of the Boreal and Tethys realms are uncertain. To address this issue and further expand our understanding of the nature of the event, we investigated the Nishinakayama Formation of the Toyora area, southwest Japan, which represents an organic-rich silty mudstone-dominated succession deposited at the shallow margin of the northwestern Panthalassa Ocean. In particular, we focused on the reconstruction of ocean redox history and biotic response, based on available new data. As a result, pyrite framboid size analysis suggested that water-column euxinia occurred during the negative  $\delta^{13}\text{C}$  excursion, although available geochemical data suggested suboxic bottom water. According to our results and previous studies that indicate a pelagic euxinia in the central Panthalassa, widespread euxinic condition was achieved in the Panthalassa Ocean during the T-OAE. Detailed sedimentological analysis of silty mudstones and sandstones revealed that terrigenous material input was increased during the negative  $\delta^{13}\text{C}$  excursion. In addition, at least in some cases during the negative  $\delta^{13}\text{C}$  excursion, terrigenous material was directly delivered from river floods by hyperpycnal flows, which may have provided oxic water into bottom water. Ammonite (e.g., *Dactylioceras* and *Harpoceras*) size analysis suggested that ammonites were, in general, negatively affected by water-column euxinia, although there were species-specific differences in biotic response between *Dactylioceras* and *Harpoceras*. Namely, the size of *Dactylioceras* decreased during the interval of water-column euxinia and its aftermath. On the other hand, the size of *Harpoceras* also decreased during the interval of water-column euxinia, but increased directly after the termination of the euxinic interval. The same pattern was also recognized in *Dactylioceras* and *Harpoceras* in Tethys realm, suggesting the global nature of biotic response to the Toarcian palaeoenvironmental perturbations.

## Terrestrial environmental reconstruction by biomarker analyses of coaly sediments in the Cretaceous Hakobuchi Formation, Yezo Group, Hokkaido, Japan

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Paleoenvironmental studies were extensively carried out in Cretaceous marine sediments in Hokkaido, Japan. However, there have been few paleoenvironmental investigations for Cretaceous terrestrial area. We focus coal and coaly sediments in terrestrial formations distributed in Hokkaido to reconstruct the variations in terrestrial environment and climate. The Hakobuchi Formation belongs to the Yezo Group in Hokkaido, Japan. This formation consists of sandstones and sandy siltstones in the Campanian to Maastrichtian. Some thin coal beds are lying the formation. Each coal bed thickness is about 2 m so the information about a cycle of the peat bog formation is preserved in narrow area. In the present study, we analysed biomarkers in the coal beds and the upper or lower sediments from the Hakobuchi Formation in the Campanian to Maastrichtian to improve the analyses for peat bog formation and coalification process and to examine variations of terrestrial environments.

Biomarkers such as *n*-alkane, hopanoid, steroid, sesquiterpenoid, and diterpenoid are mainly detected. Organic matter in coals in the Hakobuchi Formation are confirmed to be immature (sub-bituminous coal). The distribution patterns of *n*-alkanes show strong odd carbon number preferences. Each samples indicate different distribution patterns which maximising at *n*-C25, *n*-C27 or *n*-C29, and their averaged chain length (ACL) values are 26.7 - 28.4. Short chain *n*-alkanes (*n*-C23, *n*-C25) are known to be related to the aquatic ecosystem. The sample showing low ACL may have been deposited under strong aquatic ecosystem. Most samples indicate  $\alpha$ - and  $\beta$ -hopanes distribution maximising at C31. We found that C31/C30 and C31/C32 hopane ratios are well linearly correlated to ACL values. The relationships suggest that microbial degradation causes important role for peat bog ecosystem and coalification processes. Sesquiterpenoids and diterpenoids, which are derived from gymnosperm, are mainly detected. However, triterpenoids, which are originated from angiosperm, are not much detected. Thus, it is possible that gymnospermous plants were dominant in the paleovegetation in Hokkaido Island during the Campanian to Maastrichtian.

キーワード：陸上古環境、バイオマーカー、白亜紀、石炭

Keywords: terrestrial paleoenvironment, biomarker, Cretaceous, coal

## 小惑星衝突場所により変る生命史：人類出現の低確率

# The history of life changeable by asteroid impact site: low probability of appearance of humans

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An asteroid 9 km in diameter hit the hydrocarbon- and sulfur-rich sedimentary rocks in present-day Mexico 66 million years ago. Recent studies showed that the impact at Yucatan Peninsula burned hydrocarbon and sulfur in the target rocks forming stratospheric soot and sulfate aerosols, which caused extreme global cooling and draught, and in turn to a mass extinction including dinosaurs, leading to appearance of humans. The amount of hydrocarbon and sulfur in rocks varies widely depending on location, which suggests that cooling and extinction level was dependent on impact site. Here we show that probability of the significant global cooling, the mass extinction, and subsequent appearance of humans was 13% when the asteroid hit the Earth. This significant event could have occurred when the asteroid hit hydrocarbon-rich areas occupying 13% of the Earth surface. The history of life is changeable by asteroid impact sites.

キーワード：大量絶滅、白亜紀—古第三紀境界、小惑星衝突、人類出現、恐竜の絶滅

Keywords: mass extinction, Cretaceous-Paleogene boundary, asteroid impact, appearance of humans, extinction of dinosaurs

# 始新世の温暖化イベント時における光共生性浮遊性有孔虫の動態

## Faunal dynamics of photosymbiotic planktic foraminifers in the Eocene thermal event

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中生代ジュラ紀中期に出現し、現在まで繁栄を続ける浮遊性有孔虫は、その進化の過程において光共生生態を獲得し、現生浮遊性有孔虫の一部の種も細胞内に渦鞭毛藻や黄金色藻などの藻類を共生させる。浮遊性有孔虫にとっては、藻類の光合成による光合成産物が供給されることで栄養の獲得を強化し、遠洋の貧栄養な海洋表層にも生息が可能となっている。一般に共生する藻類の光合成は、宿主の石灰化を促進すると言われており、共生藻類は栄養の供給のみならず、殻の形成という観点でも重要な役割を担っている。現生のサンゴなどの研究では、この藻類と炭酸塩硬組織を構成する生物との共生関係は、海洋の温暖化の影響を大きく受け、場合によっては温暖化によって共生関係が崩壊することが報告されている。地球史においても、温暖化気候状態の時期には、同様の事象がおきていたと考えられ、古第三紀始新世の温暖化イベントの一つであるMiddle Eocene Climatic Optimum (MECO; ~40Ma) では、海水温の上昇に伴う光共生性浮遊性有孔虫の相対存在量の減少が報告されている (Edgar et al., 2013)。このように地球史における温暖化イベントは、光共生の浮遊性有孔虫多様性や存在量に影響を与えていると考えられるが、温暖化による光共生の浮遊性有孔虫の個体数の変動のメカニズムや各属の反応の違いなどの詳細については未解明な点が多い。

そこで本研究では、始新世中期に発生した温暖化の極大期における浮遊性有孔虫の群集組成解析を行い、温暖化による光共生性浮遊性有孔虫の多様性と存在量の変動を議論する。対象とした試料は統合国際深海掘削計画第342次航海において、北大西洋のNewfoundland沖 (Site U1407) より得られた、45~50Maの堆積物である。本地域においては、始新世中期に堆積物中の炭酸塩含有量の減少が確認されており、温暖化が生じていたことが示唆されている。本試料の全岩の炭酸塩の炭素・酸素同位体比を測定したところ、この炭酸塩含有量の減少と同時に酸素同位体比の減少、すなわち温暖化が生じていたことが確認された。この炭酸塩含有量の減少は、炭酸塩補償深度の浅化を反映していると推測される。さらに、この堆積物中の炭酸塩含有量の減少の前にも2回の温暖化が生じており、短い間に3回の温暖化イベントがあり、より若い時代の温暖化イベントは堆積物中の炭酸塩含有量の減少を伴うようなイベントであったことが明らかになった。この3つの温暖化イベント時における浮遊性有孔虫の化石群解析を行ったところ、最初の温暖化時に浮遊性有孔虫全体のフラックスが減少し、2回目の温暖化時には大きな変動はないものの、炭酸塩含有量の減少を伴う3回目の温暖化時にはフラックスが増大していることが明らかになった。フラックス減少時には、光共生性の種も、非共生性の種も同時に減少しており、海洋の混合層から躍層以深までの全体の変化を示していると考えられる。全岩の炭酸塩の炭素同位体比も同時に減少していることから、これは一次生産量の減少に起因すると推測される。その後、低フラックス状態が持続し、3回目の温暖化イベント時には表在性の光共生種である *Morozovella*, *Morozovelloides* のフラックスがさらに減少し、非共生種のフラックスの増大が認められた。これは、温暖化イベントに対して光共生種が大きく影響を受けたことを示しており、温暖化に起因する光共生系の崩壊を示している可能性がある。一方、同じ光共生種である *Acarinina* のフラックスは増大していることが示された。Pearson et al.(2001)では、*Acarinina* と *Morozovella* は混合層のほぼ同じ水深に生息していることが示されており、両者の違いは光共生系そのもの、あるいは光共生系への依存度の違いなどを示している可能性がある。



る。

キーワード：浮遊性有孔虫、光共生、始新世、温暖化イベント、化石群組成

Keywords: Planktic foraminifer, Photosymbiosis, Eocene, Thermal event, Faunal dynamics

# Late Eocene–early Oligocene deep-sea ostracode faunas at Integrated Ocean Drilling Program Site U1411, off Newfoundland, northwestern Atlantic

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Under the North Atlantic Deep Water (NADW), modern ostracode faunas are characterized by *Krithe*, *Poseidonamicus*, and *Henryhowella* (Dingle and Lord, 1990, *Palaeogeogra., Palaeoclimat., Palaeoeco.*, 80, 213–235). The NADW faunas are called the “psychrosphere” fauna and considered to have appeared during the Eocene–Oligocene climatic transition (e.g., Benson, 1975, *Lethaia*, 8, 69–83). Using foraminiferal carbon stable isotopes and Nd isotopes, some studies hypothesize that the NADW was initially formed during the early Oligocene (e.g., Via and Thomas, 2006, *Geology*, 34, 441–444; Katz et al., 2011, *Science*, 332, 1076–1079). The formation of the NADW may link with the “psychrosphere” fauna. The formation of the “psychrosphere” fauna is still in controversy (e.g., Dall’Antonia et al., 2003, *Mar. Micropal.*, 48, 91–106). In the North Atlantic, any studies have not studied changes in deep-sea ostracode faunas during the Eocene–Oligocene climatic transition. Here I report ostracode taxa from the late Eocene–early Oligocene ostracodes from Integrated Ocean Drilling Program (IODP) Site U1411, off Newfoundland, North Atlantic, and discuss the faunal changes during the Eocene–Oligocene climatic events.

At Site U1411 (41°37′ 5.94″ N, 48°59′ 59.94″ W), three holes were drilled on the seafloor of the Southeast Newfoundland Ridge at 3299 m depth (Norris et al., 2014, *Proc. IODP*, 342). I took 132 sediment samples of ~20 cm<sup>3</sup> volume from silty clay with nannofossils (140 to 235 m CCSF) and nannofossil chinks with foraminifers (235 to 266 m CCSF). Using the planktic foraminiferal and calcareous nannofossil biostratigraphy, the core sediments are dated to be ~37.9–33.4 Ma, the late Eocene to early Oligocene (Norris et al., 2014).

Entirely 332 specimens were obtained from 67 of 132 sediment samples. 23 taxa were identified.

Through the late Eocene to the early Oligocene, *Krithe crassicaudata* occurs most frequently.

*Henryhowella asperrima* and *Platyleberis* sp. are often found. The samples contain *Poseidonamicus pseudorobustus*. The faunas contain the genera diagnostic for the NADW. At ~36.4 Ma, the ostracode abundance dropped off from 1–27 to 1–9 specimens, indicating changes in export productivity. The decrease in the abundance fell in the Late Eocene warming event of Bohaty and Zachos (2003, *Geology*, 31, 1017–1020). The faunas show no clear changes in taxonomic composition at and above the E/O boundary (33.7 Ma). At ~33.7 Ma, an increase in abundance of *Krithe* is observed and is coincidently with “*Krithe* pulse” in the Massignano Global Stratotype Section and Point in the Tethys Ocean (Slotnick and Schellenberg, 2013, *Mar. Micropal.*, 103, 68–84).

キーワード : Eocene、 Expedition 342、 Integrated Ocean Drilling Program、 North Atlantic、 Oligocene、 Ostracoda

Keywords: Eocene, Expedition 342, Integrated Ocean Drilling Program, North Atlantic, Oligocene, Ostracoda

## 中生代水生羊膜類の骨格に起きた革新的進化

### Innovative evolutions in the skeleton of Mesozoic aquatic amniotes

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哺乳類、爬虫類、鳥類を含む系統群である羊膜類 (Amniota) は、石炭紀、乾燥した陸上での生活に適応した脊椎動物として誕生した。しかしペルム紀に入ると、メソサウルス類 (Mesosauria) やエオスキア類 (Eosuchia) など、羊膜類の一部は再び水中生活に戻っていった。ペルム紀-三畳紀境界後に現れた様々な海生羊膜類は、それまで魚類が占めていた頂点捕食者のニッチを奪うほどに繁栄した。中生代の海生羊膜類といえば、胎生、流線型の体、魚型の背鰭・尾鰭、もしくはペンギン型のフリッパーの発達、骨密度の極端な変化など、遊泳や潜水に関連した機能的制約による構造進化の好例として紹介されることが多い。一方で海生羊膜類の中には、陸上生活という制約から開放されたことにより、陸生羊膜類の基本形とはかけ離れたボディプランを獲得するものも現れた。例えば、テチス海の三畳系を中心に発見されている板歯類 (Placodontia) やサウロスファルギス類 (Saurosphargidae) では、体を覆う皮骨が発達し、カメ類の甲羅に比較される外骨格状の構造が発達することもあった。また前期三畳紀に登場した魚鰭類 (Ichthyopterygia) では、前後肢の指の数が5本よりも多くなるhyperdactylyと、指の節数が増加するhyperphalangy、一方で四肢骨格要素の形態が単純化し互いに区別できなくなっていくmesopodializationが顕著であった。後期三畳紀に現れた長頸類 (Plesiosauria) は頸椎を増やすことで長い頸を獲得し、後期白亜紀には76個もの頸椎を持つものも現れた。そして中国の下部三畳系のみから発見されているフーペイスクス類 (Hupehsuchia) は、背側の正中に1~3層に積み上がった重厚な皮骨や、隙間なく折り重なる肋骨、一部のアジ科魚類の稜鱗に似た体側の皮骨 (もしくは腹肋骨)、そして背腹2節に分節した椎骨棘突起など、他の羊膜類には見ることでできない特殊な骨格構造を数多く持っていた。以上のように、中生代の水生羊膜類の骨格形態の進化は、極めて高い自由度のもとに起こり、特に三畳紀の海洋には、現存する動物の基本ボディプランを大きく逸脱するものが存在していた。これらの生物の骨格構造およびその発生メカニズムを復元することは、羊膜類の形態進化における真の可塑性を明らかにし、羊膜類の形態がいかなる制約のもとに淘汰されてきたかを理解する鍵となるであろう。

キーワード：古生物学、脊椎動物、形態、適応、羊膜類、P/T境界

Keywords: Paleontology, Vertebrata, morphology, adaptation, Amniota, P/T boundary

# Spatial and temporal distribution of Desmostylia (Mammalia) and implications on its evolution and extinction

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Desmostylia is one clade of extinct aquatic mammals with no close living relative. Its fossil records are known from the uppermost Eocene to Miocene marine strata in the North Pacific Rim and its paleoecology is still debated. One reason of this was due to a paucity of available data concerning geographic distributions and time ranges of its taxon. However, currently, more data have become available, making analyses of spatial and temporal distributions of various desmostylians possible. Accordingly, we summarize occurrence records of desmostylians and discuss the significance and implications of their spatial and temporal patterns for their paleoecology. We reviewed previous reports of desmostylian occurrences based on the literature and a database and mapped them by stage and taxon. The result showed that the temporal range of definite desmostylian records is from around the Eocene/Oligocene boundary through 10 Ma. Furthermore, it was confirmed that Desmostylidae had a wider geographic distribution than Paleoparadoxiidae and was adapted to very cold environments. In addition, it was suggested that *Cornwallius*, a basally-diverging member of Desmostylidae, went extinct possibly through competition with more derived *Desmostylus*. The last desmostylian that survived into the late Miocene in the North Pacific Rim was *Desmostylus* spp. *Desmostylus* became completely extinct likely due to a rapid decrease of shallow marine areas associated with a major marine regression at around 10 Ma.

キーワード：漸新世、中新世、デスモスチルス類

Keywords: Oligocene, Miocene, Desmostylia

## Isotopic dietary evolution linking with lineage evolution and interspecific competitions in small mammals, using Miocene rodents as a case study

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Abiotic forces, including climate change, continental drift, and geographic barriers, have been viewed as the major driver of macroevolutionary change in organisms, evidenced by various studies from empirical, ecological, phylogenetic, and paleontological approaches on different time/spatial scales and resolutions. On the other hand, biotic interactions such as predator-prey interactions, interspecific competition for food, density-dependent natural selection has been limitedly recognized as a factor for shaping evolutionary patterns. In vertebrates, biotic interactions can be directly observable in field studies. However, the nature of long generation times in animals makes it difficult to obtain general patterns of biotic interactions apart from seasonal variations in the relatively short-term studies. In vertebrate paleontology, despite the advantage of the long-term time scales, possible morphological diversification and/or constraints due to the presence of competitors or competitive lineages is rarely documented.

In this study, we utilized two paleontological events of small mammals from in the Miocene Siwalik Group of northern Pakistan in order to evaluate isotopic dietary evolution in relation to (1) lineage evolution and (2) interspecific competitions. The first event is that murine rodents (true mice and rats) from the region record the earliest appearance of the group to its diversification into two sympatric lineages (here called *Karnimata* and *Progonomys* lineages), beginning before and continuing through a unidirectional shift from C<sub>3</sub>- to C<sub>4</sub>-dominated vegetation. The second event is that cricetid rodents (hamsters) were completely replaced by murine rodents (true mice and rats) at least within 5 million years after the earliest appearance of basal murines in Pakistan. Carbon and oxygen isotope values in enamel of first lower molars were obtained by laser-ablation GC-IRMS to infer dietary and habitat preferences, ranging from 15 to 6.5 Ma. Tooth shape of upper first molars was defined by morphometric distance of ecomorphological characters, 2D geometric morphometric analysis of tooth outline, and 3D GIS models.

For the topic of lineage evolution, our dataset demonstrates that murine rodents experienced a remarkable C<sub>3</sub>-C<sub>4</sub> dietary shift with the *Karnimata* lineage consuming a greater percentage of C<sub>4</sub> grasses than the *Progonomys* lineage at any given time. In 2D analyses, adaptive change of tooth morphology in the *Karnimata* lineage is more strongly associated with increasing chewing efficiency in the propalinal direction of mastication. However, in both clades, preliminary 3D model analysis shows that more derived (and younger) species have average slopes of cusps directed more anteriorly than more basal (and older) species, which is also related to the propalinal chewing direction. These results indicate that while both clades morphologically adapted to varying contributions of C<sub>4</sub> grasses to their diets, selection pressure forcing dental adaptations was differentially greater in the *Karnimata* lineage.

For the topic of interspecific competition, our initial data suggest that the dietary conservatism among the fossil rodents can be detected even in the C<sub>3</sub> plant-dominated region but that change in dietary niche

breath could not be observed as the variance. Throughout the 5 million-year range of coexistence, mice have isotope values similar to phylogenetically closer taxa, whose size is smaller than more distant taxa that are similar in size to the mice. Although the power of the statistics is still weak due to the small number of the samples, phylogeny is a more important factor than body size in the competition.

キーワード：古脊椎動物学、同位体古生態学、進化古生態学

Keywords: Vertebrate Paleontology, isotopic paleoecology, evolutionary paleoecology

## 深海熱水噴出域固有動物の海洋表層分散

### Larvae from deep-sea hydrothermal vents disperse in surface waters

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深海熱水噴出域に生息する動物種の多くは底生である。従って、浮遊幼生期の分散が種の地理的分布を決定し、また個体群の維持に重要な役割を果たす。熱水性動物の幼生は卵黄栄養型とプランクトン栄養型に二分でき、前者は深層で分散すると考えられている。一方、後者は孵化後に中層まで鉛直移動し摂餌・分散するとされる。演者らは、世界の熱水噴出域に生息するシンカイフネアマガイ亜科の腹足類について、種分類体系の構築、地理的分布の把握、集団遺伝解析、幼生飼育実験および同位体化学分析を行った。その結果、深海熱水噴出域の固有動物が、植物プランクトン食の浮遊幼生として有光層まで鉛直移動し、表層流により長距離分散することを初めて明らかにした。種分類、地理的分布と集団構造：太平洋・インド洋・大西洋で採集された1,000個体以上のシンカイフネアマガイ類標本について、形態および分子情報の対比を行い、既知6種と未記載の11種を含む計17種に分類した。また、多くの種が広域分布 (< 3,200 km) を示し、その分布全域にわたり任意交配集団を形成することを明らかにした。幼生飼育実験：伊豆一小笠原島弧と沖縄トラフに分布するミョウジンシンカイフネアマガイについて、半年間の幼生飼育実験と行動観察を行った。同幼生は孵化後継続的に上昇遊泳し、また生残・成長の至適水温は種の地理的分布域における表層水温と一致した。幼生期は1年以上に及び、その間、表層流により長距離分散することが示唆された。同位体比分析：シンカイフネアマガイ類の着底稚貝における貝殻酸素同位体比によっても、表層水温中での幼生殻形成、すなわち個体発生に伴う表層への鉛直移動が支持された。

上記に加え、熱水域固有の甲殻類についても集団遺伝解析を実施し、プランクトン栄養幼生の表層分散が熱水動物において一般的な事象である可能性を示した。以上の結果は、表層水温が、深海熱水噴出域に固有な動物種の地理的分布を規定する一要因であることを示唆する。これは熱水動物の生態・進化に関わる全く新たな仮説であり、光合成生態系-熱水噴出域生態系間の物質循環の観点からも極めて興味深いと考える。

キーワード：生物地理、初期生態、幼生分散、鉛直移動、表層水温

Keywords: Biogeography, early-life history, larval dispersal, vertical migration, SST