Highly precise depth control method for precise correlation of paleoclimate records

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Considering the spatio-temporal variation of paleoclimate, it is important to establish precise age depth model independent from proxy data and correlate each data and location precisely. In terms of the age, absolute / relative dating methods are used and developed to minimize the error of age estimation and correlation.
On the other hand, it is necessary to estimate the error of the depth itself to connect paleoclimate data (paleoclimate vs. depth) and age data (age vs. depth) precisely.
In the case of sediment core, there are cases when the part of the core is lacked or the shape is changed in a scale of ~cm caused by drilling, splitting and time course. The depth errors caused by these events correspond to 10 - 10000 years in the age scale. This error cannot be ignored relative to reduced error of age estimation methods. Therefore, precise depth control and evaluation of these errors are important to constrain the age error of paleoclimate data.
In the KR15-10 cruise carried near Wakasa-Bay, we corrected piston core samples in multiple locations with different depth to establish the correlation network between sediment cores taken from Japan Sea and Lake Suigetsu. In this cruise, depth control method established in Lake Suigetsu drilling projects (SG06/12/14) is applied to reduce the error of the depth.
Based on high resolution photographs of half split cores and description of the position of marker layers in each processes of the sediment core, correlation, mutual complement and depth conversion is conducted between multiple sites, holes, half-split cores and sub-samples on software. As a result, a composite depth scale is established which is compatible to each core and its data in 1mm precision which corresponds to 10 years in the sediment of Japan Sea.
This depth control method is also applied to micro tephra sampling and analysis which enables us to correlate multiple locations and other core sites.
In this presentation, we would provide the method of depth control applied in KR15-10 cruise and future prospects.

Keywords: Japan Sea, Lake Suigetsu, Age depth model

Variability of elemental carbon input to the Lake Suigetsu sediments during the last 15,000 years

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Biomass burning in geologic ages has been controlled by natural variabilities in environment such as atmospheric oxygen concentration, vegetation, and climate, while human activity may have become another major controlling factor on biomass burning since Holocene. Measurement of elemental carbon (EC) in sediment archive is widely used to reconstruct biomass burning in the past. In order to evaluate drainage-scale influence of human activity and vegetation on biomass burning, we examined the EC in SG12 sediment core collected from the Lake Suigetsu, for which high resolution stratigraphy and age model has been already established and long-term human activities since 12,000 years ago is known from the remains of Jomon. EC is also classified into soot of submicron size and coarse grained charcoal, and the former can be transported for a long distance in the atmosphere. We also tried to evaluate the soot size EC independently from the charcoal size EC by grain size separation of the sediment samples in order to distinguish charcoal input from drainage from atmospheric soot input. Thermal optical transmittance (TOT) method was used to quantify and examine the EC fraction in fine (<2 um) and coarse (>2 um) fraction of the sediment.

High temperature resistant EC is dominant in coarse fraction which resembles to the EC fraction in surface water of the Lake Suigetsu and river waters flowing into the Lake. On the other hand, fine fraction of sediment contains less high temperature resistant EC which is similar to airborne materials collected at the Rishiri Island during Siberian fire in 2014. These facts suggest that coarse and fine EC are originated from drainage and airborne materials, respectively.

Temporal variability of coarse EC flux reconstructed from SG12 core shows increase at ~6500 years ago and ~2500 years ago, but does not show rapid increase from 6500 to 4000 years ago observed in charcoal contents measured from soils in Jomon remains. Vegetation change at 6500 years ago could be more responsible for the increase in the coarse EC. The increase at 2500 years ago could correspond to the onset of Yayoi culture around the Wakasa area. Fine EC flux variation is characterized by the gradual decrease after 9500 years ago and rapid increase at 2500 years ago. This pattern is similar to the Holocene charcoal variability compiled from the data in the Asia monsoon region, which suggests that fine EC could reflect regional-scale biomass burning history.

Keywords: elemental carbon, Lake Suigetsu, Holocene

Transfer function from sand content to paleo water depth of Lake Biwa

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One hundred and twenty bottom surface sediments have been obtained along the coastal area of Northern Lake Biwa from the river mouth of Echi to off Hikone city. Each sand contents were analyzed by sieving. We made a transfer function of sand contents to paleo water depth based on sand content at each station and its sampling water depth.
In general, sand contents are more than 90% in areas shallower than 5m and less than 50% in areas deeper than 10m, that is, sediments change from sandy to muddy at areas deeper than 10m. In addition, sand contents become less than10% at areas deeper than 18m. However, areas off river mouth of Echi and Yanagawa town, sediment show relatively higher sand content than other areas. Based on these data of sand contents and water depth, we found third order approximation and made it as a transfer function. Based on this transfer function and sand content data of drilled core obtained at northeastern part off river mouth of Echi, we plan to clarify paleo water level change history of Lake Biwa.

Keywords: Lake Biwa, Lake level change , sand content

Lake-level change history based on sand content of drilled core during the last 60ka in Lake Biwa

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We here discuss the lake-level change history of Lake Biwa based on sand content of drilled core taken off the river's mouth of Echi. Drilled station located off north east of river's mouth of Echi, water depth is about 23.45m and the length of this sample is 20.5m. Subsamples were cut as 1cm in length and the sand content was measured by sieving method excluding contaminated sediments. Based on the age of widely spreading tephras and 14C ages of plant fragments we made an Age-model of the sediment. Lake-level change was estimated by the transfer function of sand content to water depth by Terada et al. Comparison of Total Organic Carbon (TOC) content profile at the central part of the lake and the sand content profile show that the lake-level was higher in cold stages before 15ka, and that higher in warmer stages after 15ka. The cause of this correspondence is still in open question. Zonal shift of the prevailing westerlies caused by global climatic changes might be one of the facters.

Keywords: Lake Biwa, Lake level change, Sand content, Sediment, Climate change

Depth variation of diatom assemblages in surface sediments off estuary of Echi River , Lake Biwa

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We investigated the diatom assemblages in surface sediment samples from the lake bottom from 5m depth to 30m depth off estuary of Echi River, Lake Biwa.The number of valves and frequency in surface diatom assemblages indicates that they are characterized by depth variation. In particular, the number of valves is characterized by remarkable increasing between 20m depth and 25m depth. And frequency of each species is characterized by remarkable decreasing of benthic and attached diatoms between 5m depth and 20m depth.Sand contents in the same samples indicates that depth variation of diatom assemblage may relate to sand contents of surface sediments.We expect that more detailed investigation of the relationship between diatom assemblage and lake depth will contribute to the reconstruction of freshwater paleoenvironments.

Keywords: Lake biwa, Off estuary of Echi River, Diatom assemblages, Water depth, Surface sediments, sand contents

The formation process of the precipitation type lamina and the estimation of paleo-precipitation in the coastal lagoon

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In the coastal area of the Sea of Okhotsk in the east part of Hokkaido located to for subarctic zone, many brackish-water lakes are distributed. Lake Mokoto has two-layer structure of polyhaline surface waters and mixoeuhaline bottom water. The bottom water shows the anoxic conditions in summer season. In this reason, the sediments of Lake Mokoto consist of organic mud with the lamination. The 09Mk-1C and 09Mk-2C cores collected from Lake Mokoto at 2009. In the soft X-ray photograph, the cyclic lamina set is observed in their core. It is considered that this cyclic lamina set is the varve depending on summer precipitation from result of core analysis. In 2015, we were able to take the new core (15Mk-3C core). We have observed a new lamina set in detail from 2009 to 2015, and compared with precipitation pattern in Abashiri Region. And we are discussed about the possibility of paleo-precipitation analysis from the past of the lamina pattern.

As a result of comparison with 15Mk-3C and 09Mk-1C cores using by the soft X-ray photograph, it is possible to correlate with the two cores in lamina level except for some horizons. Because of correlation lines are substantially parallel, the two cores are seems to shows the same sedimentation rates. From the correlation of two cores, new sediments show the 13cm during about 6 years (sedimentation rate: 2.2 cm/y).

New sediments are subsampled in ca.1.25 mm interval, and were carried out CNS elemental analysis. In low density lamina, Total organic carbon (TOC) , total nitrogen (TN) and total sulfer (TS) contents show the high values, and C/N ratios show the low values. In high density lamina, these parameters had the opposite tendency. These results are suggested that the sediments of high density lamina deposited during the precipitation time.

It compared the lamina and precipitation patterns during 6 years. Relatively high density lamina was identified 116 lamina. On the other hand, the total precipitation of >20mm of 7 days has been observed 108 times. Therefore, if the formation of relatively high density lamina is due to rainfall, it would be formed by the 7 days total precipitation of >20mm. High density lamina set corresponds to when the 7 days total precipitation of >60m is continuously occur in a short term. The combination patterns of lamina and lamina set almost coincides with the precipitation pattern. For this reason, high density lamina are formed during precipitation term.

However, there was no significant difference in the thickness of the high density lamina when low and high precipitation. It is considered that the excess water mass containing the suspension is discharged from the system without being deposited in the lake. Thick high density lamina set, such as those found in this core, seems to be a thick high density lamina in the condition of low sedimentation rate. A thick high density lamina correspond to when the annual precipitation amount is large. Therefore, there will be possibility of estimating the degree of precipitation by analyzing the thickness of high density lamina.

Keywords: precipitation type lamina, paleo-precipitation, Varve, Lake Mokoto

Pleistocene deep-sea ostracodes at IODP Site U1426 and their implication for paleoenvironments

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In the Sea of Japan, the Quaternary glacial-interglacial climate changes have affected deep ocean floor environments as well as coastal environments and biota [e.g., Kitamura and Kimoto, 2006, Palaeogeogra., Palaeoclim., Palaeoeco., 236: 355–366; Watanabe et al., 2007, Palaeogeogra., Palaeoclim., Palaeoeco., 247, 50 –64]. Little is known about the Pleistocene deep-sea ostracodes and their response to environmental changes. We present Pleistocene ostracodes at IODP Site U1426 (37°2.00′N, 134°48.00′E; 903 m water depth). Twenty-one taxa were obtained from 87 Pleistocene (2.0–1.2 Ma) sediments of the interval between 123.50 and 218.14 mcd. Ostracodes occur from sediment samples with L* values of more than 33. Benthic ostracode accumulation rates (BOARs) exhibit less than 14 ind/cm^2/kyr. At 180 mcd, BOARs show a change: BOARs indicates maxima of 0.6–4.2 ind/cm^2/kyr above 180 mcd (~1.7Ma), whereas BOARs show maxima of 1.7–14 ind/cm^2/kyr below 180 mcd. *Acanthocythereis dunelmensis*, *Krithe antiswanensis*, *Krithe hemideclivata*, *Krithe reversa* , and *Robertsonites tabukii* are found ubiquitously. The ostracode fauna indicates oxic condition, alternation of export productivity, and possibly warm water-mass. Generally ostracodes are sensitive to oxygen contents. Their population vanishes in condition with oxygen contents of less than 0.4 ml/l O_2[Dingle, 1995, Mar. Geol., 122, 207–225]. We infer that the sediments with high L* values (>33) were deposited at oxic condition (> 0.4 ml/l O_2). Because BOARs are influenced by export productivity [Yasuhara et al., 2012, Paleobiol., 38, 162–179], the change in BOAR at 180 mcd suggests alternation of export productivity. According to Kitamura (2009, J. Quat. Sci. 24, 880–889), who discuss the surface and intermediate water-masses during the Pleistocene, the flow of the Tsushima current was intensified after 1.7 Ma. The change in surface water-mass probably made effects on surface productivity and benthic ostracodes. *R. tabukii* [= *R. reticuliforma* of Ozawa, 2003, Paleontol. Res., 7, 257–274], that lives in seafloor environments with water depth of 150–250 m and temperature of 2–5°C, indicates a warmer water-mass that the modern intermediate water with 0–1°C temperature.

Keywords: Sea of Japan, Ostracoda, Pleistocene, Deep sea

Reconstruction of paleoceanographic environment using planktonic foraminifera fossils from the Mera Formation of the Chikura Group distributed in the southern most part of the Boso Peninsula

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The Mera Formation of the Chikura Group, distributed in the southern most part of the Boso Peninsula, is thought to be deposited during from the late Pliocene to the Early Pleistocene including the Northern Hemisphere Glaciation (NHG) onset time (Kotake et al., 1995). Because the Boso Peninsula faces the Kuroshio-Oyashio convergent area, the Chikura Group seems to have sensively recorded paleoceanographic variations during the time. The aim of this study is to recnstruct the paleoceanographic environment off the Boso Peninsula during the onset time of NHG by assemblage analyses of planktonic foraminifera fossils and paleotemperature estimation using a transfer function method.
In this study, we used rock samples taken from 40 horizons in a succession at the middle part of the Chikura Group which corresponds to a period of 2.30-3.14 Ma defined by Tokoro et al. (2011) and Okada et al. (2012). We have extracted foraminiferal tests from collected rock samples by the sodium sulfate method, and identified a total of 10 genera 27 species of planktonic foraminifera fossils.
We reconstructed an influence of water mass from geographical zones (Arctic, Subarctic, Transition, Subtropical, Tropical), which are regulated by the water temperatures, deduced by a characteristic species assemblage observed at the each zone.
In addition, we performed a principal component analysis on the identified planktonic foraminiferal assemblage data to estimate water mass contribution and quantitative reconstruction of water temperature based on the method using factor loadings and a transfer function proposed by Takemoto and Oda (1997). As the result, we estimated that the cause of cooling at 3.1-3.0 Ma was by the influence of a cold water mass or the Tsugaru current, cooling at 2.7-2.5 Ma was by a domination of the Oyashio current, and warming at 2.5-2.3Ma was by the weakening of the Kuroshio current.

High-resolution continuous lithostratigraphy of middle to upper Miocene in Yurihonjo, Akita

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The middle to late Miocene is the time of global cooling. According to Lear et al. (2000), who reconstructed changes in the volume of ice sheets during the past 50 My, expansion of the ice sheets occurred in three steps during Cenozoic, and the second step approximately at 14 Ma was significant one due to the growth of the east Antarctic ice sheet.
During the middle Miocene, the east Antarctic ice sheet expanded and stabilized, which probably caused the change in global deepwater circulation pattern. Simultaneously, the organic carbon-rich siliceous sediments including the Monterey Formation and the Onnagawa Formation started widely accumulating in the coastal area of the Pacific Rim region. Deposition of these organic carbon-rich sediments might have drawn down the atmospheric CO_2, thus acting as a positive feedback to accelerate global cooling. These sediments are also known as a petroleum source rock. Thus it is important to study the origin and nature of these sediments as well as the timing and extent of their deposition.
In the process of expansion of Antarctic ice sheet and global cooling during the Middle Miocene, orbital-scale changes in $\delta^{18}O$ have been amplified and associated with switches between dominance of 100 ky cycles and 41 ky cycles (e.g. Holbourn et al., 2007), suggesting instability of the climate system. Tada (1991) reported the occurrence of centimeter-scale black-white banding observed in the siliceous rocks of the Onnagawa Formation, which he interpreted as reflecting millennial-scale changes in paleoceanography that could have been related to instability of the climate system. Thus, it is important to study the origin and variability in the composition and texture of the Onnagawa and the overlying Funakawa formations. To study the orbital to millennial-scale variabilities in the Onnagawa and Funakawa Formations and their temporal changes during the middle to late Miocene, it is critical to reconstruct a continuous sequence of the Onnagawa and Funakawa formations.
To accomplish this objective, we established a nearly continuous sequence of the Onnagawa and Funakawa formations with 1 ky-scale resolution. The research was conducted on the Kubota-river north route in Yurihonjo city, Akita, on which parts of the sequence of the Onnagawa and Funakawa formations are exposed repeatedly. The result are integrated with columnar sections constructed at the Ushigoe and the Yagiyama routes 11 km to the southwest of the studied area by Kurokawa (2015MS). A composite columnar section is constructed, which revealed the occurrence of the black-white banding intervals and termination of the siliceous sediments deposition (the Onnagawa/Funakawa boundary). We also extracted microfossils from the sequences to develop the better age model. The result will be presented at the meeting.

Keywords: Miocene, Siliceous rocks, the Onnagawa Formation, the Funakawa Formation

Paleoenvironmental records in sclerosponges from the Ryukyu Islands, Japan

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Sclerosponges, living in dark environments of tropical to subtropical shallow oceans, precipitate calcium carbonate skeleton with growth bands. They grow slowly at an approximate rate of <1 mm/year unlike corals (~1 cm/year) but can be so long-lived for several decades to hundred of years like corals. Skeletal oxygen isotopic ratios reflect variations in sea surface temperature and seawater with the latter being closely related to salinity reflecting the precipitation-evaporation balance at the sea surface and changes in water mass transport. In contrast to zooxanthellate corals, which occasionally show positive correlations between skeletal oxygen and carbon isotopic ratios, there do not exist vital effects in the secretion of sclerosponge skeleton. Previous studies showed significant decrease trends in the carbon isotope records of sclerosponges and corals toward the present, which is probably a result of isotopically-light carbon dioxide had been added into the atmosphere/ocean from fossil fuel burning. Therefore, sclerosponges are shown to provide annually resolved time series of proxy records of the ocean environments since the Industrial Revolution. However, longer (>100 year) proxy records from sclerosponges were derived only from material examined from the Atlantic Ocean. Here we present oxygen and carbon isotope records from sclerosponges collected from Kume-jima, Okinawa-jima, and Miyako-jima, the Ryukyu Islands in the North Pacific. Soft X-ray images showed highly developed skeletal growth bands with >100 high/low density layers. The secular changes in carbon isotopic composition of the sclerosponges were consistent with previously reported data from the Atlantic and the Pacific corals and sclerosponges. The long-term oxygen isotopic trends of the samples are characterized by slight depletions throughout their living periods, indicative of an overall trend toward warmer ocean environment around the Ryukyu Islands. Our sclerosponge-based estimates of the sea surface temperature and salinity may document thermal and hydrologic variations in the Ryukyu Islands, furthering a better understanding of northwestern tropical-subtropical Pacific climate change for the last several centuries in conjunction with coral-based long proxy records.

Keywords: sclerosponge, skeleton, oxygen isotope composition, carbon isotope composition, paleocean, the Ryukyu Islands

Assessing of variation of the Indonesian throughflow using a coral core collected from Seribu Island, Indonesia.

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The Indonesian throughflow (ITF) runs from the Pacific into the Indian Ocean through the Indonesian archipelago. The ITF varies heats and water budget between the Pacific and Indian Ocean, and may affect on variations of the El Niño/Southern Oscillation (ENSO) and Asian monsoon. In addition, there is a seasonal surface current corresponding to the monsoon in this area. During the northwest monsoon from January to March, the eastward surface current carries seawater with low density and salinity from the Java Sea into the surface layer of the southern Makassar Strait, and this low salinity water, which is called “freshwater plug”, restrain transportation of ITF in the surface layer of the Makassar Strait. Conversely, during the southeast monsoon, the westward surface current removes the “freshwater plug” from the southern Makassar Strait, therefore, the transportation of ITF in the surface layer of the Makassar Strait is not restrained. Since the behavior of the “freshwater plug” alters heat transportation from the Pacific into the Indian Ocean in the surface, it may influence the Asian monsoon and the Indian Ocean dipole [Gordon et al., 2003]. Then, in this study, we analyzed geochemical tracers used as water temperature and salinity in the coral core which grew up in the Java Sea where is affected by the “freshwater plug”. Consequently, we reconstructed sea surface temperature and sea surface salinity for about 20 years during 1982–2003. We will discuss these reconstructed marine environments in relation to variation of the “freshwater plug” and ITF.

Coupled oxygen isotope records of inclusion water and carbonate from a stalagmite in Hoshino Cave, Okinawa

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Millennial scale abrupt climate changes have been occurred during the last deglaciation. However, the land climate change in Japan is unclear due to sparsity of the high-time resolution paleoclimate record. In this study, we have measured isotope ratios of fluid inclusions and the calcium carbonate of a speleothem in a subtropical island. A stalagmite sample (HSN2), which was broken during a construction work of tourist corridor, was collected in Hoshino cave at Minami Daito Island, Okinawa Prefecture. Isotope ratios of the fluid inclusions were measured using the CRDS-based isotope measurement system. The analytical method was based on Uemura et al. (GCA, 2016), but the most of processes has been automated. The stalagmite covers the last deglaciation period (13-21 kyr). Water content of the stalagmite significantly differs in each layers. The water content correlates with the pattern of stripes of the cross section of the sample. There are weak correlation between the oxygen isotope ratio of the fluid inclusions and that of calcium carbonate.

Keywords: speleothem, stalagmite, isotope, fluid inclusion

Oxygen and hydrogen isotope analyses of fluid inclusions in Holocene stalagmite from Niigata prefecture

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The climate in East Asia is influenced by the East Asian Winter Monsoon (EAWM). Recently, the EAWM variations during Holocene have been revealed by the oxygen isotope ($\delta^{18}O$) record of stalagmite calcite from Fukugaghuchi cave (Sone *et al.*, 2013). In this study, we show oxygen and hydrogen stable isotopes of fluid-inclusion water in the stalagmite. The stalagmite (FG01) in Fukugaguchi cave in Niigata, Japan (Sone et al., 2013) was used for fluid inclusions analyses. The analytical method was based on Uemura et al. (2016), but most of operations were automated. Although water content of FG01 was very low (average 0.006 wt.%), fluid-inclusion isotope data covering 4000-8000 yrs BP were measured successfully.

Keywords: Speleothem, stalagmite, fluid inclusion, stable isotope

cave air monitoring and oxygen isotopic variation in drip water at Inazumi Cave, Oita, Japan

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Variation in oxygen isotopic ratios of stalagmite has been used as useful proxy for reconstruction of rainfall amount and pattern since drip water forming the stalagmite is originated from meteoric water. The original value of isotopic ratios in the drip water is controlled by the meteoric water, however, the final isotopic composition of the drip water is determined by in-cave processes such as evaporation and CO_2 degassing. Therefore, it is important to understand how the initial $\delta^{18}O$ of the drip water is changed by the in-cave processes before it is imprinted in the stalagmite.

Here, we conducted 3 days and 2 nights cave air monitoring and sampling the drip water at Inazumi Cave, Oita, Japan from February to December, 2014. For the cave air monitoring, cave air temperature, relative humidity and cave air CO_2 were measured. For sampling the drip water, the drip water before and after hitting on the handrails was collected in daytime and midnight during the monitoring periods. The meteoric water was sampled outside and near Inazumi Cave monthly. $\delta^{18}O$ and δD were measured for both the drip water and the meteoric water and HCO_3^- was measured for the drip water.

As a result, while the cave air temperature and relative humidity were stable through a whole year, the cave air CO_2 showed distinct seasonal variation, indicating that the cave air CO_2 might be the key to control both CO_2 degassing and kinetic fractionation of $\delta^{18}O$ of the drip water. While HCO_3^- showed seasonal and sequential variation as the cave air CO_2 was lowered, $\delta^{18}O$ and δD did not show, indicating that CO_2 degassing does not strongly affect $\delta^{18}O$ of the drip water as kinetic fractionation or that CO_2 hydroxylation and hydration might dominate in the drip water to maintain isotopic equilibrium.

$\delta^{18}O$ and δD of the drip water was plotted on or close to meteoric water line made by the meteoric water sampled around Inazumi Cave, indicating that the drip water is originated from the meteoric water around Inazumi Cave and evaporation does not affect $\delta^{18}O$ and δD of the drip water. Plus, $\delta^{18}O$ and δD of the meteoric water showed wider variation (-4.69~-13.23‰, -23.12~-101.51‰, respectively) than the ones of the drip water (-7.8~-8.41‰, -54.28~-57.08‰, respectively), indicating that the meteoric water is mixed well in host carbonate rock and homogenized drip water is produced. The mean value of $\delta^{18}O$ and δD of the drip water was the closest to the one of MJJASO (from May to October) of precipitation, indicating that the $\delta^{18}O$ and δD of the drip water might be controlled by summer season precipitation, which dominates approximately 80% precipitation amount out of all precipitation around Inazumi Cave.

$CaCO_3$ farming is now in progress at Inazumi Cave and $\delta^{18}O$ of precipitated $CaCO_3$ and the feeding water will be compared hereafter to check if isotopic equilibrium is maintained between them or not.

Keywords: stalagmite, δD and δ18O, paleoclimatology, drip water, meteoric water, isotopic equilibrium

Centurial-scale cycle observed in oxygen isotope of Holocene stalagmites from central Gifu Prefecture, Japan

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We report the Holocene oxygen isotope profiles successfully obtained from two stalagmites in Gujo City, Gifu Prefecture, where meteoric oxygen isotope appear distinct seasonal pattern (low in winter and high in summer). Holocene sections of stalagmite OT02 (5.3 cm thick) and OT03 (15.3 cm) from exhibit more than 10 cyclic changes in its oxygen isotopic values in a period of 11-2 ka. Estimated ~650-yr wave length broadly conforms with that of solar activity reconstructed based on radio carbon anomaly. The periodicity is also conformable with historical climatic periods, such as Little Ice Age and Medieval Warm Period. Temperature change was unlikely responsible for the stalagmite isotope because the phase unmatched with the solar activity. The stalagmite oxygen isotope was low during the cold phases of lower solar activity, and likely records the change in average isotopic composition of the meteoric water. Meteoric water samples collected at a reference site (Ogaki City) clearly indicate seasonality in the oxygen isotope values. Meteoric waters in winter generally record low isotopic values, likely owning to the Rayleigh distillation that occurs in water vapor mass from the Japan Sea. The stalagmite records at Gujo can be the change in the winter proportion of meteoric water. This would have increased the stalagmite oxygen isotope during colder periods. Similar centurial-scale cycles appear in the Holocene stalagmite from Mie Prefecture. We suggest that such cyclic change can be extended back to Yanger Dryas.

Keywords: stalagmite, Holocene, oxygen isotope

On the possibility of tree-ring $\delta^{18}O$ in Java, Indonesia for paleoclimate proxy

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The Indonesian region plays a key role in global climate system because active convection in this region is considered as a heat and moisture source which drives global circulation. Although $\delta^{18}O$ in tree-ring has been used to reconstruct hydroclimatic and atmospheric circulation, there are only a few paleoclimate reconstruction based on $\delta^{18}O$ in tree-ring in Indonesia (Schollaen et al., 2013, Poussart et al., 2004). In this study, we measured tree-ring $\delta^{18}O$ in Java Island to explore the possibility of tree-ring $\delta^{18}O$ as proxy.
We used four teak (*Tectona grandis*) samples collected at Sumedang, Western Java. Samples were cut into annual rings after cellulose extraction. $\delta^{18}O$ of individual rings were measured by TCEA-IRMS. We analyzed 59 years (1940-1998). Time series variation of $\delta^{18}O$ are correlated between the four samples, and EPS (expressed population signal) values are 0.89-0.93. In addition, the $\delta^{18}O$ time series of this study (Western Java) are very similar to that of Schollaen et al.(2013) (Eastern Java). This suggests common climate signals preserved in teak tree-ring in Java Island. $\delta^{18}O$ time series of our samples shows positive correlation with that of precipitation in the last dry season and negative correlation with that of precipitation in rainy season (growing season). Schollaen et al. (2013) suggests this is because dry season precipitation has relatively high $\delta^{18}O$ compared with rainy season precipitation.
We checked the correlation with DMI (Dipole Mode Index). The results show tree-ting $\delta^{18}O$ in Western Java has a negative correlation with last dry season DMI. This is probably because DMI has a negative correlation with dry season precipitation in Java Island (Ashok et al., 2003).
For future plan, we are going to analyze using tree-ring isotope model, in order to assess the reliability of tree-ring $\delta^{18}O$ as climate proxy in Java.

Keywords: tree-ring, paleoclimate, Indian Ocean Dipole

Basic Study of Paleoclimate Reconstruction Using Width of Teak Annual Rings in Java, Indonesia

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Tree ring has been regarded as one of the useful paleoclimate record media and measuring tree-ring width, among several proxies such as $\delta^{18}O$ and $\delta^{13}C$, is one of the approaches to reconstruct and interpret the history of precipitation at high and mid latitude. At low latitude, teak has been widely used for paleoclimate reconstruction because teak is the one of few trees that can make tree rings. The tree ring of teak is, however, not growing in a concentric fashion and the width on the disk might have bias from place to place. Although some previous researches (e.g., D'Arrigo et al., 1994; Schollaen et al., 2013) showed positive relationship between teak's tree-ring width and precipitation at Indonesia, the measuring methods of these researches do not take the bias of tree-ring width into account.
Here, we developed new measuring methods to improve the issues above and to reconsider if teak's tree-ring width can reconstruct paleoclimate such as precipitation. Two different measuring approaches were developed: "method of approximation as circle or sector (method 1)" and "method of approximation as trapezium (method 2)". Four teak samples were used: one of them is from Dungus area and the others are from Cepu, Indonesia.
As a consequence, method 1 was larger than method 2, and this might be because the boundaries of tree rings have curved and the length of boundaries were long. With method 1 and method 2, we developed tree-ring index as D'Arrigo et al. (1994) and Schollaen et al. (2013) have done and the tree ring index was made by two ways: three-year and five-year running average. The result showed that both method 1 and method 2 showed the mostly the same in all the samples by each running average, indicating that both method 1 and method 2 can be applied as the tree-ring index. Besides, $\delta^{18}O$ of all samples also showed mostly the same values between individual samples, showing the possibility that not only tree-ring width but also $\delta^{18}O$ can be used for determining the date of tree-ring.
Moreover, the tree-ring index showed the following correlation with the following climate factors; positive correlation between two samples and precipitation in early rainfall season, which is consistent with Schollaen et al. (2013); positive correlation between all four samples and dry season Southern Oscillation Index (SOI) and between three samples and rain season SOI, which is consistent with Murphy and Whetton (1989); negative correlation between three samples and one-year average (August to July) SOI; and negative correlation between two samples and dry season DMI.
As describe above, teak seems to be useful for paleoclimate reconstruction. It is necessary to be further verified by additional data from other teak samples in other area.

Keywords: tree ring, tree-ring width, dendroclimatology, dendrochronology

How did climate variations affect rice yields in Early Modern Japan? -comparison between tree-ring oxygen isotope data and Menjo (tax bill) records

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Recent progress in paleoclimatology enables us to investigate how climate changes affected society in the past, in collaboration with historical documents and/or archeological records. For example, Buckley et al. (2010) show that multi-decadal variations in hydroclimate are considered to be a contributing factor in the demise of Angkor. However, it is challenging to investigate how climate changes affected crop yields, which are directly linked to human life.

In the present study, we explored the relationship between climate variations and rice yields using tree-ring oxygen isotope ratios and Menjo (tax bill sent from a local load) records in Early Modern Japan. A tree-ring oxygen isotope chronology was established using several trees collected from central Japan. By comparing with instrumental climate data, the chronology showed a significant negative correlation with summer precipitation and relative humidity. On the other hand, annual rice yields were estimated using Menjo records collected from a total of four villages, which were located along lakefront of Biwa Lake. Specifically, numerical data of Nokoridata, which is closely related to rice yield, were extracted from the Menjo records.

The tree-ring oxygen isotope data showed a significant positive correlation with mean rice yields estimated from Menjo records of four villages, indicating that increase in precipitation leaded to rising lake level of Biwa Lake, which in turn resulted in reduction of rice yields due to floods of crop fields.

(Reference)

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Keywords: tree ring, historical document, rice yield

Diagnose oscillation properties of $\delta^{18}O$ embeded in ice cores from Antarctica and Greenland

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Analysing water stable isotopes is one of the ways to understand global climate change in the past. The temperature proxy using ice cores has been established in glaciology, and is defined as oxygen isotope $\delta^{18}O$. The objective in our presentation is to investigate the relationship between the temperature proxy, $\delta^{18}O$ and solar activity.

Periodicities in an annual ice-core $\delta^{18}O$ record (Graf et al. 2002) obtained from Dronning Maud Land (DML), Antarctica, were examined. We obtained 21-year and 194-year cycles in the data with Fourier and Autoregressive model time series analyses. We will also discuss significance for the obtained power peaks and their relation with the known solar modulation cycles about 22-year and 200-year.

DML ice-core might be affected by the cosmic rays that directly reflected the solar magnetic activity. We will also analyze a Greenland ice core for comparison.

Keywords: oxygen isotope ratio, ice cores

Depositional evidence for the Kamikaze Typhoons from Western Kyushu, Japan

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In the late 13th century, Kublai Khan, ruler of the Mongol Empire, launched what was at the time the world's largest armada in an attempt to conquer Japan. Early narratives describe the decimation/dispersal of these fleets by the "Kamikaze" of 1274CE and 1281CE– a pair of intense typhoons sent by the gods to protect Japan from invasion. Preserved wreckage provides evidence for the larger of the Mongol defeats; however, the probability of two major typhoons impacting this area in such close succession today is relatively low. Here we present a 2000 yr sedimentary reconstruction of typhoon overwash from a coastal lake near the location of the Mongol invasions (Lake Daija). Two marine-sourced flood deposits date to the Kamikaze typhoons and are the events of record in the reconstruction. Results from an additional nearby lake (Lake Kawahara), provide secondary depositional evidence for the events in the form of an extreme freshwater discharge event, thus helping to delineate deposits as storm-induced rather than tsunamigenic. The complete Daija reconstruction indicates greater regional typhoon activity relative to modern beginning around 250CE and extending past the timing of the Kamikaze events to 1500CE. It is difficult to conclusively attribute a pair of extreme weather events to varying climate. However, our results support the occurrence of two major typhoons in the late 13th century near the site of the Mongol invasions and show that extreme events of this nature were more frequent during the timing of the invasions as compared to present day. The role of the paired Kamikaze typhoons in preventing the conquering of Japan by the Mongol fleets may therefore serve as an important example of how an increase in severe weather associated with changing climate has helped to shape major geopolitical boundaries of today.

Keywords: Typhoons, Tropical Cyclones, ENSO, Coastal Flooding

Storm beds of the Ashiya Group and climatic change at 29Ma

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The Oligocene Ashiya Group, distributed in North Kyushu, consists entirely of marine sediments in back arc basin prior to the opening of the Japan Sea. It is divided into the Yamaga, Norimatsu, Jinnoharu Sakamizu and Waita Formations. The sequence boundary was recognized between Norimatsu and Jinnoharu Formations which is assigned to ca. 29 Ma based on the U-Pb age dating of zircon in intercalated tuff. This sequence boundary is thought to correspond to the largest sea level fall in Haq curve during the mid-Oligocene. The aim of this study is to describe the sedimentological characteristics of the thick-bedded storm beds in the Jinnoharu Formation above the 29 Ma sequence boundary, and to compare wavelength, amplitude and thickness of the storm beds of the Jinnoharu Formation with those of Waita Formation.

The Jinnoharu Formation represents some parasequence sets of shoaling upward, ranging from lower shoreface to upper shoreface environments. The parasequence set begins with ravinement deposits at base, passes to alternating beds of sandstone and siltstone, amalgamated thick storm beds, and ends with Ophiomorpha sandstone. The amalgamated storm beds succession is about 10 meters thick with intercalations of slump bed at bottom and two lenticular Ophiomorpha burrow horizons. Hummocky and/or swaley cross-stratification, sub-parallel lamination and multi-grading lamination are well identified internally. The average thickness of each storm beds in the Jinnoharu Formation attains to about 85 cm, whereas that of the Waita Formation reduces to less than half, about 31 cm. In addition, the wavelength and amplitude of storm beds of the Jinnoharu Formation is larger than those of Waita Formation. The relationship between bed thickness and wavelength of storm beds in both the Jinnoharu Formation and the Waita Formation shows linear relationship of the exponential function, suggesting that bed thickness and wavelength of storm beds were controlled primarily by intensity of storm waves. These observations suggest that potentiality higher frequency and strength of storm activity during the deposition of the Jinnoharu Formation, just after the large sea-level fall of 29Ma, than that of Waita Formation.

Sudden depositional environment changes above the 29 Ma sequence boundary can be also observed in the Nichinan Group in South Kyushu and Nishisonogi Group in West Kyushu. Beginning of deep sea fan sedimentation in the Nichinan Group and increasing of hyperpycnal sedimentation with abundant siderite nodules and orthoqartzite pebbles in the Nishisonogi Group are thought to be related to the frequent flooding on land from paleo-Asian continent. Such a remarkable change of sedimentation in various environments from coastal, shelf to deep sea deposits across the 29 Ma sequence boundary suggests that drastic climatic change in relation with the glaciation of Antarctica during the Oligocene.

Search for the ejecta deposits of the 0.79 Ma impact (source of Australasian tektite) in NE Thailand

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Impacts of extraterrestrial bodies can cause catastrophic effects on Earth's environment. For example, the Cretaceous-Paleogene mass extinction event was accepted to be caused by the impact of an asteroid of ca. 10 km in diameter (Alvarez et al., 1980; Schulte et al., 2010). A large extraterrestrial impact produces a crater and spreads pulverized, melted, and vaporized rock over large areas forming an ejecta layer. The morphology and the size of the impact crater and the distribution pattern of the ejecta depend on the size, velocity, and angle of the impacting body. Therefore, a crater and an ejecta layer provide information on the nature of the impact event (Melosh, 2011; French, 1998). Ejecta deposits contain shock indicater such as tektite and shocked quartz. Tektites are spherical glassy droplets solidified from the melt of the target rock formed by impact events (Glass and Simonson, 2012; McCall, 2001). Tektites are reported from 4 limited areas called strewn fields and the source craters for 3 out of 4 strewn fields were discovered. The exception is Australasian tektite strewn field, the largest and the youngest strewn field among the four, whose source crater is not yet discovered although its location is estimated as in the east part of Indochina Peninsula (Glass and Koeberl, 2006; Ma et al., 2004; Prasad et al., 2007; Schnetzler, 1992). Consequently, the nature of this large impact event (the size of the source crater is estimated as about 40 km in diameter by Glass and Koeberl (2006)) is not well understood. Although microtektite layers were identified at many marine sites, the ejecta layer has never been identified on land.This is one of the reasons why the source crater has not been found. There are several sites where Australasian tektites are reported from a reddish brown gravel layer called "laterite" layer or the base of the overlying muddy sand layer in NE Thailand (Fiske et al., 1996, 1999; Songtham et al., 2011, 2012; Tamura, 1992). However, the presence of tektite (and/or shocked quartz) is not enough to identify the ejecta deposit because of the possibility of re-deposition (Fiske et al., 1996; Koeberl and Glass, 2000; Langbroek, 2015).Size distribution analysis, petrographic observation and chemical composition analysis of spherical grains were conducted on samples obtained from the basal gravel layer under the "laterite" layer, the "laterite" layer and the muddy sand layer that overlies the "laterite" layer at Krahad and Kok Yai sections in NE Thailand to explore the evidence of impact.The preliminary result of examination will be presented at the meeting.

Keywords: extraterrestrial impact, Australasian tektite, Shocked quartz

Distributions of long chain diols in modern sediments from the Seto Inland Sea: Implications for paleoenvironments

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Long chain diols are widely distributed in both marine and freshwater environments. Previous studies have been proposed the use of long chain diols as paleoenvironmental indicators. Various ratios of C_{28}–C_{32} 1,13-, 1,14- and 1,15-alkyl diols have been proposed as markers for freshwater influence or upwelling (Diol index; Versteegh et al. 1997; Rampen et al., 2008; 2014), as well as a proxy for the past sea surface temperature (Long chain diol index; Rampen et al., 2012). Several distinct organisms have been suggested as biological sources for long chain diols; i.e. marine and freshwater Eustigmatophyte algae (1,13- and 1,15-alkyl diols) and the marine diatom genus *Proboscia* (C_{28} and C_{30} 1,14-alkyl diols).
In the present study, we investigate the long chain diol compositions in the surface and subsurface sediment cores from the Seto Inland Sea to examine the relations of diol compositions and environmental factors in the coastal region. The cores were taken from Osaka Bay and Harima-nada Bay (eastern part of Seto Inland Sea), in which lengths are 20 cm and 40 cm, respectively. These cores are divided and analyzed in every 5 cm (12 samples).
The long chain diols predominantly consist of C_{30} and C_{32} 1,15-alkyl diols in both Osaka Bay and Harima-nada Bay. Low abundance of C_{28} and C_{30} 1,14-diols implicates the occurrence of the diatom genus *Proboscia* in Seto Inland Sea, however its siliceous tests have not been identified. The rest of long chain diols are probably derived from Eustigmatophyte algae or the other unknown producers.
A ratio between C_{30} and C_{32} 1,15-alkyl diol is clearly different between Osaka Bay and Harima-nada Bay, while the general distributions of long chain diols are not significantly varied with depth within each location. The relative abundance of C_{32} 1,15-alkyl diol is higher than most marine sediments reported in previous studies, which possibly attributed to the strong influence by riverine input due to the vicinity to the Yodo River estuary.
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Keywords: Long chain diols, Eustigmatophyte, algal biomarker, modern sediment, coastal area, Seto Inland Sea

Comparison between fossil diatom assemblages and algal biomarkers in modern sediments from Seto Inland Sea.

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Microalgae play an important role as a primary producer, and are known as useful environmental indicators in the hydrospheric ecosystem. However, most of the microalgae except diatom have decomposable tests and are hardly preserved in the sediment so that it is difficult to reconstruct their temporal change. Organic molecules (biomarkers) are recently used as another indicator to evaluate the dynamics of primary producers and to reconstruct paleoenvironments. There, however, has few investigations for correlations between monitoring data for algal production, fossil assemblage, and biomarker compositions in the field. Seto Inland Sea underwent human-induced, eutrophication after the WWII, and drastic change of eutrophication was well recorded in the sediment. In the present study, we investigate the fossil diatom abundances and biomarker concentrations in surface and subsurface sediment cores from Seto Inland Sea. The cores were taken from Osaka Bay and Harima-nada Bay (eastern part of Seto Inland Sea), in which lengths are 20 cm and 40 cm, respectively. These cores are divided and analyzed in every 5 cm (12 samples). Although the precise age of the core has not been determined yet, it could be deposited for several decades, according to the sedimentation rates by previous study (Yasuhara *et al.*, 2007).
Diatomaceous species such as small *Thalassiosira* spp. and *Neodelphyneis pelagica*, which were reported by previous study (Hirose *et al.*, 2008), are observed as the dominant taxa in all samples. The valve contents (valves / 1 g dry sediment) are higher in sediments from the Osaka Bay than Harima-nada Bay, indicating variations of their productivity. The vertical distribution of valve content show a increasing trend reflecting eutrophication in Harima-nada, on the other hand, it doesn't show clear trend in Osak Bay. To the contrary, the concentrations of steroids (except dinoflagellate-derived dinosterols), which are synthesized in eukaryotic microalgae, are higher in Harima-nada Bay than Osaka Bay, and decrease toward the upper layers. Futhermore, highly branched isoprenoids (HBIs), which are biomarkers of specific diatom taxa, shows very similar distributions to those of fossil diatoms. These results suggest the effect of productivity of other algal taxa that are hardly preserved in the sediment as fossils, and the different process of diagenesis of diatom valves and organic molecules. We also discuss the detailed characteristics of each diatom taxa and biomarker molecules which are contained in specific taxa.
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Keywords: diatom assemblage, algal biomarker, modern sediment, coastal area, Seto Inland Sea, human-induced eutrophication

Sediment trap samples stored in Kyushu University

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Organic carbon produced by phytoplankton sinks to the ocean interior as sinking particles. This process plays an important role in oceanic carbon cycle. In order to investigate contents and fluxes of the sinking particles, sediment traps, funnel shaped instrument with rotating sampling vials to trap sinking particles, are deployed in the deep-sea. At Department of Earth and Planetary Sciences of Kyushu University, many sediment trap samples collected by Professor Emeritus Kozo Takahashi are archived in a refrigerator (wet sample) and storage (dried filter samples). These samples were collected from around the world, mainly from the North Pacific and its marginal seas. These samples are valuable material to understand oceanic biogeochemical cycles.

Keywords: sinking particles, archive sample

Late Holocene environemtal changes in west Mongolia revealed by the lacustrine sediment analyses

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We present the environmental changes in Northwest Mongolia during the last 3000 years based on the core analyses of the saline water and fresh water lakes.

Keywords: Continental interior Asia, History of terrestrial environments, Solar forcing

Late Quaternary paleoceanographic changes in the northeastern Arabian Sea; Inferred from sedimentary organic matter records.

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The northeastern Arabian Sea is characterized by a widespread midwater oxygen minimum zone (OMZ), between 80 to 1300 m, with oxygen concentrations reaching values of <0.05 mL/L^{-1}at present. In particular, biogenic particle fluxes in this region have experienced large seasonal changes due to strong monsoonal winds in summer and winter. Here we report carbon and nitrogen isotope data for a sediment core (ER-4) collected from this region. Synchronous downcore variations in the δ^{15}N record, which are explained by regional changes in the isotopic composition of subsurface nitrate, and hence denitrification were found. Moreover, these variations are synchronous with Indian monsoon changes during the glacial-interglacial cycles, thereby establishing a link with global climate. We discuss that these climate linked variations in this region that are likely to have experienced marine biogeochemical cycles during the Late Quaternary.

Keywords: Arabian Sea, organic matter, oxygen minimum zone (OMZ), δ15N

Multi-elemental data structure of the Indian Ocean deep-sea sediments recording the early Eocene hyperthermals

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Multiple transient global warming events occurred during the early Paleogene. The most prominent of these events was the Paleocene-Eocene thermal maximum (PETM) at ~56 Ma, which is characterized by a rapid and extreme global warming by 5-8°C, severe ocean acidification, and a distinct negative carbon isotope excursion in the marine and terrestrial realm. In addition, several PETM-like global warming episodes called 'hyperthermals' during the early Eocene period (56-52 Ma), accompanying rapid and pronounced negative excursions in the carbon isotopic composition ($\delta^{13}C$), have also been recognized worldwide recently.
Here we have constructed a comprehensive geochemical data set including major- and trace-element contents, $\delta^{13}C$, and $CaCO_3$ contents of 250 bulk sediment samples taken from ODP Sites 738 and 752, both located in the Indian Ocean. The analytical results show that the sediments of these cores record multiple carbon isotope excursions and reductions of carbonate contents, probably corresponding to the PETM and some of the early Eocene hyperthermals. We apply Independent Component Analysis to the compositional data matrix, and describe the fundamental structure of the multi-elemental data set on the basis of the extracted geochemical independent components.

Keywords: deep-sea sediment, Indian Ocean, climate change, hyperthermals, Independent Component Analysis

The warm climate of the Mid to Late Pliocene as seen in MIROC climate modelling experiments

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These past few years has seen much interest in the modelling of the warm climate of the Mid to Late Pliocene, approximately 3 million years ago. This period represents the most recent time in the earth's history when atmospheric carbon dioxide levels were comparable to those of today. In this sense, it has drawn much attention because of possible parallels with near future climate, helped by the availability of proxy datasets from the ocean and other sources. Recent interest has been further fuelled by The Pliocene Model Intercomparison Project (PlioMIP) which has brought together the paleodata analysis group, PRISM, and various international climate modelling groups to expand the scientific community's knowledge of this period. Now into its second phase, PlioMIP has set out specific protocols for climate model experimental design, utilizing the latest datasets related to Pliocene vegetation, soils, ice distribution and ocean bathymetry, while concentrating on a time-slice to limit temporal uncertainty
We ran several Pliocene climate modelling experiments using the atmosphere-ocean coupled model, MIROC4m. These include experiments using the boundary conditions specified in the first phase of PlioMIP in addition to one which has incorporated most of the latest datasets from the second phase. Zonal mean surface air temperatures increase by about 10 deg C at high latitudes, accompanied by a decrease in the equator-to-pole temperature gradient. As with many other climate models, the polar amplification appears smaller than that suggested by proxy data in PlioMIP. Initial results from experiments using the latest boundary conditions, in particular a closed Bering Strait, suggest that this amplification is further weakened.

Keywords: Pliocene, Climate modelling, Paleoceanography

Paleoceanographic reconstruction using siliceous microfossils from the Atlantic sector of the Southern Ocean

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Abundant siliceous microfossils such as diatoms are often found from the Neogene-Quaternary sediments in the Southern Ocean, therefore, the fossil diatoms give us important information of environmental changes in the past. However, paleoceanographic studies based on diatom analysis that focus on the long-term paleoenvironmental changes are very rare, whereas most studies have dealt with the Last Glacial Maximum and Holocene environments. Furthermore, the other siliceous microfossils such as diatom *Chaetoceros* resting spores and chrysophyte cysts seem to be useful paleoenvironmental indicators to reconstruct changes in the upwelling system and to assess the influence of freshwater to the Southern Ocean.

In this study, the changes in the microfossil assemblages of 'normal' diatoms, *Chaetoceros* resting spores and chrysophyte cysts are investigated in order to estimate a long-term trend of paleoceanographic changes (e.g., changes in sea-ice distribution, and location and strength of upwelling and the Antarctic Circumpolar Current system) around the Southern Ocean. In the current presentation, we would like to present and discuss on the paleontological data derived from the ODP Site 689 and DSDP Site 513 materials (Atlantic sector of the Southern Ocean).

Keywords: the Southern Ocean, diatom, resting spore, chrysophyte cysts, ODP, DSDP

SST variation derived from siliceous microfossils at ODP Site 704 in the Southern Atlantic Ocean for the last 6.3Myrs

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Reconstruction of sea surface temperature (SST) is one of the important keys to estimate paleo CO2 variation. Because alkenone SST proxy in higher latitude ocean sometime shows uncertainties due to low alkenone concentration in sediment samples, the SST dataset based on another proxies should be prepared. Biogeographical distribution of silicoflagellate and some diatom taxa corresponds to distribution of cold and subtropical water masses. At ODP Site 704 (46.9°S, 7.4°E, annual SST 5.6° C) in the South Atlantic Ocean, latitudinal migration of subpolar and subtropical surface water masses were estimated for the last 9 million years based on silicoflagellate and diatom fossils in the sediment core samples. Although the fossil preservation was poor in the oldest period from 9 Ma to ~6.3Ma, the extinct genus *Bachmannocena* considered as a temperate or cosmopolitan species was observed for the period. Continuous silicoflagellate occurrence was observed from ~6.3Ma to present. The silicoflagellate-derived climatological SST was 9°C for 6Ma. The subtropical genus *Dictyocha* intermittently dominated the assemblage from ~6Ma to 4.6Ma. When the *Dictyocha* events occurred, the estimated SST temporally rose to 11-12°C. The co-occurrence of cold and subtropical water species probably reflect that the subpolar/subtropical boundary is located around the studied site. After the *Dictyocha* events, SST decreased to ~4°C from 4.6Ma to 2.1Ma. The relative abundance of sea ice-related species in the silicoflagellate assemblages increased from 2.2Ma. The minimum SST reaching to ~0°C was recorded at 1.9Ma. The SST after 1.8Ma usually ranged from 2.5 to 7.4°C except for three samples characterized by high dominance of subtropical species. Long-term trend of silicoflagellate SST was similar to SST proxies byalkenone and Mg/Ca of planktic foraminifer test. However, silicoflagellate SST was usually 2-4°C lower than other SST proxies, and this difference may be partially explained by different seasonality of silicoflagellates, planktic foraminifer, and calcareous nannoplankton. Further evaluation on our SST data is required for the reliable SST reconstruction at this site.

Keywords: silicoflagellate, alkenone, foraminifer, South Atlantic Ocean

