The potential for a high-resolution, Quaternary paleo-observatory network in the Japan, Yamato, and Ulleung Basins

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The Quaternary hemi-pelagic sediments of the Japan, Yamato, and Ulleung (JYU) basins are characterized by centimeter- to decimeter-scale alternations of dark (org-C rich) and light (org-C poor) clay to silty clay that are known to reflect variations in the East Asian summer monsoon (EASM) in association with millennial-scale abrupt climatic changes known as Dansgaard-Oeschger Cycles (DOC). These dark layers can be traced across the deeper (>500 m water depth) parts of the JYU basins, and therefore can be used as synchronous markers.
In the summer of 2013, IODP Expedition 346 drilled 7 sites in the JYU basins, and the 6 sites deeper than 800 m water depth are characterized by dark and light layering. Intercalation of the dark layers show millennial-scale variations in dark and light layers started *c.* 1.45 Ma with over 250 dark layers deposited repeatedly since then. In addition, approximately 100 tephra layers have been correlated across these 6 sites, and as a result we have obtained over 300 time slices with an average resolution of 5 k.y. covering the entire JYU basins.
We have constructed an age model for the Quaternary interval at Site U1424 off Akita using 10 geomagnetic polarity boundaries and 12 marker tephra layers as time constraints. This was then tuned using the gamma ray attenuation density (GRA) profile, which reflects diatom abundance, to the LR04 $d^{18}O$ stack to develop an age model of higher resolution and precision. This high-resolution and high-precision age model is projected to the other 5 sites using the correlation of dark layers and tephra layers. In this way, we have constructed a high-resolution paleo-observatory network from which to assess leads and lags in northern hemisphere climate. We will present a few examples of how to utilize the network.

Keywords: High-resolution, Quaternary, paleo-observatory network, IODP Expedition 346

Marine tephras in cores obtained by IODP Expedition 346: Stratigraphy, chronology and correlation

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Mary tephra beds are intercalated in marine sediment sequences around the Japanese islands. During IODP Expedition 346, the sediment cores were obtained from 7 sites in the Japan Sea and 2 sites from the northern East China Sea. Many tephra beds are observed in the cores from these sites. Several tephras were correlated to the age-known widespread tephras in Pliocene-Quaternary age, and some were used for inter-core and inter-site correlation. Results clearly indicate the importance of marine tephra study for establishing stratigraphy, chronology and correlation.

Keywords: tephra, IODP, stratigraphy

Oxygen isotope stratigraphy for the Japan Sea during the last 1 Myr using shallow marine sediment at IODP Site U1427

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The Japan Sea is sensitive to the glacial-interglacial sea level variation because of narrow and shallow straits, which connect with adjacent seas. The oxygen isotope change in the Japan Sea is, therefore, distinct from so-called “standard isotope curve.” While previous studies have tried to construct unique isotope stratigraphy for the Japan Sea using deep sea sediments, it is problematic that foraminiferal fossil do not occur continuously in the deep sea sediment due to significant change in paleoceanographic environment. Moreover, determination of marine isotope stages using planktonic isotope is not straightforward because lighter peaks correspond to both glacial and interglacial maxima.
The 570 m long sediment core is drilled during IODP Expedition 346 from ~330 m seafloor (Site U1427) off Tottori Prefecture. The sediment at this site lacks dark-light alternation, which generally observed in sediment from deep sites, indicating that the deep sea anoxic events at glacial maxima did not affect the depth of U1427. Therefore, well preserved benthic foraminifera are continuously observed except for some intervals. Here we analyzed benthic foraminiferal isotope at 1 m intervals in order to construct isotope stratigraphy for 1 Myr. Fortunately, the bottom water at the depth of U1427 is affected by surface freshening event at glacial maxima but not affected by Tsushima Warm Current at interglacial maxima. Therefore, the lighter value of benthic oxygen isotope reflects the glacial freshening event. The interglacial maxima are recognized by occurrence of warm water species of Radiolarians. By combining with tephrochronology, we have constructed oxygen isotope stratigraphy for 1 Myr.
Benthic foraminifera as well as calcareous nannofossils and ostracods are absent at intervals of MIS12 and 16. Because diatom species that prefer low salinity water are observed in these intervals, surface water freshening at these glacials were more severe than other glacials for benthic foraminifera.

Keywords: Japan Sea, isotope stratigraphy, glacial-interglacial cycle, Integrated Ocean Drilling Program

Paleoceanographic implications of radiolarian fossil assemblages in sediments from shallow water depths

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Radiolarian fossil analyses have been usually carried out using materials from deep-sea sediment sample, which is expected abundant occurrence of their fossils. However, if the condition is better, radiolarian fossils can be preserved even in the near shore sediments from shallow water depths. Such radiolarian assemblages from the shallow waters provide important information about paleoceanographic condition.

Radiolarian fossils can be used as indicators of surface and deep-water environments because of their discrete living depths for each species. In the present day, radiolarian assemblages in the Japan Sea are characterized by warm water species in shallow depths related to the Tsushima Current, while the cold-water species dominates in intermediate and deep waters related to the Japan Sea Proper Water [JSPW]. However, there is no guarantee that their depth zonation was same as the present day from analysis based on deep-sea sediments. On the other hand, radiolarian assemblages in sediments from shallow depths must be composed of only shallow dwellers, and doesn't include deep dwellers. Therefore, it is expected that comparison of radiolarian assemblages between deep-sea and shallow water sediments provide us important information about the past depth zonation of radiolarians.

IODP Site U1427 is located at 330 m water depth in the Japan Sea off Tottori, southwestern Japan. In this site, abundance of *Cycladophora davisiana*, which is a deep dwelling species related to deeper than 1,000 m of the present JSPW, increased during some intervals including MIS-12. This means that habitat depth of this species had shifted to shallower than 300 m in these periods, probably related to declined ventilation with low salinity surface water.

Keywords: Coastal environment, Tsushima Current, Japan Sea Proper Water

High-resolution XRF core scanner analysis of the Japan Sea sediments (IODP U1425) and its paleoceanographic implication

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Quaternary hemipelagic sediments of the Japan Sea have distinct dark and light layers, and these layers are correlated with Dansgaard-Oeschgar cycles (Tada et al., 1999). Previous studies revealed that these dark and light layers are characterized by variations of organic content and C/S ratio, the latter reflecting sea floor redox state, calcareous and siliceous production rates (Tada et al., 1999), and aolian dust and terrigenous fluxes (Irino and Tada, 2000; 2002) for last 200kyr. In the summer of 2013, IODP Exp. 346 drilled hemipelagic sediments of the Japan Sea, and revealed that these dark and light layers became distinct around 1.5 Ma (Tada et al., 2015). However, variability of these dark and light layers and other paleoclimate proxies with respects to their periodicities and amplitudes in association with Glacial-Interglacial cycles are not well studied because high-resolution quantitative analyses of thousands of samples generally require significant time and efforts. High-resolution and high-speed analytical methods are necessary with this regard so as to reveal millennial-scale variability of paleoclimate proxies during last 2.6Myr, entire Quaternary.
In this study, we conduct high-resolution, high-speed analysis of chemical composition using XRF core scanner (ITRAX) in CMCR (Center for Advanced Marine Core Research), Kochi University, to examine elemental variability in association with dark and light layers in the hemipelagic sediments of the Japan Sea. We used sediments recovered from Site U1425 located on Yamato Rise. We analyzed top ~100m of the sediments with 2mm resolution, and obtained elemental variability of entire Quaternary with 20 to 200 years resolution. In this presentation, we will show high-resolution reconstruction of burial rates of biogenic silica and carbonate, bottom redox state, aolian dust and terrigenous fluxes at the site during the entire Quaternary.

Keywords: XRF core scanner, Quaternary, dust, dark and light layer, redox, IODP Exp. 346

Assessment of time-dependent evolutionary rates of rodent mitochondrial DNA based on paleoclimatic calibrations of the Japanese Islands

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Use of the reliable time-dependent evolutionary rates of mitochondrial DNA might allow us to built realistic evolutionary scenario with phylogenetic inferences, covering a broad time scale based on the phylogenetic inferences. Other than using fossil evidence, it is possible to estimate evolutionary rates by relying on the well-established temporal framework of the Quaternary glacial cycles that would likely have promoted both rapid expansion events and interisland dispersal events. We are now focusing on the mitochondrial cytochrome *b* (*Cytb*; 1140 bp) sequences of a temperate species of wood mice (*Apodemus argenteus* and *A. speciosus*) from the Japanese Islands to assess evolutionary rates (site/million years) and obtained ca. 11% and 3% under assumption of rapid expansion and a priori information of the Quaternary climate fluctuation around 10 and 130 k years ago (ka), respectively (Suzuki et al., 2015). In addition, assuming that land-bridge like structures were created intermittently at glacial maxima of 100 k year intervals and shaped divergence patterns of the *Cytb* sequences of the larger Japanese wood mice *A. speciosus*, we obtained estimated evolutionary rates of 3.3 to 2.7% with presumed calibrations of 140, 250, 350 and 440 ka, through comparison of sequences from peripheral remote islands. In survey of rapid expansion signals in the lesser Japanese wood mouse *Apodemus argenteus* and three continental congeneric species from Asia and Europe, three levels of t values can be categorized into three levels, 3.9, 5.0-5.7 and 7.8-8.1. Adopting the idea in which the climate turned to be warm after preceded time of rapid cooling at 15, 53, 82 and 119 ka based on available pollen fossil evidence of trees including *Quercus* species, the evolutionary rates were estimated to be 11.4, 4.4-5.0, 3.1%, respectively. Here we propose the use of the time-dependent evolutionary rates (11~2.7%/site/million years) for the time span of 10 to 450 ka, hoping that it can be applicable to other species of murine rodents including mice and rats.
Reference: Suzuki Y, Tomozawa M, Koizumi Y, Tsuchiya K, Suzuki H (2015) Estimating the molecular evolutionary rates of mitochondrial genes referring to Quaternary Ice Age events with inferred population expansions and dispersals in Japanese *Apodemus*. *BMC Evolutionary Biology*, 15,187.

Keywords: mitochondrial DNA, evolutionary rate, Japanese Islands, Apodemus species, Quaternary glaciation

Optically stimulated luminescence dating back to 100ka and sedimentation rates of dark versus light layers in the Japan Basin

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Sediments in the Japan and Yamato Basins record millennial-scale changes in the East Asian Monsoon as alternations of dark and light layers. The gray-scale profile showing this millennial-scale variability has been correlated with the $d^{18}O$ record from Greenland ice cores (GISP2). However, this correlation between millennial and orbital scale changes becomes less certain during the last interglacial and the Holocene period, largely as a result of a paucity of biogenic carbonate used for ^{14}C and isotope stratigraphy; there is significant age uncertainty over this time period.
We have used optically stimulated luminescence (OSL) dating of fine-grained detrital quartz (that are aeolian in origin) to provide high-resolution numerical age models for cores U1424C and U1425C drilled in the southeastern margin of the Japan Basin, and the Yamato Rise, during IODP Expedition 346.

We report our attempts to: 1) assess whether surface sediment of the cores are consistent with modern age; 2) test the reliability of OSL ages by comparison with tephra chronology and orbitally-tuned age models based on the correlation between the GRA record and the LR04 stack; 3) date cores U1424C and U1425C to construct a robust 120 ky age model with a resolution of 10 ky; and 4) conduct high-resolution dating of several pairs of dark and light layers to estimate short term changes in sedimentation rate, in particular over the last ~30 ky. We show OSL dating of fine aeolian silt in Japan Sea sediments shows great potential to establish independent numerical chronologies, and this is especially useful in cores where isotope stratigraphies and/or gray-scale signatures are poorly reconciled.

Keywords: Optically stimulated luminescence dating , IODP Expedition 346, quartz

Is Central Europe the ‘witch's brew’ of Pleistocene paleoclimate studies? -The magnetic fabric approach

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The study of Pleistocene climate is one of the fastest growing disciplines in Earth Sciences. One of the best tools to obtain more information about the Pleistocene in terms of the terrestrial environment is the investigation of loess. The different varieties of loess together constitute one of the most widespread terrestrial sediments, which was deposited, altered, and redeposited in the course of the changing climatic conditions.
Central Europe is one of the most complex part of Europe from the sense of the present day’s climate conditions. The climatic components are influenced by all of the North Atlantic, Mediterranean (African) and Siberian (Asian) climate. The recent complexity arise a question about the Pleistocene paleoclimate of the area, and possibly makes it the ‘witch's brew’ of paleoclimate studies.
970 pieces of samples were taken from Paks profile (Central Europe, Hungary), one of the well-known sediment succession of the area, to reveal some component (e.g. wind direction) of the early Middle Pleistocene paleoclimate by anisotropy of magnetic susceptibility (AMS) measurements.
Weak anisotropy, quasi isotropic fabric and poorly defined orientation were revealed by the confidence ellipsoid of individual samples. Despite the character of individual samples, the ‘sample-populations’, related to various layers, had characteristic alignment on stereoplots. Proper changes of the basic AMS parameters (e.g. degree of anisotropy and shape of the susceptibility ellipsoid), were also identified in the profile.
Two main sedimentary environments were revealed by the AMS analysis. The homogeneous loess was characterized by well-defined horizontal foliation plane, strongly oblate (lentil shape) susceptibility ellipsoid. Weak, temporarily changing, W, NE and S(E) transport/deposition (wind) orientations were also defined, indicating influences of North Atlantic, Siberia and Western Asia respectively. The character of the fabric indicated low energy transport and relatively calm environment during deposition.
In contrast, the magnetic fabric of the moderately-poorly sorted, coarser, and partly fine laminated materials show higher variability. The fabric of the sandy aleurite and sand layers are characterized by oblate, triaxial and prolate (rugby ball -like) susceptibility ellipsoid either. Generally, these sediments have stronger anisotropy compared to the loess. AB plane imbrication and the influence of slope during deposition were revealed by the stereoplot analysis. The magnetic fabric, characterized above, suggests stronger, possibly water-lain transport processes and redeposition on slope. The quick changes of the paleoenvironment were indicated by the radical change of the orientation of the transportation in short geological period, and it could be induced by the rapid change of the paleoclimate.
Paleosol horizons, intercalated in sediments, were also observed. Based on the degree of the development and the structure of the paleosol, various magnetic fabrics are defined. Generally, the paleosols are characterized by oblate/triaxial susceptibility ellipsoid and weak anisotropy. Horizontal and quasi inverse fabric were observed on stereoplots. The characters above, possibly indicate the alteration of the fabric by biogenic activity (reworking) and vertical pedogenic processes. SW and W orientation (influence of Mediterranean) were detected in the fabric of

well-developed soils, however these orientations are possibly not reliable due to the effect of pedogenesis.
High variabilities of the paleoenvironment were described during the early Middle Pleistocene in Central Europe. The wind system was possibly similar to the recent ones, however, some component (e.g. orientation of dominant paleowind direction) became stronger during the glacial or interglacial phase.

Keywords: anisotropy of magnetic susceptibility, Middle Pleistocene, wind direction

East Asian Monsoon variations in marine isotope stage 19 by magnetic and grain size data of Chinese loess deposits

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Marine isotope stage (MIS) 19 is an important target of study, because of its similarity with the Holocene in term to orbital element, and occurrences of the last geomagnetic polarity reversal and cooling event. Loess-paleosol deposits in the Chinese Loess Plateau (CLP) are a good archive of the climate changes of glacial-interglacial cycles and paleomagnetic variations. Thus, loess-paleosol deposits provide a good opportunity to study the climate of MIS 19 and the Matuyama-Brunhes transition (MBT).
We analyzed magnetic susceptibility (MS), frequency dependence (FD) and grain size (GS) of loess-paleosol deposits from two sections in the CLP, to restore detailed monsoon variation in MIS 19. In paleoclimate studies in the CLP, MS is regarded as a proxy of summer monsoon intensity, and GS as that of winter monsoon intensity. The sections are about 7 and 8 m thick, which are from Xifeng in Central CLP and Lingtai about 100 km south of Xifeng, respectively. Specimens were collected at about 2.5 –30 cm intervals. Detailed paleomagnetic analyses, which have been already carried out, reveal the Matuyama-Brunhes transition (MBT) with multiple polarity swings in both sections.
In both sections, MS and FD show similar variations well correlated with the glacial sea-level or ice volume changes indicated by marine oxygen isotope data, having two peaks correlated to highstands MISs19.3 and 19.1, respectively, and a minimum to lowstand MIS19.2. Only the Lingtai section has low MS and FD interval correlated to MIS 20.2. Median GS and the percentage of coarse grains (CG) (Xifeng: φ>16 μm, Lingtai: φ>20 μm) show grains become coarse as MS decreases or summer monsoon intensity weakens at MISs 20.2 and 19.2. These results suggest that both of summer and winter monsoon intensities are essentially controlled by orbital forcing, especially by the precessional component. Therefore, weak winter monsoon is expected to occur during a warm period correlated to highstand. However, coarsening occurs many times in the strong summer monsoon interval correlated to MIS 19.3. In Lingtai, the maximum mean GS almost reaches to that of the glacial period (MIS 20.2). We define the anomalous interval as intensified winter monsoon zone (IWMZ). The uppermost part of the IWMZ is overlapped with the MBT. Many marine core data show the MBT is preceded by a long interval of low paleointensity that starts from around highstand MIS 19.3. The temporary winter monsoon strengthening during the summer monsoon peak may be related to the MB reversal, especially to the low paleointensity.

Keywords: winter monsoon, Matuyama-Brunhes boundary, Chinese Loess Plateau, MIS 19, magnetic susceptibility, grain size

Millennial scale paleoceanographic features during marine isotope stage 19 in Osaka Bay and North Atlantic

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Detailed variations of paleoclimate and paleoceanography are important to clarity the complex environments of Marine Isotope Stage (MIS) 19, a distinct interglacial, that includes a geomagnetic reversal and a cooling event, characterized by a unique orbital situation with minimum of the 400-kyr eccentricity cycle and small amplitude variations in insolation. We examined recently published or obtained high-resolution paleoceanographic data of MIS 19 to extract distinctive common features. Sea-level proxies based on diatom assemblage and grain size data from an Osaka Bay core with an average accumulation rate (a.r.) of 64 cm/kyr show precession-related signals of highstands 19.3 and 19.1, and lowstand 19.2. In addition, they show many sub-orbital scale features at a few kyr intervals, including features spanning for less than 1 kyr. These orbital and suborbital scale features are also observed in high-resolution marine oxygen isotope data from planktonic foraminifera from IODP site U1313, North Atlantic, where an average a.r. 5.4 cm/kyr is estimated. Using the features as tie-points, an age model for U1313 was constructed by transferring the astronomical ages of the Osaka Bay core. The age model shows the Matuyama-Brunhes boundary (MBB) at U1313, the effect of lock-in depth corrected, is dated to be 778 ka, which is 1 kyr older than that for Osaka Bay. High-resolution alkenone-based SST data from U1313 show the warmest interval lying after the MBB, as the warmest climate is observed in Osaka Bay. The age model shows that the warmest SST interval for U1313 ranges in age from about 776 to 772 ka, which is partly overlapped with the warmest climate interval from about 777 to 774 ka for Osaka Bay, both much delayed with the highest sea-level peak at 780 ka. The delayed post-reversal warming in Osaka Bay is interpreted to be caused by the climate cooling associated with the low field intensity during the reversal transition. The millennial scale features common for both sites are also observed in the core data from the Chiba section, a candidate for the GSSP for the early to middle Pleistocene boundary. The features are probably global.

Keywords: MIS 19, sea-level variation, Matuyama-Brunhes boundary, Osaka Bay, North Atlantic

Middle Pleistocene sea-level variations in Osaka Bay well correlated with marine oxygen isotope stratigraphy

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The Osaka Group consists of Plio-Pleistocene sediments continuously deposited in the Osaka Basin. It mainly consists of freshwater deposits in the lower part, and alternating marine and freshwater layers in the upper part. Each marine layer has been designated as Ma-1, Ma0, Ma0.5, Ma1, etc, and correlated with interglacial highstands. However, marine layers Ma6, Ma7, and Ma8 possibly correlated with Marine Isotope Stages (MISs) 15 and 13, have not been studied well and correlations with MISs are obscure because of low amplitude precession-related signals for marine isotope data. Recent studies revealed many marine clay layers defined based on lithology are partly lacustrine. In this study, we examine sea-level changes with diatom and sulfur analysis of Ma6, Ma7, and Ma8 in the Osaka Bay 1700-m core (GS-K1 core) to construct more detailed and precise correlations with eustatic sea-level changes. The aquatic environment and diatom assemblages in Osaka Bay are strongly affected by eustatic sea-level changes through the Kitan Strait, and also by a huge amount of freshwater from the Yodo River. Diatom taxa were grouped into five ecological categories according to salinity tolerance: marine, marine-brackish, brackish, brackish-freshwater, and freshwater. We adopt 3 per mil of sulfur contents to empirical criterion which defines a marine/freshwater boundary. Parts of Ma6 defined in the previous study are lacustrine. The thickness of marine interval is 27.6 m, which is 0.8 m shorter than before. In the lower part of new Ma6, we found a single sea-level highstand correlated with MIS 15.5. The upper part has a zone of no diatoms. However, this zone is marine because it has high sulfur content over 3 per mil. In Ma7, marine interval is newly defined to be 13.9 m thick, which is 5.4 m shorter than the previous one. In the center of new Ma7, we found a single sea-level highstand correlated with MIS 15.1. Between the new Ma6 and Ma7, we found a lacustrine layer of 3.2 m thick that can be correlated with MIS 15.2. We also investigated Ma8, and found Ma8 splits into two marine intervals, probably caused by desalination due to eustatic sea-level fall correlated with MIS 13.2. A tentative astronomical age model shows an average accumulation rate for MIS 15 is 0.86 m/ka, which is much higher than an average for the middle Pleistocene (0.52 m/ka). The high accumulation rate may reflect that tectonic activities including uplifting in mountain areas and subsidence in the basin became high during MIS 15 (621-576 ka) in the Kinki District.

Keywords: sea-level change, Middle Pleistocene, Osaka Group, diatom, Marine Isotope Stage 15, Marine Isotope Stage 13

The Pacific Decadal Oscillation and Japanese history

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The Pacific Decadal Oscillation (PDO) influences climate and the weather in circum-Pacific region. In this study, we discuss changes in Japanese society and famines based on our proxy record of the PDO during the last 2900 years.
A Beppu Bay U^{K}_{37}'-based temperature record indicates that the amplitude of the PDO was larger from 300 BCE to 100 BCE, from 1200 CE to 1500 CE, and from 1700 CE to 1900 CE. The first period corresponds to the late Yayoi period that was characterized by a succession of wars. The second period corresponds to the developing period of medieval feudal society. In the Muromachi period, riots frequently occurred when the PDO was in the positive phase. In the Edo period, major three famines occurred when the PDO was in the positive phase. The positive PDO likely tended to induce a cool-wet or a hot-dry summer in Japan, resulting in lean harvest, destabilizing society.
Diatom records from the Japan Sea and the Okhotsk Sea indicate an intensification of the Tsushima and Soya Warm Currents around 1200 CE (Koizumi et al., 2006; Shimada et al., 2000), which may have been related to the shift of the behavior of the PDO. This timing corresponds to the period of Ainu culture establishment. Changes in fishery resources caused by intensified warm currents may have changed the life style of Hokkaido residence.

Keywords: PDO, paleotemperature, human society

High resolution climate reconstructions in historical times based on the diary weather descriptions and old meteorological records

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The data and methods for scientific research on climatic variations in historical times should be examined carefully in terms of their reliability and methodology for climatic reconstructions. There exist various kind of proxy documentary series of historical data in Japan, among which continuous records of daily weather descriptions in old diaries since 17th century would give us reliable climatic information with high resolution in time and space. Although the quality and quantity of daily weather records are not unified, some diary records include very detailed weather and wind information with several times in a day.
Old meteorological instrumental data, such as those observed in Nagasaki by Dutch medical doctors during 1820s-1850s, and meteorological observations in several cities (Tokyo, Yokohama, Osaka, Mito et al.) by Japanese people, are also valuable and effective for studying long-term climatic variations in Japan. Also, many Light-house meteorological records observed in Japan during 1870s-1880s have been recovered.
Imaging and digitization of old paper-based instrumental meteorological records must be carried out before these records are lost to decay. This kind of activity called “data rescue” is now taking places all over the world. We have recovered instrumental temperature and pressure data for several locations in Japan from the 19th century, a period for which no instrumental records were believed to exist. The recovered data were collected by Dutch, German, French, British, American and Russian visiting Japan and also by Japanese astronomers trained by the Dutch at the time. The data allow extending the beginning of the instrumental record back from 1872 to 1819.The recovered temperature and pressure data were converted to modern units and digitized into computer readable form. The pressure data were corrected for temperature, height, and gravity where needed. The temperature data were homogenized to compensate for changes in recording location. Then, both data sets were homogenized to account for varying observation schedules.
By combining the proxy data (e.g., diary weather records and old meteorological records) with JMA meteorological data properly, it would be possible to reconstruct long-term temperature time-series which is useful for predicting future climate change.

Keywords: climatic reconstrucition, climate variation

Accuracy evaluation of climatic reconstruction with historical daily weather record using old diaries written in the observation period

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Weather records of old diaries are useful source for climate reconstruction in historical times in Japan. Those records have been compiled for since the 11th century for the capital (Kyoto) area, and are widely available for since the 18th century for most part of Japan. Although daily weather records have an advantage of accessibility and high temporal resolution, their description is qualitative and dependent on subjectivity of the author, and therefore evaluation of their accuracy is necessary for reconstructing long-term climatic variation by compiling historical weather records together with modern observed meteorological data. In this study we collected several types of historical daily weather records including private diaries of merchants and scholars and official dairies of temples written in the late 19th to early 20th centuries that parallel meteorological observational records. By comparing weather records with observed data on the daily basis, we found weather descriptions of “light rain”, “rain” and “heavy rain” correspond to a broad range of daily precipitation without distinct boundaries and about one fourth of rainy days are missed in weather record of diaries. Referring to plural diaries and using climatic indices derived by accumulating weather descriptions for months or seasons (such as number of rainy days) is essential to enhance reliability and objectivity of climate reconstruction using such subjective and qualitative information. On the other hand, sharp boundary was found between daily temperatures corresponding to weather descriptions “rain” and “snow”, which implies rain/snow ratio is a promising proxy for winter temperature in the central part of Japan.

Keywords: historical daily weather record, accuracy evaluation, observation period

Present situation and future prospects of the oxygen isotope ratio dendrochronology in the northeastern Japan

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Oxygen isotope ratio ($\delta^{18}O$) dendrochronology has the potential to be conveniently and accurately dating a variety of tree species of old wood material (old building materials, woody remains and natural buried woods). For this reason, $\delta^{18}O$ dendrochronology has been attracting attention as a new dating method in various fields of history, archaeology and geology (Nakatsuka & Sano 2014). Building of tree-ring $\delta^{18}O$ master chronology mainly has progressed in the central and western Japan, reaching already 4300 years ago in some areas (Kimura et al. 2014). On the other hand, it has been delayed in northeastern Japan. Therefore, in this region, the major part of the historical era remained blank data. Because of tree-ring $\delta^{18}O$ is defined in the precipitation and relative humidity of the growing environment, dating is difficult in between the master chronology and old wood material of different rainfall pattern area. Since northeastern Japan is affected by the northeast wind that coming from Okhotsk high in the summer, it is desirable to build independent master chronology (Nakatsuka 2015).
In view of this situation, we has been working on the tree-ring $\delta^{18}O$ analysis of the woody remains and natural buried woods from Aomori Prefecture to Niigata Prefecture. As a result, it succeeded to get in nearly consecutive tree-ring $\delta^{18}O$ data over 1200 years of 5-16 century.
As a result of comparing this data with the existing central Japan $\delta^{18}O$ standard annual ring curve, we found common components on these. Now, we are concidering the reconstruction of the climate field from the spatial pattern of tree-ring $\delta^{18}O$. In this report, we describes an overview of these surveys and analysis, the future prospects.

Keywords: Tree-rings, Oxygen isotope ratio, Climate reconstruction

Stalagmite growth and farming by Jomon Man in mid-Holocene

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Stalagmite study based on U-Th dating in my laboratory has represented new aspects on the Late Pleistocene-Holocene paleo-moisture in Japanese Islands. In turn, results of the U-Th dating imply that growth of many studied stalagmites slowed or stopped in 4000-6000 years ago although dripwater are still active on these stalagmites. This is clearly due to low Ca concentration of the dripwater, and only a few stalagmites are fed by enough Ca concentration for calcite precipitation. Thus, Ca concentration of dripwaters in Japan decreased in mid-Holocene.
Dripwater Ca concentration is primary controlled by pCO_2 at soil/limestone interface where limestone is dissolved. Then, temperature, moisture, and vegetation abundance are main factor for soil CO_2 produced by root respiration and microbial decomposition of organic matter. If the soil CO_2 in the limestone areas decreased in 4000-6000 years ago, at least one of the factors drastically changed at this period.
Considering relatively stable climate during Holocene, the most likely factor was declined vegetation. In addition, inferring from the age of 4000-6000 years ago, a fundamental cause was farming by Jomon Man that had expanded in Honshu in mid-Holocene. It is well known that they preferred to live in limestone areas because they could hide from rain. Their burnt farming may have destroyed thick forest vegetation and resulted in decreasing soil pCO_2 and dripwater Ca, and ultimately in the declined stalagmite growth. We have only little supporting evidence for this hypothesis, but the mid-Holocene peak of fine-grained charcoal in lake deposits implies active farming by Jomon Man. Further examination is required to study detailed charcoal-pollen occurrence in lake deposits, as well to perform radiocarbon dating for burnt wood from the Holocene archeological sites.

Keywords: stalagmite, Holocene, Jomon

Fossil coral-based reconstruction of the Mid-Holocene ocean environment in Okinawa-jima, Japan

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Quaternary paleoclimate records have been extracted from climate proxies such as deep-sea sediments, ice sheets, trees, speleothems, and corals. Continuous long cores from sediments and ice sheets play a leading role in Quaternary paleoclimate reconstructions, although the slow rates of sedimentation frequently preclude them from reconstructions on seasonal and interannual time scales. However, fossil coral archives provide high resolution windows of generally short duration with which to investigate past atmospheric and oceanic conditions at the tropical/subtropical sea surface. Massive *Porites* corals, living in shallow waters of the tropical to subtropical oceans, precipitate annually banded aragonite skeletons. These colonies provide robust chronological control and allow sub-sampling at monthly-to-seasonal resolution. The ages of fossil corals are determined accurately by radiocarbon and uranium-series dating methods. Oxygen isotope composition of coral skeleton reflects variations in sea surface temperature and seawater oxygen isotope composition (salinity) with the latter being closely related to the precipitation-evaporation balance at sea surface and changes in water mass transport. Long-lived corals can be a powerful proxy for documenting paleoceanography at seasonal, interannual, and decadal time scale, but only a few long-records of >50-year have been published from fossil corals. Here we present bimonthly resolved oxygen and carbon isotope composition time series from mid-Holocene corals in coral reef sediment cores drilled at the west coast of Okinawa-jima, the Ryukyu Islands, Japan. Our coral-based climate reconstruction significantly shows seasonal-to-decadal time scale variability of thermal and hydrologic conditions in the northwestern subtropical Pacific during the mid-Holocene.

Keywords: coral skeleton, fossil, oxygen isotope composition, carbon isotope composition, paleo-temperature, the Ryukyu Islands

Heinrich events and last glacial recorded in a stalagmite from Mie Prefecture, Japan

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Stalagmites record physicochemical conditions in isotope and elemental composition in their carbonate fraction. Here, we investigate 10-cm-long stalagmite KA03 collected from Kiriana cave in Mie Prefecture. This stalagmite has high concentration of uranium and provides accurate U-Th ages. Results of dating show that the stalagmite has been growing during the last 80 kyr almost continuously. The oxygen isotopic curve of KA03 generally follows the records from the Chinese caves and Greenland ice-sheets in terms of 1) drastic decrease at the B/A warming, and 2) high isotopic intervals corresponding to the Heinrich events. However, KA03 lacks the millennium changes of Dansgaard-Oeschger cycles, which have been reported in a stalagmite from Gifu Prefecture. A distinct feature of KA03 oxygen isotope is a linear increase from 37 ka to the Last Glacial Maximum (LGM). Assuming that the isotope is a proxy of humidity, the amount of rainfall had been decreasing from 37 ka to LGM. Because the locality is generally dry in winter season, the stalagmite KA03 is a significant record of the East Asian summer monsoon.

Decadal to centennial-scale Asian dust transport changes during the last thousand years recorded in Lake Suigetsu sediment

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Knowledge of decadal to centennial-scale variations in Asian dust transport is critical to understand the interactions between Asian dust and natural environment, and is also important to estimate past atmospheric circulation changes. Here we estimated temporal changes in the content and depositional flux of aeolian dust in sediment core SG12 from Lake Suigetsu, central Japan, during the last thousand years based on the depositional flux (please see Suzuki et al., presented in this session) and grain size of detrital materials.
First we focused on the last century and compared the estimated dust flux changes to the meteorological records. The estimated dust flux shows decadal-scale change with the decrease during 1952–1974, which could be explained by weaker westerlies in lower latitudes including central Japan, reflecting weaker Aleutian Low during the corresponding period.
Similar decadal-scale changes are observed throughout last thousand years, suggesting dominance of similar decadal-scale climate systems in the East Asia and the north Pacific. In addition, the dust record exhibits centennial-scale changes with the decreases during 11–12th, 15th and 18–19th centuries. We will further compare our result with pollen record from Lake Suigetsu and tree-ring records in Asian region, and discuss nature and mechanisms of decadal and centennial-scale climate changes in East Asia.

Keywords: Asian dust, last 1000 years, Lake Suigetsu, decadal-vriation, centennial-variation

Climate and environmental changes during the past 1000 years reconstructed from fluxes of detrital materials of different sources to the Lake Suigetsu sediment

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Fluxes of detrital material in the sediment reflect various climatic factors such as rainfall through river discharge and wind system through transport of eolian dust. Because flux of detrital material is controlled by relatively simple physical process, it has high potential to become a quantitative paleoclimate proxy. If we want to utilize detrital flux as a paleoclimate proxy, we have to separate detrital fluxes from different sources and correlate their records with observational and historical records to specify the physical processes that control the detrital inputs.

In this study, we used Lake Suigetsu sediment core (SG12) drilled in 2012 for chemical and mineralogical analyses to specify different sources of detrital material and estimate their mixing ratio. Because Lake Suigetsu sediment is known to have high-precision and high-resolution age depth model, we can correlate sedimentary record with historical record precisely.

We conducted XRF analysis for major elements' composition and XRD analysis with Rietveld data analysis method to quantify mineralogical composition. Using these data, we conducted factor analysis to extract end members' compositions of the sediment. XRF and XRD measurement is also conducted for detrital materials collected in Hasu River, the major watershed of Lake Suigetsu, and its tributaries to compare with end-members extracted by factor analysis to estimate their sources. In this presentation, we will introduce the chemical + mineralogical data analysis method to reconstruct temporal changes in detrital fluxes from different sources during the past 1000 years.

Keywords: Lake Suigetsu, Factor analysis, Rietveld method

The isotopic measurements of oxygen and hydrogen in Dome-Fuji (Antarctica) ice core: Annually-resolved temperature reconstructions of the past 2000 years

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We present annually-resolved temperature and SST (sea surface temperature) reconstructions of the past 2000 years based on water (oxygen and hydrogen) isotope measurement on a shallow ice core drilled in 2010 at Dome Fuji station, East Antarctica. Those isotopic data are expected to yield information to elucidate the past climatic condition, and they are planed to contribute to integrated efforts for the reconstruction of temperature profile of the past 2000 years, in such as PAGES 2k project.
Dome Fuji station is located on a summit of Dronning Maud Land at an altitude of 3810 m a.s.l. (above sea level) (77° 19' 01" S, 39° 42' 12" E) in East Antarctica. The 10 m depth mean snow temperature at Dome Fuji is -57.3 °C[1)]. The inland area around Dome Fuji has been recognized to be especially unique: The snow and ice there contain much stratospheric information. The direct evidence for this comes from tritium contents originated from the nuclear bomb tests in the 1960s; the tritium fallout at the Dome Fuji site is outstandingly high among 16 snow pit samples widely collected over Antarctica[2)].
To date the concerned Dome Fuji ice core called DFS10, we applied volcanic signature matching to transfer the West Antarctic Ice Sheet (WAIS) Divide ice core chronology constructed by annual layer counting as used in the study by Sigl et al. (2014)[3)]. Based on this chronology of the DFS10 ice core and the measurements of isotopic ratios of oxygen and hydrogen, we have examined the annual changes of $d^{18}O$ to reconstruct the temperature of the past 2000 years. In our presentation, we confine ourselves to discuss the oscillation periodicity that we observed in the oxygen isotope record in our data: The periods of approximately 10, 20, and 200 years were found. We will present the time series analyses for this in detail, and will discuss the origin of this periodicity.
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Keywords: isotope ratios of oxygen and hydrogen, temperature reconstructions of the past 2000 years, Dome-Fuji

Paleoceanographic reconstructions of surface ocean conditions in the East China Sea since the last glacial maximum based on diatoms

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The East China Sea (ECS) has four surface water-masses. The first one is the Chinese coastal water in the north characterized by low salinity, low temperature and high nutrient. The other three water masses are flowed into the ECS from the south: the Kuroshio surface water; the Kuroshio subsurface water; and the Taiwan warm water. The Kuroshio surface water and the Taiwan warm water are characterized by high salinity, high temperature and low nutrient. The Kuroshio subsurface water with high salinity, low temperature and high nutrient penetrates into continental shelf region. During the last glacial period, sea level dropped to -120 m. Therefore, most of the continental shelves of the ECS were aerially exposed and the Yangtze River mouth must have advanced eastward. Diatom assemblages are highly sensitive to environmental changes such as salinity, temperature, nutrient availability. Thus, diatoms have a great potential to reconstruct past environmental changes in surface water of the ECS. However, paleoceanographic studies employing diatom assemblages have been very limited in the ECS. Only Tanimura et al. (2002) suggested that *Paralia sulcata*, a representative near shore species, dominated during the last deglacial termination.

14.1 m-long sediment core was obtained from the Danjo Basin, northern part of ECS (KY0704-PC01, 31°38.35'N, 128°56.64'E, 758 m water depth). Sediment samples for diatom analyses were sub-sampled at every 5 cm and added 30% hydrogen peroxide to degrade organic matter. For light microscope observation, suspended samples were dropped onto coverslip and mounted with Pleurax (Mount Media). For scanning electron microscope (SEM) observation, suspended samples were filtered with membrane filters with a nominal pore size of 0.45 μm and coated by Osmium tetroxide. Diatom taxa were identified under field emission scanning electron microscope (FE-SEM, JEOL JEM-7001F) and light microscope (LM, Olympus BX50 and BX53). 200 diatom valves were counted under LM for each slide.

A total of 45 diatom species were encountered. We classified them into three environmental groups, i.e., near shore, near shore to open ocean, and open ocean. Near shore, near shore to open ocean, and open ocean groups were characterized by *Paralia sulcata*, *Thalassionema nitzschioides*, and *Nitzschia bicapitata*, respectively. Since last glacial period, *Paralia sulcata* and *Thalassionema nitzschioides* have accounted for 25% to 80% in total diatom assemblage. In particular, *Paralia sulcata* was dominated during the last glacial-deglacial periods with low sea-level, suggesting enhanced coastal water input. At 8 ka, *Nitzschia bicapitata* accounted for >20% in total diatom assemblage suggesting warm water flowed into the northern ECS from the subtropical Pacific and the South China Sea flowed into the northern ECS. Based on detailed microscopic observation, we identified that both *Paralia sulcata* and *Thalassionema nitzschioides* in our samples were not a single species but multiple species. These species suggested that repeated intrusion of Chinese coastal water into the Danjo Basin during Holocene.

Keywords: East China Sea, Diatom

Variations in East Asian summer monsoon in the last 400 ky deduced from results of Mg/Ca-sea surface temperature and oxygen isotope of IODP Site U1429

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The East Asian summer monsoon (EASM) system is involved in the hydrological cycle and in latent heat and energy transport, and thus plays a crucial role in the regional and global climate system. Modern summer sea surface salinity in the northern part of the East China Sea (ECS) is mainly controlled by the discharge of the Yangtze River, which reflects East Asian summer monsoon (EASM) precipitation in the drainage area of the Yangtze River. Site U1429 was drilled by Integrated Ocean Drilling Program (IODP) Expedition 346 in the northern part of the ECS to reconstruct the Yangtze River discharge in high temporal resolution (~100 year resolution). A ~200 m long sediment succession was recovered, which covers the last 400 ky based on a benthic foraminiferal oxygen isotope. A record of oxygen isotope of seawater ($\delta^{18}O_w$) was reconstructed, based on high-resolution Mg/Ca and oxygen isotope measurements of the planktic foraminifera *Globigerinoides ruber.* The $\delta^{18}O_w$ shows variations that have been in concert with Chinese spleothem oxygen isotope records on millennial to orbital scales. However, comparison with a global mean $\delta^{18}O_w$ reveals that the $\delta^{18}O_w$ of U1429 follows the global mean except from MIS 7.3 to MIS 6.4 and from MIS 5.4 to MIS 4, when the $\delta^{18}O_w$ of U1429 was higher than the global mean during MIS 7.2, 6.4, 5.4, 5.2, 4 and lower during MIS 7.3, 7.1, 6.5, 5.3, 5.1. These intervals correspond to higher eccentricity periods during the last 400 ky. During these time periods, the amplitude variations of the regional $\delta^{18}O_w$ increased, suggesting that the 23 ky amplitude of the EASM precipitation was also enhanced. These results suggest that the 23 ky amplitude of the EASM precipitation has been modulated by the eccentricity.

Keywords: Monsoon, East China Sea, Milankovitch cycle, Mg/Ca-temperature, Oxygen isotope

Mid to Late Pleistocene paleoceanographic history of the northern East China Sea based on radiolarian data (IODP Exp. 346 Site U1429)

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The East China Sea (ECS), is a marginal sea, influenced by the East Asian Monsoon (EAM) and Kuroshio Current (KC). The hydrography of the northern part of this area is highly influenced by discharges of fresh water from the Yangtze River during summer lead by the East Asian summer monsoon. In summer-autumn 2013, the IODP Expedition 346 could retrieve sediments cores in the northern ECS from Site U1428 and U1429 in order to reonstruct the regional paleoceanographic history of this area, focusing on the interaction between East Asian Summer Monsoon, Yangtze River discharges and Kuroshio Current. On the other hand, radiolarians are micro-organism group bearing siliceous skeletons, widely distributed in the world ocean, living from shallow to deep water masses. In the ECS, few studies increase our knowledge's concerning radiolarian ecology and its relationship with temperatures changes. Therefore, we have investigated changes in radiolarian assemblages down core Site U1429 since the Mid- Pleistocene for clarify the fluctuation pattern in KC water and Yangtze River discharges through the Pleistocene glacial/interglacial climatic changes. We have also reconstructed past Summer Sea Surface Temperature based on shallow water radiolarians in order to discuss the possible interaction and impact of the EAM, Yangtze River discharges and KC on the regional hydrography
As a summarizing result, we identified that radiolarians related to Kuroshio Current waters, such as *T. octacantha* group and *D. tetrathalamus* were abundant at the MIS 1, MIS 5e and MIS 7, which caused a warming of the regional shallow water (>26 ℃). During de-glacials, the abundances of radiolarians related to the Yangtze River discharges (e.g. *P. obeliscus* and *C. calvata*), drastically increased. During glacials, *L. setosa*, a species related to temperate coastal water dominated the assemblages involving a cooling of the shallow waters (between 21 and 22℃). Several changes could be also identified for the intermediate water during the studied time interval. We recorded high abundances in taxa related to subarctic water during glacials (MIS 2 and 6), while, intermediate water dwellers specific to the ECS show their higher abundances during interglacial (MIS 1, 5), excepting the MIS 6 and 7.

Keywords: East China Sea, Paleoceanography, Radiolarians

Paleoenvironmental change associated with sea level drop during Marine Isotope Stage 3 in the Bonaparte Gulf

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During the Marine Isotope Stage 3 (MIS 3), ice volume changed in the short period and increased to the maximum volume in the Last Glacial Maximum (LGM). Accurate relative sea level records at far-field site, remote form ice-covered area, provide the ice volume information. However, the MIS 3 sea level records at far-field site are limited by the availability of dataset. The Bonaparte Gulf, northwestern Australia, is tectonically stable region and located at the far field. This Gulf has the carbonate platforms, which were exposed during the sea level lowstand. We show the paleoenvironmental change associated with sea level drop during MIS 3 using the marine sediments core from the Bonaparte Gulf. The primary information for the timing of exposure is calcium variation standardized by titanium. Total organic carbon, C/N ratios, and ^{14}C age offset (offset between the carbonate and organic matter age) also provide the paleoenvironmental information on the exposure of carbonate platform. We concluded that sea level drop occurred at ca. 26 ka, which is consistent with previous works as Huon Peninsula records. This drop is associated with Heinrich event 2.

Keywords: Sea Level, Paleoenvironmental change, Radiocarbon dating

Iceberg discharge from the Laurentide ice sheet to the western Arctic Ocean during the last glacial period

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The last glacial was characterized by millennial-scale abrupt climate changes, such as the Dansgaard-Oeschger (DO) cycles. The Heinrich events (HE) are a potential trigger of the abrupt warming from stadial to interstadial states, but the DO cycles were not always associated with the HE. The rate of cooling from interstadial to stadial states were variable, and its factor controlling the rates remains an open question. To answer these questions, the reconstruction of icebergs discharges in the western Arctic Ocean is necessary.

In this study, we established the stratigraphy of the Chukchi Borderland sediments during last 76,000 years and assigned the provenances and transport processes of sediments. We tried to discuss the iceberg discharges from the Laurentide ice sheet and their influences on the warming and cooling of glacial millennial climate changes. For this purpose, we used five sediment cores retrieved from the western Arctic Ocean by during 2011 and 2012 RV “Araon” cruises. We analyzed ice-rafted debris (IRD) content, mineral composition, grain size distribution, color, organic carbon, total nitrogen and total sulfur contents, stable carbon isotopes of organic matter, and glycerol dialkyl glycerol tetraethers (GDGT) compositions in those sediments.

Dolomite-rich layers were recognized at 9 ka, 11 ka, 42-35 ka, 45 ka, and 76 ka. Sedimentological properties suggest that they were derived from the Canadian Arctic Archipelago by iceberg rafting. Their deposition occurred when the sea level was 40-80 m lower than today. We suppose that the northern margin of the Laurentide ice sheet reached to the Arctic Ocean, and the calving of icebergs was not prevented by thick ice shelf nor sea ice during the periods. The deposition of dolomite-rich layers at 9 ka and 45 ka corresponded to H0 and H5 events, respectively. At both timings, interstadials continued longer than other interstadials. We speculate that the large collapse of the Laurentide ice sheet delayed ice-sheet build-up and a resultant cooling. Evidence of no iceberg discharge into the western Arctic during 53-11 ka indicates that the warming of interstadials 1 to 4 was not related to the collapse of the Arctic sector of the Laurentide ice sheet. A kaolinite-rich layer was found during the last deglaciation, which enables us to speculate that the deposition was related to the collapse of ice dam and an event of freshwater discharge.

Temporal flux change in diatom assemblages in seasonal sea-ice covered region off Sakhalin Island in the Okhotsk Sea

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"Ice" is a subsystem of the Earth's climate system and reconstruction of past ice-sheet and sea-ice dynamics is one of the important topics for paleoenvironmental sciences. Sea-ice floating on the sea-surface plays a key role in constraining sea-surface temperature because of its high albedo and insulation effect between atmosphere and ocean. Ice algae in sea-ice and ice-rafted debris (IRD) are representative proxy for past sea-ice coverage. Diatom frustules are made of biogenic opal which can be well-preserved in sediments as a micro fossil. Therefore, to understand a relationship between modern diatom assemblage and sea-ice coverage helps to reconstruct past sea-ice distribution.

Time-series sediment trap was moored at Station M4 off Sakhalin in the Okhotsk Sea from September, 1999 to June, 2000. Based on satellite observation, sea-ice covered at Station M4 December 1999 to April 2000. Nakatsuka et al. (2004) reported biogenic opal flux at Station M4, showing the low fluxes when sea-ice was covered.

In this study, We investigated diatom assemblages in 21 sinking particle samples at Station M4 from September, 1999 to June, 2000 by using light microscope (LM) and field emission scanning electron microscope (FE-SEM). A total of 36 diatom species including sea-ice and sea-ice related species were encountered during the microscopic observation. Diatom fluxes at Station M4 were significantly low when sea-ice covered. The diatom flux in November (sea-ice free) was greater than 30 times as that in April (sea-ice maximum). Diatom assemblage at Station M4 also changed with sea-ice coverage. During sea-ice free period, *Shionodiscus* and *Proboscia* species were abundant. Sea-ice related species started to increase with sea-ice coverage. Resting spore of *Bacterosira bathyomphala* was a major diatom taxa during sea-ice development. During sea-ice maximum, *Fragilariopsis cylindrus* flux showed pronounced peak. We found that flux peaks of each sea-ice related species. This suggests that diatom assemblages have a potential to reconstruct not only for presence of past sea-ice but also for magnitude of past sea-ice.

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Keywords: Okhotsk Sea, Diatom, Flux, Sea-ice

Elemental carbon contents in the Bering Sea sediments during glacial-interglacial cycles

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Elemental carbon (EC) is produced by incomplete combustion of organic matter. EC can be well-preserved in sediments because of the low volatility and chemically inert compared with organic carbon (OC). Although EC has a potential to be a proxy for paleo-fire, our knowledge on EC change during glacial–interglacial cycle is limited. In this study, we measured EC contents in the Bering Sea sediments for the last 500 kyrs during the glacial-interglacial cycles. In summer 2009 during Integrated Ocean Drilling Program (IODP) Expedition 323, sediment core was drilled at Site U1343 on a bathymetric high near the Bering slope (57°33′N, 175°49′W, water depth: 1950 m). Age model of U1343 cores was established based on oxygen isotope stratigraphy of benthic foraminifera as well as bio- and magneto-stratigraphies. The established age model enables us to identify each glacial and interglacial periods based on Marine Isotope Stage (MIS). Selected sediment samples from typical glacial (MIS 2 and 12) and interglacial (MIS 1, 5, 9, and 11) were used for EC analysis. EC contents were measured by thermal separation method using Semi-Continuous OC-EC Field Analyzer (Sunset Laboratory Inc.). Thermal separation method is one of the carbon component analyses, which distinguish between EC and OC based on volatility. Volatilization temperature of EC is higher than that of OC. Before measurements, carbonate was removed by 20% acetic acid. EC contents at Site U1343 were high in glacial and low in interglacial periods. During glacial periods, vast continental shelves in the Bering Sea near Site U1343 were aerially exposed (Beringia) due to sea-level drop. We suggest that high EC contents during glacial periods were likely due to an increase in transportation of sediment from the Beringia.

Keywords: Elemental carbon, Bering Sea

Biomass burning history deduced from elemental carbon variability at IODP Exp. 346 Site U1423 during the last 4 million years

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The burning of trees and grasses produces charred particles such as charcoal and soot that may be transported long distances via winds and rivers to coastal, deltaic, and ocean environments where they may become preserved in the sediments. Charcoal contained in sediments has been widely used as a proxy for biomass burning and human activities as well as climate change. Charcoal and soot in Cenozoic marine sediments at IODP Exp. 346 Site U1423 was measured to examine the regional history of biomass burning in the East Asia and carbon sequestration in the ocean.
IODP Exp.346 Site U1423 is located in the northeastern Japan Sea and the water depth is 1785 m. Relatively low Linear sedimentation rates (LSRs) are anticipated based on results from the site survey. The LSR are likely to be low enough to detect the contribution of minor amount of charcoal or soot from the surrounding land. One hundred nine samples have been collected from interval between 0 and 200 m CCSF-D which cover the last 4.3 m.y. Charcoal and soot were measured as elemental carbon (EC) in coarse (>2 um) and fine (<2 um) fractions, respectively, using thermal optical transmittance (TOT) method followed by grain size separation using repeated settling. Organic carbon (OC) was also quantified during the process.
EC and OC in both coarse and fine fractions are higher from 0 to 1.8 Ma and lower from 1.8 to 4.3 Ma with large variation, which suggests more frequent or intense biomass burning since 1.8 Ma. The fact that dark layer samples contain higher OC and EC also suggests net carbon input or preservation controls the amount of OC and EC in the sediments. Comparison of OC and EC variabilities with vegetation change reconstructed from pollen analysis suggests that OC and EC was high both in coarse and fine fractions in warm and wet environment. Terrestrial biomass and precipitation could be major control on EC supply. Fine EC varies independently from coarse EC, which suggests remote origin of fine EC. High temperature resistive EC is associated with grass dominant vegetation, while coarse EC is lower (fine EC is higher) when wood vegetation is dominant suggesting that vegetation type could affect the type of burning products.

Keywords: biomass burning, elemental carbon, IODP Expedition 346 Site U1423

Coupling of climate, dust and productibity in the Southern Ocean during the late Miocene to Pleistocene

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Dust potentially affects global climate via the direct and indirect effect on radiative balance of the atmosphere and by supplying essential limiting micronutrients such as iron to the ocean. In fact, supply of dust to the Southern Ocean increases during the glacial periods of the late Pleistocene may have contributed to the decrease in concentration of CO_2, suggesting strong coupling of climate, dust and productivity in the subantarctic Southern Ocean during the Pleistocene. However, link among the climate, dust and productibity in earlier times and its role in the evolution of the long-term climate since the late Miocene have remained unclear. Here we report long-term record of SST, dust and productivity in the Southern Ocean over the past 10 million years based on the analysis of marine sediments from ODP Site 1123, South Pacific sector of the subantarctic zone. Our new records show strong coupling of climate, dust and productivity over the past 10 million years with increase in dust and productivity during cold glacial periods including the late Miocene cooling (6-7 Ma). This finding suggests that the Southern Ocean played a key role in drawdown of atmospheric CO_2 level during the late Miocene.

Keywords: Climate change, SST, Late Cenozoic, dust, productivity, Southern Ocean

“Diatomaceous ocean weathering”: a new concept to understand the paleoceanic environment

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“Diatomaceous ocean weathering” is a novel physiological action of diatoms, where diatoms disintegrate silicate minerals and incorporate metals in the minerals into their frustules.

The action was inferred in discussing the rare earth element (REE) composition of siliceous matter in diatom-rich settling particles in the Bering Sea. Since then, we have foraged pieces of evidence for the radical action of diatoms. The evidence includes: 1) a fully-consistent picture of the oceanic REE cycling, 2) a balance in REE budget in a water column identified using Nd isotope ratios, 3) evenly-distributed SEM images of Al in diatom frustules, 4) presence of authigenic Al, which is spectroscopically different from that in clay minerals, and 5) numerous earlier analytical studies reporting failure to separate elements in clay and those in diatom frustules.

In this paper, how the new knowledge on the diatomaceous action will affect the interpretation of the distribution of Nd isotope ratios. An example to apply the action to Nd isotope variation recorded in ferromanganese crusts will be presented. It will be shown that quite distinct, but surprisingly reasonable changes in the paleoceanic environment (pCO_2 and Si concentration) will be emerged from the discussion.

Keywords: diatoms, weathering, Nd isotope ratio

Biogeochemical cycles and conditions for photic zone euxinia in the ocean

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Ocean anoxic events (OAEs) have occurred repeatedly during the Phanerozoic. Sedimentological studies have revealed that there was sometimes hydrogen sulfide in the water column, which is called ocean euxinia. Organic geochemical studies of black shales deposited at some of OAEs have revealed the presence of a specific molecule (biomarker) isorenieratane which is derived from green sulfur bacteria. Because these obligatory anaerobic photoautotrophic bacteria require both the light and hydrogen sulfide, it is indicated that there was hydrogen sulfide in photic zone (an uppermost 100~200 m of the surface ocean) at that time. This is remarkable because the photic zone is usually oxic owing to mixing with the overlying atmosphere which contains molecular oxygen as much as that of today throughout the most of the Phanerozoic. The condition and mechanism to cause such a photic zone euxinia (PZE) have been largely unknown. In order to understand PZE, we model the physical-chemical water column structure and the biogeochemical processes for the surface ocean. A new one-dimensional marine ecosystem-biogeochemical model, which has a high vertical resolution of ~5 m, was developed, and a series of parameter studies were performed. We found that the depth of chemocline (= the depth of dissolved oxygen/hydrogen sulfide boundary) resides at around 150 m which is determined by the limit of photosynthesis of algae due to light and also by the use of hydrogen sulfide due to green sulfur bacteria. We also found that the PZE is caused when the concentration of phosphate in seawater is higher than 8 mM which corresponds to the riverine flux of ~2.5 times the present value for the pelagic zone, while at the coastal upwelling regions PZE would be achieved when phosphate is higher than 5 mM which corresponds to the riverine flux of 2.1 times the present value. The riverine phosphate is derived from continents through chemical weathering, hence these two estimates correspond to the climatic conditions of 6 K and 11 K warmer than it is today, respectively. This result is consistent with the case of OAE2 (in the mid-Cretaceous, about 95 Ma) which occurred at the period of climate warming

Keywords: photic zone euxinia, ocean anoxic event, biogeochemical cycle

Changes in the Oligocene planktic foraminiferal depth habitat related to thermocline deepening in the eastern equatorial Pacific

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Planktic foraminiferal depth habitat is a key to accurate reconstruction of paleoceanographic records. Oligocene-Pliocene long-ranging species *Dentoglobigerina venezuelana* lived in the mixed-layer (shallower) in the eastern equatorial Pacific during the early Oligocene while the same species calcified within thermocline depth (deeper) during the late Oligocene and Miocene. The exact timing of its depth habitat change and possible relationships with Oligocene climate dynamics are still unknown.

Here we reveal successive isotopic record of *D. venezuelana* along with *Paragloborotalia siakensis* group (mixed-layer dweller) by using sediments at IODP Site U1334 in the eastern equatorial Pacific throughout the Oligocene. Two-step depth habitat changes of *D. venezuelana* are recognized: 1) from upper to lower mixed-layer (~27.4 Ma), and 2) lower mixed-layer to thermocline depth (~26.3 Ma). In addition, planktic foraminiferal faunal assemblage also experienced significant change from dominant thermocline (deeper) species to abundant mixed-layer (shallower) species, suggesting depth habitat shifts of *D. venezuelana* was closely related with thermocline deepening in the eastern equatorial Pacific.

Multiple sites (Sites U1334, U1333, and 1218) comparison of first isotopic shift (~27.4 Ma) revealed southward depth habitat change of *D. venezuelana* within ~200 kyr, implying thermocline deepening occurred with reduced steepness in the eastern equatorial Pacific. Consequently, we advocate global warming condition during the late Oligocene likely caused thermocline deepening with upwelling decrease in the eastern equatorial Pacific, guiding *D. venezuelana* to adapt deeper depth in the water column.

Keywords: eastern equatorial Pacific, Oligocene, depth habitat, planktic foraminifera, oxygen-carbon isotope ratio

Deep-sea Circulation Turnover Recognized in the Transition Period from the Warm Period to the Cool Period in the Cretaceous

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Globally warm climates from the Albian to the Coniacian were followed by cool climates from the Campanian to the Maastrichtian. Although deep-sea circulation is related to global climate, this relationship remains unclarified in the Cretaceous. This paper reconstructed deep-sea circulation during the middle to late Cretaceous using carbon and oxygen isotopes from benthic foraminiferal tests at 1,000-2,000 m paleowater depth in the Pacific, Indian, North Atlantic, South Atlantic, and Southern Oceans. The carbon isotope data showed that the water masses in the Pacific and Indian Oceans were newer than those in the North Atlantic during the early Cenomanian and Coniacian, but the reverse occured during the OAE 2, the mid-Campanian, and the Maastrichtian. Deep-sea temperature determinations based on the oxygen isotope data showed that the reverse of the global deep-sea circulation characterized the transition from the warm to the cool period. Based on the current understanding of the relationship between deep-sea circulation and temperature during the Paleocene-Eocene Thermal Maximum, the sources of the warm-water circulation culminated at the OAE 2 wheras the cool-water circulation derived from the middle-low latitudes and high latitudes.

Keywords: Cretaceous, Deep-sea circulation, benthic foraminifera, carbon isotope, oxygen isotope

Linkage between LIPs formation and environmental changes in Pacific during the Cretaceous OAE 2.

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Mid Cretaceous period (120-90 Ma) is characterized by the greatest value in the rate of ocean crust production over the past 150 million years. During this period, a lot of Large Igneous Provinces (LIPs) were emplaced in the Pacific, Atlantic and Indian oceans. Since the emplacement ages of the Cretaceous LIPs are concurrent with the Oceanic Anoxic Events (OAEs), various hypotheses explaining the linkage between the LIPs and OAEs have been proposed since the end of 1980's. A popular hypothesis attributes the high productivity and thereby ocean anoxia to the increased supply of biolimiting metals into photic zone during the LIPs formation (e.g., Snow et al., 2005). Another hypothesis explains the reason of increased productivity that elevated sea level as well as pCO_2 by LIPs eruption caused increase in global warming and continental runoff, which delivered terrestrial nutrient to ocean surface (e.g., Monteiro et al., 2012).
In order to understand linkage between large volcanic eruption and environmental change during OAE 2 (94 Ma), we examined the OAE 2 intervals of the Great Valley Group and the Yezo Group exposed in California, USA and Hokkaido Japan, respectively. The former sequence was deposited in the continental slope of eastern Pacific while the latter was in the continental slope of western Pacific. The samples were analyzed for total organic carbon content (TOC), degree of pyritilization (DOP) and assemblage of benthic foraminifera. The analytical results were correlated with the Os isotope stratigraphy and U-Pb zircon ages of tuffs obtained from the same samples by Du Vivier et al. (2015). Os isotope of the studied sequences exhibit abrupt decrease 35,000 year before the onset of the OAE 2 and gradual increase 200,000 years after the onset of the OAE 2 (Du Vivier et al., 2015). Based on the results of benthic foraminifera, TOC and DOP analyses, most of the studied sequences exhibit oxic environment in both sections. However, two short term dysoxic intervals were identified. One is the interval from the onset of the OAE 2 to 50,000 year after onset of the OAE 2, and another is that from 200,000 to the 300,000 after the onset of the OAE 2. The two dysoxic intervals are identical between the western and eastern Pacific, and accord well with the horizons of increase in Os isotope ratio. These evidences suggest that increased runoff caused the depletion of dissolved oxygen in the ocean at least in the eastern and western Pacific continental margins during the OAE 2.
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Keywords: Cretaceous, LIPS, OAE

Decadal- to orbital-scale paleoclimatic changes in the mid-Cretaceous “supergreenhouse” evidenced from Mongolian lacustrine records

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Understanding the global climate system during extremely warm “supergreenhouse” periods, such as the mid-Cretaceous, is one of the major aims of paleoclimatology. Hasegawa et al. (2012) suggested the drastic shrinkage of the Hadley circulation and enhanced mid-latitude hydrological cycle with wavier westerly jet stream during the mid-Cretaceous, based on the spatio-temporal reconstruction of desert distribution and paleo-wind pattern. However, the mechanism of such a drastic change in atmospheric circulation system have been poorly constrained, due to the lack of appropriate datasets. Here we present results of our ongoing research project targeting on annual- to orbital-scale paleoclimatic reconstruction based on a mid-Cretaceous lacustrine record in Mongolia.
The Aptian lacustrine deposits (Shinekhudag Formation) are widely distributed in southeastern Mongolia. In the type locality Shine Khudag area, the formation is about 250 m thick and composed alternating beds of dark gray shale, light gray dolomitic marl and yellowish dolomite. The shale and dolomite successions are rhythmically alternated (decimeter-, meter-, tens of meter-scale), which are thought to be formed primarily by lake level changes reflecting precipitation changes. Dark gray shale bed is well-laminated, consisting of micrometer-scale couplets of algal organic matter and detrital minerals. To obtain the continuous paleoclimatic record of this unique lacustrine deposit, we have drilled two scientific research cores (CSH01, 02) in Shine Khudag area in 2013 and 2014 summer.
Based on the radiometric age dating and detail chronostratigraphic study, the Shinekhudag Formation is considered to be deposited between ca. 123–119 Ma, and the calculated sedimentation rate is ca. 6.3–12.5 cm/kyr (Hasegawa et al., in revision). Given the average thickness of micro-lamination and calculated sedimentation rate, micrometer-scale laminations (couplets of organic matter and detrital minerals) in shale and dolomitic marl beds are most likely varves, reflecting seasonal cyclicity. Lacustrine varve record is a powerful tool to reconstruct detail climatic and chronological record (e.g., Wolff et al., 2011; Nakagawa et al., 2012). Thus, the Shinekhudag Formation have a potential to record the annual-scale climatic change and seasonal changes in mid-latitude Asia during the Aptian time.
In order to obtain the paleoclimatic signals and their controlling factors from the Shinekhudag lacustrine record, we performed XRF and ICP-MS analysis for major and minor element compositions of the bulk samples. Based on the factor analysis of major and minor element compositions, several climatic signals (e.g., precipitation, redox condition of lake bottom) were obtained. Spectral analysis of each factor scores reveals that cycles involving approximately 2, 6, 20, 40, and 100 kyr, based on the average sedimentation rate of 10 cm/kyr. The later values are in accordance with orbital precession, obliquity, and eccentricity cycles, respectively. Therefore, Shinekhudag

lacustrine deposits are interpreted to record the millennial- to orbital-scale paleoclimatic changes during the mid-Cretaceous “supergreenhouse” period.
Furthermore, although precipitation proxy (e.g., Si/Al, Ca/Al) shows a strong precession and eccentricity cycles, proxy for redox condition of lake bottom (e.g., P/Al, U/Al, Mo/Al) shows a clear obliquity cycles, suggesting different responses to the orbital insolation. Both the sediment mineralogy and palynofacies assemblages correspond also to the precession and eccentricity-paced precipitation (lake level) changes, except for the calcite contents and algal cysts abundance. Lake surface productivity signal is thought to be more sensitive to orbital insolation forcing. Thus, to verify the variation and cyclicity of lake surface productivity signal and its relationship to other climatic signals, elemental analysis (TOC, TN, TS) are now conducting.

Keywords: lake, greenhouse, varve, precipitation, productivity, orbital forcing

