

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

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 *Ceratospyris 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.

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 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 diatom production recorded by DI2 at 2.7 Ma was possibly related to global paleoceanographic changes such as the northern hemisphere glaciation (NHG).

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.

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

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

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Quaternary hemipelagic sediments in the Japan Sea have distinct dark and light layers. These alternations of dark and light layers are associated with Dansgaard-Oeschger cycles (Tada et al., 1999). Previous studies focused on the last 200 kyr and showed that dark layers are rich in organic matter compared to light layers, and organic matter is a main cause of dark color of the sediments (Tada et al., 1999; Nakajima et al., 1998). Also, as marine organic matter content in the sediments reflect surface productivity and ocean redox conditions, a hypothesis was proposed that intensity of East Asian Summer Monsoon (EASM) rainfall control formation of organic rich dark layers (Tada et al., 1999; Tada, 2012). Therefore, organic matter content in the Japan Sea sediment deposited in older ages provide us useful information about EASM variability in the Quaternary.

In the summer of 2013, IODP Exp. 346 Asian Monsoon drilled at seven sites in the Japan Sea, and obtained long hemipelagic sediment cores back to entire Quaternary (Tada et al., 2015). Alternations of distinct dark and light layers existed for last 1.5 Myr (Tada et al., 2015). Reconstruction of organic matter content from these alternations of dark and light layers will provide us useful paleoclimate information, however, analysis of organic matter content for more than several hundred dark layers are not realistic. In this study, we use bromine (Br) content for estimation of marine organic matter content in the Japan Sea sediment. Br is concentrated in marine plankton (Masuzawa et al., 1988), and thus correlations between bromine content and total organic carbon (TOC) content in the sediments are reported (Ziegler et al., 2008). Furthermore, since Br concentration is higher in marine organic matter than terrestrial organic matter (Berg and Solomon, 2016), Br is proposed as a proxy for marine organic carbon (MOC) (Ziegler et al., 2008). However, this possibility is not verified.

In this study, we analyzed TOC and carbon isotope in the Japan Sea hemipelagic sediments recovered from Sites U1424 and U1425 during IODP Exp. 346. Since carbon isotope reflects ratios of marine and terrestrial organic matter, we calculate MOC from TOC and carbon isotope results. We also measure Br content in the same sediment using XRF core scanner (ITRAX) in Kochi University, Japan.

The results show good correlation between MOC and Br content. Therefore, Br could be used as a proxy to estimate MOC in the Japan Sea sediments.

Br variability measured by ITRAX in ~50yr resolution shows same variation with oxygen isotope record obtained from Chinese speleothem (Cheng et al., 2016) during last glacial period. Thus, estimated MOC variability record will provide us useful information to discuss about variability of EASM rainfall during the last 1.5 Myr.

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

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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.

Keywords: Japan Sea, redox sensitive elements

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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Asian monsoon climate system has started about 50 Ma, after the collision of the Indian and Eurasian continents followed by uplift of the Himalaya and Tibetan Plateau. It has influenced sediments in the Japan Sea through changes in the intensity of continental weathering and ocean currents. These sediments are characterized by cm-scale alternation of C_{org} -rich dark layers and C_{org} -poor light layers which is most likely due to temporal changes in the nutrient status and/or oceanic redox conditions. In order to obtain insights into the evolving oceanic redox state and the monsoon system, we conducted sulfur speciation and isotope analysis of the marine sediment core samples recovered in the central Japan Sea by IODP Exp. 346.

The light layers have lower S_{py} (0.03~0.25 wt.%) contents when compared to the dark layers (0.26~1.49 wt.%). The C_{org} contents have similar distribution (0.34~1.10 wt.% for light layers and 1.16~3.38 wt.% for dark layers). However, the S_{SO4} contents (0.02~0.64 wt.%), the $d^{34}S_{py}$ values (-34 to -38‰) and the $d^{34}S_{SO4}$ values (0 to -10‰) did not show such light-dark distinction. Elevated S_{py}/C_{org} ratios (0.03~1.00) in the dark layers are interpreted to represent sulfide formation in the anoxic water column by bacterial sulfate reduction. During deposition of light layers, oxidation of sulfide minerals could have released sulfate without significant isotope fractionation. Regardless of the type of the sediments (dark vs. light), sulfate was not limiting during bacterial sulfate reduction, as reflected in the sulfur isotope compositions. We speculate that, during deposition of dark layers, enhanced summer monsoon activity caused heavy rainfall and increased source-rock weathering, runoff of the Yangtze River, and nutrient input into the East China Sea and the Tsushima Warm Current. Inflow of nutrient-rich and less salty water into the Japan Sea triggered enhanced biological activity, water-column density stratification, transport of organic matter into deeper ocean and consumption of dissolved oxygen, and ultimately the creation of anoxic water body to allow bacterial sulfate reduction (syngenetic sulfide formation) to occur. On the other hand, during deposition of light layers, enhanced winter monsoon activity caused cooling of surface water of the Japan Sea, often creating down-going oxygen-rich water mass to ventilate the deep water (and break up density stratification). Oxidic condition in the deep water did not allow accumulation of massive organic matter and formed light-color sediments. Biogenic sulfide formed, if any, during diagenesis (no syngenetic sulfide formation).

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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The Asian monsoon climate system has started about 50 Ma, after the collision of the Indian and Eurasian continents followed by uplift of the Himalaya and Tibetan Plateau. Monsoon influences atmospheric circulation, rainfall, weathering, riverine transport, and ocean currents. It has influenced sediments in the Japan Sea, where occur cm-scale alternation of C_{org} -rich dark and C_{org} -poor light layers. This alternation is most likely due to temporal changes in the nutrient status and/or oceanic redox conditions, which are likely caused by the fluctuations in the intensity of continental weathering and ocean currents, both of which were ultimately caused by the variable monsoon system. In order to obtain insights into the evolving oceanic redox state and the monsoon system, we conducted phosphorus speciation analysis for the drillcore marine sediments recovered by IODP Exp. 346 in the central Japan Sea (e.g., Tada et al., 2015).

Phosphorus, along with nitrogen, is the limiting nutrient for the primary production of the ocean. Supply of phosphorus to the surface ocean is limited to inflow of rivers that contain products of continental weathering. On a long timescale, phosphorus is the most important limiting nutrient for primary production. Phosphate supplied from rivers is taken by organisms in the surface ocean as organic P. More than 99% of the produced organic matter are decomposed and released into the ocean again as inorganic phosphate for recycling. Only some can survive and reach to the ocean bottom.

In an oxic ocean like today, phosphate adsorbs onto precipitating Fe-(oxyhydr)oxide particles. Its fate depends on the redox state of the deep ocean. In an oxic deep ocean, phosphate adsorbed on the Fe-(oxyhydr)oxides reach to the ocean bottom and removed from the ocean. However, if the deep ocean is anoxic, the phosphate-bearing Fe-(oxyhydr)oxides undergo reductive dissolution, where Fe^{2+} and PO_4^{3-} are released into the waterbody. If the deep ocean is euxinic (i.e., stagnant, anoxic, and sulfidic), the released Fe^{2+} combines with sulfide formed by activity of sulfate-reducing bacteria, and phosphate would form carbonate fluoroapatite (CFAP) with carbonate ions produced upon decomposition of organic matter during bacterial sulfate reduction. The CFAP is highly insoluble and preserved in sediments.

In order to explore changes in the nutrient status and redox conditions that were influenced by Asian monsoon, we investigated phosphorus speciation in the marine sediments recovered in 2013 in the central (core U1423) and northeastern (core U1425) parts of the Japan Sea by IODP Exp. 346. The samples were quantified for five P-bearing species (P_{abs} , P_{Fe} , P_{auth} , P_{det} and P_{org}) by modified SEDEX method of Ruttenberg (1992) and Ruttenberg et al. (2009).

The most abundant P-bearing species is P_{auth} (Ave. 0.044 wt.%), followed by P_{org} (Ave. 0.016 wt.%) that show negative correlation with P_{auth} contents (at U1423). The least abundant species is P_{abs} (Ave. 0.004 wt.%). These results suggest that organic matter produced in the surface ocean was decomposed to release phosphate, which eventually formed authigenic apatite in the sediments, implying that the ocean was oxic and/or biological activity was enhanced. These results are consistent with Ce/Ce* values as a proxy of oceanic redox condition. Furthermore, layers rich in phosphorus are mostly dark in color, suggesting active summer monsoon; increased rainfall in east Asian regions promoted continental weathering and riverine input (by the Yangtze River) of nutrients like phosphorus, which flow through the

Tsushima Current and entered into the Japan Sea.

Using the same core samples used in this study, sulfur speciation and isotope analyses have been done and will be reported elsewhere. Iron speciation analysis is being done. Much more work is obviously necessary to better constrain the past nutrient status and redox conditions in the Japan Sea that were influenced by the evolving Asian monsoon system.

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.

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.

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.

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.

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

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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East Asia region including Japan is under the effect of East Asian Monsoon and Typhoons, which produce large amount of rainfall and subsequent flood events. Based on the observation and numerical modelling, it is indicated that occurrence of heavy precipitation could be affected by the increase of sea surface temperature in the vapor source. On the other hand, there are secular variations of occurrence, route and magnitude of typhoons and they could be affected by other climate conditions such as route of westerly and SST in the low latitude area, source regions of Typhoon.

To understand the major controlling factor of occurrence and magnitude of heavy rainfall and flood events in the long term, correlation of paleoclimatic record with heavy precipitation and flood record is necessary. However, existing method to reconstruct precipitation such as pollen and stalagmites can only obtain long term (monthly to annually) averaged data, which is not enough for the record of heavy precipitation and flood events occurring within a few days. In this study, for the proxy of heavy precipitation and flood events, we utilized the “event layers” which are preserved in the sediment as a result of geologically instantaneous phenomenon such as floods and flux of detrital material which increase with heavy precipitation. Using the near surface sediment of Lake Suigetsu, we correlated sedimentary record with observational record and two proxies for heavy precipitation and flood events are established;

1) Flux of detrital material from river basin would increase with the increase of heavy precipitation (>50mm/day).

2) As a result of a flood event, a light gray event layer would be deposited. Thickness of light gray event layer represents total amount of precipitation during the flood event.

Based on these two proxies, we reconstructed semi-quantitative record of heavy precipitation and flood events in the last 7000 years. In this presentation, we would discuss about the correlation of the record with other flood records and climate records around East Asia region which potentially control precipitation pattern.

Related to this presentation, establishment of proxy for reconstructing heavy precipitation and flood event based on correlation of sediment and observation is presented in H-SC07 session, and identification of flood and earthquake in this study and correlation with local environmental change would be presented in M-IS 23 session.

Keywords: Lake Suigetsu, varved sediment, flood, Holocene