

東アジアモンスーンの進化と変動そしてヒマラヤ-チベットの隆起との関連性 Evolution and variability of East Asian monsoon and the potential relationship with Himalaya-Tibet uplift

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Monsoon is climatic phenomenon driven by heat capacity contrast between the continent and ocean, so every continent has its own monsoon system. Asian Monsoon is by far the largest monsoon system on the globe. Although it is regional phenomenon, it exerts significant influence on the global climate. The extremely large size of Asian Monsoon system is considered as having been caused by the presence of Himalaya and Tibetan Plateau (HTP). The large size and high altitude of HTP resulted in higher temperature at ca. 5000 m altitude compared to the surrounding area during summer that resulted in ascending air and development of low pressure cell over the plateau. Topographic effect could be also important to enhance summer monsoon. Large size of Asian continent enhanced cooling over continent during winter, resulted in development of high pressure cell known as Siberian High. HTP plays a role of topographic barrier that keeps Siberian High stronger and stable. Consequently, presence of HTP could have been playing a crucial role to strengthen Asian Monsoon. If correct, uplift of HTP could have resulted in intensification of Asian Monsoon.

Climatic simulations can be used to test the hypothesis that uplift of HTP has intensified Asian Monsoon if uplift history of HTP is known well. However, timings, modes, and magnitudes of HTP uplift have been poorly understood until recently. Situation is rapidly improved recently due to accumulation of thermo-chronological data from the various parts of HTP. Namely, collision of Indian Subcontinent against Eurasian Continent approximately at 40 Ma caused the 1st phase of Tibetan uplift that raised southern Tibet close to the present height by 35 Ma. From 25 Ma to 15 Ma, Main Central Thrust (MCT) and South Detachment System (STDS) in frontal Himalaya were activated and lower crust was extruded and eroded extensively. Approximately at 15 Ma, these fault system ceased their movements and east-west extension started in Tibet. From 15 Ma to 10Ma is the 2nd phase when Tibetan Plateau grew southeastward and possibly also northward. The 3rd phase of uplift started from approximately 5 Ma when northwestern Tibet, TienShan and Altai Mountains uplifted. Using this uplifting history of HTP as a boundary condition, it is possible to estimate what kind of paleoclimatic changes are expected in response to these 3 uplift phases based on climate simulation results.

In this presentation, I will review a recent progress in researches on tectonics-climate linkage as HTP uplift and Asian Monsoon evolution as an example.

キーワード: モンスーン, ヒマラヤ-チベット, テクトニクス-気候リンクージ, 東アジア, 日本海, 偏西風ジェット
Keywords: Monsoon, Himalaya-Tibet, Tectonics-Climate Linkage, East Asia, Japan Sea, Westerly Jet

Pre-Miocene Birth of the Yangtze River Pre-Miocene Birth of the Yangtze River

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The development of fluvial systems in East Asia is closely linked to the evolving topography following India-Eurasia collision. Despite this, the age of the Yangtze River system has been strongly debated, with estimates ranging from 40?45 Ma, to a more recent initiation around 2 Ma. Here, we present new ⁴⁰Ar/³⁹Ar ages from basalts interbedded with fluvial sediments from the lower reaches of the Yangtze together with detrital zircon U/Pb ages from sand grains within these sediments. We show that a river containing sediments indistinguishable from the modern river was established before ~23 Ma. We argue that the connection through the Three Gorges must post-date 36.5 Ma because of evaporite and lacustrine sedimentation in the Jiangnan Basin before that time. We propose that the present Yangtze River system formed in response to regional extension throughout eastern China, synchronous with the start of strike-slip tectonism and surface uplift in eastern Tibet and fed by strengthened rains caused by the newly intensified summer monsoon. Birth of the eastward flowing Yangtze River around the Oligocene/Miocene boundary changed largely the 'source to sink' regime in the East Asia-West Pacific region

キーワード: Yangtze River, birth, Tibetan Plateau, drainage capture, Asian monsoon

Keywords: Yangtze River, birth, Tibetan Plateau, drainage capture, Asian monsoon

The missing volcanic record captured by dispersed ash in sediment of the Japan Sea/East Sea and NW Pacific Ocean

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Volcanic ash in marine sediment provides a wealth of information not only about volcanism and arc evolution, but also potentially regarding climate change, geochemical mass balances, hydration of marine sediment during alteration, the geodynamics of subduction zones, and other key components of the earth-ocean-atmosphere system. Ash occurs both as discrete *layers* as well as isolated grains and shards *dispersed* throughout the bulk sediment, and with highly variable grain sizes.

The study of this dispersed component has lagged behind the sedimentologic and chemical assessment of the ash layer record. For example, while decades of smear-slide studies of bulk sediment in volcanic-rich regimes have presented visual estimations of the abundance of volcanic glass, shards, and other components, the quantitative importance of the dispersed ash or cryptotephra remains largely unconstrained on local, regional, and global scales. Also, compared to the often visually stunning ash layer records, which in certain settings can leave single layers with thicknesses of 10s of cm, the dispersed ash component and cryptotephra are unable to be visually differentiated from detrital clay.

We summarize here preliminary results regarding the distribution, composition, and accumulation of dispersed ash in sediment from the Japan Sea/East Sea (gathered during IODP Expedition 346, Asian Monsoon, and ODP Legs 127/128), and compare it to the record provided by discrete ash layers. We will interpret our work in the context of our ongoing studies of dispersed ash throughout the northwest Pacific, Nankai, and Izu-Bonin regions, which is based on sediment from DSDP/ODP/IODP Sites 52, 444, 579/581, and 1149, as well as from Sites C0011 and C0012.

Multivariate statistical treatments are an integral part of our approach, as the bulk determination of the major, trace, and REEs provides the chemical context for our determination of provenance, and the statistical models allow distinctive resolution of the different aluminosilicate components based on their individual geochemical signature(s). A corollary benefit of our approach is an improved determination of the eolian component, as we are able to discern how contributions of dispersed ash have been inadvertently attributed to the eolian aluminosilicate inventory. Q-mode Factor Analysis can help determine the number, and composition of, potential end member contributions. Applying these results in conjunction with Total Inversion, a linear regression technique, allows determination of the compositional variation of these end members.

Consistent with the qualitative smear-slide estimates, in these ash rich regions we find that the dispersed component can account for up to 40% of the total sediment. We are able to document abundances to a relatively high degree of precision (+/- 3-5%) on a sample-by-sample basis, and are further able to distinguish between different chemistries of the dispersed component, and document sources that change through time and space. In addition to providing an overview of “ the missing volcanic record ”, we will discuss some ongoing challenges, including how to best examine the relationship between the composition of the discrete ash layers compared to the discrete component, and what information can be gained from examining similarities and differences between their respective sources.

キーワード: volcanic ash, sediment chemistry, Japan Sea, East Sea, volcanism
Keywords: volcanic ash, sediment chemistry, Japan Sea, East Sea, volcanism

MIS01-04

会場:314

時間:4月29日 15:10-15:25

日本海堆積物中のテフラ：対比・層序と火山活動史
Tephrochronology and evolution of volcanic activities in Japanese islands during late
Cenozoic

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日本海のテフラ研究についてレビューし、その古海洋・古気候研究における重要性について紹介する。

キーワード: テフラ, 日本海, 層序

Keywords: tephra, Japan Sea, stratigraphy

東アジア縁海の半遠洋性堆積物中に含まれる風成塵の同定 Identification of Asian dust in hemipelagic sediments of East Asian marginal seas

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Detrital fraction contained in marine sediments can be generally 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. The inland deserts such as Taklimakan and Gobi are large detrital sources for the East Asian marginal seas, and the detrital fraction in the sediments collected from the abyssal part of the Japan Sea / East Sea has been regarded as the mixture of eolian dust and the detritus derived from the Japan Arc. This feature can be used to reconstruct the variability of provenance and transport pathway of detrital fraction in the sediments. Relative contribution of dust from Taklimakan / Gobi could be strongly affected by dust availability in source area and wind system transporting the dust. Major changes in such detrital provenance are more easily reconstructed from the proximal soil record at loess plateau, where many provenance studies have been conducted. Loess can be classified into two types based on their element composition. One is typical loess distributed close to desert area. The other is peripheral soil (weathered loess) distributed surrounding typical loess and desert area. Weathered loess is distributed in the northeastern and southern China in modern times. Spatial distribution of these two types of soils have been also changed from time to time. In order to detect the change in provenances and interpret the terrestrial environment using detrital proxies in the marginal sea sediments, it is necessary to know the variability or range of the element and mineral composition of a particular provenance during the targeted time periods as well as the sorting biases during the transportation.

キーワード: 半遠洋性堆積物, 風成塵, 供給源, 鉱物組成, 元素組成, 同位体組成

Keywords: hemipelagic sediment, aeolian dust, provenance, mineral composition, element composition, isotope composition

Carbon and Sulfur Cycling in Shallowly Buried Sediment of the Japan Sea/East Sea Carbon and Sulfur Cycling in Shallowly Buried Sediment of the Japan Sea/East Sea

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Continental slopes cover about 10% of Earth's surface and represent the primary repository for sediment and organic carbon accumulation on long-time scales. For decades, the geochemical community has introduced and discussed various models for how ocean carbon and sulfur chemistry changes over time. Remarkably, in most of these models, the seafloor on continental slopes is either absent or passive. In the latter case, the prevailing view is as follows. During burial, organic carbon passes through a gauntlet of microbially mediated reaction in shallow sediment, especially including organoclastic sulfate reduction and methanogenesis. Although these reactions generate dissolved species (HCO₃⁻, HS⁻, CH₄), burial fluxes exceed those of upward advection or diffusion. The end process, therefore, is accumulation of remnant solid organic carbon, authigenic carbonate, and authigenic Fe-sulfides. As suggested in several recent papers, this view may be incorrect. Instead, on the slope, a good fraction of solid organic carbon bypasses organoclastic sulfate reduction to produce dissolved inorganic carbon, dissolved organic carbon, and methane at depth. Large portions of these species return toward the seafloor because upward dissolved fluxes exceed burial. However, upward migrating methane reacts with dissolved SO₄²⁻ to produce HCO₃⁻ and HS⁻ via AOM in shallow sediment. The end process is still accumulation of remnant solid organic carbon, authigenic carbonate, and authigenic Fe-sulfides, but the fluxes are linked through the formation, storage and consumption of methane.

It is entirely possible that variations in methane cycling within slope sediments drive significant long-term and short-term changes in ocean carbon and sulfur concentrations. To entertain this idea, however, the broad Earth Science community needs quantified fluxes of solid and dissolved components from appropriate settings. One current problem is that very few locations on continental slopes that have detailed pore water profiles extending 200 m below the seafloor with companion sedimentary records.

IODP Expedition 346 drilled multiple holes at seven sites across the Japan Sea/East Sea. The primary objective behind this cruise was late Neogene and Quaternary paleoceanography: more specifically, to reconstruct changes in surface and deep ocean water properties, riverine outflow, and dust input over the last 5-10 million years, which might be linked to the evolution and temporal differences in the Asian monsoon system. One interesting outcome of this goal was that the sites span a wide range of slope environments with considerable variation in organic carbon accumulation. Another was exquisite sediment recovery, with spliced cores between holes giving complete records from the seafloor to several hundred meters.

Expedition 346 provided a golden opportunity to chase the dynamic geochemical cycling of carbon and sulfur on continental margins. Using a combination of rhizon sampling and whole round squeezing, about 680 pore water samples were collected at the seven sites and analyzed for a broad array of dissolved species. The shipboard pore water geochemistry profiles generated on Expedition 346 are truly remarkable in terms of species examined, their detail across zones of chemical reaction, and the ability to directly couple them to the sedimentary record. Here, on behalf of the Expedition 346 scientists, we discuss the generation of the pore water profiles and their significance to carbon and sulfur cycling on continental slopes. For example, at Site U1427, there is no question as to the dominant process and where species are being produced and consumed in shallow sediment. Upward migrating CH₄ is reacting with SO₄²⁻ via AOM to produce HCO₃⁻ and HS⁻, the first product leaking to the seafloor, the latter product being consumed into sulfide minerals.

MIS01-06

会場:314

時間:4月29日 15:40-16:00

キーワード: Methane, AOM, carbon cycle, sulfur cycle
Keywords: Methane, AOM, carbon cycle, sulfur cycle

日本海における *N.incompta* の Mg/Ca 古水温計と完新世気候復元への適用 N.incompta Mg/Ca-paleothermometry in the Japan Sea and its application to Holocene climate reconstruction

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We present new core-top calibration for *Neogloboquadorina incompta* Mg/Ca-paleothermometry in the Japan Sea using 15 core-top surface sediments taken from the southern Japan Sea. Using this new Mg/Ca-paleothermometry, we generate the first high-resolution Mg/Ca-derived SST record for the past 7000 years from the sediment core (YK10-7-PC09) taken from 738 m water depth off Niigata. The age model for core YK10-7-PC09 was based on 8 AMS ¹⁴C data of mixed planktic foraminifera, and the conventional ¹⁴C ages were converted to the calendar ages using Marin13 and delta R of 0±100 yr. Trace metal/Ca ratio of *N.incompta* was measured by a SF-ICP-MS (Thermo Fisher Element II) and the precision (1sigma) of Mg/Ca ratios of the international CaCO₃ standard (BAM-RS3) was 0.786±0.008 (n=100).

We have performed paired analyses of $\delta^{18}\text{O}_{\text{c}}$ and Mg/Ca ratios of *N. incompta* at 15 sites. First, to calculate the mean temperatures of waters in which the foraminiferal shells were formed (i.e., calcification temperature), we have used modern local salinity and temperature data (<http://www.jodc.go.jp/>) in the following paleotemperature equation; $T (^{\circ}\text{C}) = 21.4 - 4.19 \times (\delta^{18}\text{O}_{\text{c}} - \delta^{18}\text{O}_{\text{sw}}) + 0.05 \times (\delta^{18}\text{O}_{\text{c}} - \delta^{18}\text{O}_{\text{sw}})^2$ (Oba, 1980). The $\delta^{18}\text{O}_{\text{sw}}$ was calculated from the following salinity- $\delta^{18}\text{O}_{\text{sw}}$ equation in the Japan Sea ($\delta^{18}\text{O}_{\text{sw}} (\text{‰ VSMOW}) = 0.27 \times \text{Salinity} - 8.98$; this study). The comparison of the predicted $\delta^{18}\text{O}_{\text{c}}$ values with the measured $\delta^{18}\text{O}_{\text{c}}$ shows that *N. incompta* shells were formed at 0-125 m water depths from June to December in the Japan Sea. Given that previous studies show that *N.incompta* dwells in the shallow waters (<100 m) in November to December (Kuroyanagi and Kawahata., 2004; Sagawa et al., 2013), we calculated the calcification temperatures at each site assuming shells were formed in November to December. The cross plot of the calcification temperatures and the Mg/Ca ratios for our core-top samples gives the following equation; $\text{Mg/Ca (mmol/mol)} = 0.361 \times \exp(0.043 \times \text{Temp})$.

Using this new Mg/Ca-paleothermometry, the 7000-years *N.incompta* Mg/Ca records (0.6 to 0.9 mmol/mol, n=127) from core YK10-7-PC09 were converted to the temperature record. Compared to the present winter SST of ca.15 °C, the 7000-year SSTs varied from 13.5 °C to 20.8 °C. We identified four periods (ca.6000 yr BP, 4000-3500 yr BP, 3000-2300 yr BP, and 800 yr BP) that were warmer than the present and distinct colder periods at ca.4500 yr BP and ca.1500 yr BP than the present. This SST variability for the past 7000 years was almost consistent with the record of relative abundance of *F.doliolus*, which is the dominant species in the Tsushima Current (Koizumi et al., 2006). This finding indicates that the Tsushima Current influx might have changed with time and altered the heat transport into the Japan Sea, and probably induced significant changes in terrestrial precipitation and vegetation over the northern part of Japan facing the Japan Sea.

Keywords: Japan Sea, Holocene climate change, Mg/Ca-paleothermometry, Tsushima Current, *Neogloboquadorina incompta*

Shallow water environmental change in the Sea of Japan during the last 30 kyr deduced from foraminiferal isotopes
Shallow water environmental change in the Sea of Japan during the last 30 kyr deduced from foraminiferal isotopes

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The Sea of Japan is a marginal sea that connects with North Pacific and adjacent marginal seas by four shallow straits. Because water depth of the deepest straits today is ~130 m (Tsushima Strait and Tsugaru Strait), environments of Sea of Japan have been strongly affected by sea level fluctuations related to the glacial-interglacial cycles. Previous studies report that foraminiferal oxygen isotope variation from Sea of Japan is distinct from that commonly seen in seas of the world. Since Sea of Japan is nearly isolated from adjacent seas during the glacial maxima, salinity of surface water significantly decreases, and therefore foraminiferal isotopes show the lowest values due to the unique fresh water balance. The peak value of oxygen isotope is ~0.5 per mil at the last glacial maximum, which is ~2.5 per mil lighter than at 30 ka. We review literature data and present new results of two sediment cores from northeastern and southern part of Sea of Japan. The new data from southern core has ~70-yr resolution and shows abrupt shift that may correspond to abrupt climate change reported from the Greenland ice core and Asian monsoon proxy data of Chinese Cave and Loess. The new results suggest that the surface environment of Sea of Japan is sensitive to eustatic sea level change as well as abrupt climate changes.

Keywords: Sea of Japan, oxygen isotope, planktonic foraminifer

鮮新世—更新世移行期における日本海の海洋循環変化：微化石に残された痕跡 Micropaleontological evidence of oceanic circulation changes in the Japan Sea during Pliocene to Pleistocene transition

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Oceanic circulation in the Japan Sea is characterized by flowing of the Tsushima Warm Current and deep-water formation during the interglacial periods, while deep circulation was stagnant due to weakened deep convection with development of the low salinity surface water during the glacial periods. Such cycles of oxic and anoxic deep-water conditions recorded in sediments as alternations of light and dark hemi-pelagic mud layers occurred since ca. 2.5 Ma near Pliocene to Pleistocene transition. The results of micropaleontological studies from previous ocean drilling sites and many onshore sequences have provided various insights into oceanic changes related to global climatic and regional tectonic events during Pliocene to Pleistocene.

Fossil records of shallow dwelling plankton and shelf related benthos are composed of the assemblage associated with upper water environments. Warm-water ostracods and molluscs are rarely recognized from onshore sequences in Japan along the Japan Sea side during the Pliocene climatic optimum (3.2 to 2.7 Ma), and they were most likely associated with subtropical water mass entered from the southern strait. However, planktonic foraminiferal and radiolarian assemblages in hemipelagic sediments suggest that the warm-temperate water was originated from the northern strait during this period. Such conflict interpretation could be explained by a characteristic surface circulation, which was composed of two different water sources from the northern and southern straits. The warm water mass from the southern strait was restricted flowing along the Japanese coastal area, while another water mass from the northern strait was present offshore areas of the sea. Abundance of cold-water calcareous nannofossil species increased significantly at 2.75 Ma corresponding to the global cooling. In this period, ostracode assemblage also indicates cooling in the intermediate water. According to planktonic foraminifers and radiolarians, significant inflow of the subtropical water from the southern strait started at 1.7 Ma, which might be related to the deepened Tsushima Strait and the Okinawa Trough (ca. 2 Ma).

Deep-water environments in the Japan Sea are little known compared with that of shallow environments. Benthic foraminifers in deep-sea sediments changed their faunal composition from agglutinated fauna to calcareous fauna through 3 to 2 Ma. Similarly, deep-water radiolarians show faunal replacement from the Pacific-type deep dwellers to the Japan Sea-type deep dwellers at ca. 2.6 Ma. Such faunal changes recognized from benthic foraminifers and radiolarians imply that the unique deep-water circulation in the Japan Sea was formed with geographical isolation from the Pacific deep water. In actual, this timing is almost coincident with beginning of oxic and anoxic cycles in the Japan Sea. It is likely resulted from either the global cooling or local tectonic motion during the Pliocene to Pleistocene transition.

キーワード: 微古生物学, 古海洋学, 地球規模寒冷化, 構造運動, 対馬海流, 深層水

Keywords: Microfossils, Paleoceanography, Global cooling event, Tectonic event, Tsushima Warm Current, Deep water

Evolution of the Kuroshio Current and its impact on East Asian marginal seas Evolution of the Kuroshio Current and its impact on East Asian marginal seas

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Quaternary is characterized by the onset of the Quaternary ice ages as well as the progressive cooling of the high latitude. Many proxy records from high latitude evidence this. On the other hand, records from low latitudes indicate that the sea surface temperature of the tropical warm pool regions remained relatively stable during the last 4 Ma. Hence these suggest a dramatic increase in the zonal (west?east) and meridional (north?south) gradients in sea surface temperature, which was accompanied by a progressive cooling of the water upwelled along the eastern margins of the Pacific. It is most likely believed that the evolution of the west-east and north-south temperature gradients in the North Pacific is closely related to the evolution of the western boundary current and North Pacific subtropical gyre during the Plio-Pleistocene. It, in turn, caused changes in weather and climate patterns of East Asian margins. In this presentation, previously published data and hypothesis will be reviewed to clarify future researches related to these.

キーワード: Kuroshio, North Pacific Subtropical Gyre, sea surface temperature

Keywords: Kuroshio, North Pacific Subtropical Gyre, sea surface temperature

過去2万6千年間の北西亜熱帯太平洋における中深層水循環
Variations in intermediate water and ocean circulation during the last 26 ka based on a
new benthic Mg/Ca calibration

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In order to understand variations in ocean circulation at intermediate depth in the North Pacific in subtropical area, bottom water temperatures (BWT), carbon isotope of benthic foraminifera, and oxygen isotope of seawater were reconstructed since 26 ka off east main Okinawa Island, northwestern Pacific. A new regional Mg/Ca calibration for benthic foraminifera *Cibicides wuellerstorfi* was established in order to convert benthic Mg/Ca value to temperature, based on twenty-nine surface sediment samples, including core top samples, retrieved around main Okinawa Island. On the other hand, in order to reconstruct changes in water properties since 26 ka, core GH08-2004 that was retrieved from water depth of 1166 m off east main Okinawa Island was used in this study. As a result, during the LGM from 24 ka to 18 ka, BWT showed relatively constant as approximately 2 °C, which was ~1.5-2 °C lower than today. One of the prominent features of our BWT records was a millennial scale variation in BWT during the last deglaciation. During the last deglaciation, BWT was higher in Heinrich Stadial 1 (H1) (~17 ka) and Younger Dryas (YD) (~12 ka), while lower in Bølling/Allerød (BA) interval (~14 ka). During the interval from 17 to 15 ka, BWT tended to decrease in association with a decrease in carbon isotope of *C. wuellerstorfi*, likely interpreted as increased upwelling of the older water mass that was stored in the abyssal Pacific during the glacial time. The timing of the signal of the upwelling coincided with deglacial atmospheric CO₂ rise initiated at ~17 ka, suggesting the increased upwelling in the subtropical northwestern Pacific from 17 to 15 ka contributes the carbon release to the atmosphere from the Pacific.

北太平洋亜熱帯ジャイアの長期発達史：第四紀後期の記録からの予測 Long-term evolution of the North Pacific subtropical gyre: Implication from the late Quaternary record

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The North Pacific subtropical gyre drives a transportation of huge amount of heat from low to high latitude area to maintain warm climate in the northwestern Pacific area. This gyre system largely controls the zonal temperature gradient and west-east asymmetric climate, currently observed in the Pacific Ocean. The stepwise enhancement of these temperature gradients has partly been observed in the equatorial and east Pacific area since the late Pliocene. However, a lack of long-term observation in the west Pacific Ocean impedes a better understanding of the development of the Pacific climate.

The Kuroshio Current, flowing from the Okinawa Trough to eastward off the Japan, act as a heat-transfer along the North Pacific subtropical gyre margin. The variation in this surface current would reflect to the changes of the West Pacific climate. Especially, the Okinawa region is an ideal place for paleoenvironmental reconstruction, as (1) the Kuroshio Current shows an oscillation with surrounding water masses and (2) the sediments are buried in high rate. Through the short-term paleoceanographic records in the Okinawa region, the planktonic foraminiferal assemblage showed the decrease of the Kuroshio indicator and increase of the coastal- and cold-water masses indicators under the modern Kuroshio path (the East Chia Sea) during MIS 2. Interestingly, the long-term record, which was the first to cover the past 200 kyrs in this region, represented different oceanic condition during MIS 6. The indicator of the upper intermediate water in the subtropical gyre increased over whole of the Okinawa region at this time. Moreover, the Mg/Ca paleo-temperatures in the surface and upper intermediate layers showed that warming in the upper intermediate layer was continuing from MIS 6 to MIS 5e, while warming in this layer was rapidly stopped at MIS 2. Both records of the paleo-temperature and planktonic foraminiferal assemblage congruently suggest the development of the intermediate water in the North Pacific subtropical gyre during MIS 6, instead of the dominance of cold water mass observed during MIS 2. The intermediate water has likely been undergone an independent process from the changes of the surface water masses at least by MIS 5. Even the 200 kyrs record successfully inferred two different glacial mechanisms of MIS 2 and 6, associating with the changes of surface water masses and deeper waters. Future study with longer record will lead a comprehensive understanding how the modern water column structure has been developed in the Pacific Ocean.

キーワード: 北太平洋亜熱帯ジャイア, 黒潮, 水柱構造, 更新世

Keywords: North Pacific subtropical gyre, Kuroshio, water column structure, Pleistocene

日本海における後期鮮新世の海洋構造の変化 Changes of water structures in the Sea of Japan during the Late Pliocene

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現在の日本海は、北上した対馬暖流が北部で冷やされて沈み込み、酸素に富んだ日本海固有水を生み出している。この沈み込みは約 2.5 Ma 頃の表層水の冷却と沈降に伴い、はじめて形成されたと考えられている (上栗・本山, 2007)。しかし、その詳細な時期の特定や水温変化は不明である。また、後期鮮新世の間氷期には、現在より暖かい中層水が存在したことが貝形虫化石群集から指摘されている (Irizuki et al., 2007) が、その具体的な水温には幅がある。そこで本研究では、貝形虫殻の Mg/Ca を用いて、浅海と中層の水温を定量的に復元し、その差から温度勾配や海洋構造を明らかにすることを目的とした。

試料は新潟県胎内市の胎内川沿いに段丘崖を形成する鍬江層から連続的に採取した。海洋酸素同位体比ステージ (MIS) G19-G13 の層準について、中層水種である *Krithe* 属および浅海種の *Cytheropteron miurense* と *Cytheropteron sawanense* を用いて、殻の Mg/Ca から水温を定量的に復元した。中層および浅海の水温とその変動は MIS G16 を境に大きく変化した。中層水温は MIS G19-G16 は 0-10 °C と短い周期で大きく変動したのに対し、MIS G15-G13 は 3-7 °C と比較的安定していた。また、浅海水温は G16 以前は中層水温より高い値を示したのに対し、G15 以降は中層水温と近い水温を示す傾向が認められた。これらのことから、G19-G16 は日本海に存在した浅海から中層水域の成層構造が明瞭であったが、G15-G13 は鉛直混合が強化され、温度勾配が緩くなり水温変動がより小さくなったことが推察される。MIS 15-G13 はそれ以前と比べて間氷期の酸素同位体比が小さいことから、世界的寒冷化に伴い、間氷期に表層水温が低下したことに起因するかもしれない。

キーワード: 日本海, 後期鮮新世, 貝形虫, Mg/Ca, 海洋構造
Keywords: Sea of Japan, Late Pliocene, ostracode, Mg/Ca, water structure

中期中新世女川層に見られる堆積リズム Sedimentary Rhythms in the Middle Miocene Onnagawa Formation in Northern Japan

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中新世中期から後期にかけて、層状珪質岩を主体とする地層が環太平洋域に広く出現する。アメリカ、カリフォルニア州の海岸沿いに分布するモンテレー層や東北日本の女川層などがその代表例である。女川層は、“硬軟互層”と呼ばれる、比較的硬いポーセラナイトと比較的軟らかい珪質泥岩の互層を主体とし、平行葉理が比較的よく保存された白黒のポーセラナイトの細互層がその下部に見られる。女川層に見られるこうした硬軟互層や明暗互層の堆積リズムは、センチメートルからメートルスケールの堆積リズムを示す事が知られており、メートルスケールのリズムは、ミランコビッチサイクルに駆動された海水準変動に伴って変化する日本海内の水塊構造の変化を反映していると解釈されているが (Tada, 1991)、一方、センチメートルスケールの互層については、千年スケールの変動を反映する事は明らかにされているものの、その変動の成因や周期構造については未だ解明されていない。

そこで本研究では、女川層に刻まれる明暗互層の成因や周期構造を解明し、日本海の水塊構造の変化、そしてグローバルな環境変動との関連性を解明することを目指す。そのために、まず女川層の連続柱状図を作成し、微化石やサイクル層序から詳細な年代モデルの構築を行っている。その上で、女川層の珪質岩の化学分析を行い、シリカフラックスと碎屑物フラックスを割り出す。各フラックスの時間変動から日本海の水塊構造について議論し、グローバルな環境変動と比較することを計画している。

発表では、秋田県矢島町で行ったフィールド調査の結果について紹介する。

キーワード: 中新世, 女川層, 堆積リズム

Keywords: Miocene, Onnagawa formation, Sedimentary rhythm

水月湖における、色・化学組成データに基づく過去二万年間のハス川起源碎屑物フラックス変動復元 Reconstruction of detrital flux to Lake Suigetsu during the past 20kyrs based on Color and XRF data

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水月湖は、湖底堆積物に存在する年縞の計数、多数の¹⁴C測定と、これらの結果を中国鍾乳石の記録とウイグルマッチングすることで得られた、非常に高精度な年代モデルで知られている。この特徴を活かせば、超高精度で時間解像度の高い過去の気候変動史を復元することができる。水月湖堆積物をもちいて、これまで花粉や珪藻分析による古気候研究が行われてきた。しかし、堆積物中の碎屑物に着目した研究は少なかった。これは、水月湖に流入する堆積物が風成塵、湖周辺斜面からの流入物、隣接する三方湖を介してハス川から流入する河川起源懸濁物の3種類から構成されると考えられ、これらの識別が困難であるという理由からである。しかし、我々の最近の研究から、ハス川起源碎屑物の寄与率を推定する方法が明らかになった（古気候・古海洋変動セッションでの発表#01575を参照）。

本研究では、ハス川から流入する碎屑物のフラックスについて、色データを使って主要元素の因子分析から得られた因子の含有量を推定することにより過去二万年間の変動の高解像度復元を試みた。

まず、Qモード因子分析と因子軸の斜交回転により、主要元素組成の分散を説明できる因子を推定した。この結果、4つの因子が抽出され、因子2の特徴はハス川起源懸濁物と類似していることがわかった。次に、主要元素組成のデータ数には限りがあるため、因子2の寄与率をより高精度で測定がなされている色データを使って、因子2負荷量（含有量）との間で重回帰分析を行い、両者の関係式を導出した。

因子2のフラックスは、因子2含有量の推定値、乾燥かさ密度、堆積速度の積によって求めた。フラックス変動には長期・短期的なトレンドが存在し、短期変動はフラックスの急激な増加とその後の緩やかな減少という特徴を持ち、地震を示すと考えられている「イベント層」と同時に発生していた。長期変動（ハス川からの河川水流出量、すなわち降水量を反映すると思われる）は、中国鍾乳石から得られた東アジアモンスーン強度の変動と逆のトレンドを示した。この結果は、南中国において降水量が多い時期に、水月湖周辺では降水量が減少していた可能性があることを示唆する。

キーワード: 水月湖, 退氷期, 完新世, 因子分析, 重回帰分析

Keywords: Lake Suigetsu, Deglaciation, Holocene, Factor analysis, Multi-regression analysis

過去15万年間の東アジア冬季モンスーン変動 The East Asian winter monsoon variability during the past 150,000 years

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東アジア冬季モンスーンの軌道強制に対する応答はいまだ明らかではない。本研究では、南シナ海と西部太平洋暖水塊地域の水温差を東アジア冬季モンスーンのプロキシとしてみなし、過去15万年間の東アジア冬季モンスーン変動を復元した。水温差変動は歳差運動周期を示し、モンスーンが低緯度域日射変動に応答するとする Kutzbach (1981) の仮説と調和的であったが、モンスーンが離心率変動に応じるとする従来の海洋堆積物およびレスにもとづく研究の結論とは矛盾した。冬季モンスーンの大極は5月の近日点に対応し、6月近日点で極大になるとする Kutzbach (1981) モデルとは完全には一致しなかった。東アジア冬季モンスーン強度変動はインド夏期モンスーン強度変動とちょうど逆位相である、このふたつのモンスーンのダイナミクスが連携していたことが示唆された。

キーワード: 東アジア冬季モンスーン, 南シナ海, 西太平洋暖水塊, 歳差運動, 水温

Keywords: The East Asian winter monsoon, The South China Sea, The Western Pacific Warm Pool, Precession, Sea surface temperature