

The effect of insolation and greenhouse gases on sea ice variations in the Okhotsk Sea during the past 180,000 years

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Sea ice is a critical and sensitive component of the Earth's climate system, and has undergone dramatic reductions in extent and thickness for much of the Arctic in the last few decades (Budikova, 2009; Bader et al., 2011). However, studies covering orbital timescales are still lacking, largely due to the lack of a reliable sea ice proxy in the subarctic regions, or marine sedimentary archives with sufficient age control and temporal resolution. Here we reconstruct high-resolution subarctic Pacific sea ice and summer sea surface temperature records for the past 180,000 years using novel organic geochemical proxies in the central Okhotsk Sea. Our sea ice reconstruction shows significant precession (23-kyr) cycles, which are coupled to local autumn insolation during intervals of low-mid atmospheric CO₂ concentrations (<~260 ppm). We also find that the Okhotsk Sea was ice-free during the mid-late Holocene and throughout the penultimate interglacial (Marine Isotope Stage 5e) when CO₂ concentration exceeded this threshold, suggesting that both insolation and atmospheric CO₂ levels are responsible for controlling sea ice variation in the Okhotsk Sea on orbital timescales. A proxy-model comparison reveals general agreement between the two approaches.

Keywords: Sea ice, Seasonality, Orbital pacing, CO₂ radiative forcing

中期中新世から更新世における日本海の放散虫化石層序-IODP Exp.346- Radiolarian biostratigraphy from Middle Miocene to Late Pleistocene in the Japan Sea-IODP Exp.346-

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In the Integrated Ocean Drilling Program (IODP) Exp. 346, sampling by drilling was conducted at seven sites (U1422–U1427 and U1430) in the Japan Sea. Radiolarians in moderately well preserved states were found in most samples throughout the sequence in varying abundance. Forty-one radiolarian datum events were identified in this study, and the radiolarian zonation that best divides the middle Miocene to Pleistocene sequences with updated ages of radiolarian datum events estimated based on the geomagnetic polarity time scale (GTS) 2012 was applied to the sedimentary sequences in the Japan Sea. Here, four new radiolarian zones are proposed for the Quaternary of the Japan Sea, and one zone is slightly revised to adjust for differences among other zones. The sequences collected at the sites extended from the Pleistocene *Ceratospyrus borealis* Zone to progressively deeper zones as follows: Site U1427, four zones to the Pleistocene *Schizodiscus japonicus*; Site U1422, six zones to the late Pliocene *Hexacantium parviakitaense* Zone; Sites U1423, U1424 and U1426, eight zones to the early Pliocene *Larcopyle pylomaticus* Zone; and Sites U1425 and U1430, fourteen zones to the middle Miocene *Eucyrtidium inflatum* Zone. The absence or extremely rare occurrence of *Stylatractus universus* and *E. matuyamai* indicates that *S. universus* lived in the deep water of the northwestern Pacific and had not been able to migrate into the Japan Sea across the Tsugaru Strait since the Pliocene.

キーワード：放散虫化石層序、日本海、統合国際掘削計画第346次航海

Keywords: Radiolarian biostratigraphy, Japan Sea, IODP Exp.346

Latitudinal changes of radiolarian assemblage in the Japan Sea during Pliocene to Pleistocene

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The Japan Sea (3,700 m maximum water depth) is a marginal sea of the northwestern Pacific, connected to adjacent marginal seas and the Pacific Ocean through four shallow straits (sill depth<130 m). The only inflow of oceanic water is derived from the Tsushima Warm Current (TWC), which enters the Japan Sea through the Tsushima Strait (130 m in depth) in the south.

Radiolarians are one group of the planktic Protista distributed in the world oceans and their fossil records are widely used as a proxy for paleoceanographic study. In the summer 2013, IODP Exp. 346 drilled seven sites in the Japan Sea and two sites in northern part of the East China Sea. We have analyzed radiolarian fossils for all these sites. In this study, geographic distributions of radiolarian assemblage in the Japan Sea during Pliocene to Pleistocene are discussed, such as their relation to global climatic changes and topographic changes with local/regional tectonics.

Significant variations of the well-preserved radiolarian assemblage recorded in the drill sites imply unique oceanic circulation changes in this sea through the examined period. The radiolarian species such as *Dictyocoryne* spp. and *Tetrapyle* spp., which characterize the TWC water occurred commonly during interglacial periods since 1.7 Ma suggesting a beginning of warm water inflow from the southern strait. Relative abundance of these subtropical radiolarians tends to be much higher at the southern sites than at northern sites, related to the relative contribution of the TWC. On the other hand, during the Pliocene period, minor influence of subtropical water was only recognized at the southern site suggesting influence of the TWC restricted to the southern coastal area.

Paleoenvironmental changes of sea surface layer in the IODP Site U1423 recorded by algal biomarkers over the last 4 Ma

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The oceanographic condition in the Japan Sea has significantly changed from its establishment in the Miocene to present associated with global climate change, the intensification of the Asia monsoon system, and local tectonics in the Japanese islands. These changes have been evaluated mainly on the basis of microfossil compositions such as the foraminifera, radiolarian and diatom in marine sediments. However, long-term and continuous variations in sea surface temperature (SST) and marine production have been hardly reported by the biomarker investigations. In the present study, we conduct biomarker analysis such as the long-chain alkenone and alkyl diols in the sediment samples recovered from the IODP Site U1423 in the northeastern Japan Sea, which is under the direct influence of the Tsushima Warm Current (TWC) at the present, to reconstruct the long-term and continuous paleoceanographic variations over the last 4 Ma.

The SSTs estimated by long-chain alkenone unsaturation ratio ($U^{K'_{37}}$) range 9–25 °C over the last 4.0 Ma. The SSTs are generally higher than 20 °C during 4.5–3.0 Ma, and gradually decrease during 3.0–1.6 Ma. Subsequently, the alkenone-based SSTs show the large fluctuation with remarkably lower values since 1.6 Ma.

The SSTs estimated xx during 4.5–1.6 Ma are almost similar to those in the northern part of the subtropical gyre (ODP site 1208; LaRiviere et al., 2012), which indicates substantial influence of the warm water current in the study site. On the other hand, the SSTs since 1.6 Ma are obviously lower than those in the ODP Site 1208 during several periods suggesting the restriction in the inflow of the warm currents into the Japan Sea because of the shallowing and/or narrowing of the southern gateway. In addition, dark color sediment layers are also observed in the horizons deposited from 1.6 Ma, and concentrations of long-chain alkenones are remarkably higher in these layers. These results suggest the establishments of anoxic bottom water probably caused by the restriction in the water exchanges.

The values of the diol index 2 (DI2), which is proposed as an indicator for diatom *Proboscia* production estimated from the compositions of long-chain alkyl diols, are higher during 4.5–2.7 Ma. This result suggests that diatom production was enhanced under eutrophic condition. The rapid decrease in the values of DI2 is observed at 2.7 Ma, which is synchronous with the decline in the biogenic opal sedimentation rate in the NW Pacific. In addition, no major local environmental changes were recorded in the estimated SSTs in Site U1423. Thus, the decreasing the diatom production recorded by DI2 at 2.7 Ma was possibly related to global paleoceanographic changes such as the northern hemisphere glaciation (NHG).

キーワード：アルケノン古水温、ジオール指標、日本海、古海洋

Keywords: alkenone-based temperature, Diol index, Japan Sea, Paleoceanography

Evolution of central Asian aridity since the middle Miocene: evidence from sediment grain size record at IODP Site U1430 from the Japan Sea

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236 samples from Integrated Ocean Drilling Program (IODP) Site U1430 of Expedition 346 in the Japan Sea were analyzed for grain size distributions using end-member modeling algorithm (EMMA) in order to investigate the Asian aridity history since about 15 Ma. Three independent grain-size end members (EM1, EM2 and EM3) were identified with modal grain size of 2 μm , 12 μm and 50 μm , respectively. The proportion of end-member EM1 (finest) varies between 5% and 48% with an average of 27%. The EM2 (medium) content ranges from 14% to 84% with an average of 56%, whereas the EM3 (coarsest) has an average of 17%. EM1 was interpreted as the mixture of eolian dust from central Asia transported by westerly and suspended sediment from the Japan Arcs by rivers and ocean currents. EM2 was mainly derived from eolian dust of central Asia by the near surface East Asian winter monsoon rather than the westerly over 5000 m. The coarsest end member EM3 can be considered as mixture of volcanic clastic and biogenic silica (i.e., diatom). We apply the ratio of EM2/EM1 as the proxy of intensity of the aridity of central Asia. The variation of EM2/EM1 ratio implies the long-term and stepwise drying of central since the Middle Miocene, especially at 11.8 Ma, 8.6 Ma, and since about 3.6 Ma. The phased uplift of Tibetan Plateau and global cooling may have played a significant role in strengthening the Asian aridity since the middle Miocene.

Keywords: Japan Sea, grain size, central Asian aridity, middle Miocene

Cyclo-stratigraphy of the Pliocene-Miocene interval in the Japan Sea sediments and timings of paleoceanographic changes

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Middle Miocene - Pliocene paleoceanographic changes have been reconstructed using deep-sea sediments from Atlantic and southern Pacific at high-resolution [e.g., Westerhold et al., 2005]. The results revealed a close linkage between changes in ice volume and changes in orbital parameters. However, an orbitally-tuned continuous age model for the Middle Miocene to Pliocene has not been yet established in the North Pacific. Therefore, high-resolution age model is necessary to correlate to other climate record and reconstruct paleoceanographic change in this period.

Since the Middle Miocene the Japan Sea has been a semi-closed marginal sea. Because the sea has been connected with the north Pacific by relatively shallow sills, its paleoceanographic condition has been sensitive to glacio-eustatic sea-level changes.

In this study, we utilize Integrated Ocean Drilling Program cores recovered from Sites U1425 and U1430 during Exp. 346. We constructed continuous sedimentary records at these two sites by revising the shipboard splices. Based on revised splices and a biostratigraphically-based age models [Kamikuri et al., in press], we converted GRA data from depth series to time series, extracted ca. 400- and 41-kyr cyclicities. Then, we tuned them to 400-kyr eccentricity cycle and 41-kyr obliquity cycle, respectively, to construct orbitally-tuned age models.

Based on this orbitally-tuned age model, we examined temporal changes in element composition of the sediments analyzed by XRF core scanner (ITRAX) to explore its paleoceanographic implications.

In the presentation, we will discuss the timings of paleoceanographic events observed in the Japan Sea and their relation with other paleoclimate events.

キーワード : Miocene-Pliocene、日本海、サイクル層序、XRFコアスキャナー、IODP Exp.346

Keywords: Miocene-Pliocene, the Japan Sea, Cyclo-stratigraphy, XRF core scanner, IODP Exp.346

XRFコアスキャナー (ITRAX)で測定された臭素を用いた、日本海堆積物中の海洋起源有機物量の推定

Reconstruction of marine organic carbon content in the Japan Sea sediments from Br variability measured by XRF core scanner

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日本海第四紀半遠洋性堆積物は特徴的な明暗の互層を持ち、その変動はダンスガード-オシュガー・サイクルと同期していることが知られている (Tada et al., 1999)。主に過去20万年間を対象とした研究から、暗色層は明色層に比べて有機物に富むことが知られており、有機物が堆積物の色を暗くする主要因であることが示されている (Tada et al., 1999; 中嶋他, 1998)。また、堆積物中の有機物量は日本海内の生物生産や酸化還元状態を反映していることから、東アジア夏季モンスーンによる降水量の変動が有機物含有量の制御要因となっている可能性も示唆されている (Tada et al., 1999; 多田, 2012)。従って、さらに過去に遡って日本海堆積物中の有機物量の変動を調べることで、アジアモンスーンの変動を含めたより広域的な気候変動の手がかりを得られることが期待される。

2013年夏に行われたIODP Exp. 346 Asian Monsoonでは、日本海内の複数地点において第四紀の日本海半遠洋性堆積物が連続的に得られ、少なくとも過去約150万年間について明暗互層が存在することが確認された (Tada et al., 2015)。この明暗互層の有機物量、特に海洋起源有機物量を復元することで、過去の日本海の海洋変動を明らかにすることが期待されるが、過去150万年間の暗色層は数百枚におよび、通常の分析手法で有機物量を復元するには膨大な時間を要する。

そこで本研究では、堆積物中の臭素量を用いて海洋起源有機物量を推定することを試みた。臭素は海洋プランクトン中に高濃度で取り込まれるため (Masuzawa et al., 1988)、海洋堆積物中の有機炭素量とBr濃度は相関を持つことが知られている (Ziegler et al., 2008)。さらに、陸源有機物中のBr濃度は海洋起源の有機物に対して低いため (Berg and Solomon, 2016)、Brが海洋起源の有機炭素 (MOC: Marine Organic Carbon) の指標となる可能性が示唆されている (Ziegler et al., 2008)。しかし、この仮説は十分に検討されていない。

本研究では、IODP Exp. 346で採取されたSite U1424とSite U1425のコアを対象に、全有機炭素量と炭素同位体比を測定した。炭素同位体比が陸起源と海起源の有機物の割合によって変化することを利用し、測定された炭素同位体比と全有機炭素量からMOC量を計算した。また、高知大学のXRFコアスキャナー (ITRAX) を用いて堆積物中の臭素濃度を測定した。

その結果、同一層準で得られたMOC量と臭素濃度は良い相関を示した。従って、日本海半遠洋性堆積物においては、臭素がMOCの指標として使用できると考えられる。

XRFコアスキャナーを用いて約50年間隔で連続的に測定された堆積物中の臭素は、中国で得られた鍾乳石の酸素同位体比記録 (Cheng et al., 2016) と最終氷期においてよく似た変動を示していた。従って、臭素濃度を用いた日本海堆積物中のMOC量推定は、東アジア夏季モンスーンの変動をさらに過去に遡って考察する際に有用な手がかりとなることが期待される。

キーワード：XRFコアスキャナー、日本海、第四紀、海洋起源有機物、臭素 (Br)、IODP Exp. 346

Keywords: XRF core scanner, the Japan Sea, the Quaternary, marine organic matter, bromine (Br), IODP Exp. 346

Redox history of deep water in the Japan Sea during late Pleistocene based on trace elements

Redox history of deep water in the Japan Sea during late Pleistocene based on trace elements

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The Japan Sea is a semi-closed marginal sea surrounded by Eurasia continent and Japanese and Sakhalin islands and its oceanography has been sensitively affected by climate changes in the past. Redox condition of the Japan Sea has been varied between oxygen-rich (oxic) and oxygen-poor (anoxic to euxinic) conditions repeatedly, which resulted in deposition of light and dark layers. Possible mechanism(s) of anoxic deep water developments in the Japan Sea has been discussed comprehensively such as high surface productivity and density stratification of the water column caused by isolation due to low sea levels during the glacial stages (Tada et al., 1999). This study aims to reconstruct redox history of Japan Sea deep water during the last 150 ka. (MIS1-MIS6) when significant changes in the bottom water redox condition have been previously reported (e.g. Watanabe et al., 2007). We used the sedimentary cores recovered during IODP Exp. 346, from Sites U1423 and U1425 in the northeast and central parts of the Japan Sea.

After acid digestions, about 100 samples were analyzed by ICP-MS and ICP-AES for major and trace elemental compositions. Results indicate that studied samples from dark colored muddy layers are enriched in redox sensitive elements such as Mo, U, and V, while these elements show low concentrations in the light-colored layers. Highest Mo concentrations are found in dark layers in MIS2 (glacial stage) and MIS5 (interglacial) that exceed 10 ppm, more than ten times higher than the average concentration in mudstone inferred from AUCC values (Average of Upper Continental Crust, McLennan 2001). These high Mo values consist with features of sulfidic oceanic conditions such as modern Cariaco Basin and Black Sea where high burial flux of S-bonding Mo occurs, indicating that those dark layers of the Japan Sea reflect euxinic depositional environment. To characterize anoxic-euxinic conditions in the Japan Sea, we compared Mo/U ratios in each dark layer. The Mo/U ratios in the dark layers in MIS2 are high, meanwhile the Mo/U ratios in MIS5 are relatively low. These high and high but relatively low Mo/U in MIS2 and MIS5 resemble to the pattern from similar to that from the restricted Cariaco Basin with sulfidic water column is development and high productive open-ocean settings such as eastern tropical Pacific marginal region, respectively. The difference of pattern of Mo and U enrichment in the euxinic dark layers in glacial and interglacial stages could be due to oceanic setting condition in each stage. In the glacial stage with low sea level, the Japan Sea was isolated from surrounding ocean that caused development of sulfidic water column and enhanced Mo burial into sediment. On the other hand, euxinic depositional condition in interglacial stage would have been formed below oxygen minimum zone developed by high organic matter sink from high productive surface water depth.

キーワード：日本海、酸化還元鋭敏元素

Keywords: Japan Sea, redox sensitive elements

日本海の約3～22万年前の海底堆積物(IODP Exp. 346)の硫黄の地球化学：モンスーンの変遷を探る

Sulfur isotope geochemistry of the Japan Sea sediments (IODP Exp. 346) 30 ~ 220 kyr ago: Implications for the evolution of Asian Monsoon climate system

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約5000万年前に生じたインド大陸とユーラシア大陸の衝突によるヒマラヤ山脈とチベット高原の形成に伴い、東アジア帯の気候に影響を与えるモンスーン気候システムが形成された。このモンスーン気候の影響により、日本海堆積物には数cm～数十cm間隔で有機炭素の量の違いによって生じる明暗互層が発達する。この違いは、一次生産の変動、あるいは有機物の保存効率の変動を反映している。前者の場合は栄養塩の状態、後者の場合は堆積環境の酸化還元状態の変動を表している。これらの変動は大陸風化や海流の変動により生じるものであり、究極的にはモンスーンの変遷によって生じる。逆に、日本海の明暗互層の堆積物の分析により、モンスーン変動を解明できる可能性がある。

そこで本研究では、統合国際深海掘削 (IODP: Integrated Ocean Drilling Program) の第346次航海によって2013年の夏に日本海で掘削された明暗互層の堆積物試料を用いて、酸化還元状態の変化を調べるために、硫黄の形態別存在量と安定同位体組成により海洋環境を復元し、モンスーンの変遷を解明することを試みた。

小林 (2013) の連続抽出法を用いて、試料中の硫黄種を酸揮発性硫黄 (AVS: Acid Volatile Sulfur)、黄鉄鉱 (S_{py} : FeS_2)、硫酸塩鉱物 (S_{SO4})、有機態硫黄 (S_{org})、元素状硫黄 (S^0) の5形態に分けて定量した。黄鉄鉱と硫酸塩鉱物の硫黄の安定同位体組成は、九州大学のEA-IRMS (元素分析計-オンライン質量分析装置)を用いて測定した。有機炭素 (C_{org}) の存在量は、高知大学海洋コア総合研究センターのEAで測定した。

暗色層では S_{py} 量 (0.26～1.49 wt.%)と、 C_{org} 量 (1.16～3.38 wt.%)が高い値を取り、明色層では S_{py} 量 (0.03～0.25 wt.%)と C_{org} 量 (0.34～1.10 wt.%)が低い値を取った。 S_{SO4} 量(0.02～0.64 wt.%)も、明暗層で S_{py} 量と同様の挙動を示した。 S_{py} / C_{org} 比は0.03～1.00の値を取った。黄鉄鉱と硫酸塩鉱物の安定同位体組成値 ($d^{34}S_{py}$, $d^{34}S_{SO4}$)は、試料深度や明層暗層に関係なく、それぞれ-38‰～-34‰および-10‰～0‰であった。

S_{py} 量と C_{org} 量の関係および $d^{34}S_{py}$ 値から、暗色層は嫌気的な水塊中での硫酸還元によって形成された黄鉄鉱を含むことが明らかになった。日本海中央深部での嫌気的な水塊の形成過程は以下のものが考えられる。夏季モンスーンの発達により東アジア地域で雨が降り、栄養塩が豊富とされている長江由来の河川水の流量が増大し、対馬海流に乗って日本海に流入して栄養塩濃度を上昇させ、活発化した生物活動によって生産された有機物の分解により、海中の溶存酸素量が減少して嫌気的となった。冬季モンスーンが発達した際は、日本海表層の冷却によって溶存酸素濃度の高い日本海固有水の沈み込みが起き、深海に酸素が豊むようになった。

今後、IODP Exp. 346の別の（深度も異なる）掘削地点から採取した試料に関して同様の分析を行い、日本海水塊の酸化還元状態の構造の変遷を明らかにしていきたい。

日本海の約3~22万年前の海底堆積物 (IODP Exp. 346) のリンの地球化学：モンスーン気候の変遷を探る

Phosphorus geochemistry of the central Japan Sea sediments (IODP Exp. 346) 30~220 kyr ago: Implications for the evolution of Asian Monsoon climate system

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約5000万年前に生じたインド大陸とユーラシア大陸の衝突によるヒマラヤ山脈とチベット高原の形成に伴い、東アジア一帯の気候に影響を与えるモンスーン気候システムが形成された。このモンスーン気候の影響により、モンスーン流水域に当たる揚子江からの流出が対馬海流に乗って日本海へと運ばれるため、モンスーン気候の影響により日本海堆積物には数cm~数十cm間隔で有機炭素の量の違いによって生じる明暗互層が発達する。この違いは、一次生産の変動、あるいは有機物の保存効率の変動を反映している。前者の場合は栄養塩の状態、後者の場合は堆積環境の酸化還元状態の変動を表している。これらの変動は大陸風化や海流の変動により生じるものであり、究極的にはモンスーンの変遷によって生じる。逆に、日本海の縞状堆積物の分析により、モンスーン変動を解明できる可能性がある。

そこで本研究では、統合国際深海掘削計画 (IODP: Integrated Ocean Drilling Program) の第346次航海によって2013年の夏に日本海で掘削された明暗互層の堆積物試料Site U1423 (JB-2A) の上部 (3~22万年前: 2.1~13m)、Site U1425 (YR-1A) の上部 (5~11万年前: 2.1~4.7m)を用いて酸化還元状態の変化を調べるため、リンの形態別存在量により海洋環境を復元し、モンスーンの変遷を解明することを試みた。

リンは、海洋の一次生産を制限する制限栄養塩 (limiting nutrient) 元素であり、堆積物中のリンの形態別存在量は堆積環境の酸化還元状態や生物生産の環境因子により変化するため、これらの分画から過去の堆積環境の重要な情報を得ることができる。

Ruttenberg (1992) を改良した方法でリンを5形態 (吸着性リン: P_{abs} , 鉄結合態リン: P_{Fe} , 自生アパタイト態リン: P_{auth} , 碎屑性リン: P_{detr} , 有機態リン: P_{org}) に分画した。測定はモリブデンブルー法、モリブデン錯体-有機溶媒抽出法 (Watanabe and Olsen, 1961)による吸光光度法で行った。

U1423試料中のリンの主要な形態は、 P_{auth} (Ave. = 0.044 wt.%) であった。次いで多く存在したのが P_{org} (Ave. = 0.016 wt.%) であり、 P_{auth} と逆相関をとった。またU1425試料においても主要なリンの形態は P_{auth} (Ave. = 0.048 wt.%)、次いで P_{org} (Ave. = 0.026 wt.%)であった。

海洋深層が酸化的である時、溶存酸素により有機物が分解されてしまうため有機態リンの存在量はわずかなる。最終的に放出されたリン酸は、自生アパタイト態リンとして堆積物中に保存される。即ち、これらが逆相関となる挙動を示していることから、海洋表層で生成された有機物が沈降し、海洋が酸化的であったがゆえに分解され、後に自生アパタイト態リンとなったことが言える。これらが主要な形態であることから、(1)海洋は酸化的であるということ、(2)表層での生物活動が盛んであったということ、の二点が考えられる。加えて、 P_{auth} 量が酸化還元の指標として用いられるCe量と相関を示した。これにより(1)の考えを裏付けることができる。また、特に全リン量が高い試料は暗色層のものが多かったことから、暗色層では夏季モンスーンが発達し、東アジア地域で雨が多く降ることにより、栄養塩が豊富とされている長江由来の河川水の流量が増大し、対馬海流を流れ、日本海に流入したと考えられる。今後、さらに海洋の状態およびモンスーンの変化の定量化を進めるべく、異なるプロキシの地球化学分析を進めていきたい。

キーワード：アジアモンスーン、日本海

Keywords: Asian Monsoon, Japan Sea

Depositional history of terrigenous materials at ODP Site 797 based on the revised stratigraphy projected from complete records of sediment sequences obtained during IODP Exp. 346

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Detrital fraction contained in marine sediments have been widely used as climate proxies because variations in provenance and mineralogy could be affected by the precipitation distribution and weathering intensity. Element composition of marine sediment is essentially controlled by the mineral composition that is also affected by sorting effect during their transport process. Therefore, these features have been also applied to the variability of provenance and transport pathway of detrital fraction of the sediments at ODP Site 797 in the abyssal part of the Yamato Basin in the Japan Sea. Detrital fraction in this ODP "legacy" core has been regarded as the mixture of aeolian dust and the detritus derived from the Japanese Islands (Irino and Tada, 2000; 2002). This knowledge was utilized to reconstruct the millennial-scale aeolian dust variation in order to clarify the east Asian monsoon variability.

Although sediment sequence collected at ODP Site 797 could be potentially used for the reconstruction of high temporal resolution and long history of Asian monsoon, the sediment sequence was not continuously recovered because no splice record was established at the time of the drilling where the Hole B was deepest and covered the sequence since the late Miocene. On the other hand, the Japan Sea was revisited by IODP Exp. 346 cruise which aimed the long-term paleomonsoon reconstruction, and more than triple APCs technique used during the cruise enabled us to establish nearly completely continuous sediment records since Miocene. Site U1424 close to ODP Site 794 as well as U1425 on the Yamato Rise especially provided excellent continuous records, and their 5 mm resolution brightness and 2.5 cm resolution GRA density profiles can be used to revise the stratigraphy of "legacy" cores collected during the former ODP cruises in the Japan Sea.

In order to establish the detailed occurrence of the central to east Asian monsoon variability during the last 800 kyr, we will re-examine the stratigraphy of Site 797 based on the precise correlation of physical properties to U1424 and U1425. Using the element composition of Site 797 sediments, the temporal variations of detrital subcomponents such as the Asian dust and the detritus derived from Japanese Islands will be reconstructed, which could enable us to calculate the long-term flux variations of these detrital subcomponents. We expect to demonstrate how "legacy" cores may become useful under the light of newly drilled IODP cores, and deepen our understanding of the east Asian monsoon variability during the Pleistocene.

キーワード : ODP Site 797、IODP Exp. 346、改訂層序、陸源碎屑物

Keywords: ODP Site 797, IODP Exp. 346, revised stratigraphy, terrigenous materials

High resolution paleomagnetism, magnetic susceptibility, and core color reflectance data from Site U1443 –preliminary results

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International Ocean Discovery Program Site U1443 is located at Ninety East Ridge in the southeastern Indian Ocean. At Site U1443, the recovered cores date to ~25 Ma. A high resolution chronostratigraphy from this Site is needed to achieve better understanding of long-term climate evolution over the Indian Ocean and subcontinent. Shipboard paleomagnetic measurements revealed reasonable polarity patterns throughout the last ~25 Ma; however limited demagnetization steps have left ambiguity in the age assignment of the interval between ~13 to ~25 Ma. Shipboard rock magnetic data showed promising variability that could be related to paleoenvironmental change. To build on these findings, u-channel and discrete samples were taken for detailed measurements. Paleomagnetic measurements were successful in recovering polarity patterns consistent with the shipboard measurements. Magnetic susceptibility and color reflectance data revealed subtle but correlated changes, including the observation of ~20-30 cm cycles that were not identified from shipboard measurements. On the basis of sedimentation rate estimates (~0.8 cm/kyr), the observed cycles may be driven by the ~41 kyr obliquity cycle. Rock magnetic measurements on discrete samples indicate a mostly homogeneous magnetic mineralogy of oxidized titanomagnetite. Thus, the cyclicity is likely to reflect changes in the concentration of this mineral magnetic component. Integration of the magnetic stratigraphy with the cyclicity will provide a high resolution chronostratigraphy.

キーワード : Indian Ocean、Paleomagnetism、 Expedition 353

Keywords: Indian Ocean, Paleomagnetism, Expedition 353

The change in the environment and tectonics from Late Paleocene to Early Miocene in the Northeastern Tibetan Plateau

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Cenozoic is the time of global cooling from the early Eocene greenhouse to the Quaternary icehouse. The Eocene-Oligocene Transition (EOT) is the first rapid cooling step in the Cenozoic that occurred around 34 Ma. One of the critical changes during the EOT is the emergence of the permanent Antarctic ice. DeConto and Pollard (2003) suggested that the decrease of the percentage of carbon dioxide in the atmosphere during Eocene-Oligocene was the probable cause of the abrupt cooling at the Eocene-Oligocene Boundary (EOB), but exactly when and the reason why the reduction in the atmospheric occurred is not clear. Raymo and Ruddiman (1992) hypothesized that the intensification of weathering associated with the uplift of the Himalaya and Tibetan Plateau (HTP) caused atmospheric decrease. Although it is essential to clarify when and how HTP evolved and how its evolution was related to the atmospheric decrease, in order to test this hypothesis, the timing and mode of the HTP uplift is still under debate (Tada et al., 2016). In the northeastern Tibetan Plateau, the aridification and cooling linked with the elevation increase were suggested to have started before the EOB based on the pollen record (Dupont-Nivet et al., 2008). However, clear evidence of the tectonic uplift event and its temporal relationship with EOB is needed for further discussion. In this research, we examined the provenance of quartz in the terrestrial sediments of the Lanzhou Basin, the northeastern Tibetan Plateau to detect the signal of uplift and examine the temporal relation between the uplift, cooling and the desertification.

We conducted field survey at the Duitinggou section in the northeastern edge of the Tibetan plateau, make a route map and a columnar section, and collected samples for analyses. We correlated our columnar section with a columnar section of Zhang (2015) constructed at the nearby section, and projected their age model, which is constructed based on magnetostratigraphy to our columnar section. We analyzed the grain size distribution of major lithologies to distinguish the sedimentary facies and characterize the lithological units. We also measured Electron Spin Resonance (ESR) intensity of quartz in the two grain size fractions to examine the provenance changes.

According to the result, Duitinggou section can be divided into six sedimentary units from 1 to 6 in ascending order and based on the constructed age model, the age of Duitinggou section ranges from about 57.6 Ma to 18.9 Ma, i.e. from Late Paleocene to Early Miocene.

Based on the result of the grain size analysis, we classify four patterns of the grain size distributions interpreted as fluvial sediments, lacustrine sediments, aeolian deposits and mixed sediments, respectively. The $>63\ \mu\text{m}$ sandstone samples were considered to have represented as mostly fluvial sediments. A gradual increase in the ESR intensity of quartz from 50 Ma to 24 Ma is interpreted as the evidence of unroofing in the source area. It seems that the uplift of the source area occurred before 50 Ma. A sudden decrease in the ESR intensity around 24 Ma suggested a major tectonic uplift and exposure of low grade metamorphic rocks occurred at that age, which might be related to the uplift of the northeastern Tibetan Plateau that started around 24Ma.

キーワード：北東チベット、隆起、蘭州盆地、EOT、ESR

Keywords: Northeastern Tibet, Uplift, Lanzhou basin, EOT, ESR

Paleoweathering condition in the middle Miocene to the early Pliocene period in the Japanese Islands

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The middle Miocene to Pliocene is recognized as a period that has changed the East Asian monsoon. In the Japanese Islands, the Middle Miocene to Pliocene fluvial formations include aluminous clayey horizons with well-preserved pedogenic features and are known as pottery material. These formations, therefore, can be a useful to reconstruct of weathering conditions. Description of paleosols and geochemical and mineralogical research were carried out in the Middle Miocene (10-11 Ma) and the Early Pliocene (3-4 Ma) sediments in the central Japan in order to illuminate the weathering condition in far east Asian margin.

Each of the formation was mainly deposited in lacustrine environment. Paleosols can be divided into 11 pedotypes. In the Middle Miocene, the main pedotypes, which are characterized by thick soil horizons with Bt horizons, gilgai microrelief and rich illuviated clay, are equivalent to vertisol and ultisol. In the Early Pliocene, the main pedotypes, which are characterized by thinner soil horizons, prominent relict beds and rarely illuviated clay, are correspond to ultisol and inceptisol. Hydromorphic paleosols, besides, are developed in the Early Pliocene.

The major elemental geochemistry of the lake sediments shows that the Middle Miocene sediments were supplied from severe weathered sources with CIA values of 80-94. The Pliocene sediments show the CIA values of 72-90 suggesting the relatively weak weathering condition. Behavior of major and REE elements within paleosol profiles shows a marked loss of Na₂O without leaching of REE, which should inherit the composition of source rocks, in the middle Miocene. In the early Pliocene, eluviation of Na₂O are less reconstructing the weakly developed paleosols. The clay mineral composition of the middle Miocene sediments, additionally, shows higher kaolinite contents than that of the early Pliocene sediments.

The weathering condition in the middle Miocene to Pliocene in Japanese Islands may be affected by the influence of warm water current and initiation of the Eastern Asian monsoon. The middle Miocene period (10-11 Ma) is considered to have been under the intenser weathering condition than one in the early Pliocene period (3-4 Ma), which corresponds with the initiation of drying in Asian interior and the invasion of tropical sea water into the middle latitude in the northwest Pacific Ocean.

キーワード：化学風化、中期中新世-前期鮮新世、粘土鉱物、古土壌、地化学、河川堆積物

Keywords: chemical weathering, Middle Miocene-Early Pliocene, clay minerals, paleosol, geochemistry, fluvial sediments

完新世後期における中部日本地域の強雨・洪水記録の空間的普遍性と、周辺地域の気候変動との関係

Spatial property of heavy precipitation and flood history during the Late Holocene in central Japan and correlation with climate change in surrounding region

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日本を含む東アジア地域はモンスーンや台風などの影響下にあり、強雨やそれに伴う洪水の多発する地域である。観測記録の解析やモデル研究から、強雨の発生が水蒸気発生源での海水温上昇に影響を受けている可能性が示唆されている。また、台風の規模、経路、発生数には経年変化が存在しており、これらの変動要因としては発生源である低緯度地域の気候や偏西風経路などの大気循環に影響を受けている可能性がある。長期スケールにおいて、これらのうちどのようなメカニズムが強雨・洪水の発生を支配しているかどうか明らかにするためには、気候境界条件が現在と同じ完新世後期において、強雨・洪水記録と周辺地域の古気候記録との関係を検討する必要がある。しかし、一般的な雨量記録媒体（花粉、鍾乳石など）から得られる雨量変動記録は年スケールの期間の平均値であり、短期的な現象である強雨・洪水の記録としては不十分だった。そこで本研究では、洪水などの突発的な現象の結果として堆積物中に保存される「イベント層」および、強雨に伴って河川から流入する碎屑物フラックス変動に着目して、完新世における強雨・洪水史の定量復元を試みた。そのために、福井県水月湖堆積物の表層堆積物を用いて、これらの堆積物に含まれている河川起源碎屑物フラックスの復元および観測記録との対比を行った。その結果、以下のような強雨・洪水プロキシを確立した。

1)河川起源細粒碎屑物フラックスは、50mm/day以上の強雨頻度を反映する。

2)洪水により、細粒碎屑物から構成される明灰色イベント層が堆積する。その厚さは洪水時の総雨量を反映する。

本発表では、これらの結果を応用して過去7000年について得られた強雨・洪水記録を周辺地域で得られている降水量変動や洪水記録と比較し、さらに周辺地域の降雨制御要因との関係を議論する予定である。

関連して、観測と堆積物の比較による強雨・洪水プロキシ開発の詳細についてH-SC07セッションで、本研究で得られた災害復元記録における洪水・地震の区別やローカルな堆積環境変動との比較をM-IS23セッションで発表する。

キーワード：水月湖、年縞、洪水、完新世

Keywords: Lake Suigetsu, varved sediment, flood, Holocene