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Rapid change of atmosphere in the Hadean Earth: Beyond Habitable Trinity on a tightrope

Rapid change of atmosphere in the Hadean Earth: Beyond Habitable Trinity on a tightrope

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Surface environment of Hadean Earth is a key to bear life on the Earth or not. All of previous works assumed that high PCO2 has been decreased to a few bars in the first a few hundreds millions of years (e.g., Zhanle et al., 2011). However, this process is not easy because of material and process barriers as shown below. Four barriers are present.

First, the ultra-acidic pH (<0.1) of 4.4Ga ocean prevented the precipitation of carbonates at mid-oceanic ridge or its pseudo-system through water-rock interaction after the birth of primordial ocean. To overcome this barrier, primordial (anorthosite + KREEP) continents must have been above sea-level to increase pH rapidly through hydrological process.

Second, major cap rocks on the Hadean oceanic crust must have been komatiite with minor basaltic rocks to precipitate carbonates through water-rock interaction and transport them into mantle through subduction at higher than the intermediate P/T geotherm on the Benioff plane. If not, carbonate minerals are all decarbonated at shallower depths than the Moho plane. Komatiite production depends on mantle potential temperature which must have been rapidly decreased to yield only Fe-enriched MORB by 3.8Ga.

Third, the primordial continents composed of anorthosite with subordinate amounts of KREEP basalts must have been annihilated until 4.0Ga to alter pH to be possible to precipitate carbonates by hydrothermal process. The value of PCO2 must have been decreased down to a few bars from 35 bars at TSI (total surface irradiance) = 75% under the restricted time limit. If failed, the Earth must have been Venus state which is impossible to bear life on the planet.

Fourth is the role of tectonic erosion to destroy and transport the primordial continent of anorthosite into deep mantle by subduction. Anorthosite + KREEP was the mother ' s milk grow life on the Earth, but disappeared by 4.0Ga or even earlier, but alternatively granites were formed and accumulated on the Earth to supply nutrients for life. This is time-dependent process to increase new continents.

Fifth is the water content 3-5km thick, if the value was over, no way to bear life nor evolution afterwards.

After all, the Hadean Earth has passed the really naive tightrope processes to bear life. If any of above five conditions was lost, life has not been appeared.

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世界古地理と生命進化：その３　古生代
Global paleogeography and life evolution: 3. Paleozoic

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In modern oceans, there is no remaining information about past oceans older than 200Ma. For reconstructing paleo-plate motions with respect to collision-amalgamation of continents, on-land geology, in particular, orogenic belts that cemented older continents provide a sole source of information.

The onset of the Paleozoic is marked by the Gondwana semi-superocntinent formation at 540Ma around the South Pole. During the Paleozoic, Gondwana broken up, whereas Laurentia aggregated to form a real supercontinent by 430 Ma. Immediately after that, Gondwana began to be rifted, and its fragments and other blocks such as Baltica, Kazakhstan, Siberia, N China, South China, Indochina, and smaller pieces of Cimmeria, were dispersed; most of these were eventually amalgamated to from the northern half of Pangea, i.e., Laurasia.

The mode of mantle dynamics was represented by the high MORB production rate during 540-350Ma, almost the same as that in the Cretaceous, but it dropped after 350 Ma, probably by the activation of Pacific superplume. According to such continental assembly/ disassembly, sea-level changed remarkably as represented by the glaciation/deglaciation; the major Gondwana glaciations during the Carboniferous-Permian with 3 more minor episodes; the Paleozoic-Mesozoic transition interval might be close to the snowball Earth condition with extremely cold climate. The continent dispersion/amalgamation likely drove the development of remarkable floristic provincialism, e.g., Gondwana, North America, and Angara, that particularly reflected the formation of Laurentia. Not only the post-Ordovician land trees, this also controlled the diversification pattern of soil bacteria, moss, and land animals. Biodiveristy changes including mass extinctions occurred in accordance with the secular change in seawater Sr isotope ratio; extremely high in the Cambrian with high bio-divesrification, and the minimum at the G-L boundary (Permian) with onset of the greatest mass extinction.

キーワード: 古地理, 古生代, 超大陸, ゴンドワナ, パンゲア, 生命進化
Keywords: paleogeography, Paleozoic, supercontinent, Gondwana, Pangea, evolution

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ネオジム同位体シグナルからみた後期白亜紀北西太平洋における中／深層水形成
Neodymium isotopic signature for deep/intermediate water formation in the late Cretaceous northwestern Pacific

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白亜紀は，地球史において最近の典型的な温室地球時代として知られており，大気中の二酸化炭素濃度の増加に対する気候感度を推定する際の極相のひとつとして多くの研究が行われてきた．未だに大気中の二酸化炭素濃度の推定には不確定要素が多いものの，海洋水温は様々な緯度や海域において解析され，表層水温の緯度勾配や表層・深層水温の時代変遷等が明らかにされてきた．

近年では，地球表層におけるエネルギー循環の担い手の一つとして，当時の海洋循環に関する研究も盛んに行われるようになってきた．しかし，これらの研究の多くは大西洋を対象としたものであり，白亜紀においては唯一の大洋であり，全球のエネルギー循環に大きな影響を及ぼしたと考えられる太平洋においてはほとんど議論が行われてこなかった．これは，太平洋においては白亜紀の堆積物を含む多くの海洋プレートが海溝部での沈み込みに伴い消失していることが大きな要因となっている．そこで，本研究では，白亜紀の北西太平洋の大陸プレート上に堆積した前弧海盆堆積物を研究の対象とすることで，これまで議論が不十分であった，白亜紀における太平洋の海洋循環の一端を明らかにすることを試みた．研究の対象とした蝦夷層群は，当時の太平洋の北西部に位置しており，水深約 400m 程度の海盆に堆積したものである．この堆積物中に含まれる魚歯化石を抽出し，そのネオジム同位体組成を計測することで，白亜紀後期チューロニアン期後期からカンパニアン期初期における北西太平洋の海洋循環を議論する．

魚歯化石から得られたネオジム同位体組成は－１から－２ ε-unit 程度を中心として分布し，極めて高い値を示した．先行研究によりカンパニアン期からマーストヒリチアン期の赤道太平洋（シャツキー海台）で得られた，－４から－５ ε-unit という値と比較してもより高く，これまで得られている白亜紀のネオジム同位体組成の中でも最も高い値の一つに相当する．これは，北西太平洋の島弧による火成活動に由来すると想定される radiogenic なネオジムを多く含む水塊が存在していたことを示すと考えられる．太平洋の赤道付近で得られている値とも異なることを考慮すると，当時の蝦夷層群が堆積した北西太平洋北緯約 40 度付近には，北西太平洋由来の中，ないし深層水の形成があったと考えることが妥当である．この北西太平洋における中／深層水の形成は，気候モデルによる解析からも示唆されており，特に，白亜紀前期から中期にかけての最温暖期から寒冷化傾向に向かう白亜紀後期においては，北西太平洋で深層水が形成されることが予測されていた．この中／深層水がどの程度の水深にまで達していたか，については現時点では議論することができないが，本研究により，白亜紀後期における海洋循環系の新たな一面が明らかになった．

キーワード: 白亜紀, 海洋循環, ネオジム同位体, 北太平洋, 深層水, 中層水
Keywords: Cretaceous, Ocean circulation, Neodymium isotopes, North Pacific, Deep water, Intermediate Water

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白亜紀温室地球の初期寒冷化のカギ：北太平洋縁辺域のシャンパーニュ階ーマーストリヒト階泥質堆積物
Campanian-Maastrichtian clay-rich sequences along North Pacific Margin: Early Cooling History of Cretaceous Greenhouse

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北太平洋沿岸域には日本，極東ロシア，およびカナダ・アメリカの太平洋岸という広い範囲にわたって白亜紀の陸源堆積物が分布している．複数のセクションで生層序や化学層序の研究が進められ，アプト階からマーストリヒト階に対比されている．大型化石や微化石の生層序に加え，炭素同位体比（δ^{13}C）層序はこれらの層位範囲の中で重要な層準-例えば OAE2 層準-を特定することに貢献してきた．泥が卓越するが故，一部のセクションでは保存が極めて良好であり酸素同位体比の測定が可能である炭酸塩化石が産出する (Moriya et al., 2003).

本研究ではシャンパーニュ階からマーストリヒト階について検討する．この範囲の炭素同位体比層序については，最近欧州を中心に総括がなされ (Voigt et al., 2012)，汎世界的な寒冷化の初期フェーズが記録されていることがわかってきた (Moriya, 2011; Friedrich et al., 2012)．北部「古太平洋」は莫大な熱容量を持っていたと考えられ，その古海洋環境は，この時代以降の温室地球から氷室地球への転換に関する環境変化を理解するうえで重要な視点を供給すると考えられる．

北海道とサハリンに分布する蝦夷層群とその相当層，およびカナダ太平洋岸（ブリティッシュコロンビア）に分布するナナイモ層群について検討を進めている．蝦夷層群からは，明瞭な 1.4-2 ‰の負の δ^{13}C のエクスカーションが見られている．サハリンでは，シャンパーニュ期／マーストリヒト期境界は生層序と古地磁気によって時代を固定することで炭素同位体比のシャンパーニュ階／マーストリヒト階境界事件 (CMBE) とその付随イベントが同定されている．

ナナイモ層群の古地磁気と生層序 (Haggart et al., 2011; Ward et al., 2012) から，δ^{13}C 層序における CMBE が推定される相違範囲を中心に検討を進めたところ，これに対応する 1.5 ‰の負のエクスカーションがノースアンバーランド層上部に確認された．このことにより，サハリン，北海道，およびブリティッシュコロンビアの CMBE 層準を高精度で対比することが可能になった.

キーワード: 白亜紀, 温室地球, 寒冷化, カンパニアン, マーストリヒシアン
Keywords: Cretaceous, Greenhouse, Cooling, Campanian, Maastrichtian

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生痕化石によって乱された生痕化石：Chondrites と Phycosiphon に乱された Phymatoderma と，その古生態学的意義
Composite trace fossils: Phymatoderma reburrowed by Chondrites/Phycosiphon and its paleoecological implications

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Composite *Phymatoderma* specimens from the Pliocene deep-sea Shiramazu Formation in Japan, particularly those reburrowed by *Chondrites* and *Phycosiphon*, were analyzed to reveal the differences caused by the activities of these trace-makers. *Phymatoderma* reburrowed by *Phycosiphon* is significantly larger than non-reburrowed *Phymatoderma*, whereas *Phymatoderma* reburrowed by *Chondrites* shows no significant difference in burrow diameter compared with non-reburrowed *Phymatoderma*. The recognized size selectivity (i.e., preference for larger burrows) by the *Phycosiphon* trace-makers can be explained by considering the different feeding strategies of these two ichnogenera; namely deposit-feeding *Phycosiphon*-makers, which must have processed a significant mass of sediment to obtain sufficient organic matter, whereas chemosymbiotic *Chondrites*-producers, which did not require a lot of sediment to obtain nutrients. In order to test these interpretations, records of the Phanerozoic trace fossils reburrowed by *Chondrites*/*Phycosiphon* were compiled. Consequently, the *Phycosiphon* -preference toward relatively larger burrows was recognized, which supports the results of this study. The compilation also indicates that the burrow size has become a limiting factor for the *Phycosiphon*-producers that tried to rework the sediments within previous subsurface burrows, at least for 80 million years.

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古生物多様性評価に対する地質年代単元の長さの影響
The influences of durations of geologic time units on diversity assessments

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The study on global diversity change has been at the center of paleontological studies during the past quarter-century. It is well known that the diversity estimates are readily biased by unevenness of sampling density and there have been many debates on how to remove sampling overprints. In addition, taxonomic richness in a given chronological interval can be also biased by variation in time interval duration because the piled up diversity becomes much greater as the interval gets longer. However, there is no simple solution for this problem because the rate of taxonomic turnover is not uniform through time; that's why we can define discrete chronostratigraphic units with various durations. In addition, actual data registered in the Paleobiology Database indicate less correlation between sampled-in-bin taxonomic richness and time interval duration.

In the present study, the following simple computer simulations were performed to understand biases on diversity estimates derived from variation in time interval duration of chronologic units. A total of one million hypothetical taxa originated and went extinct at each time step (= 0.1 Ma) during the Phanerozoic at a given rate. In the present simulations, most (80%) of the turnovers were set to be concentrated at the boundary between intervals. The following different conditions were adopted for the turnover rates and sampling probability per time step within the interval; 1) fixed independent of the interval duration or 2) inversely proportional to the interval duration. The sampled-in-bin richness was counted for each age in each simulation.

As a result of the above simulation, a positive correlation between piled up diversity and time interval duration was generated when sampling probability was fixed through time. This result seems a natural consequence because the number of sampling for each bin depends on the duration of the time interval and the sample-size effect was not removed in the present analysis. The correlation was particularly remarkable when the mean turnover rate was high and/or probability of sampling was low. However, such a correlation was found also in some cases even when the sampling probability per time step was inversely proportional to the interval duration. In the latter case, the correlation was significant when the sampling probability was moderate.

キーワード: 古生物多様性, 地質年代単元長
Keywords: paleobiodiversity, time interval duration

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北西太平洋における上部漸新統・下部中新統の放散虫化石層序
Upper Oligocene to Lower Miocene radiolarian biostratigraphy in the Northwest Pacific

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Ocean Drilling Program Leg 145 Hole 884B core provides the most continuous Neogene sequence of pelagic sediments in the northwest Pacific. We examined radiolarians from the Upper Miocene to Lower Miocene sediment of the core to establish subdivided radiolarian biozones.

The Upper Oligocene sequence can be divided into three zones, *Actinomma* sp. A, *Hexacontium* sp. B and *Cyrtolagena laguncula* Zones, in ascending order. The Lower Miocene sequence can be divided into four zones, *Botryopyle* sp. B, *Pentactinosphaera hokurikuensis*, *Stichocorys subligata* and *Dendrospyris sakaii* Zones, in ascending order. Each of *Botryopyle* sp. B Zone and *P. hokurikuensis* Zone has been subdivided into subzones a, b and c.

Some episodes of significant faunal changes of radiolarians are identified within the studied interval. They seem not to reflect global cooling events but to reflect some regional events.

キーワード: 放散虫, 化石帯, Site 884, 北太平洋
Keywords: Radiolaria, biozone, Site 884, North Pacific